U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY — BULLETIN NO. 81. - 90

B. T. GALLOWAY, *Chief of Bureau.*

EVOLUTION OF CELLULAR STRUCTURES.

BY

O. F. COOK AND WALTER T. SWINGLE.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

ISSUED AUGUST 4, 1905. Jan

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905. — 1906

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., May 31, 1905.

SIR: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 81 of the series of this Bureau, the accompanying technical paper entitled "Evolution of Cellular Structures."

This paper was prepared by Messrs. O. F. Cook and Walter T. Swingle, and has been submitted by the Pathologist and Physiologist with a view to its publication.

The accompanying plate is necessary to a complete understanding of the text of this bulletin.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

PREFACE.

Ever since the epoch-making discovery of Charles Darwin there has been a steadily increasing influence of the theory of evolution on the scientific study and practical utilization of the plants and animals on which agriculture is based. The present paper marks a step in the further working out of the doctrine of descent, inasmuch as it embodies results of an association of the data won in two very different fields of investigation; one making the cell its object of study, the other occupied with the species. The results herewith presented open new views as to the nature of higher animals and plants which can not fail to stimulate research and which promise to have great economic significance in the determination of the actual and latent capacities of the organisms utilized by man.

A. F. Woods,
Pathologist and Physiologist.

Office of Vegetable Pathological
and Physiological Investigations,
Washington, D. C., May 8, 1905.

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INTRODUCTION.

The value of a new point of view lies in the fact that it permits new relations to be perceived. By means of the kinetic theory of evolution it has become possible to understand that organic development has been carried forward through gradual improvement of the methods of descent rather than by environmental causes. Instead of there being a law of heredity which tends to keep the individuals of a species uniform, or exactly alike, the tendency, especially among higher plants and animals, is to maintain, inside the species, a diversity of form and structure, most conspicuously manifested in the phenomenon of sex.

This intraspecific diversity is neither accidental nor incidental, but of great physiological and evolutionary importance. The interweaving of distinct lines of descent is necessary to sustain the strength and vital efficiency of the individual organisms, and to continue the evolutionary progress by which the species adapts itself to changing environments or enters new ones. Interbreeding is as indispensable for the species as for the individual, or even more so, for seedless plants continue their individual existences after the coherence of the specific group has been lost.

Normal and long-sustained evolutionary progress is not accomplished on single or narrow lines of descent, but is possible only for large companies of interbreeding individuals; that is to say, for species. It is thus no mere accident, but a fundamental necessity, which brings about the association of organic individuals into species and determines what might be called the specific constitution of living matter. Species are sexual phenomena; they have come where they are only through symbasis; that is, as groups of interbreeding individuals, traveling together along the evolutionary pathway.

This interpretation of familiar biological facts is supplemented and confirmed by the study of the processes of cell conjugation, which are the means of symbasic interbreeding. Among simple organisms conjugation is a periodical incident in the multiplication of equal and independent cells. Higher stages of organization were reached by the production within the same species of many kinds of cells and the building of these into large colonies or compound individuals. There was, however, a very early limit to the structures which could be built of the primitive, simple type of cells, as illustrated by the filament of the lower alga, the vegetative mycelium of the fungus, and the thallus of the liverwort. The plant series would have culminated, apparently, with the leafy axis of the moss if the basis of organization had not been changed from the primary or simple type of cells to the double or sexual type.

In undifferentiated unicellular or equal-celled (isocytic) organisms the successive generations of cells may be thought of as joined into a network by an occasional conjugation. The cells at the knots of the network are, as we know, double, being formed from the association of two nuclei and the accompanying protoplasms. They are often strikingly different from the remainder of the cellular fabric of descent, and have been given special names, such as oospore, zygospore, and resting spore. In the first or lowest category of sexual organisms only one cell in each generation is double; there is only one large bead at each node of the genealogical network. (See Pl. I.) A second type of organic structure was initiated when an organism attained the art of forming two or more of these double cells by division.[a] It is of such double cells that all the higher plants and animals are built. The new type of organization was not merely supplementary to the old; it was a new biological invention, giving rise to a new category of vitality, which not only outstripped the old type of structural organization, but even caused it to be abandoned and eliminated as a worse than useless impediment.

Organisms which were farthest ahead on the primitive basis have fallen far behind since the new course of development was opened. In such groups as the liverworts, mosses, and ferns the diversity of the two types of organic structure is strikingly obvious, and has received extensive study for years past under the name of "alternation of generations." Ample homologies have been found in the highest groups of plants to show that the so-called alteration of generations was everywhere in ancestral condition, and that all have followed essentially the same history in having abandoned the simple type of cell for the double as the basis of structural development.

[a] The terminology followed in this paper presupposes for convenience the existence of the cellular type of organization common to most animals and plants. The conclusions here reached apply with equal force, however, to organisms such as the Infusoria among the protozoa, the Siphonocladiaceæ among the algæ, and the Saprolegniales and Mucorales among the fungi, in all of which groups considerable structural differentiation is attained without any division of the organism into cells. Such forms as Caulerpa and Acetabularia among the Siphonocladiaceæ reach a considerable size and even show a well-marked differentiation into the analogue of stem and leaf, rhizome and root, without the enormously expanded thallus being divided up into cells at all, although very numerous nuclei arise by subdivision and are scattered throughout the cytoplasm. These nuclei could be double, in which case such plants would be directly homologous to the double-celled organisms described in the following pages.

That these converging data pointed to something of fundamental evolutionary significance has been confidently believed since the publication a decade ago of Strasburger's epoch-making essay entitled "The Periodic Reduction of the Number of the Chromosomes in the Life-History of Living Organisms,"[a] but a new evolutionary standpoint was required before the larger import of the facts could be perceived. The reduction of chromosomes is indeed a striking and unique phenomenon in the life history of organisms, and it naturally became the focus of interest in the rapidly developing science of cytology. A new point of view was the more necessary, however, because of an unfortunate choice of terms which has undoubtedly tended to prevent the perception of the true relations of the facts, as it now interferes with a correct description of them. We refer to the characterization of the higher, double-celled, spore-bearing "generation" as "asexual." Appreciating the primitive character of such structures as the prothallus in ferns, Strasburger asserted that a new "asexual generation" had been intercalated into the life history of organisms. It is now perceived that for cytological purposes this is not the whole truth, and that for evolutionary purposes it is not true at all. The new "generation" was not merely intercalated into the *life history* of the organism; it was intercalated into the *sexual process*. It is, therefore, not asexual, but sexual, and in a higher degree than the so-called sexual generation. The latter bears, it is true, the cells which conjugate, but the former is produced *during the actual process of conjugation*. Organic perfection has been attained, not through the development of an "asexual generation," but by the lengthening out of the sexual process itself; not by abandoning or avoiding sexuality, but directly by means of it.

Among the lower plants the single cell formed by conjugation accomplishes in a brief space of time all the cytological processes which in the higher plants come between fertilization and chromosome reduction. Sexual fusion is immediate and complete, and takes place during a brief period of interruption of the growth and subdivision of vegetative cells. If the vegetative fern prothallus is to be termed sexual because it produces antheridia and archegonia, the sporophyte is sexual to the second degree, for it is built of conjugating cells, containing, until synapsis and the subsequent reducing divisions, a double number of chromosomes, the parental chromatin elements being still unfused. However important chromosome reduction may be, it is, after all, only a corollary or sequel of the *doubling conjugation*. It was not the reducing division, but *the long postponement of the reduction division*, which permitted higher types of organisms to be developed by means of double, sexual cells.

A special evolutionary significance was ascribed to the chromosome

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[a] Strasburger, Edward, Annals of Botany, 1894, 8: 281–316.

reduction because cytology was approached from the standpoint of the somatic tissues of the higher plants and animals. This current interpretation reverses, however, the historical course of events. The reducing division was not an expedient incidental to the adoption of a process of sexual reproduction by organisms previously sexless. *It was not the reduction to fewer chromosomes, but the retention of the double number, that constituted the important step in sexual reproduction and made possible the evolution of complex higher organisms.* It is, therefore, not the reducing division, but the doubling conjugation, which should constitute the datum point or base line for tracing cytological homologies.

THE ELIMINATION OF THE SIMPLE-CELLED PHASE.

Chromosome reduction brought about by synapsis, or the fusion of the chromatin elements, followed by two special nuclear divisions, is not, historically speaking, the beginning of the sexual process, but the end of it. Chromosome reduction stands in no special causal relation to the subsequent conjugation. The number of cell generations formed between synapsis and conjugation differs greatly in the various natural groups, and merely shows how far the organism still adheres to its old simple-celled life history. Fecundation and synapsis, as the beginning and the end of the sexual process, would seem to be directly comparable in all organisms which have developed a double-celled sexual phase.

From the physiological standpoint, it may be an advantage to dispense with the simple-celled phase and thus shorten the period between the chromosome reduction which marks the end of one conjugation and the cell fusion which begins another. Synapsis relieves organic fatigue by means of new nuclear configurations, and has been thought of as a stimulant of vital activity or energy of growth, the benefit of which can be secured for the new double-celled structure by very prompt conjugation, as occurs in all the higher plants and animals. This consideration would help to explain the organic inferiority of such a group as the ferns, which, although they have developed a double-celled phase, continue to waste the energy derived from synapsis on a worse than useless simple-celled structure.

In all animals above protozoa this reduction of the simple-celled phase has gone so far as to result in its complete elimination, for the two peculiar nuclear divisions which occur in rapid succession immediately after synapsis constitute an essential part of chromatin reduction. That these phenomena noted are indissociably connected stages in the process of chromosome reduction has been emphasized recently by Farmer and Moore,[a] who propose the convenient term maiosis to

[a] Farmer, J. B., and Moore, J. E. S. On the Maiotic Phase (Reduction Divisions) in Animals and Plants, in Quarterly Journal of Microscopical Science, n. s., No. 192 (vol. 48, No. 4), Feb., 1905, pp. 489–557, pl. 34

include synapsis and the subsequent heterotype and homotype nuclear divisions.[a]

ALTERNATION OF STRUCTURAL TYPES.

"Alternation of generations" is an expression borrowed from zoology; its application to the archegoniate plants has introduced endless complexities, and can be justified, after all, only by false analogies. Alternation of generations was discovered by Chamisso in a species of Salpa, a marine animal belonging to the Tunicates; but here, as well as in the traditional zoological example of the Aphides, or plant lice, the phenomena have entirely different evolutionary significance from the so-called antithetic alternation of generations in the archegoniate. Generations or individual life cycles of Salpa and of plant lice, which were originally alike, have become different, so that now parthenogenetic generations alternate with sexual generations. To make the archegoniate plants a parallel instance, it would be necessary to assume that what is now called the sporophyte was originally another thallus, or something that corresponded to one, which later on became modified into the sporophytic "generation." To state the case in this way may seem quite superfluous, since nobody has made such a suggestion. Strasburger and others have repeatedly declared that the so-called asexual generation had been intercalated—that is, added anew—and not substituted for something else. This, however, makes it only the more obvious that the sporophyte is a generation only in a very loose and inaccurate sense, and not because it corresponds to or takes the place of any other generation. The simple fact is that, instead of forming merely one oospore as the result of fertilization, the archegoniates have come to form a whole sporophyte or double-celled structure by the multiplication and progressive sterilization of potentially sporogenous tissue, as Bower has shown.[b]

Bower's generalization is, however, only a half truth, since the sterilization, or, better, the arrest of spore formation of some of the cells, is conditioned on the possibility of continued subdivision and growth of the fertilized egg, and this can occur only when there is a definite

[a] To recognize, however, as Farmer and Moore do, these two cell generations as a distinct "maiotic phase" in the life history of Metaphyta and Metazoa does not seem warranted, since chromosome reduction is apparently a mechanical necessity resulting from sexual conjugation and is consequently brought about in a practically identical manner in all symbasic organisms, from the lowest to the highest. Maiosis is rather a connecting link at the node in the network of descent than a distinct phase subject to expansion or contraction as organisms mount in the scale of evolutionary progress. On the other hand it is clear that the two peculiar cell generations occurring during maiosis can not properly be classed with the double-celled phase that usually precedes or with the simple-celled phase that usually follows, but constitute a transition stage marking the end of one generation and the beginning of another.

[b] Bower, F. O. A Theory of the Strobilus in Archegoniate Plants. Annals of Botany, 8:343–365. 1894.

postponement of some stage of sexual fusion, for if the final stage is once reached and the chromatin fuses, no further growth is possible, and a new generation is inaugurated automatically. When sexual fusion is immediate and complete, i. e., when nuclear fusion follows close on cell conjugation and is in turn at once succeeded by chromatic fusion, no development of the oospore can occur; it simply breaks up into four spores. Such was once the fate of the eggs of all organisms, and such is still their fate in the lower plants. All development of the fertilized egg other than a simple splitting into four spores is due to an arrest of the process of sexual fusion which permits its expansion into a mass of double cells, such as constitute the bodies of higher animals and plants.[a] It is, however, clear that the effect of such an arrest in the process of sexual conjugation and consequent intercalation of a double-celled phase in the life history of the organism is to lengthen the life cycle; it lessens the number of generations instead of making more of them.

Notwithstanding half a century of endeavor, botanists and zoologists have not yet found in the higher animals any definite homologue of the so-called antithetic alternation of generations discovered by Hofmeister[b] in the archegoniate plants. The whole idea of alternating generations must, however, be abandoned and emphasis placed instead on the expansion of the oospore or fecundated egg into a double-celled phase that comes to occupy a larger and larger part of the life cycle as organisms mount higher in the scale of evolutionary progress. It then becomes evident that in higher animals (Metazoa) the expansion of this phase has gone so far that the simple-celled stage has been completely suppressed, and in consequence their life history is as free from alternating phases as that of the lower plants, though for a very different reason. The lower groups show no expansion of the fertilized egg. The higher animals consist of nothing else.[c]

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[a] It is clear that the expansion of the fertilized egg could occur in siphonaceous algæ and fungi without any cross walls forming between the nuclei as they arise by subdivision. The mature thallus of an Acetabularia is obviously the enormously expanded syngamete and may or may not contain double nuclei. On the other hand, the Infusoria may be found to consist of one double cell, the successive cell generations not adhering to form a tissue.

[b] Hofmeister, W., Vergleichende Untersuchungen der Keimung, Entfaltung und Fruchtbildung höherer Kryptogamen und der Samenbildung der Coniferen. Leipzig. 1851.

[c] This fact is obscured, but not negated, by the splitting up during chromosome reduction of the egg and sperm mother cells of animals into four gametes, which are simple cells, but which are no longer capable of further development unless they conjugate. As previously noted (p. 13, footnote a), these two cell generations occurring during chromosome reduction constitute a transition stage between the old and the new generations and can not properly be classed with the simple-celled phase.

The occurrence of alternating phases in the life history of an organism indicates that it is in an unstable evolutionary condition, since it has not yet attained the

That there are two unicellular stages in the life history of an organism should not be allowed to introduce any confusing technicalities. For genealogical purposes the spore is quite as much the descendant of the antherozoid and the egg cell as it would be if the other tissues of the sporophyte had not been intercalated. From chromosome reduction to chromosome reduction, from spore to spore, or from egg to egg is one generation, and not two. The prothallus is no more mysterious than any other piece of ancient history. The ferns were originally liverworts, the capsules of which had the good fortune to get roots into the ground and keep on growing, but they have not yet learned to dispense with their first vain attempt at building a structure on a simple-celled basis.

SEXUALITY A MECHANISM OF EVOLUTION.

Stress has also been laid upon this supposed alternation of "sexual" and "asexual" generations in the belief that a clew was here to be gained regarding the nature of sex and of attendant "mechanisms of heredity." But since only one generation is really involved instead of two, and since the phase of existence which has been termed asexual is in reality the more strongly sexual, it is not surprising that these expectations have not been realized. Sexuality facilitates interbreeding and makes it the more effective by distributing new variations throughout the species; it is, in short, a mechanism of diversification and of evolution, a fundamental and universal fact which stands squarely in the way of the alleged law of heredity under which organisms would breed true and be exactly alike. This notion of a uniform and unchanging heredity,[a] or of any natural tendency to such a condition of organic

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most effective type of organization. The persistence of a clearly two-phased condition in the vascular cryptogams and of a reduced alternation of phases, even in the highest algæ and flowering plants, is a proof of the extreme slowness of the evolutionary progress of the plant kingdom. Animals seem to have passed through the diphase period of their existence before the dawn of geologic history, and appear in the oldest fossil-bearing strata, not only as completely double-celled organisms but highly differentiated ones at that. Not only are there no traces of the two-phased progenitors which must have gone before the lowest known fossil organisms, but up to now zoologists have not realized the need of postulating such forms at all, and have been content to derive the higher animals from merely simpler but always completely double-celled ancestors, which, of course, are not primitive. It seems not improbable that the completely double-celled condition has been reached independently by different groups of higher animals, just as it has been approximated, though not attained, by the Fucaceæ and the phanerogams among plants. The animal kingdom does not contain, so far as is now known, a single species that shows alternating phases in its life history; it has no counterparts of all that wealth of forms which in the plant kingdom bridge the interval from the protophytes to the flowering plants.

[a] "The modifications introduced into palingenesis by kenogenesis are vitiations, strange, meaningless additions to the original, true course of evolution."—*Haeckel, Evolution of Man, vol. 11, p. 460, note 9.*

stagnation, can well be relegated to the limbo of hypotheses which have not proved useful. Heredity is not a mechanism or a force; it is merely another name for the property of organic continuity or succession. There is no more heredity in an organism at one stage of its life history than at another.

Sexual and other diversities inside specific lines are not useless morphological complexities or mere failures in the execution of a fundamental plan of complete uniformity. Diversity, interbreeding, and evolution are physiological factors of the highest importance in maintaining vital efficiency.

Morphologically speaking, sexuality is a specialization of the internal diversity of the species, and among plants, at least, it has been attained independently in a large number of unrelated natural groups. There are grades of sexual differentiation just as there are of organic structures. Moss plants and fern prothalli may be sexually differentiated and the differentiation may occur farther back in the spore itself, or even in the sporophyte or double-celled phase, as in the flowering plants and the higher animals. Thus in the same species there may be two sexualities, one in the simple-celled stage and another in the double, and these may have no homology or causal connection, except as they both serve the same purpose of promoting more efficient symbasis. Indeed, the sexuality of the highest types of organization is not merely double, but threefold; the individual has sex, as a whole; the double cells of which the body is composed are a part of a sexual process, and the simple cells which it produces for the initiation of a new generation are sexually differentiated.

TWO TYPES OF DOUBLE-CELLED STRUCTURES.

That organisms are everywhere associated in species is not because of some undiscovered principle or mechanism of heredity; it is simply because the interweaving of the lines of individual descent is being maintained, without which the specific association would be dissolved into indefinite radial divergence and degeneration, as among the varieties of bananas and other plants long propagated from cuttings. Many explanations have been conjectured for the supposed absence of sexual reproduction among the higher groups of fungi. From the standpoint of a symbasic evolution, however, it becomes evident that the existence of true, coherent species among these fungi is a sufficient evidence of interbreeding, and hence of sexuality. There is in many groups a deficiency of specialized sexual organs, but these are rendered unnecessary by abundant opportunities for direct conjugation among the mycelial filaments.

That the cells of the more complex reproductive tissues of the higher fungi are known to have two nuclei, while in the younger mycelium there is only one, might also have been accepted as proving that conjugation had taken place. This does not mean, of course, that cross-fertilization is indispensable for spore production among the fungi, but their habits of growth certainly give many opportunities for conjugations between mycelia of different descent, by which the existence of compact and well-defined species can be maintained, although the peculiar structure of fungous tissues permits extreme variability of the size and external form of the fruiting bodies.

In structural complexity, size, longevity, and other measures of organic efficiency the binucleate fungi have an intermediate position in the plant series. Their wide distribution and extensive differentiation into species, families, and orders are evidences of ample opportunities in time and environment, so that it is not unfair to explain their evolutionary limitations by reference to their peculiar type of organic structure.

Sexual reproduction is accomplished through conjugation or fusion of cells, a process which may be divided into three stages: (1) Plasmapsis, the fusion of the cytoplasm or unspecialized protoplasm; (2) karyapsis,[a] the fusion of the nuclei or nuclear protoplasm; (3) synapsis, the fusion of the chromatin. The binucleate cells of the fungi may be said to have passed the stage of plasmapsis, but karyapsis, or true fecundation, like that of the higher plants and animals, has not taken place.

For the form of sexuality which produces the binucleate cell structures of the higher fungi the name *apaylogamy* is proposed, in allusion to the fact that the two nuclei have not yet associated. The higher stage, where the nuclei fuse but the chromosomes remain apart, may be called *paragamy*, which implies that the union is still incomplete, but that a more intimate relation has been established. These two double-celled conditions may be further contrasted with *haplogamy*, the primitive method of undeferred combination of the sexual cells, nuclei, and chromatin.

To the "asexual generation," which is not asexual and not a generation, the term *paragamic phase* may be applied among the higher plants and animals, the tissues of which are composed of cells with a

[a] The etymology of these terms will be obvious to all students of biology, *plasma* and *karyon* being the familiar Greek renderings of protoplasm and nucleus, respectively. The other element, ἅψις, signifies a binding or tying together and also a mesh or network, a meaning especially appropriate in view of the reticular structure of living matter.

The series might be completed more logically by using the distinctive word *mitapsis* as a substitute for synapsis, which in its etymology is scarcely more than a Greek equivalent for the general term conjugation. Mitapsis is derived from μίτος, a thread, and alludes to the threadlike condition assumed by the chromatin during the process of chromatic fusion.

double number of chromosomes. The binucleate structures of the fungi may be referred to as the *apaylogamic phase*. The so-called "sexual generation" may be called the *haplogamic phase* in both cases. These new terms might not be necessary if words were used for descriptive purposes only, but in the present instance they have general implications too important to be disregarded.

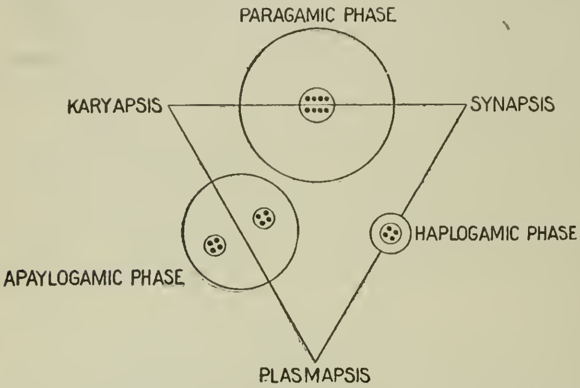

Fig. 1.—Diagram showing the different types of cell structures and their position in the life history of organisms.

Haplogamic structures are built between synapsis and plasmapsis, apaylogamic between plasmapsis and karyapsis, paragamic between karyapsis and synapsis. Between the three critical points of cytological activity there are three intervals, in which the organism can pause to gain additional size or numbers by vegetative division of cells. The relations between the cell structures and the nuclear processes are illustrated by the accompanying diagram (fig. 1).

No organisms have, however, structures built in all the three phases. The relative importance of each phase in the life histories of the different natural groups can also be illustrated by simple diagrams, as shown in figure 2.

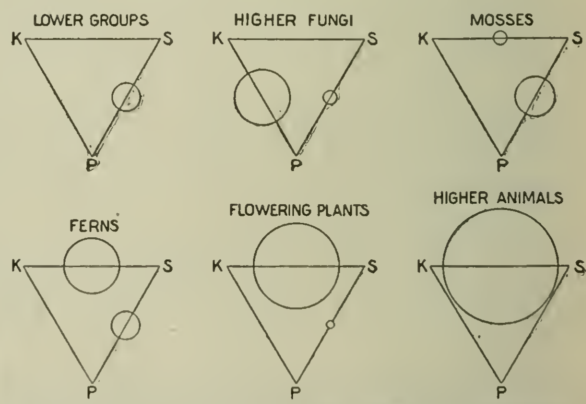

Fig. 2.—Diagram showing the relative importance of the paragamic, apaylogamic, and haplogamic phases in the life history of various groups of organisms.

The relative importance of the different phases in the life history of the various groups of organisms can be represented in another way, as is shown on Plate I. The diagrams on this plate show in addition a network of descent in its simplest form, composed of successive generations linked together at the first stage of conjugation. The generations themselves are seen to be composed of alternating simple and double celled phases in organisms of intermediate evolutionary rank, and finally the double-celled phase is shown to be an expansion of the fertilized egg, which constitutes an increasingly large part of the life history as organisms mount higher in the scale of evolutionary progress.

It is thus easy to understand why the two types of double-celled structures have very unequal possibilities of organization. Two nuclei are evidently better than one, but their association is too slight, apparently, to gain much of the vital stimulus consequent upon the more effective method of conjugation followed by the higher plants, where the chromosomes of two fused nuclei lie in juxtaposition in the new nucleus. The higher organisms have not merely double cells, but, what seems to be vastly more important, compound nuclei, a more advanced and energized stage of the sexual process, which enables them to maintain for exceedingly long periods of time the power of growth and subdivision.[a]

The intercalation of the double-celled structure does not change the order of nuclear events in cross-fertilization, but it may be said to change fundamentally their chronological and physiological relations. The true historical sequence of conjugation is plasmapsis, karyapsis, and synapsis, but the apparent and practical sequence in the higher plants and animals becomes synapsis, plasmapsis, and karyapsis, the synapsis which ends one conjugation being followed closely by the plasmapsis which begins another. The suspension of nuclear changes for vegetative growth no longer occurs between synapsis and plasmapsis, but between karyapsis and synapsis, the double-celled, paragamic structure being built, as already stated, on a new and highly sexual plane, that is, out of cells in a state of prolonged sexual union.

If, as may be supposed, the benefit of synapsis lies in the making of new associations of the ancestral chromatin elements, it is obvious that the bringing of two such newly energized nuclei together would produce a condition which, for want of other words, might be called a multiple vital tension. The double-celled type of structure involves, therefore, not merely a transfer of emphasis to a new part of the life-cycle, but a new and improved sexual process, which raises the biological equation to a higher power. From this standpoint it is obvious that the morphological diversities of sex have a fundamentally important and truly physiological function in building up and maintaining the efficiency of the complex organization of the higher plants and animals. It is as illogical to ascribe the internal diversity of

[a] As noted before, some organisms, such as Caulerpa and Acetabularia, show a considerable degree of evolutionary progress, and have not as a matter of fact attained the cellular type of organization at all; they may, however, be found to have double nuclei and to be very striking examples of the expansion of the fertilized egg.

species to external environmental causes as to arbitrary mechanisms of heredity.

The extent to which the static concept of a normally unchanging heredity has obscured evolutionary thought and investigation could not be better shown, perhaps, than by the fact that, notwithstanding the great multiplicity of terms which have been proposed for all the imagined kinds of variations, no name has been suggested for this normal and necessary intraspecific diversity. The deficiency may be made good by the use of the word *heterism* for the whole group of phenomena, ranging from mere individual diversity to the highest specializations of heterism, exemplified by sexes, castes, and polymorphic conditions. It is true that the members of a species look alike when compared with those of other species, and there may be no harm in ascribing this likeness to heredity, but there is nothing to show that this heredity of general resemblance has anything to do with evolution except as an incidental result. Evolution does not take place between species, but inside of them; it is not an *inter*specific phenomenon, but *intra*specific. Its principal factors are heterism and symbasis, not heredity and environment, as believed by the selectionists, nor heredity and segregation, as supposed by the mutationists.

HEREDITY IN RETICULAR DESCENT.

The greater efficiency of the double nuclei is, however, only one more evidence of the importance of sex as a means of diversity and of bringing diverse protoplasms together. The nuclear network of chromatin which controls the activities of the cell corresponds to the network of descent through which the cell has come into existence. Symbasis, or diversity of descent with normal interbreeding, is the foundation of the strength and vitality of the organism, because it increases the efficiency of the nuclei of the component cells.

Inbreeding or defective fertilization, on the other hand, would cause nuclear deterioration, as so strikingly shown by Maupas in the so-called senile degeneration of ciliate Infusoria induced by keeping them too long without cross-fertilization. This phenomenon is, indeed, closely parallel to senile degeneration, but there is, nevertheless, an important difference. In true senile degeneration the vigor of the cells is declining because of the absence or long postponement of conjugation. In monobasic degeneration, conjugation may take place, but is not effective because of insufficient diversity of descent. Monobasis is the antithesis of symbasis; it means descent without cross-fertilization, on single or very narrow lines. The inevitable result is degeneration, with a rapidity proportional to the closeness of the inbreeding and the complexity of the organisms.

This intimate relation between organic descent and organic structure enables us to understand the phenomena of organic succession without resorting to abstract principles or to hypothetical mechanisms of heredity. The network of descent is, as it were, a map showing the alternative routes of the developing organism, and permitting normally any combination of ancestral characters, as may well result from the endlessly varying arrangements into which the ancestral chromatin elements may fall at the time of synapsis or chromatic fusion. Twins developed from the same ovum would have the same arrangement of chromatin, which accords with their close similarity of form, but otherwise there is unlimited diversity, even among the simultaneous offspring of the same parents. It would seem, therefore, that instead of a mechanism of heredity inside the reproductive cells there is an automatic device for insuring diversity. The higher the organization the more complex the descent, and the greater the variety of nuclear configurations and the resulting individual diversity.

Nevertheless, inheritance is not governed merely by chance, nor limited even to the infinity of nuclear networks to be made by the combinations possible among the ancestral chromatin elements. With the greater vitality of interbred organisms is associated also a stronger heredity or prepotency of the wild or more broadly symbasic types when such are crossed with inbred domesticated varieties. New variations, too, appear to have the same effect as diversity of descent in lending greater vigor and prepotency. Even mutations, or degenerative variations induced by inbreeding, are prepotent on their own plane of symbasis—that is, when crossed only with their own inbred relatives—though they are promptly obliterated or "swamped" when brought into contact with the broadly symbasic wild type, the prepotency of the diverse descent being far greater than that attaching to the inbred variation. It is the prepotency of variations which renders evolution truly kinetic; for the methods of organic descent are such as to bring about a spontaneous change of type. The environment often influences the direction of this vital motion, but is in no proper sense an actuating cause.[a]

Cells are the units of organization, but species, as groups of interbreeding individuals, are the units of evolution. The causes of evolution are not revealed by hypothetical subdivisions of cells into character units or determinate elements, but by ascertaining the methods of descent through which interbreeding maintains organic strength and evolutionary progress. Cells divide themselves, as we know, into other cells, and species into other species, but it is only as cells and as species that their vital, organic, evolutionary activities are accomplished. *Individuals* vary and mutate, but only *species* evolve. To classify the various stages and functions of organisms under general and abstract terms may be desirable, but for evolutionary purposes it

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[a] Cook, O. F. Natural Selection in Kinetic Evolution, Science, n. s., 19: 549. 1904.

is the network of descent which represents the concrete, significant fact, and it is this which can be resolved, if necessary, into its component lines, polygons, or nodes, to furnish units for the calculation of quantitative effects of inheritance, as in Galton's Law of Ancestral Resemblances and Filial Regression, under conditions of normal symbasic descent, or in Mendel's Laws of Disjunction, in hybrids of abnormally inbred varieties.

The recognition of the double character of the cells of the higher plants and animals permits many other phenomena of inheritance to be understood, though it seems to take us farther than ever from the hope of a merely mechanical explanation of the nature of heredity itself. If conjugation were concluded immediately, the well-known phenomena of sterile hybrids would be impossible, the sterility which puts an end to their existence being due, as now known, to the failure to perform synapsis or chromatin fusion. On the other hand, it may be that crosses between narrowly inbred varieties sometimes have the power of passing by the period of synapsis without a true fusion of the parental chromatin, perhaps in a manner corresponding to that in which Thalictrum produces seeds parthenogenetically, by avoiding chromosome reduction. The germ-cells might have a preponderance of chromatin from one parent or the other, or might even be quite unmixed, as claimed for Mendelian hybrids. It is obvious, however, that to explain Mendelism in this manner is to admit the essential abnormality of the phenomenon.

SUMMARY.

It has been held self-evident that there can be nothing in evolution except heredity and environment, and it was a simple deduction from such an aphorism that differences must all be due to environment, since "heredity would, if nothing interfered, keep the descendants perfectly true to the physical characters of their progenitors." Such heredity, however, is a pure figment of the scientific imagination; it is a hypothesis which lends us no aid in understanding the facts of organic succession. A stereotyped heredity could make nothing new; the interbreeding of diverse individuals and the prepotency of new variations are the constructive factors, not heredity and environment.

Symbasis is the method, interbreeding the means, and sexuality the mechanism whereby organic evolution has been accomplished; these are the concrete and efficient causes of the vital motion of species. The association of organisms into species of similar individuals is not brought about by a predetermining hereditary mechanism, but by symbasic interbreeding. The highest organization has not been attained in "asexual generations," but in structures completely and essentially sexual, built wholly of conjugating cells. There has been

no evolution away from sexuality. Long-continued violations of the law of symbasis bring only degeneration.

This interpretation of evolutionary facts opens the way to an adequate physiological explanation of the significance of sex, and affords also a working theory of the chief cytological complications that have arisen as a consequence of sex—complications that have hitherto rendered obscure the nature of the cell-bodies of higher animals and plants.

The external diversity of organic nature and the internal diversity of cells and of reproductive processes take on new and unexpected significance. Both are shown to be consequences of sexual specialization, without which no evolutionary advance beyond simple-cell colonies has been possible. More than this, gradations in the perfections of the higher double-celled structure are correlated with definite stages of evolutionary progress, so that from the structure of an organism its kind of sexuality can be deduced. Evolution becomes, in the new view, a physiological rather than a morphological process, since the methods of descent affect the quality and efficiency of the organism even more promptly and fundamentally than they do its external form.

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PLATE.

6

EXPLANATION OF PLATE.

The circles (○), eights (8), and thetas (⊖) represent in each case the nucleus or nuclei belonging to a cell, and the succession of cell generations is shown by a string of nuclei either simple, in pairs (apaylogamic double cells), or fused (paragamic double cells). The half circles (⌓ ◡) and quadrants (◸ ◹) represent the two cell generations formed during chromosome reduction. The brackets [ ] represent a cell at the period or periods when the organism is reduced to a unicellular condition. All the signs for nuclei could be supposed to be inclosed by a cell wall, which has been omitted for the sake of clearness. For the same reason only the cell lineage leading directly up to the formation of the gametes has been shown, and no account has been taken of the enormous multiplication of cells which occurs not only to build up the bodies of animals and plants but also to form many gametes. Only a few of the numerous cell generations which make up the organisms in question are shown.

EXPLANATION OF SIGNS.

P	Plasmapsis—fusion of the cytoplasm, or unspecialized protoplasm.
K	Karyapsis—fusion of the nuclei, or nuclear protoplasm.
Ⓢ	Synapsis—fusion of the chromatin elements.
	Heterotypic and homotypic divisions following synapsis.
OOOO	Nuclei of haplogamic phase—structures composed of simple cells having nuclei and chromatin elements completely fused.
8888	Nuclei of apaylogamic phase—structures composed of double cells, each having two unfused nuclei.
⊖⊖⊖	Nuclei of paragamic phase—structures composed of double cells having single nuclei containing unfused chromosomes.
[ ]	Cell, at periods where the organism is reduced to a single cell.
	The expanded egg.

EXPLANATION OF FIGURES.

Fig. 1.—Lower organism, such as Sphæroplea, having only simple-celled (haplogamic) tissues. The fertilized egg undergoes no development beyond merely splitting up into four spores when it germinates.

Fig. 2.—Higher fungus, such as Agaricus or Puccinia, showing alternation of simple-celled and double-celled phases, the latter apaylogamic, i. e., with two unfused parental nuclei in each cell. The fertilized egg has expanded into a mass of apaylogamic tissue.

Fig. 3.—Moss, showing alternation of a long simple-celled and a short double-celled phase, the latter paragamic, i. e., with parental nuclei fused but with their chromosomes still distinct and unfused. The fertilized egg has expanded slightly into a mass of paragamic tissue.

Fig. 4.—Fern, showing alternating phases as in moss (figure 3), but with a short simple-celled phase and a long double-celled phase, the paragamic phase having developed at the expense of the haplogamic. The fertilized egg has expanded very much into a mass of paragamic tissue.

Fig. 5.—Flowering plant (phanerogam), showing alternation of a very short simple-celled phase with a very long double-celled phase, the paragamic phase having developed greatly at the expense of the haplogamic. The egg mother-cell develops only one cell (macrospore). The fertilized egg expands into a large mass of paragamic tissue in which the greatly reduced haplogamic phase develops in a semiparasitic manner, it having no free existence.

Fig. 6.—Higher animal, having only double-celled tissues, the haplogamic phase having been completely suppressed by the greatly expanded paragamic phase. The egg mother-cell develops only one egg. The fertilized egg has expanded into a large mass of tissue.

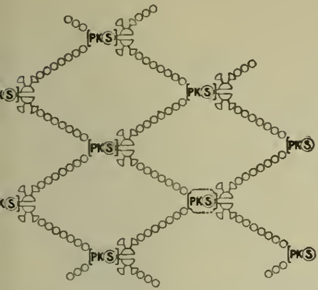


FIG. I.—LOWER ORGANISM.

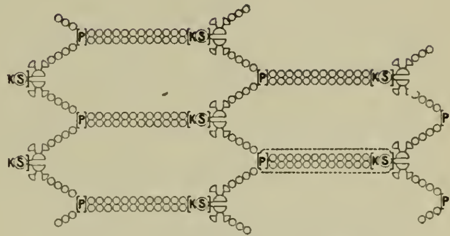


FIG. 2. HIGHER FUNGUS.

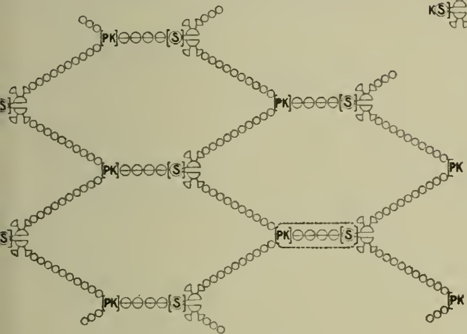


FIG. 3.—MOSS.

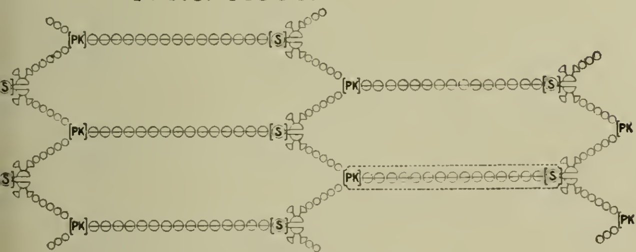


FIG. 4.—FERN.

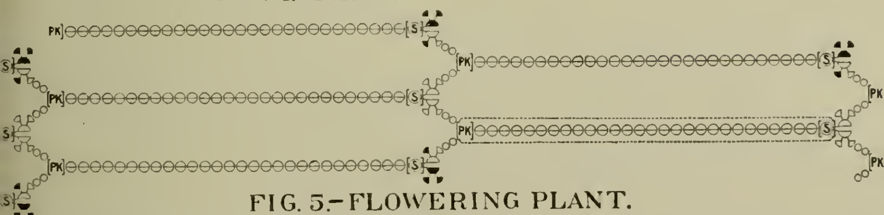


FIG. 5.—FLOWERING PLANT.

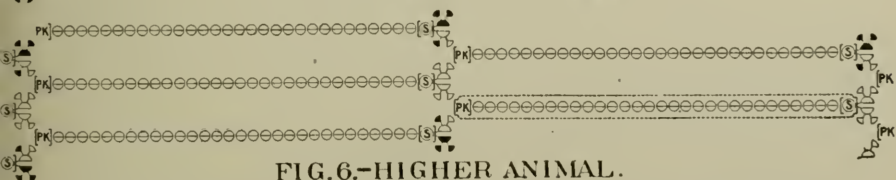
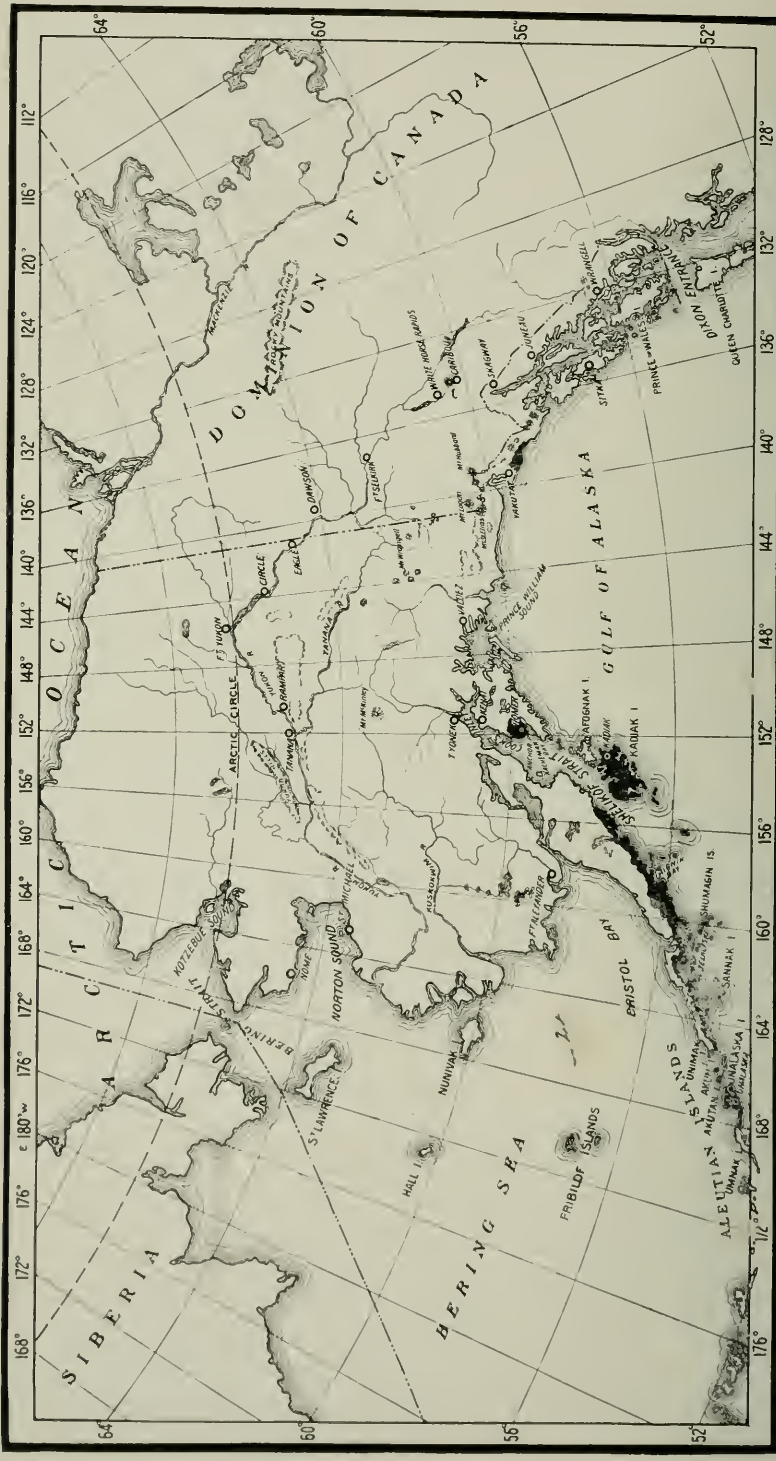


FIG. 6.—HIGHER ANIMAL.

DIAGRAM ILLUSTRATING THE NETWORK OF DESCENT, SUCCESSION OF GENERATIONS, ALTERNATING PHASES, AND EXPANSION OF THE FERTILIZED EGG.

A



Map of Alaska.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 82.

B. T. GALLOWAY, *Chief of Bureau.*

GRASS LANDS OF THE SOUTH ALASKA COAST.

BY

C. V. PIPER,

AGROSTOLOGIST IN CHARGE OF FORAGE PLANT INTRODUCTION.

GRASS AND FORAGE PLANT INVESTIGATIONS.

ISSUED AUGUST 22, 1905.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1905.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 19, 1905.

Sir: I have the honor to transmit herewith a paper entitled "Grass Lands of the South Alaska Coast," and to recommend that it be published as Bulletin No. 82 of the series of this Bureau.

This paper was prepared by Mr. C. V. Piper, Agrostologist in Charge of Introduction of Grasses and Forage Plants, Grass and Forage Plant Investigations, and has been submitted by the Agrostologist with a view to publication.

The four plates accompanying the paper are necessary to a proper understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

Since the discovery of gold in Alaska in 1897 continuous calls for information concerning the agricultural possibilities of the Alaska Peninsula have come to the Department of Agriculture. Much valuable information on this topic has been secured by the Office of Experiment Stations largely through the Alaska experiment stations at Sitka, Kenai, and Copper Center in charge of Prof. C. C. Georgeson, but as the work of these experiment stations was necessarily largely local in character, and as it was highly desirable to study conditions in sections remote from the stations, the Office of Experiment Stations requested the Bureau of Plant Industry to send some one to explore as large an area of the Alaskan country as might be feasible. Accordingly Prof. C. V. Piper, of the Office of Grass and Forage Plant Investigations, was detailed to make this exploration under the joint auspices of the Office of Experiment Stations and the Bureau of Plant Industry. The summer of 1904 was spent in this work. The area explored is shown in black on the map constituting Plate I. Many interesting facts relating to agricultural possibilities in the region covered were recorded, and Professor Piper discusses them in the following pages in detail.

For further information concerning the results of this exploration the reader is referred to the Annual Report of the Office of Experiment Stations for the year 1904.

W. J. Spillman, *Agrostologist*.

Office of Grass and Forage Plant Investigations,
Washington, D. C., April 14, 1905.

CONTENTS.

ILLUSTRATIONS.

GRASS LANDS OF THE SOUTH ALASKA COAST.

INTRODUCTION.

A glance at the accompanying map of Alaska (Pl. I) will show that the coast line beginning at Dixon Entrance, in longitude 132°, latitude 54° 30′, and extending to Unalaska, in longitude 166° and latitude 54°, is nearly in the form of a semicircle, or, rather, of a half ellipse, the east and west diameter of which would be about 2,000 miles and the north and south diameter about half this distance. Near the northernmost part of this coast line are two large inlets, the eastern one Prince William Sound, the western one Cook Inlet. It will be further noticed that islands are very numerous on the coast and that the coast line is much indented by narrow inlets or fiords, a fact better shown on larger maps. The principal places mentioned in this paper are likewise indicated on the map. Officially, the region from Mount Saint Elias eastward is known as southeastern Alaska, that west of this peak as southwestern Alaska. From an agricultural standpoint, however, there is a much better and very marked dividing line. From Cook Inlet eastward practically all of the lands lying near the coast are densely timbered up to an altitude of 2,000 to 3,000 feet. From Cook Inlet westward, excepting Afognak Island and a small portion of Kadiak Island, the lands are devoid of timber, and are for the most part grass covered.

The total area of the coast grass lands is about 10,000 square miles, nearly all of which lies between Cook Inlet and Unalaska, a distance of about 700 miles. At least one-half of this land would seem capable, in time at least, of profitable utilization. From various causes it has remained until now practically unused.

South Alaska is a mountainous country, a great range of snow-capped peaks on the mainland paralleling the entire coast. Eastward from Cook Inlet great numbers of glaciers arise in the higher mountains, and many of these rivers of ice extend downward to the sea. Westward from Cook Inlet no glaciers reach the sea, although many of the mountain peaks are from 5,000 to 8,000 feet high. This striking difference apparently depends on a much smaller annual rainfall and snowfall.

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In general the lands are hilly, sometimes rising abruptly from the seashore, but seldom too steep to afford a luxuriant grass covering. More often, however, the hills near the coast are low and rounded, with intervening valleys. In places there are wide areas contiguous to the coast of from 100 to 1,000 feet elevation and comparatively level. Most of the smaller islands, too, have comparatively gentle slopes, and either are under 1,000 feet elevation or have but few hills reaching above that height. The coast line everywhere is indented by numerous bays or inlets, into many of which rivers flow. At the heads of these bays there are, as a rule, considerable areas of flat or nearly flat lands. Such locations naturally afford the most advantageous sites for agricultural settlements, especially as these flat lands are exceedingly well grassed, and with little preliminary labor can be prepared for mowing.

Where the land is level it is very likely to be wet and covered with a growth of peat moss. Under such circumstances it supports but a scanty vegetation. Even on the hillsides this peat moss may become established, and where it does so the grasses quickly become less luxuriant. The decay of this moss and of other vegetation results in the formation of a humous soil, very retentive of moisture. So deep does this humus become that the real soil is often entirely concealed. Where it is possible to destroy this moss by burning, the result is always a heavy crop of grass or other plants. Most of the land that lies at less than 1,000 feet elevation is covered by a most luxuriant growth of native grasses. Over large areas these grasses are frequently 6 feet high, thus furnishing a large quantity of fodder. On the remaining areas, lying at higher elevations or on exposed slopes, the grasses are too short to cut for hay, but furnish splendid grazing.

That grass in Alaska is exceedingly abundant and fairly nutritious and that cattle will thrive upon it are facts beyond question. But these facts in themselves are not sufficient to enable a prospective settler thinking of engaging in stock raising to determine whether or not such a venture would be likely to prove profitable. The mere abundance of grass of fair quality is not sufficient to insure success in stock raising in an isolated region like that under consideration.

The following statements regarding the Alaska grass lands and the factors that have a bearing on their profitable utilization are based on as complete a survey as one season's work would permit, together with the facts previously recorded by reliable authorities. A detailed report of the conditions actually observed will appear in the Annual Report of the Office of Experiment Stations for 1904. The present bulletin designs rather to cite these facts in their bearing upon the south Alaska grass lands as a desirable field for stock raising.

THE LOCATION OF THE GRASS LANDS.

The accompanying map (Pl. I) indicates the general location of the southern Alaska areas which are covered with grasses. These areas differ considerably in detail and are here discussed separately.

KADIAK ISLAND.

Kadiak Island, which lies off the mouth of Cook Inlet, is about 100 miles long by 50 miles wide. It is mountainous in character, the hills rising more or less gently from near the seashore to heights of 1,000 to 3,000 feet. At the end of July, 1904, there was still considerable snow at 2,000 feet (Pl. IV), but this is said to be quite unusual. This island, like most of the Alaska coast, is much cut into by long, narrow bays, into most of which flow streams. The flat lands lying at the deltas of these streams are, as a rule, very heavily covered with grasses (Pl. II). The slopes also, up to an altitude of 1,500 feet, are well grassed, except where there are thickets of alder or willow; but these slopes are usually too steep to utilize otherwise than by grazing. The total area of these hillside lands is much greater than that of the approximately level stretches, in the proportion of at least 20 to 1.

On the hillsides the principal grass is bluetop (*Calamagrostis langsdorfii*), which often covers large areas in a pure growth. This was exceedingly fine on hillsides burned over in March, by which means the old straw and moss were destroyed, thus permitting better drainage and making the soil warmer. In such places this grass is often 6 feet high. On the contrary, if the hills are burned over in June the fire is likely to kill the grass roots as well as the moss, with the result that fireweed usually takes possession of the ground.

Other grasses than bluetop on the hillsides are relatively unimportant, though sometimes considerable areas of Siberian fescue occur, and on the higher slopes are a number of low grasses of forage value.

On the flat lands before mentioned the tall beach sedge (*Carex cryptocarpa*) forms a broad fringe along the shores of the bays and sloughs, especially on lands which are occasionally covered by tide water. Back of this sedge, beach rye (*Elymus mollis*) forms a more or less broad zone, often mixed with patches of a coarse bluegrass (*Poa glumaris*). In the still drier portions bluetop occupies the ground almost exclusively. The three plants mentioned furnish the great bulk of forage on Kadiak Island, and indeed on most parts of the Alaskan coast, but the bluetop is more abundant than all of the other grasses combined.

Bluetop has slender stems and thin leaves, thus curing very readily and making a sweet and palatable hay. Beach rye, on the contrary, has thick stems and thick leaves, in consequence of which it cures slowly. Beach sedge has a three-sided, solid, pithy stem, and is therefore very difficult to dry. All three of these plants grow so luxuriantly that they often yield 3 tons of hay or more per acre.

Of forage plants other than grasses the lupine and fireweed, hereafter described, are both abundant. In a green state they are readily eaten by sheep, but cattle prefer the grasses.

In portions of the island which have been more or less closely grazed for some years it was noticeable that the taller wild grasses had largely disappeared, being replaced principally by bluegrass (*Poa pratensis*) and wild barley (*Hordeum boreale*). Cattle seem to be much more fond of the former than of the latter grass, although in parts of northern Europe the wild barley is considered a most excellent grass.

All of Kadiak Island, except a small portion in the extreme northeast, is practically timberless, as are most of the adjacent islands. In the valleys, however, there is usually a small number of cottonwoods and willows, and on wet slopes scrub willows and alders form dense thickets. Afognak Island, however, which lies northeast of Kadiak, is quite densely covered with spruce.

ALASKA PENINSULA AND ADJACENT ISLANDS.

The whole region to the west of Kadiak Island might briefly be described as similar to that island, but entirely deviod of timber, the shrubs being more scrubby and the grasses less luxuriant. The peninsula itself is very mountainous, and for considerable stretches along the coast the hills rise abruptly from the water's edge. In the bays and inlets, however, there are frequently considerable areas of comparatively level lands well grassed, though seldom as luxuriantly covered as those before mentioned. The islands lying off the coast are comparatively low, and some of them are said to be exceedingly well adapted to stock raising. Such areas as were examined indicate that in general there is a greater variety of forage grasses than to the eastward, but most of them are smaller in size.

At the present time there is a mail steamer plying once a month between Valdez and Unalaska. This boat carries the mail, and stops at such points as business demands. The population of this entire region is exceedingly sparse, and many of the outlying islands would probably have to be reached by means of sailing craft.

UNALASKA AND THE NEIGHBORING ISLANDS.

Unalaska and the neighboring islands differ on the whole comparatively little from Kadiak Island, though the vegetation as a rule is decidedly less luxuriant. The grasses are much the same in kind, although differing in their relative abundance. Some difficulty would be experienced on these islands in finding sufficient tall grass to furnish winter fodder in case large quantities were necessary, though in some of the more sheltered valleys small areas were observed where the grasses were very tall. There is quite a herd of cattle at Unalaska which, according to local reports, receive but very slight attention during the winter, only a small quantity of feed being cut for them. The principal advantage of Unalaska and the neighboring islands would seem to lie in the fact that they are on the line of travel of the vessels going to the Yukon and to Nome. If sufficient numbers of cattle were raised on these islands, doubtless little difficulty would be experienced in finding a market for them at the above-mentioned points. Indeed, a Seattle company, which purposes, among other things, to engage in cattle raising primarily for these northern markets, has already begun operations on Akun Island.

KENAI PENINSULA.

Kenai is the name given to the large peninsula lying between Cook Inlet and the Gulf of Alaska. That portion of it on the east side of Cook Inlet and north of Kachemak Bay, comprising an area 100 miles long by 20 to 30 miles wide, is an extensive plateau. Its southern portion, on Kachemak Bay, lies 500 to 1,000 feet or more above the sea level. It slopes mainly to the westward, so that that part from Anchor Point northward is but 100 to 200 feet above the sea level. Most of this land is timbered with spruce, but there are considerable areas of grass near Anchor Point, near Homer, and on the north side of Kachemak Bay.

At Homer there is an extensive sand spit, about 4 miles in length and from one-fourth to 1 mile across, which supports a good growth of several grasses and sedges. Beach rye is the most important and most abundant, but red fescue, bluegrass, and seashore grass furnish considerable grazing. At the base of the spit the land rises gradually to the high plateau above, the scattered timber giving the appearance of mountain parks. The open portions of this land support a luxuriant growth of bluetop, often 6 feet tall. At a rough estimate the open grass lands in this vicinity comprise about 2,000 acres.

The site of a proposed Finnish colony is on the north side of Kachemak Bay, not far from its head. From the colony site to the head of the bay are extensive tide flats, which are mainly covered with sedges about 2 feet high. The marshy nature of these lands, together with the coarse nature of the forage, makes them of but limited value. Undoubtedly they can be much improved by diking.

The grass lands of the colony site proper consist of about 500 acres of excellent land, covered with a luxuriant growth of bluetop. These lands lie close to the seashore and less than 100 feet above it. Back of these lands are hills 500 to 1,500 feet high, the plateau on the top of which consists in part of extensive grass areas. Much of this grass is bluetop, often 6 feet high. Other areas are pure growths of Siberian fescue. Interspersed with these are several other good grasses, but none of them in great quantity. These plateau grass lands are apparently very extensive. To render them accessible will, however, require the building of roads or trails up to the easiest slopes. At Anchor Point there is but little grass land near the seashore, but on the plateau behind are considerable areas much like those just described. The plateau at this point is, however, much lower.

An important circumstance in relation to all of the grass lands of this region lies in the fact that they are underlaid with coal, which is exposed for miles in the bluffs along the coast. In view of this fact it is doubtful if title to the land can be gained by homesteading it.

At Kenai there are no naturally grassed lands, except the sand dunes along the beach and the marshes lying inside of them. The dunes are covered principally with beach rye and bighead sedge (*Carex macrocephala*). In the brackish marshes red fescue and seashore grass are plentiful. Here also is found poison parsnip (*Cicuta douglasii*) in small marshes, and there is a record of some native cows having been killed by it several years ago.

THE YAKUTAT PLAINS.

The only extensive areas of grass lands known in southeastern Alaska are those lying in the river valleys near the coast south of Yakutat. Inasmuch as these lands have been several times referred to in reports, and as they are now in part accessible owing to the building of the Yakutat and Southern Railway, a careful examination was made of them. The above-mentioned railway has been built primarily to reach the several rich salmon streams flowing into the ocean south of Yakutat, it being impracticable to fish them by approach from the ocean. This railway is projected to be built to the Alsek River, a distance of 45 miles. At present it is built only to the Setuck River, 10 miles from Yakutat.

Practically the whole of this region is an old glacial moraine, composed of fine gravel, which slopes very gently to the seashore. The land close to the seashore is somewhat higher than that lying behind, and is heavily timbered. Owing to this strip of higher land most of the streams flow parallel to the coast for some distance near their debouchments. It is along the valleys of these streams that the grass lands lie, but owing to the flatness of the land and the slight elevation above the sea level they are very ill-drained, notwithstanding the gravelly nature of the soil.

Traveling along these rivers in a canoe one receives the impression that the grass is tall and rank on these flat lands. This, in fact, is the case on a very narrow strip just along the river banks, where there is a fine growth of bluetop (*Calamagrostis langsdorfii*) and sedge (*Carex sitchensis* Presc.). This strip of tall grass is, however, nearly always confined to the immediate banks of the rivers. The great mass of the land is covered with a thin layer of bog moss, which supports but a scant vegetation of grass and sedges less than a foot high.

It is a conservative statement to say that fully 80 per cent of these Yakutat grass lands are thus scantily grassed. Apart from this scant amount of grass, which practically precludes the cutting of winter forage, another serious difficulty presents itself in the fact that poison parsnip (*Cicuta douglasii*) occurs quite plentifully over all the land that is the least boggy, which, as before stated, is 80 per cent of the area. Thus, even if these meadows were used only for grazing, great care would need to be exercised in the spring, when grass is scanty and the sweet but very poisonous tubers of this plant are frequently forced to the surface by the frost.

While the above statements are true concerning the Yakutat meadows as a whole, there are small areas which are exceptional. For example, along the lower Ankow River occurs a narrow strip of several hundred acres well grassed with silver-top (*Deschampsia cæspitosa*) and beach rye (*Elymus mollis*) and free from Cicuta. Care would need to be exercised in utilizing even this, as the surrounding boggy lands bear an abundance of poison parsnip.

Again, the strip of land lying just within the ocean dunes is often well grassed with beach rye and red fescue (*Festuca rubra*).

A particularly good area of arable land lies along the railway where it reaches the Setuck River. This consists of 3 or 4 square miles of gravelly, well-drained, level land, at present looking much like a worn-out meadow. It is apparently very well adapted to such cultivated grasses as smooth brome-grass and tall meadow oat-grass. It will undoubtedly grow all sorts of hardy vegetables. The present grass covering is rather scanty, but it is probable that this can be greatly increased by cultivation. This particular piece of land is well worthy of the attention of homesteaders.

It is within the bounds of possibility that the larger part of the Yakutat plain can be drained and made into fine meadow lands. In its present state, however, this land is not adapted to stock raising, with the exception of such small areas as above noted.

IMPORTANT FACTORS RELATING TO THE AGRICULTURAL VALUE OF THE GRASS LANDS.

In determining whether or not the grass lands previously described offer a desirable field for settlement, a number of factors that bear more or less directly upon the problem need consideration. These factors may be discussed in the following sequence:

(1) The abundance and permanence of the feeds available.
(2) The possibility of raising forage on cultivated lands.
(3) The known facts in regard to live-stock raising.
(4) The available markets.
(5) Transportation facilities and freight rates.
(6) The desirability of south Alaska as a home.
(7) The choice of a location

THE ABUNDANCE AND PERMANENCE OF NATIVE FODDER PLANTS.

Live-stock husbandry in Alaska will have to depend primarily upon the native plants, supplemented in time, perhaps, by such additional ones as experiments shall indicate may compete with the native plants, or which upon cultivated land will yield heavily enough to be profitable. The most important and abundant of the native forage plants are as follows:

Bluetop.—Bluetop (*Calamagrostis langsdorfii*) is by far the most plentiful tall grass in Alaska, growing along the whole coast. On Kadiak Island and the Kenai Peninsula it is especially abundant, often being 6 feet high and very dense (Pl. III). It grows with special luxuriance on hillsides that have been burned over early in the spring. This burning destroys the moss, and thus makes the soil better drained and warmer. Bluetop also flourishes on the level boggy lands, but prefers a well-drained soil. Owing to its thin stems and leaves it cures very readily, and is therefore the usual hay grass of Alaska. It is often called redtop, but this name should be restricted to the true redtop, a very different grass.

There are no accurate data bearing on the point as to how well this grass will withstand continued cutting, but the general belief is that it rapidly becomes thinner in stand. It is noticeable about villages where cows are kept that the bluetop is scarce, being replaced by other grasses, especially bluegrass and wild barley. The area of bluetop is so great, however, that in many places it would be quite practicable to manage so as not to cut the same plats two years in succession, which practice would probably maintain the density of the stand.

Beach rye.—Along all the quiet shores and inlets of Alaska, wherever there is low land near the beach, there is a strip of beach rye (*Elymus mollis*) occurring just above high-tide level. Sometimes this strip is only a few feet wide, but on the low level lands near the heads of fiords there are often large areas of it 3 to 5 feet high (Pl. II, fig. 2). One patch of it examined had been cut the year previous, and on this the stand was scarcely half as dense as on neighboring pieces which had not been cut. This observation accords with the experience of others.

Where sand dunes occur on the coast, as at Kenai and near Yakutat, beach rye is an important sand binder. In such locations it is often very different in appearance from that found in other situations, the heads being short and thick. This is the result of infestation by a parasitic worm.

Bluegrass.—The true Kentucky bluegrass (*Poa pratensis*) is common all along the Alaska coast, where it thrives to perfection. It shows a tendency to occupy the ground where closely grazed, and cattle exhibit a marked preference for it. Several closely allied species also occur, and it is an important fact that they persist and increase where other grasses disappear, which seems to insure the permanence of pasturage of a high quality.

Silver-top.—The very nutritious grasses known as silver-top (*Deschampsia cæspitosa* and *D. bottnica*) occur in some abundance, especially in gravelly soils, whether on the hillsides or near the seashore. Owing to their stems being nearly leafless they yield but little hay, but the numerous fine basal leaves furnish most excellent forage.

Siberian fescue.—Siberian fescue (*Festuca altaica*) makes large tussocks, especially in gravelly soil and in open timber up to 1,000 feet elevation. In such locations it often makes a nearly pure growth It seems to be fully as nutritious as the well-known sheep fescue, but is a much larger grass.

Sedges.—Two tall species of sedge, *Carex cryptocarpa* and *C. sitchensis*, in places make dense stands 3 feet high or more, especially in wet soil; in the case of the former, more especially in tidal marshes. Considerable quantities of this sedge were cut for hay near Kadiak, and it is said to furnish excellent feed. These sedges are both quite smooth and soft, unlike most others.

Alaska lupine.—The blue-flowered plant known as Alaska lupine (*Lupinus unalaschensis*) is quite tall, often 3 feet high, and sometimes occupies large areas almost to the exclusion of other plants. It is thick leaved and rather fleshy, and is the only leguminous plant that is really abundant in Alaska. Sheep eat it readily. Should it prove palatable as well as nutritious to cattle the problem of a good winter ration for milch cows would be considerably simplified. Experiments with it as silage, both pure and mixed with grass, are much to be desired.

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With the exception of this plant the only legumes of forage value in the grass regions are two species of wild pea, both of which, unfortunately, are rather scarce.

Fireweed.—The well-known plant called fireweed (*Epilobium angustifolium*) often occupies the ground to the exclusion of others, especially where the land has been burned over in summer and the grass roots thus destroyed. Sheep seem fond of it. It is possible that this plant may prove profitable as silage, at least when mixed with grasses, but no tests with this end in view seem to have been made. Its great abundance at times makes such a test desirable.

There are three possible ways of preserving the above-mentioned plants for winter feed. The more easily dried—as bluetop and bluegrass—may be made into hay. Continued sunshiny weather on the Alaska coast is not to be depended upon, so that haymaking is accomplished only with much uncertainty. Where one needs but a small amount of fodder, little difficulty is experienced in selecting the few necessary sunshiny days. Where, on the contrary, one needs great quantities of winter feed, haymaking is impracticable. Resort in such cases must be had either to brown hay or to silage. Brown hay is simply half-cured hay, made by stacking the grass green or half dry—really a compromise between hay and silage. Sometimes salt is scattered over the layers while it is being stacked. It is more or less used in all countries where haymaking is difficult. While analyses show it to contain practically as much nutriment as hay or silage, cattle are not eager for it, and it can be considered only an emergency feed.

Unquestionably when large quantities of winter forage are needed for stock, silage must be depended upon, and undoubtedly, all things considered, it will be the most satisfactory feed. Practically the only Alaska forage plant thus far used as silage is beach rye, and the experiences with this plant of Prof. C. C. Georgeson, special agent in charge of the Alaska Agricultural Experiment Stations, and of others who have grown it, show it to be both palatable and nutritious. In all probability other Alaskan grasses, and perhaps other plants, will be found to be quite as satisfactory.

Where timber is available silos may be constructed of logs, like the one at the Sitka Experiment Station. This silo has the advantage of enabling a man to utilize his own labor. On the other hand, the material for stave silos can be secured at very reasonable prices, and this doubtless is the best silo to use in the timberless regions.

FOOD VALUE OF NATIVE ALASKAN GRASSES.

Chemical analyses have been made of the principal Alaskan grasses, and while these can be properly interpreted only in connection with digestion experiments, their comparison with the analyses of standard grasses furnishes some measure of their value.

Analyses of Alaskan grasses (air-dried samples taken when in flower).

Species.	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Calamagrostis langsdorfii (Bluetop)	7.18	4.58	1.03	40.37	42.94	3.90
Carex cryptocarpa (Sedge)	5.85	10.32	2.12	45.34	25.72	10.65
Elymus mollis (Beach rye)	11.92	12.71	2.26	35.29	30.31	7.51
Phleum pratense (Timothy)	8.59	8.94	2.14	45.69	30.06	4.58
Poa pratensis (Bluegrass)	8.11	8.94	2.04	41.45	34.24	5.22
Deschampsia bottnica (Silver-top)	8.75	7.44	2.07	47.05	31.54	4.15
Calamagrostis aleutica	8.33	10.00	1.37	37.89	38.89	4.52

Analyses of standard grasses for comparison.

Species.	Water.	Protein.	Fat.	Nitrogen-free extract.	Crude fiber.	Ash.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Poa pratensis (Bluegrass)	17.44	10.80	3.45	46.10	22.09	7.35
Agrostis alba (Redtop)	14.30	8.48	2.84	46.77	21.71	5.90
Phleum pratense (Timothy)	15.01	6.01	3.01	41.90	29.59	4.48
Dactylis glomerata (Orchard grass)	14.30	7.34	2.28	47.08	23.58	5.42
Deschampsia cæspitosa (Silver-top)	14.30	9.04	1.06	37.20	29.03	9.37
Calamagrostis canadensis (Bluejoint)	6.87	11.19	3.45	35.82	37.18	5.49

The analyses of the Alaskan grasses were all made by the Bureau of Chemistry of the Department of Argiculture, and with the exception of the first three, from material collected in 1904, were originally published in Bulletin No. 48, Office of Experiment Stations. The other analyses have been compiled from various authorities.

CULTIVABLE FORAGE CROPS.

The experiences of a number of individual investigators, as well as the tests made at the Sitka and Kenai experiment stations, throw a good deal of light on the possibility of growing fodder plants and forage crops on cultivated land. Much more testing is necessary, however, before some of the conclusions which at present seem probable can be considered demonstrated.

In the way of grasses the tests made at Sitka by Professor Georgeson on muck soils showed tall meadow oat-grass to be the most promising. Tall fescue, bluegrass, meadow foxtail, and redtop did fairly well, while orchard grass, timothy, and Italian rye-grass were not promising. From observations on a number of these and other grasses introduced by chance, some rather definite conclusions may be drawn. Timothy is more or less abundantly introduced at various places on the coast, but does not as a rule thrive very well, being often inferior in size to the native mountain timothy. It is altogether probable, however, that a variety of timothy suited to the conditions might readily be secured by selection, as chance specimens of the plant seen were very fine. The success of such a selection, however, will largely depend on the possibility of growing seed in Alaska.

Among other useful grasses that have become accidentally introduced and show marked adaptability to the conditions are redtop, rough-stalk meadow grass, bluegrass, and fowl meadow grass.

White clover thrives everywhere along the coast and is an aggressive plant. Red clover and alsike are not promising and alfalfa does not thrive.

In the way of cereals, the earliest varieties of oats and barley will mature for two or possibly three out of five seasons. Of course, such a crop is not entirely lost if the grain fails to mature, as it can be utilized as hay or silage. On this account it will probably be wisest to grow the crop mixed with field peas, as such a mixture will make excellent silage, whereas oats alone could only be preserved as hay, a difficult thing to do so late in the season. It is to be clearly understood that under present conditions it is unnecessary to plant any cultivated ground in such crops as grass, or perhaps even legumes. The above facts are of value simply as indicating what well-known forage plants will thrive, thus to some extent showing the future agricultural possibilities of Alaska.

SILAGE ALONE AS A RATION FOR MILCH COWS.

The writer has been unable to find any published data on results obtained by feeding milch cows nothing but grass silage. Presumably the best of results would not thus be obtained.

In order to obtain some light on the subject, Dr. James Withycombe, director of the Oregon Experiment Station, was requested to conduct such a test. The results of his experiment are reported as follows:

The silage test was made on a nonbreeding Jersey cow which freshened in February, 1902. In January, 1904, this cow was fed largely on silage, with a moderate amount of mill feed and light ration of hay as a preliminary preparation. From February 1 to April 30 she was fed wholly on corn silage and a light ration of ground oats daily. She consumed during the ninety days' feeding 3,785 pounds of corn silage and 270 pounds of the oat chop. The following table shows variation in weight and her production:

Date.	Weight.	Milk.	Average test.	Fat.	Date.	Weight.	Milk.	Average test.	Fat.
	Lbs.	*Lbs.*	*P. ct.*	*Lbs.*		*Lbs.*	*Lbs.*	*P. ct.*	*Lbs.*
December 1	955	196	5.8	11.36	March 1	925	195	5.8	11.31
January 1	945	199	5.9	11.74	April 1	890	221	5.5	12.15
February 1	905	178	5.7	10.15	April 30	860			

The cow was in good condition at the close of the experiment, which indicates that silage may with safety constitute a large portion of the ration of a dairy cow.

This experiment was undertaken at the suggestion of the Government agrostologist to determine in a measure if it were practicable to winter cattle in Alaska on grass silage.

The 3 pounds of ground oats were fed daily for the purpose of bringing the corn silage up to a protein standard equaling that of mixed-grass silage.

Protein percentage of feed consumed.

Ground oats	11.56
Corn silage	1.58
Protein percentage of grass silage (approximately)	2.72

Average amount of total protein consumed daily in 42 pounds of corn silage and 3 pounds of ground oats, 1.01 pounds. Approximate amount of protein contained in 40 pounds of grass silage, 1.08 pounds.

It will thus be seen that this test indicates that cattle can be successfully wintered on grass silage and that dairy cows may be expected to yield a reasonable amount of milk when fed exclusively on this feed.

ALASKAN EXPERIENCE IN STOCK RAISING.

Hogs.—A few hogs were seen at various Alaska villages. They are fed refuse, and graze on various succulent plants when obtainable. They are very fond of wild rice, the bulb of a lilylike plant (*Fritillaria kamtschatica*), which, however, is not very abundant. Unfortunately these animals are prone to feed on fish offal and other sea refuse, and as a consequence their flesh has a disagreeable flavor. Unquestionably there is too little feed adapted to hogs to make their raising profitable in Alaska.

Goats.—Angora goats have been tested by the Alaska Commercial Company at Kadiak and by Rev. C. P. Coe at Wood Island. According to Mr. Washburn, formerly resident superintendent of the Alaska Commercial Company at Kadiak, the company had a few years ago about 50 head of these animals on Ukamak Island, near Kadiak, which were entirely self-sustaining, increasing about 60 per cent each year. The mohair is said to have been good, both in quantity and quality.

Rev. C. P. Coe, of Wood Island, has several head of Angora goats which have passed the last two winters with but little care. This year his herd has shown very satisfactory increase, and no difficulty is anticipated in wintering the kids. A large part of their feed is derived from willows and other browse, and where this is abundant the animals need but little feed in winter. Owing to their tractability and the ease with which they are kept, especially where browse is abundant, Angora goats should prove most useful animals both for the natives and for whites.

Sheep husbandry.—Two definite attempts have been made to establish sheep raising in south Alaska, though small numbers have been kept at various points for short periods. The first attempt was made by the Alaska Commercial Company, which in 1883 imported a band of about 300 sheep from California. Unfortunately no accurate record of this experiment is available, and the accounts of various persons differ considerably. Many of the sheep died the first winter, according to some reports from lack of shelter, according to others from scab. The remainder were kept on a small island near Kadiak, where the only shelter was a small grove of spruce, but in winter they were usually transferred to new grazing grounds where they could feed on the tall, dry grass. In very severe weather they were sometimes sheltered and fed hay. These sheep are said to have yielded about 5 pounds of excellent wool per head each year, and the annual increase is reported to have been about 60 per cent of the adult animals. No particular care was given them, and the last were slaughtered about six years ago. The venture, even excluding the loss of the first winter, seems not to have been profitable.

The only sheep now in Alaska are on the ranch of the Frye-Bruhn Company, near Kadiak, who have about 80 head. These sheep are the remnant of 9,000 which were shipped in from Oregon in 1902 and 1903, the remainder having perished. At first sight it would seem that this appalling loss of more than 98 per cent was conclusive evidence that sheep raising in Alaska is not likely to prove profitable. Inquiry into the causes of the mortality do not bear out this conclusion necessarily. About 500 of the sheep were drowned in March, 1903, by being caught at the head of a narrow cove by the incoming tide. One hundred and fifty head were lost by becoming frightened and jumping over cliffs. The rest of those that died succumbed to scab, which broke out in January, 1903. Owing to lack of shelter it was then impossible to treat them by dipping, as that would practically have been equivalent to killing them. The result was that all but 80 died of the disease. Thus all the mortality was due to causes entirely preventable. It was interesting to learn that several head of these sheep which ran wild survived the winter without care, and the writer was informed by trustworthy witnesses of other cases of this kind. In the light of present knowledge it is difficult to say whether sheep can be profitably raised in southwestern Alaska.

In regard to the two attempts which have been made, it is noteworthy that in both instances the animals were shipped from a comparatively warm and dry climate to one cool and notably wet; furthermore, that none of them perished from any cause directly connected with the Alaska conditions.

There are, however, some further difficulties in connection with sheep raising in Alaska which need careful consideration. It is the general opinion in Kadiak that in an ordinary winter sheep can not safely be left without care after the beginning of January. Indeed, many would place the time a month or six weeks earlier. New grass never appears before May 15, and often not until June 1. Therefore, under the best of conditions, sheep will need four and a half months of feeding and shelter. The superintendent of the Frye-Bruhn ranch, after one winter's experience, thinks that feed and shelter should be given for a longer period than that mentioned.

Another serious difficulty lies in the lateness of the lambing season. It is generally agreed that lambing should not take place before June 1. The lambs will need shelter and feed by December 1 or earlier, unless one takes serious chances of losing many.

Whether sheep raising could be made profitable at present under such conditions remains to be demonstrated. The mere fact that sheep in small numbers have wintered without care is no proof that successful sheep husbandry can thus be carried on, nor even that one or two months' feeding will suffice. The risks involved in such a procedure are too great to warrant a careful stock raiser in taking any chances.

Destructive wild animals are no menace to sheep raising on the islands. Eagles may destroy a few lambs, but these birds are easily exterminated. Kadiak bears are too scarce and too easily destroyed to merit consideration. On the mainland, however, both wolves and brown bears may prove troublesome.

In the light of present knowledge one is safe in saying that sheep can be raised on the Alaska coast if adults are given five months' feed and shelter and the lambs a month more—this with the ordinary sheep of the western ranges. With more hardy breeds better adapted to the conditions the outlook for success would be better. It need hardly be said that extreme caution should be taken to import only perfectly healthy animals. The great mortality caused by scab and the great danger of such a disease as foot-rot in a damp climate demand that extreme care be taken not to introduce these diseases.

Cattle.—Cattle have been raised at nearly all the Alaskan coast settlements ever since the Russian occupation. Some of the original stock, according to local tradition, is still represented in the band of cattle at Nannilchuck. These are small animals, but said to be very hardy. Nearly all of the cattle kept near the villages are milch cows, mostly grades, but a number of Holsteins and Jerseys were seen. When owned by whites the animals are given shelter and feed for about five months. When they belong to the natives they are forced to exist through the winter with little or no care, eking out an existence by feeding on browse and seaweeds. No accurate data could be gathered concerning the amount and character of the milk yield, but it was universally said that the milk is most excellent in summer, and good in winter when the animals are properly fed. It is unfortunate that no accurate records could be obtained as to the winter yield of cows fed only on native hay or silage.

Several herds of beef cattle have been successfully maintained in the neighborhood of Kadiak. The experience of the Alaska Commercial Company is thus summarized by Mr. Washburn, the former superintendent at Kadiak:

> We have bred stock on the islands of Kadiak, Ukamak, and on Long Island. On Long Island we have about 40 head of cattle. These cattle are fed from two to six weeks each winter. The remainder of the time they have been able to get their own subsistence. During occasional winters we have carried our stock through with no feeding. We have had very good increase from them, and should say that the percentage of calves raised from the breeding cows is about 75. The cattle on this island have not been housed except during the short period when we were obliged to feed them.
>
> On Ukamak Island we have a herd of about 20 head, which are entirely self-sustaining. We have not found it necessary either to feed or shelter these cattle during the winter season, and the increase has been fully as good as that of the herd on Long Island.
>
> On Kadiak Island we have not kept any stock cattle, but only a herd of dairy cows and some working horses. These we have, of course, fed regularly during the winter season for about five months. We are able to cure sufficient hay on a lot we have leveled, and we have used the only mowing machine in western Alaska. We have obtained very good results from feeding the Alaska hay to both cows and horses, and find that they require no more grain when fed this hay than when we feed hay imported from California.

The Frye-Bruhn Company, of Seattle, began operations near Kadiak in July, 1903, importing about 200 head of beef cattle, mostly Herefords. Owing to unpreparedness and inexperience, about 140 head of this number were lost during the first year. Most of these were killed by falling over cliffs. Owing to the fact that the earliest grass appears on the steep southerly slopes, the cattle crowded in such places; in some instances the sod, loosened by the frost, gave way and precipitated them over the cliffs. In other cases the cattle used their horns when crowded, the wounded ones losing their foothold in endeavoring to escape. As precautions, more care is taken in selecting the early feeding grounds and the cattle have been dehorned.

The common experience of cattle owners in Alaska has been that the animals fatten readily on the grass in the spring, and remain in good condition without care until late in the autumn. Some Herefords slaughtered at Kadiak in July furnished beef of remarkably fine quality.

From the experience had at the Kenai Experiment Station, oxen keep in good working condition all winter on no other feed than native grass hay and silage, and the limited experience of others has given similar results. It is not probable, however, that animals will remain fat on such feeds alone.

Nothing has been done up to the present time in the way of introducing breeds that are likely to be especially adapted to the peculiar conditions. It is highly probable, as has been pointed out by Professor Georgeson, that long-haired hardy breeds like the Galloway or the West Highland cattle will prove much more successful than breeds adapted primarily to a drier and warmer climate.

POPULATION AND AVAILABLE MARKETS.

No very accurate data are available as to the present population of the Alaska coast towns and villages, which furnish the only markets close to the grass lands. The population of the principal towns along the coast is approximately as follows: Sitka, 1,500; Valdez, 1,000; Seward, 500; Kadiak, 50; Unalaska and Dutch Harbor, 600. The total population from Valdez to Unalaska, inclusive, is about 8,000, of whom less than one-half are whites. From Valdez to Sitka, excluding the former, the population is perhaps 4,000, about half of them white. Thus the coast of Alaska from Sitka to Unalaska provides a market population at present of not more than 6,000 people, as no market for meat or dairy products can be expected so far as the natives are concerned.

No account is here taken of the towns lying along the interior channels in southeastern Alaska, whose populations aggregate perhaps 8,000 whites, though a portion of this market could perhaps be reached.

Skagway and Valdez are the principal south Alaskan points which supply the interior, and consequently are of especial importance in considering markets.

A considerable market for beef and dairy products could perhaps be established by shipping from Unalaska to the population of the Nome district and the lower Yukon. Unalaska is on the line of transportation from Puget Sound to Nome and the Yukon River, though at present few of the vessels stop there.

Thus the present available markets in Alaska for live-stock products are very limited. The supply for these markets at the present time is shipped from Puget Sound.

It is evident, however, that it is possible to raise in Alaska far more produce of this kind than the local markets can consume. The only other markets that can possibly be reached are those furnished by the cities of British Columbia and of the State of Washington. Freight rates are at present, and perhaps will be for some time to come, such that dairy products and wool are the only articles that could profitably be shipped to such distant ports.

No predictions can here be ventured concerning the future development of south Alaska. The present resources are mainly furs, fisheries, and mines. The fur industry is becoming less and less important. The fisheries are already highly developed, but are capable of considerable increase. The mines undoubtedly will become more and more important. It is probable, too, that the extensive explorations now carried on in prospecting for oil will result in the development of another important industry.

FREIGHTS AND TRANSPORTATION.

At the present time both freight and passenger rates to and between Alaskan ports may be considered moderate. The great bulk of the freight traffic is northward, a condition that is not unlikely to continue. Any permanent increase in the traffic to and from Alaskan ports will naturally be accompanied by a corresponding lowering of rates. The transportation companies doing business in south Alaska seem to be quite as liberal as conditions will permit, and so far as expressed sentiment goes their general policy will be the wise one of encouraging as far as possible any industry that promises to add to the sum total of the traffic.

DESIRABILITY OF SOUTH ALASKA AS A HOME.

Climate.—The south Alaska coast lies in the same latitude as northern Labrador, the north of Scotland, and the south of Sweden, but none of these regions is very similar to it. In fact, south Alaska has several peculiarities which render close comparison with any other region difficult. In general, the climate is a moist one, accompanied by no great extremes in temperature. The thermometer very seldom reaches zero in winter, nor does it exceed 75° F. in summer.

The following tables give the more important meteorological data as compiled from various published reports, localities in Sweden, Canada, and the State of Washington being included for comparison:

Monthly and annual mean temperatures at points in Alaska and elsewhere.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
Sitka[a]	31.4	32.9	35.6	40.8	47.0	52.4	55.4	55.9	51.5	44.9	38.1	33.3	43.3
Sitka[b]	34.2	33.0	37.2	41.9	46.9	51.6	54.4	56.6	52.3	45.7	39.8	36.0	44.5
Kadiak	30.0	28.2	32.6	36.3	43.2	49.5	54.7	55.2	50.0	42.3	34.7	30.5	40.6
Unalaska[a]	30.0	31.9	30.4	35.6	40.9	46.3	50.6	51.9	45.5	37.6	33.6	30.1	38.7
Unalaska[b]	33.5	30.5	32.6	35.2	40.4	45.9	49.6	50.3	46.0	40.4	34.6	32.8	39.3
Port Angeles, Wash	34.7	36.7	41.7	45.6	50.6	54.0	56.6	56.8	52.7	47.7	42.4	38.2	46.1
Ottawa, Canada	11.9	12.2	17.6	41.5	63.6	66.9	70.4	68.7	57.7	43.1	31.5	17.8	42.1
Stockholm, Sweden	33.5	29.5	33.8	39.5	52.5	57.0	59.1	59.3	53.6	40.6	35.6	27.3	43.4

[a] From records kept by the Russian Government.
[b] From records of the United States Signal Service

Average precipitation at points in Alaska.

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Total precipitation, May 1 to Sept. 30.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Sitka	7.95	8.02	7.78	5.03	3.89	3.87	4.14	6.67	10.94	12.96	10.77	8.52	90.54	29.51
Kadiak	6.56	3.70	4.86	4.01	5.92	4.91	3.38	4.97	7.26	8.09	6.56	7.94	68.16	26.44
Unalaska	13.81	7.68	6.48	7.51	4.49	4.26	2.78	3.40	8.64	11.98	9.30	11.81	92.14	23.57

In comparing the data for Sitka, Kadiak, and Unalaska it will be noted that the average mean temperature of Sitka is a little higher than that of Kadiak, which in turn is higher than that of Unalaska. It will also be noted that Sitka and Unalaska have about the same rainfall—considerably greater than that of Kadiak.

A matter of more practical consequence than either the copious rainfall or the comparatively high mean temperature is the rather low total of effective temperatures during the months from May to September, inclusive. By effective temperature is meant that above 43° F., at which plant growth practically begins. These totals, as compiled by Evans,[a] are as follows:

Sitka	1,479.1
Kadiak	1,152.1
Unalaska	624.5
Port Angeles, Wash	1,671.0
Ottawa, Canada	3,424.7
Scotland	1,692.7
Stockholm, Sweden	2,704.9

The difference in totals between Sitka and Kadiak is very striking, but not so much as that between Kadiak and Unalaska. Undoubtedly this effective temperature factor is the principal cause of the sharp demarcation between the timbered and the timberless regions on the Alaska coast.

Garden products.—This same factor—the low total of effective temperatures—limits also the variety of garden products that can be grown, but along the whole coast a considerable variety of vegetables is successfully raised, such as potatoes, turnips, cabbage, cauliflower, Brussels sprouts, kale, lettuce, peas, radishes, and rhubarb. Red currants and red raspberries grow wild on Cook Inlet, and these hardy varieties will thrive at most places along the coast—at Sitka even the ordinary garden varieties ripening. In southeastern Alaska salmon berries, cranberries, and huckleberries grow wild in abundance.

[a] Bulletin No. 48, Office of Experiment Stations, U. S. Department of Agriculture.

Fuel.—In the timbered region a supply of fuel is easily obtainable, while in the timberless country a rather scant quantity is secured from scrubby willows and alders and from beach drift. Coal of an inferior quality, but still fairly satisfactory for domestic use, is abundant along Cook Inlet. At present none of this is mined, but considerable quantities are gathered from exposed ledges, or from drift on the beaches. Most of the coal used along the Alaska Peninsula, however, is at present shipped from Puget Sound. In some localities the paraffin residue from oil seepage is utilized as fuel.

CHOICE OF A LOCATION.

In general, Kadiak and the neighobring islands and the Cook Inlet country are the most favorable places for live-stock raising on account of a great luxuriance of grasses and contiguity to timber. The Cook Inlet region enjoys the reputation of being the garden spot of the Alaska coast, apparently producing finer vegetables than elsewhere, though lying farther north than the Alaska Peninsula and most of the territory described in these pages. The accessible grass lands here are, however, comparatively limited.

On the other hand, Unalaska and the neighboring islands, while possessing less abundant grass and perhaps a less favorable climate, can perhaps reach markets in the Nome region and on the lower Yukon. At Yakutat, while the grass is not overabundant, the location is more favorable for shipments southward.

The prime requisite of any Alaska location is a sufficiently large available supply of winter forage. Of summer range there is an abundance nearly everywhere, but the utilization of this is definitely limited by the number of cattle one can safely winter. The all-important point is therefore to have a sufficient acreage of land from which hay or silage can be secured. By selecting locations on the flat lands that so commonly occur at the heads of the narrow fiords one can easily control for all practical purposes great areas of grazing lands.

The writer can not refrain from quoting here the following opinion of a widely traveled man from California, who for three years has been engaged in placer mining on the beach on the west side of Kadiak Island and who is seriously considering taking up a homestead and bringing his family to Alaska:

> In all my travels I have never found a place where one can live so well or so cheaply as I have done for the past three years. I can raise all sorts of hardy vegetables and berries, besides the wild ones, and have unlimited grass to keep cattle and sheep. Fish of the choicest sorts—salmon, halibut, cod, and many others—are very abundant, and the stream flowing by my cabin door swarms with trout. In the way of big game there are bears. Of small game

ducks and geese are plentiful in the spring and fall, and fresh gull eggs may be had for the gathering. To add to all this, if ready money is not available, I can always make good wages at least by washing out gold on the beach.

Surely there is here a combination of resources that makes failure well-nigh impossible.

LAND LAWS APPLYING TO ALASKA.

The following report regarding the methods by which title may be secured to agricultural lands in Alaska was prepared in the office of the Commissioner of the General Land Office, through the courtesy of the Secretary of the Interior. It refers solely to acquiring title to agricultural lands and not to the town-site or mineral laws, or to mission claims under section 27 of the act of June 6, 1900 (31 Stat. L., 330):

Section 1 of the act of Congress approved May 14, 1898 (30 Stat. L., 409), extending the homestead laws to Alaska, may be summarized as follows:

First. Extending the homestead laws and the rights incident thereto to the district of Alaska.

Second. Extending to such district the right to enter surveyed lands under provisions of law relating to the acquisition of title through soldiers' additional homestead rights.

Third. Granting the right to enter unsurveyed lands in said district under provisions of law relating to the acquisition of title through soldiers' additional homestead rights.

Fourth. Prohibiting the location in said district of any indemnity, deficiency, or lieu lands pertaining to any land grant whatsoever orginating outside of said district.

Fifth. Limiting each entry under this section to 80 rods along the shore of any navigable water, and reserving along such shore a space at least 80 rods between all such claims, and prohibiting the entry or disposal of the shore (meaning land lying between high and low water mark) of any navigable waters within said district.

Sixth. Limiting each homestead in said district, whether soldiers' additional or otherwise, to 80 acres in extent.

This section was amended by the act of March 3, 1903 (32 Stat. L., 1028), the provisions of which may be stated as follows:

The amendatory act does not specifically reenact that portion of the act of 1898 which granted the right to enter *unsurveyed* lands in the district of Alaska under the provisions of law relating to the acquisition of title through soldiers' additional rights, but it is provided thereby "that no more than one hundred and sixty acres shall be entered in any single body by such scrip, lieu selection, or soldiers' additional homestead right," which seems to negative any intention to modify or repeal the existing law with regard to the exercise of such rights in the district of Alaska further than to limit the amount which may be entered in a single body to 160 acres. Further, that portion of the amendatory act which provides that "no indemnity, deficiency, or lieu-land selections pertaining to any land grant outside of the district of Alaska shall be made, and no land scrip or land warrant of any kind whatsoever shall be located within or exercised upon any lands in said district, except as now provided by law," seems to recognize that there are such outstanding rights; but, unless soldiers' additional homestead rights are thereby considered as scrip rights, this Department is not advised as to any other law permitting the exercise of any such rights in the district of Alaska. Soldiers' additional homestead applications, under sections 2306 and 2307, Revised Statutes, are received as heretofore, but not more than 160 acres can be taken in a single body.

The act of 1898 is amended so as to increase the amount of land which may be entered as a homestead in the district of Alaska to 320 acres, and in providing therefor grants such rights to "any person who is qualified under existing laws to make homestead entry of the public lands of the United States who has settled upon, or who shall hereafter settle upon, any of the public lands of the United States situated in the district of Alaska, whether surveyed or unsurveyed." If a person be qualified, therefore, to make homestead entry under existing laws, he may enter not to exceed 320 acres, upon which he may have settled, in the district of Alaska, and without regard to the amount he might be authorized to make homestead entry of elsewhere; but the right to locate a soldier's additional homestead right in the district of Alaska, without settlement, is not thereby changed. Only 160 acres or less may be commuted.

No entry of any kind in the district of Alaska can, however, be allowed for land extending more than 160 rods along the shore of any navigable water, which is twice the extent originally permitted by the act of 1898, and along such shore a space of at least 80 rods is reserved between all claims, being the same as originally provided in the act of 1898.

HOMESTEADS.

The homestead laws secure to qualified persons the right to settle upon, enter, and acquire title to not exceeding 320 acres of public land, by establishing and maintaining residence thereon and improving and cultivating the land for the continuous period of five years.

A homestead entryman must be the head of a family or a person who has arrived at the age of 21 years, and a citizen of the United States, or one who has filed his declaration of intention to become such, as required by the naturalization laws, to which section 5 of the act of March 3, 1891 (26 Stat. L., 1095), attaches the conditions that he must not be the proprietor of more than 160 acres of land in any State or Territory, and that since August 30, 1890, he has not acquired title to, nor is now claiming under any of the agricultural public-land laws, an amount of land which, together with the land now applied for, will exceed in the aggregate 320 acres.

Where a wife has been divorced from her husband or deserted, so that she is dependent upon her own resources for support, she can make homestead entry as the head of a family or as a femme sole.

Where an unmarried woman settles upon a tract of public land, improves the same, establishes and maintains a bona fide residence thereon with the intention of appropriating the same for a home under the homestead law, and thereafter marries before making entry of said land, or before making application to enter said land, she does not, on account of her marriage, forfeit her right to make entry and receive patent for the land: *Provided*, That she does not abandon her residence on said land and is otherwise qualified to make homestead entry: *And provided further*, That the man whom she marries is not, at the time of their marriage, claiming a separate tract of land under the homestead law. (Act June 6, 1900, 31 Stat. L., 683.)

APPLICATION FOR A HOMESTEAD FOR SURVEYED LAND.

To obtain a homestead the party should select and personally examine the land and be satisfied of its character and true description.

He must file an application, stating his true name, residence, and post-office address, and describing the land he desires to enter, and make affidavit that he is not the proprietor of more than 160 acres of land in any State or Territory; that he is a citizen of the United States, or that he has filed his declaration of intention to become such, and that he is the head of a family, or over 21 years of age, as the case may be; that his application is honestly and in good faith made for the purpose of actual settlement and cultivation, and not for the benefit of any other person, persons, or corporation, and that he will faithfully and honestly endeavor to comply with all the requirements of law as to settlement, residence, and cultivation necessary to acquire title to the land applied for; that he is not acting as agent of any person, corporation, or syndicate in making such entry, nor in collusion with any person, corporation, or syndicate to give them the benefit of the land entered, or any part thereof, or the timber thereon; that he does not apply to enter the same for the purpose of speculation, but in good faith to obtain a home for himself, and that he has not, directly or indirectly, made, and will not make, any agreement or contract in any manner with any person or persons, corporation, or syndicate whatsoever, by which the title which he might acquire from the Government of the United States should inure, in whole or in part, to the benefit of any person except himself; and, further, that since August 30, 1890, he has not acquired title to nor is he claiming under any of the agricultural public-land laws an amount of land which, together with the land he is seeking to enter, will exceed in the aggregate 320 acres, and that he has not theretofore had the benefit of the homestead laws, and must pay the legal fee and that part of the commissions which is payable when entry is made, and furnish the usual nonmineral affidavit.

On compliance by the party with the foregoing requirements the receiver will issue his receipt for the fee and that part of the commissions paid, a duplicate of which he will deliver to the party. The matter will then be entered in the records of the district office and reported to the General Land Office.

The applicant must in every case state in his application his place of actual residence and his post-office address, in order that notices of proceedings relative to his entry may be sent him. The register and receiver will note the post-office address on their tract books.

INCEPTIVE RIGHTS OF HOMESTEAD SETTLERS.

An inceptive right is vested in the settler by the proceedings hereinbefore described. He must, within six months after making his entry, establish his actual residence in a house upon the land, and must reside upon and cultivate the land continuously in accordance with law for the term of five years. Occasional visits to the land once in six months or oftener do not constitute residence. The homestead party must actually inhabit the land and make it the home of himself and family, as well as improve and cultivate it.

At the expiration of five years, or within two years thereafter, he may make proof of his compliance with law by residence, improvement, and cultivation for the full period required, and must show that the land has not been alienated except as provided in section 2288, Revised Statutes (sec. 2291, Rev. Stat.), as amended by section 3 of the act of March 3, 1891 (26 Stat. L., 1095).

The period of continuous residence and cultivation begins to run at the date of actual settlement in case the entry at the district land office is made within the prescribed period (three months) thereafter or before the intervention of a valid adverse claim. If the settlement is on unsurveyed land, the latter period runs from the filing of plat in the district land office. (Act May 14, 1880, 21 Stat. L., 140.)

HOMESTEAD SETTLERS ON UNSURVEYED LANDS.

A homestead settler on unsurveyed public land not yet open to entry must make entry within three months after the filing of the township plat of survey in the district land office. (Act May 14, 1880, 21 Stat. L., 140.)

CULTIVATION IN GRAZING DISTRICTS.

In grazing districts stock raising and dairy production are so nearly akin to agricultural pursuits as to justify the issue of patent upon proof of permanent settlement and the use of the land for such purposes.

Proofs can only be made by the homestead claimant in person, and can not be made by an agent, attorney, assignee, or other person, except that in case of the death of the entryman proof can be made by the statutory successor to the homestead right in the manner provided by law.

Sections 2291 and 2292, Revised Statutes, provide for obtaining title to lands entered by a homestead settler by his heirs. The act of June 8, 1880 (21 Stat. L., 166), provides for homestead claimants who become insane.

HOMESTEAD CLAIMS NOT LIABLE FOR DEBT AND NOT SALABLE.

No lands acquired under the provisions of the homestead laws are liable for the satisfaction of any debt contracted prior to the issue of the patent. (Sec. 2296, Rev. Stat.)

The sale of a homestead claim by the settler to another party before becoming entitled to a patent vests no title or equities in the purchaser as against the United States. In making final proof the settler is by law required to swear that no part of the land has been alienated except for church, cemetery, or school purposes or the right of way for railroads, canals, or ditches for irrigation or drainage across it. (Sec. 2288, Rev. Stat., as amended by sec. 3 of the act of March 3, 1891, 26 Stat. L., 1095.)

SOLDIERS AND SAILORS' HOMESTEAD RIGHTS.

Any officer, soldier, seaman, or marine who served for not less than ninety days in the Army or Navy of the United States during the rebellion, and who was honorably discharged and has remained loyal to the Government, and who makes a homestead entry of 320 acres or less on any land subject to such entry, is entitled under section 2305 of the Revised Statutes to have the term of his service in the Army or Navy, not exceeding four years, deducted from the period of five years' residence required under the homestead laws.

If the party was discharged from service on account of wounds or disabilities incurred in the line of duty the whole term of enlistment, not exceeding four years, is to be deducted from the homestead period of five years; but no patent can issue to any homestead settler who has not resided upon, improved, and cultivated his homestead for a period of at least one year after he commenced his improvements. (Sec. 2305, Rev. Stat.)

Similar provisions are made in the acts of June 16, 1898 (30 Stat. L., 473), and March 1, 1901 (31 Stat. L., 847), for the benefit of like persons who served in the late war with Spain or during the suppression of the insurrection in the Philippines.

A party applying to make entry under the provisions of section 2304 must file with the register and receiver a certified copy of his certificate of discharge, showing when he enlisted and when he was discharged; or the affidavit of two respectable, disinterested witnesses corroborative of the allegations contained in the prescribed affidavit (Form 4–065) on these points, or, if neither can be procured, his own affidavit to that effect.

The widow or, in case of her death or remarriage, the guardian of minor children may complete a filing made by the soldier or sailor as above, and patent will issue accordingly.

SOLDIERS' ADDITIONAL HOMESTEAD ENTRY.

Any officer, soldier, sailor, or marine who served for not less than ninety days in the Army or Navy of the United States during said wars, who had, prior to June 22, 1874, the date of the approval of the Revised Statutes, made a homestead entry of less than 160 acres, may enter an additional quantity of land, adjacent to his former entry or elsewhere, sufficient to make, with the previous entry, 160 acres. (Rev. Stat., 2306.) This right was extended by section 2307, Revised Statutes, to the widow, if unmarried; otherwise to the minor orphan children by proper guardian. If there be no widow, unmarried, and no minor orphan children, the right is held to be an asset of the soldier-entryman's estate, to be disposed of by his personal representative as other personal property. (29 L. D., 510 and 658.) An assignment by the heirs will be accepted if accompanied by a certificate of the proper court showing that no administration has ever been had on the soldier's estate and that they are all the heirs entitled to the right. The right was formerly regarded as a personal one and not transferable, but under authority of the decision of the Supreme Court of the United States in the case of Webster *v.* Luther (163 U. S., 331), it is now held to be assignable without restriction, and residence and cultivation are not required in its exercise, either by the original beneficiary or by his assignee, whether the original entry was perfected or abandoned (24 L. D., 502).

It was formerly the practice, on proof of military service and original entry, under section 2306, Revised Statutes, to issue a certificate in the name of the soldier-entryman, showing his additional right and its area, but the practice was discontinued by circular of February 13, 1883 (1 L. D., 654), and it is held that there is no statutory authority for the same and that the soldier can obtain the right for himself and sell it to another without certification (23 L. D., 152).

By the act of March 3, 1893 (27 Stat. L., 593), provision is made that where soldiers' additional homestead entries have been made or initiated upon a certificate of the Commissioner of the General Land Office of the right to make such entry, and the certificate of right is found to be erroneous or invalid for any cause, the party in interest thereunder on making proof of his purchase may, if there is no adverse claimant, perfect his title by payment of the Government price for the land, but no person may acquire more than 160 acres through the location of any such certificate.

By the act of August 18, 1894 (28 Stat. L., 397), all certificates regularly issued are declared to be valid, notwithstanding any attempted sale or transfer, and holders thereof desiring to exercise a right of entry in their own names must file such certificates in the General Land Office, together with satisfactory proof of ownership and of bona fide purchase for value. If, upon examination, the proof so filed is satisfactory, an additional certificate will be attached to the original authorizing the location thereof, or entry of land therewith, in the name of the assignee or his assigns. (Circular of October 16, 1894; 19 L. D., 302.)

Existing homestead laws, while recognizing settlement upon unsurveyed public lands, do not authorize the entry or the patenting thereof until the public surveys have been regularly extended over them. This section as amended, however, in terms authorizes the entry of unsurveyed lands in Alaska, and makes provision for a private survey for the purpose of patenting the claim, if the public surveys have not been extended thereto at the time it is desired to submit proof, as is hereinafter referred to.

In executing surveys for homestead applications the instructions now prevailing will be followed, and the limit of 160 rods as to frontage will be measured along the meandered line of said frontage.

The form of the tract sought to be entered, if upon unsurveyed land, is prescribed in the act as follows:

If any of the land * * * is unsurveyed, then the land * * * must be in rectangular form, not more than a mile in length, and located upon the north and south lines run according to the true meridian.

That is, the boundary lines of each entry must be run in cardinal directions, true north-and-south and east-and-west lines by reference to a true meridian (not magnetic), with the exception of the meander lines on meanderable streams and navigable waters forming a part of the boundary lines of the entry. Thus a frontage meander line, and other meander lines which form part of the boundary of a claim, will be run according to the directions in the Manual of Surveying Instructions issued by this Office, but other boundary lines will be run in true east-and-west and north-and-south directions, thus forming rectangles, except at intersections with meander lines.

In other respects the rules previously adopted to govern surveys of claims under the act of May 14, 1898, will continue to be followed, of course taking into consideration the limitations as to area of claims.

Every person who is qualified under existing laws to make a homestead entry of the public lands of the United States who settles or has settled upon any of the unsurveyed public lands of the United States in the district of Alaska with the intention of taking the same under the homestead law shall, within ninety days from date of settlement or prior to the intervention of an adverse claim, file the record of his location for record in the recording district in which the land is situated, as provided by sections 13 to 16 of the act of June 6, 1900 (31 Stat. L., 326 to 328).

Said record shall contain the name of the settler, the date of settlement, and such description of the land settled on, by reference to some natural object or permanent monument as will identify the same.

If at the expiration of the time required under sections 2291 and 2292, Revised Statutes, and as modified by section 2305, Revised Statutes, or at such date as the settler desires to commute under section 2301, Revised Statutes, the public surveys have not been extended over the land located, the locator may secure a patent for the land located by procuring, at his own expense, a survey of the land, which must be made by a deputy surveyor who has been duly appointed by the surveyor-general, in accordance with section 10 of the act of May 14, 1898 (30 Stat L., 409), and the provisions of the act of March 3, 1903, as herein set forth.

When the survey, either public or private, as herein provided for is approved by the surveyor-general under authority of this Office, the same rules should be followed as heretofore established governing the location of soldiers' additional homestead rights, in addition to which the settler must furnish the required proof of residence and cultivation.

The office of the surveyor-general of Alaska is located at Sitka.

Section 10 of said act of May 14, 1898, also provides that all affidavits, testimony, proofs, and other papers provided for by this act and by said act of March 3, 1891, or by any departmental or Executive regulation thereunder, by depositions or otherwise, under commission from the register and receiver of the land office, which may have been or may hereafter be taken and sworn to anywhere in the United States, before any court, judge, or other officer authorized by law to administer an oath, shall be admitted in evidence as if taken before the register and receiver of the proper local land office. And thereafter such proof, together with a certified copy of the field notes and plat of the survey of the claim, shall be filed in the office of the surveyor-general of the district of Alaska, and if such survey and plat shall be approved by him, certified copies thereof, together with the claimant's application, shall be filed in the United States land office in the land district in which the claim is situated, whereupon, at the expense of claimant, the register of such land office shall cause notice of such application to be published for at least sixty days in a newspaper of general circulation publshed nearest the claim within the district of Alaska, and the applicant shall at the time of filing such field notes, plat, and application to purchase in the land office aforesaid, cause a copy of such plat, together with the application to purchase, to be posted upon the claim, and such plat and application shall be kept posted in a conspicuous place on such claim continuously for at least sixty days, and during such period of posting and publication, or within thirty days thereafter, any person, corporation, or association having or asserting any adverse interest in, or claim to, the tract of land or any part thereof sought to be purchased, may file in the land office where such application is pending, under oath, an adverse claim setting forth the nature and extent thereof, and such adverse claimant shall, within sixty days after the filing of such adverse claim, begin action to quiet title in a court of competent jurisdiction within the district of Alaska, and thereafter no patent shall issue for such claim until the final adjudication of the rights of the parties, and such patent shall then be issued in conformity with the final decree of the court.

When a settler desires to commute, the survey and homestead application must cover his entire claim, but only 160 acres, or less, thereof may be commuted, in which event the entry will stand intact as to the portion not commuted, subject to future compliance with the requirements of law within the statutory period of seven years.

Entrymen who commute will be required to pay, in addition to the price of $1.25 per acre, the same fees and commissions as in final homesteads.

Whenever a settler or other claimant desires to make entry or submit final proof, he should address the register and receiver of the United States land office at Juneau, Alaska.

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PLATES.

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DESCRIPTION OF PLATES.

PLATE I. Map of Alaska, showing the approximate location of the grass-land areas in black.

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FIG. 1.—A VIEW OF THE FLAT LANDS LYING AT THE HEAD OF WOMAN'S BAY, KADIAK ISLAND, ALASKA.

FIG. 2.—MOWING BEACH RYE ON KADIAK ISLAND, ALASKA.

BLUETOP (CALAMAGROSTIS LANGSDORFII) SIX FEET HIGH, ON KADIAK ISLAND, ALASKA, JULY, 1904.

The grass on the hillside in the background was just as luxuriant.

FIG. 1.—A VIEW OF KADIAK, ALASKA, NOVEMBER 7, 1903.

FIG. 2.—A DIFFERENT VIEW OF KADIAK, MARCH 26, 1904.

The small snowfall of this region is made very clear by these two pictures.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 83.

B. T. GALLOWAY, *Chief of Bureau.*

THE

VITALITY OF BURIED SEEDS.

BY

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ISSUED AUGUST 4, 1905.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1905.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 29, 1905.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 83 of the series of this Bureau, the accompanying technical paper entitled "The Vitality of Buried Seeds."

The experiments discussed were undertaken in order to determine the length of time that seeds of different species of plants will retain their vitality when buried at various depths. Seeds of both cultivated and wild plants were used, but special attention was given to weed seeds in order to ascertain what weeds can be eradicated by deep plowing and how long the soil must remain undisturbed before the vitality of the seeds will be entirely destroyed. The results of the first year's experiments show that the noxious character of weeds is closely associated with the length of time the seeds will remain viable in the soil, and that many weeds can be eradicated by plowing. Much additional information is given, showing the relative resistance of the seeds of cultivated plants and of those commonly designated as weeds, and the influence upon the preservation of vitality of the depth of burial, of hard seed coats, and of hulled as compared with unhulled seed.

This paper was prepared by J. W. T. Duvel, Assistant in the Seed Laboratory, and has been submitted with a view to publication.

The accompanying illustrations are necessary for a complete understanding of the paper.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE VITALITY OF BURIED SEEDS.

INTRODUCTION.

The preservation of the vitality of seeds when buried in the soil and the awakening of metabolic activity in such seeds on being exposed to conditions favorable to their germination are equally as important to the practical farmer as to the scientist. The intelligent farmer in order to combat noxious plants successfully should know how much time must elapse after heavy crops of weeds of various sorts are turned under before the ground can be plowed again with safety. He should also know what plants he can hope to eradicate in this way, for with many of our worst weeds this method would result only in failure. In fact, the reason why the majority of our most persistent weeds are so difficult to eradicate is because their seeds are capable of retaining their vitality for a number of years when buried in the soil. It thus becomes important to know how different species of seeds behave when buried under similar conditions, and how seeds of the same species behave when buried under different conditions.

KINDS OF SEEDS BURIED.

So much has already been written on the germination of seeds that have remained dormant in the soil for a number of years, in some cases even for centuries, that it seemed desirable to determine with some degree of accuracy the length of time that certain seeds will retain their vitality when buried in the soil under known conditions. Accordingly, in the autumn of 1902, 112 different samples of seeds were selected for these experiments, as follows:

TABLE I.—*List of seeds selected for the experiments.*

Laboratory test number.	Kind of seed.	Sample number.	Burial number as given on diagram.
	Poaceæ (grass family):		
16173	*Agropyron repens* (L.) Beauv. (couch grass)	100	31
16174	*Avena fatua* L. (wild oat)	71	9
16175	*Avena sativa* L. (oats)	24	8
16176	*Bromus secalinus* L. (cheat, chess)	34	36
16177	*Bromus racemosus* L. (upright chess, smooth brome-grass)	33	37
16178	*Chaetochloa verticillata* (L.) Scribn. (foxtail)	108	66
16179	*Chaetochloa glauca* (L.) Scribn. (yellow foxtail)	46	33
16180	*Chaetochloa viridis* (L.) Scribn. (green foxtail)	5	67
16181	*Eleusine indica* (L.) Gaertn. (wire-grass, crab-grass)	36	72
16182	*Elymus virginicus* L. (Virginia wild rye)	77	15
16183	*Elymus canadensis* L. (nodding wild rye)	74	13
16184	*Elymus triticoides* Buckl. (wild wheat)	69	14

TABLE I.—*List of seeds selected for the experiments*—Continued.

Laboratory test number.	Kind of seed.	Sample number.	Burial number as given on diagram.
	Poaceæ (grass family)—Continued.		
16185	*Festuca elatior* L. (meadow fescue)	38	35
16186	*Hordeum sativum* Jessen. (barley)	23	12
16187	*Panicum virgatum* L. (tall, smooth panicum)	70	32
16188	*Phalaris arundinacea* L. (reed canary grass)	93	34
16189	*Phleum pratense* L. (timothy)	112	68
16190	*Poa pratensis* L. (Kentucky bluegrass)	75	73
16191	*Secale cereale* L. (rye)	25	11
16192	*Sporobolus airoides* Torr. (hair-grass drop-seed)	12	69
16193	*Sporobolus cryptandrus* (Torr.) A. Gray (sand drop-seed)	63	71
16194	*Sporobolus cryptandrus* (Torr.) A. Gray (sand drop-seed—hulled seed)	13	70
16195	*Triticum aestivum* L. (wheat)	22	10
16196	*Zea mays* L. (corn—Boone County white)	14	1
16197	*Zea mays* L. (sweet corn—early Concord)	15	2
	Cyperaceæ (sedge family):		
16198	*Cyperus esculentus* L. (yellow nut-grass)	7	74
	Liliaceæ (lily family):		
16199	*Allium cepa* L. (onion)	27	39
	Convallariaceæ (lily-of-the-valley family):		
16200	*Asparagus officinalis* L. (asparagus)	32	16
	Moraceæ (mulberry family):		
16201	*Cannabis sativa* L. (hemp)	4	17
	Urticaceæ (nettle family):		
16202	*Boehmeria nivea* Gaud. (ramie)	2	75
	Polygonaceæ (buckwheat family):		
16203	*Fagopyrum fagopyrum* (L.) Karst. (buckwheat)	21	18
16204	*Polygonum pennsylvanicum* L. (Pennsylvania persicaria, smartweed)	9	40
16205	*Polygonum persicaria* L. (lady's-thumb, smartweed)	10	78
16206	*Polygonum scandens* L. (climbing false buckwheat)	11	41
16207	*Rumex salicifolius* Weinm. (willow-leaved dock)	107	76
16208	*Rumex crispus* L. (curled dock), not cleaned	103	39
16209	*Rumex obtusifolius* L. (broad-leaved dock, bitter dock)	102	77
	Chenopodiaceæ (goosefoot family):		
16210	*Axyris amaranthoides* L. (Russian pigweed)	1	81
16211	*Beta vulgaris* L. (sugar beet)	72	19
16212	*Chenopodium album* L. (lamb's quarters, white goosefoot)	96	79
16213	*Chenopodium hybridum* L. (maple-leaved goosefoot)	62	80
	Amaranthaceæ (amaranth family):		
16214	*Amaranthus retroflexus* (rough pigweed)	83	82
	Phytolaccaceæ (pokeweed family):		
16215	*Phytolacca americana* L. (poke, pigeon berry)	104	42
	Portulacaceæ (purslane family):		
16216	*Portulaca oleracea* L. (purslane, pussley)	86	83
	Silenaceæ (pink family):		
16217	*Agrostemma githago* L. (corn cockle)	16	43
16218	*Alsine media* L. (common chickweed)	110	84
16219	*Vaccaria vaccaria* (L.) Britton (cowherb)	55	44
	Brassicaceæ (mustard family):		
16220	*Brassica nigra* (L.) Koch (black mustard)	67	87
16221	*Brassica oleracea* L. (cabbage)	17	45
16222	*Brassica campestris* L. (turnip)	40	88
16223	*Bursa bursa-pastoris* (L.) Britton (shepherd's purse)	3	89
16224	*Erysimum cheiranthoides* L. (wormseed, treacle mustard)	58	47
16225	*Neslia paniculata* (L.) Desv. (ball mustard)	85	46
16226	*Sisymbrium altissimum* L. (tall sisymbrium)	78	86
16227	*Thlaspi arvense* L. (field penny cress)	60	85
	Rosaceæ (rose family):		
16228	*Potentilla monspeliensis* L. (rough cinquefoil)	73	90
	Caesalpiniaceæ (senna family):		
16229	*Cassia marylandica* L. (wild senna, American senna)	52	48
	Fabaceæ (pea family):		
16230	*Lespedeza frutescens* (L.) Britton (wand-like bush clover)	43	52
16231	*Medicago sativa* L. (alfalfa, lucern)	59	49
16232	*Phaseolus vulgaris* L. (bean)	20	4
16233	*Pisum sativum* L. (pea)	19	5
16234	*Robinia pseudacacia* L. (locust tree, false acacia)	37	51
16235	*Trifolium hybridum* L. (alsike clover)	50	93
16236	*Trifolium pratense* L. (red clover)	49	50
16237	*Trifolium pratense* L. (red clover) harvest of 1900	51	91
16238	*Trifolium pratense* L. (red clover) hard seed from No. 16237	68	92
16239	*Trifolium repens* L. (white clover)	41	94
16240	*Vigna catjang* Walp. (Iron cowpea)	42	3
	Linaceæ (flax family):		
16241	*Linum usitatissimum* L. (flax, linseed)	30	53
	Anacardiaceæ (sumac family):		
16242	*Rhus glabra* L. (scarlet sumac)	47	20
	Malvaceæ (mallow family):		
16243	*Abutilon abutilon* (L.) Rusby. (velvet leaf)	111	54
16244	*Gossypium hirsutum* L. (cotton)	18	6
16245	*Hibiscus militaris* Cav. (halberd-leaved rose mallow)	31	55

TABLE I.—*List of seeds selected for the experiments*—Continued.

Laboratory test number.	Kind of seed.	Sample number.	Burial number as given on diagram.
	Hypericaceæ (St. John's wort family):		
16246	*Ascyrum hypericoides* L. (St. Andrew's cross)	44	95
	Onagraceæ (evening primrose family):		
16247	*Onagra biennis* (L.) Scop. (common evening primrose)	8	96
	Apiaceæ (carrot family):		
16248	*Apium graveolens* L. (celery)	94	57
16249	*Pastinaca sativa* L. (parsnip, wild)	95	56
	Oleaceæ (olive family):		
16250	*Fraxinus americana* L. (white ash)	105	21
	Convolvulaceæ (morning-glory family):		
16251	*Convolvulus sepium* L. (hedge bindweed, great bindweed)	56	23
16252	*Ipomoea lacunosa* L. (small-flowered white morning-glory)	81	22
	Cuscutaceæ (dodder family):		
16253	*Cuscuta polygonorum* Engelm. (smartweed dodder)	63	98
16254	*Cuscuta epilinum* Weihe. (flax dodder)	82	97
	Verbenaceæ (vervain family):		
16255	*Verbena hastata* L. (blue vervain)	66	100
16256	*Verbena urticifolia* L. (white vervain, nettle-leaved vervain	79	99
	Solanaceæ (potato family):		
16257	*Capsicum annuum* L. (red pepper)	39	59
16258	*Datura tatula* L. (purple stramonium, jimson weed)	106	61
16259	*Lycopersicon lycopersicon* (L.) Karst. (tomato)	45	60
16260	*Nicotiana tabacum* L. (tobacco)	99	101
16261	*Solanum nigrum* L. (black nightshade, garden nightshade)	61	58
	Scrophulariaceæ (figwort family):		
16262	*Verbascum thapsus* L. (great mullen)	76	102
	Plantaginaceæ (plantain family):		
16263	*Plantago lanceolata* L. (ribwort, ribgrass, buckhorn)	88	105
16264	*Plantago major* L. (common plantain)	91	103
16265	*Plantago rugelii* Dec. (Rugel's plantain, broad plantain)	65	104
	Cucurbitaceæ (gourd family):		
16266	*Citrullus citrullus* (L.) Karst. (watermelon)	6	26
16267	*Cucumis melo* L. (muskmelon)	26	25
16268	*Cucumis sativus* L. (cucumber)	48	24
	Cichoriaceæ (chicory family):		
16269	*Lactuca scariola* L. (prickly lettuce)	98	107
16270	*Lactuca sativa* L. (lettuce)	28	62
16271	*Taraxacum erythrospermum* Andrz. (red-seeded dandelion)	90	106
	Ambrosiaceæ (ragweed family):		
16272	*Ambrosia artemisiaefolia* L. (ragweed)	87	63
16273	*Ambrosia trifida* L. (great ragweed)	53	28
16274	*Xanthium pennsylvanicum* Wallr. (Pennsylvania clotbur, cocklebur).	51	27
	Asteraceæ (aster family):		
16275	*Arctium lappa* L. (burdock, clotbur)	101	112
16276	*Bidens frondosa* L. (black beggar ticks)	84	64
16277	*Carduus arvensis* (L.) Robs. (Canada thistle)	80	111
16278	*Chrysanthemum leucanthemum* L. (whiteweed, oxeye daisy)	92	110
16279	*Grindelia squarrosa* (Pursh.) Dunal. (broad-leaved gum plant)	89	108
16280	*Helianthus annuus* L. (common sunflower, wild)	97	29
16281	*Helianthus annuus* L. (common sunflower, cultivated)	29	7
16282	*Onopordon acanthium* L. (cotton thistle, scotch thistle)	109	65
16283	*Rudbeckia hirta* L. (black-eyed Susan)	57	109
	Pinaceæ (pine family):		
16284	*Pinus virginiana* Mill. (scrub pine, Jersey pine)	36	30

HOW THE SEEDS WERE BURIED.

The foregoing list represents 109 species, 84 genera, and 34 families of plants. Carefully counted seeds of these samples were mixed with dry clay soil and packed in well-baked earthen pots (the common flowerpot used in greenhouses). The filled pots were covered with inverted clay saucers in order to prevent the seeds from being destroyed or becoming mixed with other seeds which might have been in the soil with which the pots were covered. By burying the seeds mixed with earth in porous clay pots of this character they were subjected to conditions almost identical with those which would exist if the seeds were buried either accidentally or by natural causes. The porous clay pots admitted of the free circulation of air and water.

The pots containing these seeds were buried at three different depths. Eight complete sets were buried from 6 to 8 inches below the surface, being covered approximately the same as would result from deep plowing. Twelve complete sets were covered to a depth varying from 18 to 22 inches, sufficiently deep in this latitude to be reasonably secure from the action of frost. Twelve more complete sets were buried at a depth varying from 36 to 42 inches where the conditions were nearly uniform, so far as the three factors which regulate the germination of seeds are concerned, namely, heat, moisture, and air (oxygen). Figure 1 shows the arrangement of the pots, which were of 6-inch, 4-inch, and 2-inch sizes, to accommodate the different kinds of seed.

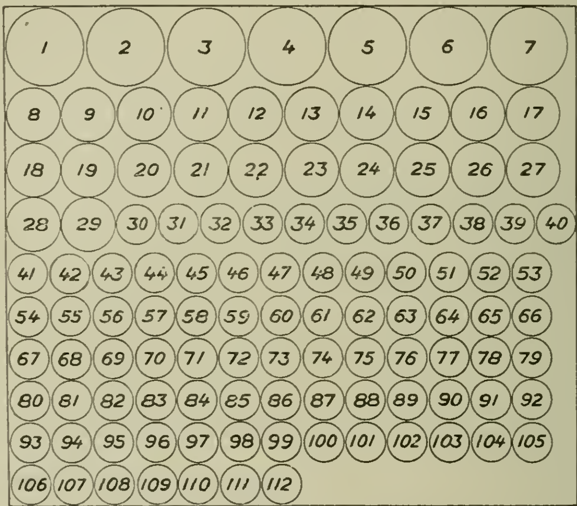


FIG. 1.—Diagram showing order in which seeds were buried.

These seeds were buried December 19 to 23, 1902, in a heavy clay soil on the Arlington Experimental Farm of the United States Department of Agriculture. With the exception of two of the duplicate samples of red clover, the seeds were of the harvest of 1902.

In each case a definite number of seeds was taken. Of the larger kinds, such as beans, peas, corn, etc., 100 seeds were used, but for the majority of the samples 200 seeds were taken. The seeds selected were for the most part of plants with which the greater number of the farmers throughout the United States are more or less familiar, either as plants of economic importance or as weeds.

In all 32 complete sets, representing 3,584 pots, were buried. One set from each of the three different depths is to be taken up as the conditions warrant and will be tested for vitality. The results of these tests are to be compared with the germination of seeds from the original bulk samples designated throughout this report as "controls."

The control samples are being stored in cloth bags in a dry room on the second floor of the Seed Laboratory. The first complete series of three sets was taken up in November, 1903, eleven months after they had been buried. The results of the first year's experiment are given in the following pages.

GERMINATION TESTS.

In making the germination tests of the buried seeds the contents of the pots, the mixture of seed and soil, were spread on sand in ordinary greenhouse flats. Along with these, in the same flats, were control samples taken from the original bulk lot of seeds, as previously mentioned. In addition, another complete set of control samples was tested in the germinating chambers of the Seed Laboratory. The temperatures given in the tables are those best suited for the germination of the different seeds.

For convenience the results of the germination tests have been divided into three groups, as follows:

A. Seeds in which the control samples, as well as those that were buried, gave only negative results when tested in the greenhouse.

B. Seeds which had either decayed or germinated and afterwards decayed while they were buried.

C. Seeds which had not completely lost their vitality while buried.

The first group, i. e., those in which both the control samples and those which had been buried failed to germinate when planted in flats in the greenhouse, consists of the following species:

1. *Axyris amaranthoides* L. (Russian pigweed).
2. *Boehmeria nivea* Guad. (ramie).
3. *Bursa bursa-pastoris* (L.) Britton (shepherd's purse).
4. *Cannabis sativa* L. (hemp).
5. *Chaetochloa viridis* (L.) Scribn. (green foxtail).
6. *Citrullus citrullus* (L.) Karst. (watermelon).
7. *Cyperus esculentus* L. (yellow nut-grass).
8. *Onagra biennis* (L.) Scop. (evening primrose).
9. *Polygonum pennsylvanicum* L. (Pennsylvania smartweed, persicaria).
10. *Polygonum persicaria* L. (lady's-thumb, smartweed).
11. *Polygonum scandens* L. (climbing false buckwheat).
12. *Sporobolus airoides* Torr. (hair-grass drop-seed).
13. *Sporobolus cryptandrus* (Torr.) A. Gray (sand drop-seed—hulled seed).

In this series the hemp should be discarded, as repeated tests failed to show any seeds from the bulk samples capable of germination. The control samples of the other seeds when tested in the germinating chambers germinated nearly as well and in some cases even better than the chamber tests which were made at the time the seeds were buried. Undoubtedly some of these seeds had decayed while buried in the soil; in fact, the watermelon seeds, *Axyris amaranthoides*, and *Sporobolus airoides* were marked "mostly decayed" when taken up. Generally speaking, the results show that the failure to germinate was not in the seeds, but that the conditions in the greenhouse were at fault, and until other tests are made these results can not be discussed with any degree of satisfaction. On the other hand, it is certain that some of the smaller seeds failed to germinate because they were covered too deeply when sown in the flats in the greenhouse.

Polygonum scandens possibly should be classified in Table III, inasmuch as some of the seeds which were buried at depths of from 18 to 22 inches and from 36 to 42 inches showed a few sprouts at the time the seeds were taken up, but after being transferred to the greenhouse no seedlings were developed. However, the failure in the germination of the control sample of *Polygonum scandens* throws it into the first group (A) with the other two species of the same genus, i. e., *Polygonum pennsylvanicum* and *P. persicaria*.

The result of the tests of the buried seed of *Sporobolus cryptandrus*, as given in this group, should be compared with the germination of the unhulled seed as given in Table III, No. 64. The control samples of both the hulled and the unhulled seed which were sown in the greenhouse failed to germinate, but all three samples of the unhulled seed that had been buried gave some germination when tested in the greenhouse.

TABLE II.—*Results of tests of seeds which had either decayed or germinated and afterwards decayed while buried.*

Sample number.	Laboratory test number.	Kind of seed.	Chamber tests.			Greenhouse tests in sand.			
			Temperature.	Original sample.	Control.	Control.	Depth of burial. 6–8 inches.	18–22 inches.	36–42 inches.
			° C.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
14	16196	Zea mays (Boone County white corn)	20-30	99.5	99	....	....	....	....
15	16197	Zea mays (sweet corn)	20-30	98.5	98.5	....	....	....	....
16	16217	Agrostemma githago	20-30	99	98.5	....	....	....	....
17	16221	Brassica oleracea	20	85.5	82	....	....	....	....
18	16244	Gossypium hirsutum	20-30	77.5	72	....	....	....	....
19	16233	Pisum sativum	20-30	99	98	....	....	....	....
20	16232	Phaseolus vulgaris	20-30	97.5	98.5	....	....	....	(a)
21	16203	Fagopyrum fagopyrum	20-30	100	98.5	....	(b)	(c)	....
22	16195	Triticum aestivum	20	99	96.5	....	(d)	....	(a)
23	16186	Hordeum sativum	20	100	98	....	(d)	(d)	(d)
24	16175	Avena sativa	20-30	70.5	91.5	95.5	0	0	0
25	16191	Secale cereale	20	100	98.5	88	0	0	0
26	16267	Cucumis melo	20-30	96.5	97	88	0	0	0
27	16199	Allium cepa	20-30	94.25	88	70.5	0	0	0
28	16270	Lactuca sativa	20-30	100	98.5	91	0	0	0
29	16281	Helianthus annuus (cult.)	20-30	97	96.5	43	0	0	0
30	16241	Linum usitatissimum	20-30	93.5	95	83.5	0	0	0
31	16245	Hibiscus militaris	20-30	98.25	92	91	0	0	0
32	16200	Asparagus officinalis	20-30	80	e69	74	f0	f0	f0
33	16177	Bromus racemosus	20-30	100	98.5	92.5	a0	0	a0
34	16176	Bromus secalinus	20-30	88.5	77	95.5	0	0	0
35	16181	Eleusine indica	35	78.25	91.5	75	0	0	0
36	16284	Pinus virginiana	20-30	18	6.5	43.5	0	0	0
37	16234	Robinia pseudacacia	20-30	14	g11.5	3.5	0	0	0

a Many had germinated and afterwards decayed.
b Approximately 10 per cent had germinated; the remainder had decayed.
c An occasional old sprout was found.
d Approximately all had germinated and afterwards decayed.
e Clipped, 87 per cent; not clipped, 51 per cent.
f Practically all had sprouted; the sprouts from seeds buried at the 36–42-inch depth were found matted in the bottom of the pot.
g Clipped.

The corn, sweet corn, corn cockle, cabbage, cotton, peas, beans, buckwheat, wheat, and barley—the first ten samples given in the foregoing table—were all so unmistakably decayed when the seeds were taken up that the contents of the pots were thrown away, no greenhouse tests being made. The first six of these samples showed no trace of any remains of old sprouts; apparently all of the seeds had decayed before germination had taken place. If germination took place it must have been comparatively soon after burial, thus giving ample time for all of the old sprouts to decay beyond identification. This, however, seems hardly probable, considering that the seeds were buried during the latter part of December, 1902; moreover, the beans, buckwheat, and barley from some or all of the different depths showed clearly the remains of well-developed radicles.

The beans which were buried at depths of from 6 to 8 and from 18 to 22 inches had decayed, while many of those buried at a depth of from 36 to 42 inches had germinated and afterwards decayed. The buckwheat from the 6 to 8 inch depth showed that approximately 10 per cent had germinated, while at 18 to 22 inches there were only the remains of an occasional old sprout, and at 36 to 42 inches all of the seed had decayed. In the wheat the greater number of the grains that were buried from 6 to 8 and from 36 to 42 inches had germinated and then decayed, while those which were buried at a depth of from 18 to 22 inches showed only decayed seed. Approximately all of the barley at the three different depths had germinated and afterwards decayed.

The last fourteen species given in this table were marked "decayed" when the seeds were taken up, but as the conditions were not so clearly indicated as in those first mentioned, germination tests were made in the greenhouse.

The results of the germination tests show that none of the pots contained any viable seeds. Of this latter group only the pots containing the *Asparagus officinalis* and *Bromus racemosus* (Nos. 32 and 33) showed remains of old sprouts. The seeds in the other pots apparently had all decayed without any germination during the time they were buried. The germination of the asparagus seed had been almost perfect. The pot buried at the greatest depth contained only a mass of sprouts, many of which were still partially alive. The *Bromus racemosus* showed that germination had taken place only in the pots buried at 6 to 8 and 36 to 42 inches, while those buried at the depth of 18 to 22 inches had all decayed before germinating.

It is interesting to note in this connection the behavior of the two species of Bromus—*Bromus secalinus* (cheat or chess) and *B. racemosus* (upright chess). The seeds of both of these species had completely lost their vitality within the eleven months in the soil, while the control samples gave a germination of 95.5 and 92.5 per cent.

respectively. These differences are more clearly shown in Plate I, A and B.

The results above stated, while perhaps not altogether conclusive, inasmuch as they represent only single tests of 200 seeds in each case, show that seeds of these two plants will not remain viable for long periods when buried in the soil.

This is particularly interesting in the case of the common cheat or chess, which is frequently a pernicious weed in the grain fields of the United States. The generally accepted opinion is that the grains of cheat will live in the soil for a number of years, the seeds germinating when conditions are most favorable, the resulting plants then crowding out the wheat. Some people even hold that in "off seasons" wheat turns to cheat, but fortunately such erroneous ideas are fast disappearing.

The results of these experiments show that cheat, whenever found growing in grain fields or elsewhere, has come from seed recently sown and has not been lying dormant in the soil. With but few exceptions the unexpected appearance of cheat comes either from seeds that have been sown unintentionally mixed with wheat or other grains so that they passed unobserved, or from seeds that have been scattered with stable manure.

Dr. Beal[a] has also shown that buried seeds of *Bromus secalinus* do not retain their vitality for a long period of years. In Beal's experiments the first test was at the expiration of five years, but not a single grain of cheat responded to the germination test at that time.

Table II includes the majority of our more commonly cultivated plants of the field or garden, all of which failed to show any seeds capable of germination after having been buried in the soil for approximately one year. This statement will hold good for the majority of our cultivated plants. There are, however, a number of exceptions. Many of these will be found in Table III, some showing that vitality was remarkably well preserved. Of these celery, parsnip, and tobacco (numbers 94, 95, and 99, respectively) should be mentioned in particular. The highest germination in each case was 64 per cent for the celery from the 18 to 22 inch depth, 63 per cent for the parsnip from the 36 to 42 inch depth, and 70 per cent for the tobacco from the 18 to 22 inch depth.

[a] Bulletin No. 5, Michigan Agricultural College, 1884.

TABLE III.—*Results of tests of seeds that had not completely lost their vitality while buried.*

Sample number.	Laboratory test number.	Kind of seed.	Chamber tests. Temperature.	Chamber tests. Original sample.	Chamber tests. Control.	Greenhouse tests in sand. Control.	Greenhouse tests in sand. Depth of burial. 6–8 inches.	Greenhouse tests in sand. Depth of burial. 18–22 inches.	Greenhouse tests in sand. Depth of burial. 36–42 inches.
			° C.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
38	16185	Festuca elatior	20–30	97	83	86	0.5	0.0	*a*0.0
39	16257	Capsicum annuum	20–30	96	97	80	.0	.0	.5
40	16222	Brassica campestris	20	90.25	86	18.5	.0	.0	*b*.5
41	16239	Trifolium repens	20	84.75	42.75	86	.0	*b*1	.0
42	16240	Vigna catjang	20–30	82.5	59.5	70	.0	1	.0
43	16230	Lespedeza frutescens	20	15	*c*1	2.5	.0	.0	1
44	16246	Ascyrum hypericoides	30	1.5	.0	.0	1	.0	.5
45	16259	Lycopersicon lycopersicon	20–30	99.25	72.5	88	.5	1	.5
46	16179	Chaetochloa glauca	20–30	55.75	37.5	18	1	1	1
47	16242	Rhus glabra	20–35	.0	.0	.0	.0	.0	2
48	16268	Cucumis sativa	20–30	100	98.5	62	.0	1	3
49	16236	Trifolium pratense	20	89.75	73	85.5	2	4	4
50	16235	Trifolium hybridum	20	91.75	84	73	2	4	4.5
51	16274	Xanthium pennsylvanicum	30	50	....	.0	.0	.0	.5
52	16229	Cassia marylandica	30	14.5	*d*98	20	3	3	5
53	16273	Ambrosia trifida	20–30	29	52.5	48	.0	*b*2	6
54	16237	Trifolium pratense (10964)	20	67.75	....	70	4.5	*b*5	6
55	16219	Vaccaria vaccaria	20–35	*e*6.5	88	68	.0	*b*4	7
56	16251	Convolvulus sepium	20–30	4	2	24	2	4	7
57	16283	Rudbeckia hirta	30	65.5	78.5	74.5	6.5	6.5	7
58	16224	Erysimum cheiranthoides	20–35	52.5	42	14.5	2	*b*5	*b*8
59	16231	Medicago sativa	20	84.5	64.5	97	*b*2	*b*9	*b*9
60	16227	Thlaspi arvense	20–30	57.25	54.5	.5	*b*11	8	11.5
61	16261	Solanum nigrum	20–30	97.75	91	12	9.5	10.5	12.5
62	16213	Chenopodium hybridum	20–30	61	18.5	10.5	7.5	9.5	13
63	16253	Cuscuta polygonorum	20–30	12	8.5	55.5	11.5	10.5	13
64	16193	Sporobolus cryptandrus	30	2.25	3	.0	.5	1.5	13.5
65	16265	Plantago rugelii	20–30	3.75	5.5	67.5	12	12	13.5
66	16255	Verbena hastata	20–30	9	.5	....	11.5	13	14
67	16220	Brassica nigra	20	1.5	13.25	34	10	*b*14	*b*14
68	16238	Trifolium pratense (hard)	20	13.75	9.25	18	*b*10.5	15.5	14.5
69	16184	Elymus triticoides	20–30	84	75	85	1.5	*b*3.5	*b*15.5
70	16187	Panicum virgatum	20–30	30.5	36.5	22	7	17	16
71	16174	Avena fatua	20–30	70.5	91.5	93.5	*b*9	*b*8	18
72	16211	Beta vulgaris	20–30	153	....	90.5	7	19.5	20
73	16228	Potentilla monspeliensis	20–30	41	83	73.5	*b*9.5	16	21.5
74	16183	Elymus canadensis	20–30	93.5	95.5	81	.0	*b*7	*b*22
75	16190	Poa pratensis	20–30	90.75	87	59	16	22	24.5
76	16262	Verbascum thapsus	20–30	82.5	98	72.5	7	7.5	25.5
77	16182	Elymus virginicus	20–35	65.25	44	83	*a*2	*b*13.5	*b*25.5
78	16226	Sisymbrium altissimum	20	88.25	86.25	76	*b*10.5	17.5	26
79	16256	Verbena urticifolia	30	1.5	.0	56.5	23.5	24.5	26.5
80	16277	Carduus arvensis	20–30	56.75	68	5	21	22.5	28.5
81	16252	Ipomoea lacunosa	20–35	98.5	*f*88	88	.20	25	33
82	16254	Cuscuta epilinum	20–30	.0	.0	.5	15.5	23.5	34
83	16214	Amaranthus retroflexus	20–30	94.75	91	61	18	22	35
84	16276	Bidens frondosa	20–30	75	52.5	25	29	33	36
85	16225	Neslia paniculata	20–35	96	97	68	23	24.5	38.5
86	16216	Portulaca oleracea	35	83.75	91.5	16	39	38.5	30.5
87	16272	Ambrosia artemisiaefolia	20–30	58.5	42.5	30.5	32	37	41
88	16263	Plantago lanceolata	30	82.5	78	67.5	41	41	41
89	16279	Grindelia squarrosa	20–30	25.75	41	87.5	30.5	36	42
90	16271	Taraxacum erythrospermum	20–30	85.75	87.5	85.5	35.5	41.5	45.5
91	16264	Plantago major	20–30	24	78	.0	39.5	43.5	46.5
92	16278	Chrysanthemum leucanthemum	20–30	96.25	91	85.75	*b*21	*b*33	*b*49.5
93	16188	Phalaris arundinacea	20–35	69.25	8	78	45	46.5	56.5
94	16248	Apium graveolens	20–30	88	83.5	72.5	48.5	64	60
95	16249	Pastinaca sativa	20–30	55.5	67	78.5	29	51	63
96	16212	Chenopodium album	20–30	67.25	58	33.5	32	63.5	64.5
97	16280	Helianthus annuus (wild)	20–30	100	97	86	43.5	64	66.5
98	16269	Lactuca scariola	20	.25	11.5	83	63.5	69	69.5
99	16260	Nicotiana tabacum	20–30	89.25	81.25	89.25	46.5	70	55
100	16173	Agropyron repens	20–30	80.24	84	23.5	20.5	*b*73	66.5
101	16275	Arctium lappa	20–30	99.75	96	88.5	42.5	63.5	73
102	16209	Rumex obtusifolius	20–30	97.5	95.5	80	73	72.5	79.5
103	16208	Rumex crispus	20–30	80.75	83.5	91	67.5	79.5	79
104	16215	Phytolacca americana	20–30	40.5	*d*88.5	84.5	7.5	66.5	80.5
105	16250	Fraxinus americanus	20–30	49.5	2	26	.0	.0	84
106	16258	Datura tatula	20–30	99	*d*54	88	*b*86	84	86.5
107	16207	Rumex salicifolius	20–30	98.25	96.5	2.5	88.5	85.5	70.5
108	16178	Chaetochloa verticillata	20–30	92.75	94.5	88.5	*b*58	71	90
109	16282	Onopordon acanthium	20–30	95.5	31	.0	86	93	90.5

TABLE III.—*Results of tests of seeds that had not completely lost their vitality while buried*—Continued.

Sample number.	Laboratory test number.	Kind of seed.	Chamber tests. Temperature.	Chamber tests. Original sample.	Chamber tests. Control.	Greenhouse tests in sand. Control.	Greenhouse tests in sand. Depth of burial. 6–8 inches.	Greenhouse tests in sand. Depth of burial. 18–22 inches.	Greenhouse tests in sand. Depth of burial. 36–42 inches.
			° C.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
110	16218	Alsine media	20–30	97	98.5	93	90.5	96.5	92.5
111[g]	16243	Abutilon abutilon							
112[g]	16189	Phleum pratense							
		Average percentage of germination		63.2	57.5	53.2	20.5	26.5	31

[a] Many had germinated and afterwards decayed.

[b] Fresh sprouts found when samples were taken up. These sprouted seeds were not thrown away, but were transplanted with the remainder of the sample and tested in sand in greenhouse, consequently those which produced seedlings are included in the percentages of germination given in the table. These fresh sprouts were found as follows:

Sample number.	Depth.	Sprouts.	Sample number.	Depth.	Sprouts.	Sample number.	Depth.	Sprouts.	Sample number.	Depth.	Sprouts.
	Inches.			*Inches.*			*Inches.*			*Inches.*	
39	36–42	1	59	36–42	1	71	18–22	Many.	92	18–22	Many.
53	18–22	3	60	6– 8	1	73	6– 8	4	92	36–42	Many.
54	18–22	1	67	18–22	2	74	18–22	Few.	100	18–22	1
55	18–22	1	67	36–42	2	74	36–42	Many.	106	6– 8	2
58	18–22	10	68	6– 8	1	77	18–22	10	108	6– 8	Many.
58	36–42	5	69	18–22	Few.	77	36–42	5			
59	6– 8	4	69	36–42	Many.	78	6– 8	1			
59	18–22	2	71	6– 8	Many.	92	6– 8	Many.			

[c] Clipped seed germinated, 59 per cent.

[d] Clipped.

[e] Germinated, 84 per cent at 20° C.

[f] Clipped seed germinated, 100 per cent.

[g] Tests interrupted.

In Table III the names of the seeds are arranged in the order of their vitality as determined by the germination tests made in the greenhouse. The list of seeds tested begins with *Festuca elatior* (meadow fescue), which showed only one viable seed, that being from the 18 to 22 inch depth, and ends with *Alsine media* (common chickweed), in which nearly all of the seeds retained their power of germination throughout the entire period that they remained in the soil. The germination of the latter, when sown in the greenhouse, was almost perfect. (See Pl. II, fig. 1.)

In many instances some of the seeds had germinated while they were buried. In most cases the seeds which had germinated afterwards decayed. In the larger seeds this could usually be determined without much difficulty, but with many of the smaller seeds no such observations could be made. However, it is more than probable that many of the smaller seeds which showed a low germination when transplanted in the greenhouse had germinated and afterwards decayed before being dug up, but this could not be satisfactorily determined by a hurried field examination. Many of the pots also contained fresh sprouts at the time the seeds were taken up. The number of fresh sprouts in each case is indicated in a footnote to Table III.

Unlike Table II, Table III includes names of but very few of our cultivated plants. The majority belong to that class of plants commonly known as weeds. These results show that but a limited number of our cultivated plants produce seeds which can retain their vitality for any length of time when buried in soil. On the other hand, the seeds of the plants which are commonly known as weeds are of strong vitality, and many of them deteriorated but very little with the treatment given. This, of course, is what we would expect. By natural selection the wild plants which survive are just those from seeds which are capable of living in the soil for a period of time more or less extended, and ultimately this factor becomes hereditary. With most of the cultivated plants the seeds are gathered and carefully saved from year to year, resulting in the loss of these inherited characteristics.

The mere fact that certain seeds retain their power of germination for a period of years when buried in the soil brands the plants which they produce as weeds. The length of time that such seeds can remain in the soil and still retain their power of germination largely determines their noxiousness. In other words, it may well be said that the pernicious character of weeds is directly proportional to the length of time the seeds will remain viable when buried in the soil. For this reason bad weeds are difficult to eradicate once the seeds are allowed to mature. (See Pl. II.)

RELATION OF DEPTH OF BURIAL TO VITALITY.

Table III shows that many of the seeds were better preserved the deeper they were buried. This is probably best explained by the difference in the three factors which govern germination, viz, *heat*, *moisture*, and *oxygen*. At the greatest depth the amount of moisture is always more uniform, the supply of air is greatly lowered, and the temperature is much reduced. The temperature decreases very rapidly as we go below the surface of the soil, and at 3½ feet is comparatively uniform throughout the year. Experiments conducted at McGill College, Montreal, Canada, by C. H. McLeod show that at a depth of 40 inches below the surface of the soil the minimum and maximum temperatures through the year were approximately 35° and 60° F., respectively.[a]

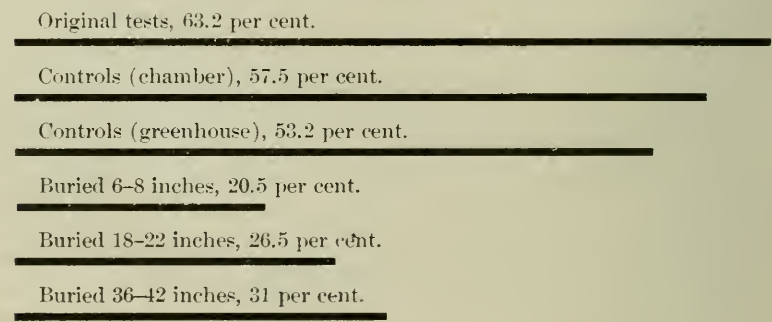
The greater number of seeds germinate best when subjected to daily alternations in temperature. These alternations do not take place at a depth of 3 feet below the surface; consequently there is a better

[a] Trans. Roy. Soc., Canada, Ser. 2, Vol. 7, Sec. III, pp. 13–16, 1901.

preservation of vitality at that depth as a result of the more dormant condition of the seeds. (See Pl. III and the diagram below.)

As was anticipated, most of the seeds which were stored in the Seed Laboratory preserved their vitality much better than those that were buried. But there are a number of cases in which the seeds were preserved practically as well in the soil as in the laboratory, the deterioration being very small in either case. However, with but few exceptions, an ample number of seeds remained germinable at the termination of the first year to produce plants in sufficient number to keep the up-to-date farmer busy for a good share of the summer in suppressing them. The average percentages of germination of all samples, including the original test and both controls, are best shown in the following diagram:

Average germination of controls and buried seeds.



HARD SEEDS.

An interesting point in these first results is in the behavior of the Trifoliums and closely related genera, including Lespedeza and Medicago. Generally speaking, these seeds are considered to be able to withstand very critical treatment, but the results of the first year's experiments show that the seeds of all of these deteriorated very greatly while in the soil.

The white clover, No. 41, germinated only 1 per cent, and showed one fresh sprout when taken up from the 18 to 22 inch depth and nothing from the shallower or deeper trenches. The red clover did but little better; No. 49, a sample of the harvest of 1902, germinated 2, 4, and 4 per cent for the three different depths of 6 to 8, 18 to 22, and 36 to 42 inches, respectively. Another sample of red clover, No. 54, germinated 4.5, 5, and 6 per cent, respectively, for the three different depths. A third sample of red clover, No. 68, germinated 10.5, 15.5, and 14.5 per cent, respectively, from the three depths. The last two samples were of Oregon-grown seed of the harvest of 1900. The original sample of this seed, No. 54, contained 51.5 per cent of hard seed. No. 68 includes only the hard seed selected from the Oregon clover by soaking in water for 18 and then for 20 hours a portion of the original bulk sample, using only the remaining hard seed.

These results, while unsatisfactory, show clearly that it is the hard seeds in the clovers which remain over in the soil for some considerable time. The alsike clover, No. 50, behaved practically the same as the sample of red clover first mentioned. The Lespedeza, or bush clover, No. 43, gave results very similar to the white clover. The alfalfa, No. 59, gave a germination of only 2, 9, and 9 per cent, respectively, for the three different depths. But in all cases a few fresh sprouts were present when the seeds were taken up, showing that the seeds were germinating and afterwards decaying.

SEEDS OF CULTIVATED VERSUS WILD PLANTS.

A number of interesting cases showing the greater hardiness of the seeds of wild plants over those of like or closely related cultivated forms were recorded. In *Helianthus annuus* (Nos. 6 and 97) the seeds from the cultivated plant—our common sunflower of the garden—all decayed, while the seeds of the wild sunflower retained their vitality and germinated 43.5, 64, and 66.5 per cent, respectively, for the three different depths. Similarly with *Lactuca sativa* and *Lactuca scariola*, Nos. 5 and 98, respectively, the common garden lettuce seed had all decayed, while the seed of the prickly lettuce, possibly the parent of our cos varieties, germinated 63.5, 69, and 69.5 per cent, respectively, for the three different depths. Another striking example is in *Avena sativa*, No. 1, and *Avena fatua*, No. 71, the latter germinating 9, 8, and 18 per cent, respectively, for the three different depths, besides showing many fresh sprouts in the two shallower depths at the time the seeds were taken up.

Furthermore, it is not uncommon to find wide variations in different species of the same genus, even where all forms are wild, e. g., Elymus, Chaetochloa, Chenopodium, Cuscuta, Plantago, etc. But in the cases above mentioned of the cultivated and the closely related wild forms the ability of the seeds to withstand such treatment as being buried in the soil has been lost by long cultivation of the plants and the careful preservation of the seeds under artificial conditions or storage, while seeds from the wild forms can survive when buried in the soil, for it is the plants from just such seeds that have survived.

SUMMARY.

The length of time that seeds will retain their vitality when buried in the soil is of much importance in the extermination of weeds.

The seeds of many of our pernicious weeds can be destroyed by deep plowing, if the soil is left undisturbed for some time.

Seeds of the cultivated plants, with but few exceptions, lose their vitality when buried in the soil.

Seeds of the plants commonly designated as weeds retain their vitality remarkably well when buried in the soil.

In general, the pernicious character of weeds is directly proportional to the length of time the seeds will remain viable when buried in the soil.

The deeper seeds are buried, the better is vitality preserved.

Hard seeds of the same species retain their vitality much better than those with softer seed coats.

Unhulled seed, especially of the grasses, is more resistant than hulled seed, and the vitality is always better preserved.

Seeds of plants from the same genus often retain their vitality in a very different degree.

Vitality is best preserved, even in weed seeds, when the seeds are carefully harvested and stored in a dry and comparatively cool place.

2'

PLATES.

DESCRIPTION OF PLATES.

PLATE I. Fig. 1.—*Bromus racemosus*, smooth brome grass. Fig. 2.—*Bromus secalinus*, cheat or chess. The two divisions at the right of each figure show the vigorous growth made by the check samples. In the three divisions at the left, A, B, and C, were planted the seeds which had been buried at depths of 6 to 8 inches, 18 to 22 inches, and 36 to 42 inches, respectively. The vitality of the seeds of these two species, which are considered as noxious weeds in the grain fields of the United States, was destroyed at the expiration of eleven months.

PLATE II. Fig. 1.—*Alsine media*, common chickweed. Fig. 2.—*Rumex crispus*, curled dock. Fig. 3.—*Datura tatula*, jimson weed. Seedlings from weed seeds which did not lose their vitality by burial for eleven months, as shown in the three divisions at the left of each flat, the germination being practically the same as in the case of the two check samples shown at the right of each flat.

PLATE III. Fig. 1.—*Elymus canadensis*, nodding wild rye. A, buried 6 to 8 inches—all killed; B, buried 18 to 22 inches—only one seedling shows in the figure, but the total germination was 7 per cent, as given in the table; C, buried 36 to 42 inches—germinated 22 per cent; the two check samples at the right made vigorous growth, germinating 81 per cent. Fig. 2.—*Fraxinus americanus*, white ash. A, buried 6 to 8 inches, and B, buried 18 to 22 inches—all killed; C, buried 36 to 42 inches—germinated 84 per cent; the check samples germinated 26 per cent, but the seedlings had "damped off" before the photograph was taken. Fig. 3.—*Phytolacca americana*, poke. A, buried 6 to 8 inches—germinated 7.5 per cent; B, buried 18 to 22 inches—germinated 60.5 per cent; C, buried 36 to 42 inches—germinated 80.5 per cent; the two check samples germinated 84.5 per cent.

The illustrations show that in many cases the vitality of seeds is better preserved at a depth of 36 to 42 inches than at shallower depths.

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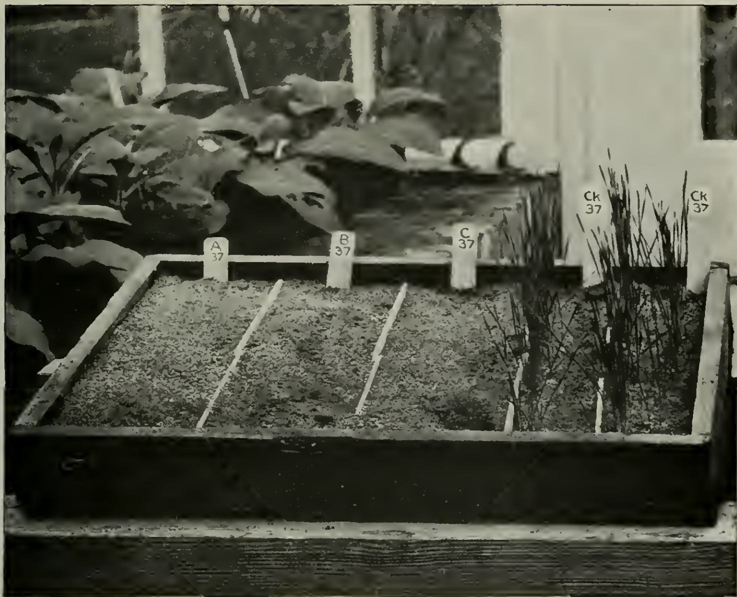

FIG. 1.—BROMUS RACEMOSUS (SMOOTH BROME-GRASS).

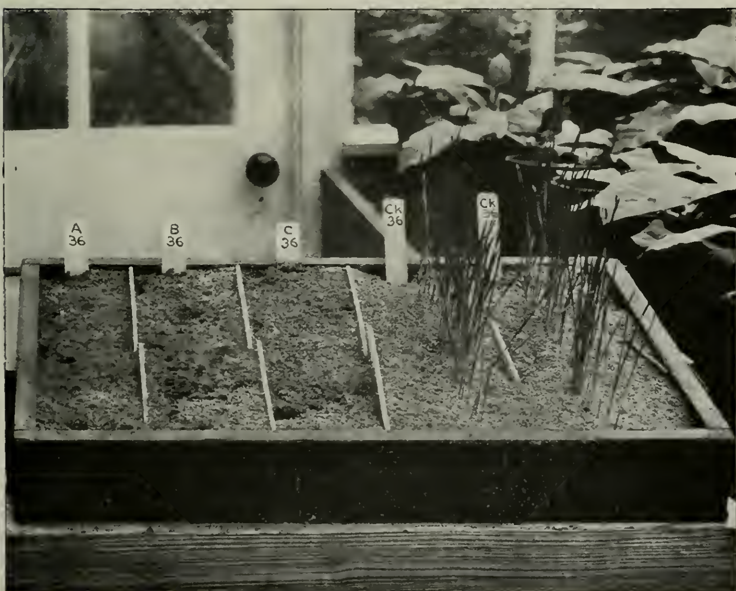

FIG. 2.—BROMUS SECALINUS (CHEAT, OR CHESS).

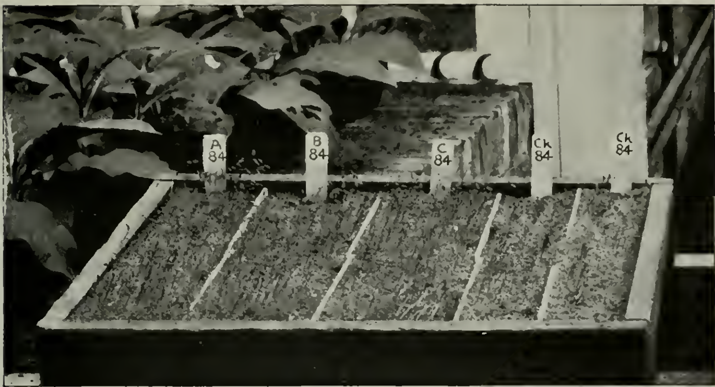

FIG. 1.—ALSINE MEDIA (COMMON CHICKWEED).

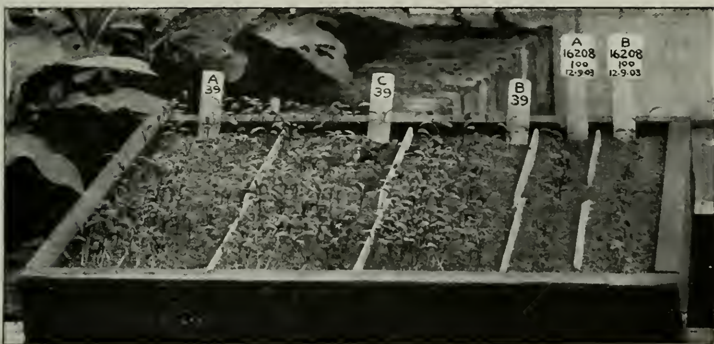

FIG. 2.—RUMEX CRISPUS (CURLED DOCK).

FIG. 3.—DATURA TATULA (JIMSON WEED).

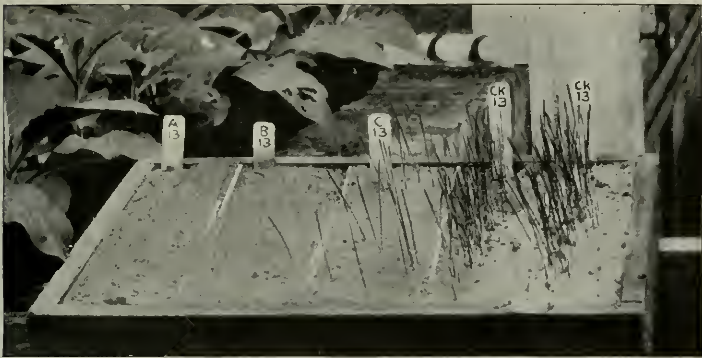

FIG. 1.—ELYMUS CANADENSIS (NODDING WILD RYE).

FIG. 2.—FRAXINUS AMERICANA (WHITE ASH).

FIG. 3.—PHYTOLACCA AMERICANA (POKE).

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 84.

B. T. GALLOWAY, *Chief of Bureau.*

THE SEEDS OF THE BLUEGRASSES.

I. THE GERMINATION, GROWING, HANDLING, AND ADULTERATION OF BLUEGRASS SEEDS.

By EDGAR BROWN, *Botanist in Charge of Seed Laboratory.*

II. DESCRIPTIONS OF THE SEEDS OF THE COMMERCIAL BLUEGRASSES AND THEIR IMPURITIES.

By F. H. HILLMAN, *Assistant Botanist, Seed Laboratory.*

ISSUED NOVEMBER 14, 1905.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 15, 1905.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 84 of the series of this Bureau the accompanying technical paper entitled "The Seeds of the Bluegrasses."

This paper was prepared by Mr. Edgar Brown, Botanist in Charge of the Seed Laboratory, and Mr. F. H. Hillman, Assistant Botanist, Seed Laboratory, and has been submitted with a view to publication.

The bluegrasses are among the most important forage plants in many sections of the United States and Europe, and large quantities of seed are harvested annually for use in this country and for exportation.

The process of cleaning the seed of the bluegrasses for market is such that many of the distinguishing characters are lost, and separate descriptions are necessary for the hand-picked and commercial seed of the same species.

The seeds of the different commercial species are so nearly alike in general appearance that at present none but the trained observer can distinguish between them. This similarity of appearance has encouraged the use of the cheaper and less desirable species, especially Canada bluegrass, for the adulteration of or substitution for the more expensive species.

The descriptions and illustrations herewith given of the bluegrasses and of their impurities will be of great value in furnishing seedsmen the necessary information to enable them to distinguish the different species.

The accompanying illustrations are necessary for a complete understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE SEEDS OF THE BLUEGRASSES.

I. THE GERMINATION, GROWING, HANDLING, AND ADULTERATION OF BLUEGRASS SEEDS.

By Edgar Brown,

Botanist in Charge of Seed Laboratory.

DESCRIPTION OF COMMERCIAL AND HAND-GATHERED SEEDS.

Great difficulty is experienced in distinguishing the seeds of the species of Poa. It is especially important to be able to recognize them, as the species vary greatly in value and the seed of one species is frequently substituted for that of another.

The descriptions of the seeds of Poa already published have been largely those of complete or hand-gathered specimens. But the seeds of some kinds as they appear on the market are more or less broken and have lost many of their distinguishing characters. The process of cleaning often rubs off the web at the base of the seed and the hairs along the sides and breaks the tip. On this account descriptions based on specimens of perfect seeds are not to be relied upon in identifying certain commercial Poas.

The mutilation of seeds during the process of cleaning is especially marked in home-grown seed of Kentucky bluegrass (*Poa pratensis*). Even the hand-gathered seed of rough-stalked meadow grass (*Poa trivialis*) is frequently so much injured about the slender apex as to increase greatly the difficulty of distinguishing it from that of Kentucky bluegrass. On the other hand, the commercial seeds of wood meadow grass (*Poa nemoralis*) and fowl meadow grass (*Poa triflora*) retain much of the pubescence on the glume, often the web, and are usually not broken on the tip.

It is important that descriptions and illustrations to be used in practical seed testing be taken from the commercial as well as hand-gathered seed and be comparative in character. Those given in this paper have been prepared from both hand-gathered and commercial seed. The term seed is here used in its popular sense.

GRADES AND QUALITY OF COMMERCIAL SEEDS.

The seeds of all species except Kentucky bluegrass are known to the American trade in only one grade. This is the so-called "fancy" grade, which is based on relative cleanness and on the bright appearance of the seed. The quality of different samples passing under this grade name is not necessarily uniform, but among the more careful dealers a purity standard of from 80 to 90 per cent is usually maintained.

The seeds of Kentucky bluegrass and of Canada bluegrass raised in this country are usually much cleaner and freer from foreign seeds than the European-grown seeds of rough-stalked meadow grass, wood meadow grass, and fowl meadow grass.

Kentucky bluegrass seed is commonly offered in two grades—"fancy," and "extra-clean" or "extra-cleaned." The latter names are a survival of the time when the seed was hand cleaned and the "extra-clean" was the best seed on the market. With the advent of improved machinery the "fancy" grade was established and it is now the only grade generally accepted by the intelligent purchaser. The "extra-clean" still on the market belies its name, since it consists of the chaff or cleanings from the fancy seed, and consequently contains only light seed. Samples of "extra-cleaned" as offered usually contain less than 10 per cent of seed.

In some cases the growers find a sale for the rough or uncleaned seed after it has been passed through a feed cutter. In this condition it has very much the appearance of fine-cut straw with a large percentage of chaff, and can be scattered over pastures and other areas, seeding them as effectually as could be done by the use of fancy recleaned seed. If well cured, the germinating quality of such seed is excellent, and the mass contains from 60 to 70 per cent of pure seed. Except for foreign trade the percentage of germination has little to do with the price and grade of bluegrass seed.

Aside from adulterated samples the purity of "fancy" seed of all species of bluegrass is usually good. Of the 2,887 samples of Kentucky bluegrass tested by the Zurich Seed Control Station from 1876 to 1903 the average purity was 86.3 per cent. Of the 69 samples tested in the Seed Laboratory of the Department of Agriculture during the past year the average purity was 75.02 per cent.

ADULTERATION.

The seed of Canada bluegrass (*Poa compressa*) is the only kind used as an adulterant of Kentucky bluegrass in this country. During the year 1904 649,451 pounds of Canada bluegrass seed were imported from Canada, practically none of which is being sold under its true name. Among the samples of seed sold for Kentucky bluegrass and sent to the Seed Laboratory for examination a large number have contained from 30 to 50 per cent of Canada bluegrass seed and several have been entirely composed of the Canada seed.

It is significant in this connection that the price of Canada bluegrass seed varies with that of Kentucky bluegrass seed, being usually about one-half that of the latter. This adulteration is not merely a simple fraud by which the farmer pays for what he does not get, but the difference in the resulting pasture or hay crop is very important. Canada bluegrass, while having many good qualities in common with other species of Poa, is by no means a pasture grass, for which purpose Kentucky bluegrass is unexcelled.

The seed of wood meadow grass (*Poa nemoralis*) is sometimes adulterated with other species of Poa, and samples have been offered under this name that contain no wood meadow grass seed. One sample tested in the Seed Laboratory contained 59.4 per cent of *Poa pratensis* and 23 per cent of *Poa compressa*, the remainder being chaff and dirt. Samples of fowl meadow grass (*Poa triflora*) have been examined which consisted largely of various common grass and clover seeds combined with an abundance of weed seeds. These samples contained small quantities of Kentucky and Canada bluegrass seeds, much chaff and dirt, and some of them no seeds of fowl meadow grass.

The seed of Kentucky bluegrass is used to adulterate that of the higher priced *Poa trivialis*, pure seed of the latter species usually being hard to obtain. Some of the German authorities say that it is necessary for every farmer to save his own seed of this grass in order to be sure that it is pure. Hunter[a] says:

> Previously to 1883 good and genuine seed of this species (*Poa trivialis*) could not be obtained in this country [England]. Seed of the *Poa pratensis* was commonly supplied for it. It is now less difficult to procure genuine seed, but large quantities of seed of *Poa pratensis* (which usually costs about one-third the price) are prepared to resemble and are sold for *Poa trivialis*, and it is only by careful microscopic examination that the nature of the seed can be determined

WEIGHT PER BUSHEL.

The standard weight of a bushel of bluegrass seed of any grade is 14 pounds. The actual weight, however, varies from 6 to 8 pounds in the case of "extra cleaned" to 27 pounds or more for especially good samples of fancy recleaned seed. In the bluegrass region of Kentucky it is the usual practice to sell the seed fresh from the strippers or cured in the chaff by the bushel of 14 pounds, but it is always weighed, not measured. The cleaned seed is always sold by the pound. As the weight per bushel of bluegrass seed depends directly on its purity, it is customary in quoting the price of "fancy" seed to accompany it with a statement as to the weight per bushel.

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[a] Treatise on Permanent Pasture Grasses, James Hunter. Chester, England, 1901.

The foreign trade is much more critical than the domestic trade, and the seed exported usually weighs from 22 to 24 pounds per bushel, while the domestic trade is content with seed weighing from 18 to 20 pounds. The heavier seed costs more per pound than the lighter seed, since there is more labor in its preparation, but it is cheaper for the purchaser.

GERMINATION.

The germination of commercial bluegrass seed is often poor. At the Zurich Seed Control Station the average percentage from 3,069 samples of Kentucky bluegrass seed tested from 1876 to 1904 was 65 per cent, while 908 samples of *Poa trivialis* tested showed an average of 72 per cent. The quality of Kentucky bluegrass seed as respects germination appears, however, to be improving. Last year's tests at the Zurich station gave an average of 68 per cent, while a few years ago 50 per cent was considered fair or satisfactory. Only the best seed goes to Europe, and consequently the percentage of germination of that offered in this country is low. As carefully cured seed will germinate from 80 to 90 per cent, the cause for the poor quality of commercial seed is doubtless to be found in the way it is harvested and cured.[a] The usual process is to pile the freshly stripped seed in ricks, either outdoors or in barns. This mass heats quickly if not stirred often during the first few days. One pile left without stirring reached a temperature of 140° F. in sixteen hours, killing all the seed.

GROWING AND HANDLING.

With the exception of our native western species, more or less seed of all the commercial Poas is gathered in Europe, where they are found wild. The harvesting is done by hand from the natural meadows, woods, or other uncultivated areas. The seed is cleaned by hand and carried to market in small quantities and collected by dealers who supply the trade. The United States furnishes Europe with Kentucky bluegrass seed, and Europe furnishes the seed of rough-stalked meadow grass and wood meadow grass, as well as of the other commercial species of Poa used in this country.

Poa pratensis (Kentucky bluegrass).—The bulk of the Kentucky bluegrass seed comes from a limited area known as the bluegrass region of Kentucky. The counties of Bourbon, Scott, Fayette, Clark, and Woodford furnish most of it, although there is a small quantity saved in Shelby County. Some is harvested in southwestern Illinois, and there is another area on the border between Missouri and Iowa where a considerable amount of seed is saved. The seed is gathered from the natural woodland pastures as well as from those where it has

[a] See Bulletin No. 19, Bureau of Plant Industry, "Kentucky Bluegrass Seed: Harvesting, Curing, and Cleaning."

been sown. It is customary to graze cattle on it nearly the entire year, as they do not materially injure the crop of seed if they are kept out for two or three weeks immediately before gathering. The seed is harvested by pulling the heads off with a stripper, the grass not being cut for hay. The cleaning is a rather difficult process, as it is necessary to rub the heads thoroughly in order to separate the seed from the web at the base. The last of the chaff and dirt which is blown out during the cleaning process is sold as "extra-cleaned" seed.

Poa compressa (Canada bluegrass).—The seed of Canada bluegrass is mostly produced in the Province of Ontario, along the north shore of the eastern half of Lake Erie. The soil is a heavy clay on limestone. In this section Canada bluegrass is not sown, but appears as a volunteer in any fields that are not kept under cultivation, making a thick growth and crowding out other grasses and weeds. It is nearly always found in wheat fields when the wheat crop is a partial failure. In this case the seed, ripening as it does at the same time as the wheat, is thrashed with it and screened out in cleaning. Where the seed is harvested alone the grass is cut with a mowing machine and cured the same as ordinary hay, and afterwards thrashed with a clover huller or grain separator. The hay is bright green, even when not cut until after the seed is ripe, and is well liked by some farmers as feed, while it is considered hard and of little value by others. A good crop is from 200 to 300 pounds of clean seed per acre. There has been some demand for this seed in the Southeastern States under the name of Virginia bluegrass. The seed is easily cleaned, as it is comparatively free from wool at the base and does not require rubbing, as does Kentucky bluegrass seed. No special machinery is used except rather long sieves to insure sufficient screening.

Poa trivialis (rough-stalked meadow grass).—The wholesale trade in the seed of rough-stalked meadow grass is largely confined to the city of Hamburg, Germany. The seed is collected in the neighborhood of that city and in the marshes of the Elbe. Seed of good quality is also supplied from Denmark, where in one locality this grass is grown especially for seed, and it is said to yield as much as 400 pounds to the acre. The seed is stripped or the grass is cut and the seed allowed to after-ripen, when it is cleaned by hand.

Poa nemoralis (wood meadow grass).—The seed of wood meadow grass is gathered by hand in the woods of Germany, and cleaned in the same manner as is the seed of *Poa trivialis*.

Poa triflora (fowl meadow grass).—Though widely distributed throughout the northern portion of the United States, this species is chiefly a natural meadow grass of lowlands, and is usually so mixed with sedges and other grasses that seed collection on a commercial scale has not thus far been undertaken in this country. The seed of this species on the market comes from Europe and is very poor.

Prof. L. R. Jones, of the Vermont Agricultural Experiment Station, reports the seed production from a nearly pure stand of this grass as amounting to 6 bushels of 19 pounds each per acre. A small plat yielded seed at the rate of over 7 bushels per acre. The seed is produced abundantly and ripens evenly. In Vermont it is harvested in the latter part of July. The name fowl meadow grass is often applied to another lowland grass, *Panicularia nervata.*

Poa arachnifera (Texas bluegrass).—The seed of Texas bluegrass is gathered by hand in northern Texas. It is cleaned by rubbing between the hands, and, owing to the long, woolly hairs at the base of the seed, it is never "fancy clean." The best seed is produced on rich, black, waxy soil, and is ripe about May 1 to 15. Only a small quantity is gathered each year, and consequently it is high priced and can not be considered as a commercial seed at the present time.

Poa annua (annual bluegrass).—The seed of the annual bluegrass is not on the market in this country, though the plant is common about dwellings, especially in the South and East, and ripens its seed throughout the summer. The seeds do not ripen evenly, the upper ones falling before the lower flowers have opened. The seed is gathered and used to some extent in Europe.

Poa alpina (alpine meadow grass).—Alpine meadow grass is best known in Switzerland, where the seed ripens from the end of June to the middle of July. The viviparous form can be propagated by scattering the buds during the hot weather.

Poa sudetica.—The seed of *Poa sudetica*, which is a European grass, is rare in the market, but is occasionally quoted by French and by German firms. It is sometimes mixed to some extent with the seeds of the meadow grasses, particularly water meadow grass (*Panicularia americana*).

In addition to the foregoing, other species of Poa occur in the western and northwestern United States, where they contribute to the native forage of the stock ranges. The seeds of these species, however, are not found in commerce.

II. DESCRIPTIONS OF THE SEEDS OF THE COMMERCIAL BLUEGRASSES AND THEIR IMPURITIES.

By F. H. HILLMAN,

Assistant Botanist, Seed Laboratory.

THE BLUEGRASSES.

The "seeds" of the species of Poa, or the bluegrasses, are the ripened florets or individual parts of the smaller clusters, or spikelets, of the general floral system of the plant. The number of florets in each spikelet varies from two to nine in the different kinds of Poa commonly found in commerce. There is some variation in the number of florets in the spikelets of each species. The florets separate readily at maturity, and well-cleaned samples of seed contain few whole or partial spikelets.

A complete, mature spikelet embraces, besides its several florets, a pair of chaffy scales, termed empty glumes, between which the florets, or at least the lower ones, rest. The empty glumes, while somewhat

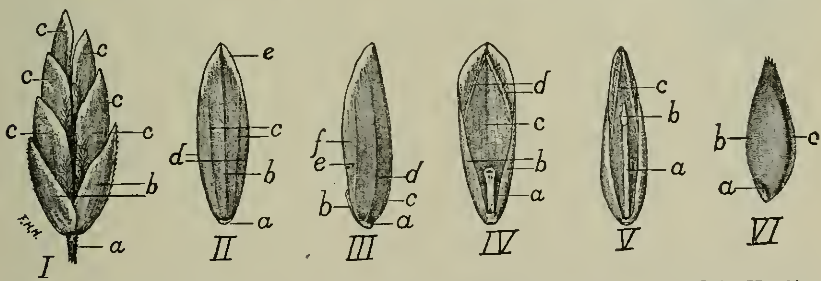

FIG. 1.—I.—A spikelet of Poa: *a*, stem of spikelet; *b*, empty glumes; *c*, florets, or "seeds." II.—Single floret, back view: *a*, callus; *b*, keel; *c*, intermediate veins; *d*, marginal veins; *e*, hyaline portion of glume. III.—Single floret, side view: *a*, callus; *b*, rachilla segment; *c*, keel; *d*, intermediate vein; *e*, marginal vein; *f*, margin of glume. IV.—Single floret, front view: *a*, rachilla segment; *b*, marginal fold; *c*, palea; *d*, keels of palea. V.—Terminal floret, front view: *a*, rachilla segment; *b*, aborted floret; *c*, palea. VI.—Caryopsis, or grain: *a*, location of embryo; *b*, keeled face; *c*, grooved face.

dissimilar, are keeled, acute, and one or three veined. The keel of each is usually hispid-ciliate above the middle. A portion of the stem of the spikelet often remains attached to the base of the empty glumes when these are found in commercial samples.

Each mature, well-developed floret or seed consists of a caryopsis, commonly called grain, two inclosing scales which, together with the empty glumes, constitute the chaff, and a slender appendage, the rachilla segment. (Fig. 1.)

The caryopsis corresponds to an individual grain in wheat, rye, and barley, and consists almost entirely of the seed proper, to which is added only the thin wall of the seed vessel. This is intimately blended with the seed coat, the two forming the covering of the true seed. The caryopsis is spindle-shaped and often broadest between the middle and the base. It is often bluntly keeled along one face and more or less evidently grooved along the opposite face. In the commercial bluegrass seeds the grain is amber-colored or dull wine-colored and semitranslucent. The surface is finely granular and dull. The kernel of the seed forms that part of the grain within the seed and seed-vessel walls. It consists of the embryo and endosperm, the latter forming the greater part. The embryo is situated at the basal extremity of the grain and is evident externally as a small ridge, often within a slight depression, on the keeled face. The grain adheres along its grooved face to the palea in some species in which free grains are not common in well-cleaned commercial seed.

The two chaffy scales of the floret differ chiefly in size, form, relative position, venation, and texture. The larger one, called the flowering glume or simply the glume, incloses the edges of the other, termed palea. The grain rests between the glume and palea, its keeled face lying against the glume. The rachilla segment is at the base of the palea and opposite the glume. It is one of the articulating sections of the rachilla, or axis of the spikelet.

The characters by which the different kinds of bluegrass seeds are distinguished one from another are afforded by the glume, palea, and rachilla segment, and involve size, form, color, veins of the glume, form and texture of the apex of the glume, and the pubescence.

The glume is stiffish and more or less pointed at the ends. Its base is marked by the presence of a small, somewhat knob-like appendage, the callus. The latter bears the scar of attachment of the floret and, in certain species, a more or less pronounced tuft of webby hairs. The back of the glume is more or less keeled along its longitudinal center. Besides the fold forming the keel, the edges of the glume are infolded along the marginal veins. The marginal folds often are most pronounced within and sometimes are confined to the lower half of the glume, in which event the upper margins usually diverge and become spreading or flaring at the apex. The keel is strongly arched lengthwise in some species and in others is nearly straight. Five veins traverse the glume longitudinally; one occupies the keel, two are at the marginal folds and are termed the marginal veins, while the other two are situated midway between the keel and marginal veins and are called intermediate or, by some authors, lateral veins. The intermediate veins exhibit considerable variation in distinctness in the different species. The vein occupying the keel extends to the apex. The apex and often the upper part of the lateral margins of the glume in most species are thin and translucent, or hyaline. The extent of the hyaline portion of the apex has much to do with the form of the latter and is variable in the different species.

The palea is commonly more delicate in texture than the glume, being partially hyaline. It usually is shorter than the glume, but in some species equals or exceeds it in length. The difference in length usually is most evident in the lower florets of the spikelet. Two veins traverse the palea lengthwise and nearly meet at its apex. The margins of the palea are more or less acutely infolded along these veins, which are called the keels of the palea. The keels are mostly covered by the glume in some species, while in others they are almost wholly exposed. There is some variation in this respect, however, among seeds of the same species. The apex of the palea is often notched.

The rachilla segment is nearly cylindrical and usually somewhat curved. It is slightly expanded at the apex, which is obliquely truncate, its terminal surface constituting the scar of attachment to the succeeding floret. Different florets in the same spikelet in certain species exhibit a marked variation in the length of the rachilla segment, which is shortest in the lower florets and conspicuously longer in the terminal one, where it usually bears an aborted floret as a small, pointed appendage.

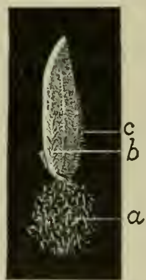

FIG. 2. — Unrubbed Kentucky bluegrass seed (*Poa pratensis*): *a*, web; *b*, pubescence of marginal vein; *c*, pubescence of keel.

The surface of the florets of different species of Poa is subject to considerable variation. Some florets are smooth, or glabrous; others bear numerous minute, stiffish hairs, rendering the surface rough, or scabrous; and some have a fine, appressed pubescence covering a part of the surface. Most of the species have a more or less silky pubescence on the keel and marginal veins below the middle or somewhat higher on the keel. The intermediate veins are more rarely pubescent. The keels of the palea are usually fringed with minute hairs, or are hispid-ciliate, but in some species they are silky pubescent. The basal web is wholly wanting in some species and in others varies from a few fibers to a copious tuft. It readily separates from the floret in most species. The rachilla segment is usually smooth, but in some species it is appressed pubescent. The presence of the hairs on the marginal veins often necessitates that care be used in examining the rachilla segment with respect to pubescence. (Fig. 2.)

The color of mature seeds varies from very light brown to dark brown. Sterile seeds are usually lighter or straw colored. Immature seeds are more or less tinged with green; some are purplish. In certain species the glume is tinged with golden yellow near the apex. The aborted terminal floret and all the hairs are white. The rachilla segment is lighter colored than the glume or palea.

Poorly cleaned samples are apt to contain many sterile florets. These are slender, sometimes shrunken, and usually lighter colored than the grain-bearing florets, which are comparatively plump and often dark colored, owing to the color of the grain appearing through the thin palea. (Fig. 3.)

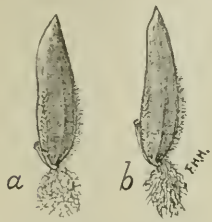

Fig. 3.—Seeds of Kentucky bluegrass (*Poa pratensis*): *a*, grain bearing; *b*, sterile.

The recognition of the several species of Poa, when the identity is questionable, requires the use of a good lens and a knowledge of the principal distinguishing characters. A sample under examination should be spread thinly on a sheet of paper, or, better still, on a black surface. With a good light and means for turning the seeds over while under the lens, they can easily be examined with reference to size, color, distinctness of veins, character of pubescence, the condition of the margins of the glume, etc. Exposing the different sides of the florets to the light while under examination is often absolutely essential in determining the nature of the veins and pubescence.

KEY TO THE SEEDS OF THE MORE COMMON SPECIES OF POA AS FOUND ON HERBARIUM SPECIMENS.

Basal web present.
- Web very persistent and conspicuous .... *P. arachnifera.*
- Web easily removed, small; keel of the glume pubescent.
  - Intermediate veins distinct.
    - Intermediate veins sharply defined as narrow ridges; glume margins narrow, not easily seen from the side; marginal veins usually smooth. *P. trivialis.*
    - Intermediate veins usually not sharply defined; glume margins broader, easily seen from the side in fertile florets; marginal veins pubescent. *P. pratensis.*
  - Intermediate veins indistinct.
    - Rachilla segment smooth or nearly so; florets 2–2½ mm. long.
      - Florets usually broader above than below the middle; apex usually flaring; rachilla segment smooth .... *P. compressa.*
      - Florets not evidently broader above than below the middle; apex usually golden yellow; rachilla segment sometimes rough .... *P. triflora.*
    - Rachilla segment usually pubescent.
      - Florets 2½–3 mm. long, usually not yellow at the apex. ..... *P. nemoralis.*

Basal web not present.
- Florets strongly pubescent.
  - Intermediate veins distinct; palea keels prominent, often arched forward. *P. annua.*
  - Intermediate veins indistinct; palea keels not arched................ *P. alpina.*
- Florets not pubescent .... *P. sudetica.*

KEY TO COMMERCIAL BLUEGRASS SEEDS AFTER PREPARATION FOR MARKET.

Seeds *4–6 mm. long;* web longer than glume, forming a woolly tuft *and causing the seeds to cling in bunches in the sample* .... *P. arachnifera.*

Seeds 2–2¾ mm. long, usually rubbed free from hairs and disconnected in the sample, *often more or less torn at the apex;* commonest commercial kinds.

Intermediate veins distinct; seeds contracted at the apex *and not wider above than below the middle;* hyaline margin of apex seldom present in rubbed seed. *P. pratensis.*

Intermediate veins very indistinct; seeds broader above than below the middle; hyaline margin of apex usually evident *and flaring* .... *P. compressa.*

Seeds 2–3 mm. long, chiefly unrubbed; disconnected or clinging somewhat in the sample; usually not torn at the apex; smooth or the pubescence on the veins and the web more or less evident.

Intermediate veins indistinct.

Rachilla segment usually pubescent; long, sterile rachilla segments conspicuously common; *intermediate veins scarcely evident;* keel and marginal veins pubescent; apex of seed often flaring; seed 2½–3 mm. long .... *P. nemoralis.*

Rachilla segment smooth; intermediate veins but slightly evident; keel and marginal veins pubescent; apex of seed sometimes flaring; *seed 2–2½ mm. long.* *P. triflora.*

Intermediate veins very distinct.

Rachilla segment smooth and slender; keel pubescent, marginal veins usually smooth; apex of seed acute and compressed; *seeds often distinctly curved as viewed from the side* .... *P. trivialis.*

COMPARISON OF THE PRINCIPAL DISTINGUISHING CHARACTERS OF BLUEGRASS SEEDS.

Species.	Florets.				Glume.				Palea.	Rachilla segment.	Aborted floret.
	Number in the spikelet.	Length.	General form.	Apex.	Intermediate veins.	Silky pubescence.	Basal web.	Color.			
		mm.									
P. pratensis.	3–5	2–2¾	Lanceolate or ovate-lanceolate.	Acute, mostly torn in commercial seed.	Distinct; not sharply defined, slender ridges; smooth.	On keel and marginal veins; absent in commercial seed.	Well developed; absent in commercial seed.	From light brown to dark brown, often purplish.	Equal to or somewhat shorter than the glume; keels hispid-ciliate and more or less exposed.	⅛ to ⅙ the length of glume; smooth.	Minute.
P. compressa.	3–9	2–2¼	Oblong-obovate or lanceolate.	Usually obtuse; torn or flaring in commercial seed.	Indistinct or apparently wanting; smooth.	Same as in *P. pratensis.*	Slight; absent in commercial seed.	Straw-colored or light brown, sometimes purplish.	Same as in *P. pratensis.*	⅛ to ⅙ the length of glume; smooth.	Minute.
P. trivialis.	2 or 3	2–2½	Narrowly lanceolate, often curved.	Acute; usually hyaline-edged and entire; distinctly keeled.	Sharply defined as slender ridges; smooth.	On keel; marginal veins smooth; often present in commercial seed.	Slight; usually absent in commercial seed.	Light brown, sometimes purplish.	Same as in *P. pratensis.*	Very slender, ¼ to ⅓ the length of glume; smooth.	Minute.
P. nemoralis.	2 or 3	2½–3	Lanceolate or ovate-lanceolate.	Obtuse or acute; hyaline and often flaring.	Indistinct; smooth.	On keel and marginal veins; present in commercial seed.	Same as in *P. trivialis.*	Light brown, sometimes yellowish at the apex.	Same as in *P. pratensis.*	Slender, ¼ to ⅓ the length of glume; pubescent; long, sterile segments abundant.	Often as long as the rachilla segment.
P. triflora.	2–4	2–2½	Same as in *P. nemoralis.*	Acute or slightly flaring; hyaline.	Same as in *P. nemoralis.*	Same as in *P. nemoralis.*	Same as in *P. trivialis.*	Light brown, usually yellowish at the apex.	Same as in *P. pratensis.*	Slender, ¼ to ⅓ the length of glume; smooth or rough.	Often long.

P. arachnifera.	4 or 5	4–6	Narrowly lanceolate.	Acuminate; hyaline-edged; not flaring.	Usually distinct as narrow ridges; smooth.	Same as in *P. nemoralis.*	Very copious; persistent; present in commercial seed.	Straw-colored or light brown.	Shorter than glume; keels hispid-ciliate.	$\frac{1}{3}$ to $\frac{1}{2}$ the length of glume; smooth.	Minute.
P. annua.	3–5	$1\frac{1}{2}$–3	Robust; ovate-lanceolate.	Acute or broadly flaring and hyaline.	Distinct; more or less pubescent.	On all the veins or only on keel and marginal veins; often on surface between the veins at base.	None.	From light brown to dark brown.	Equal to or shorter than glume; keels prominent, arched, pubescent.	Stout, $\frac{1}{4}$ to $\frac{1}{3}$ the length of glume.	Minute.
P. alpina.	3–6	$2\frac{1}{2}$–$3\frac{1}{2}$	Obovate or ovate-lanceolate.	Acute or flaring, hyaline.	Indistinct or evident below the middle; smooth or pubescent.	On keel and marginal veins and on surface between the veins at base.	None.	Light brown, sometimes purplish and yellowish.	Equal to or shorter than glume; keels exposed, slightly pubescent and hispid-ciliate.	From minute to $\frac{1}{3}$ the length of floret; smooth.	Minute.
P. sudetica.	2 or 3	3–4	Lanceolate or ovate-lanceolate.	Acute or acuminate; keeled and merely hyaline-edged.	Distinct for nearly or quite their full length; scabrous.	None; veins and often the general surface scabrous.	None.	Light brown to dark brown, sometimes purplish.	Equal to or exceeding the glume, often separated from it at the apex.	$\frac{1}{5}$ to $\frac{1}{2}$ the length of floret; the sterile segment tapering.	Minute or sometimes conspicuous.

DESCRIPTIONS OF SPECIES.

Poa pratensis L.

KENTUCKY BLUEGRASS, JUNE GRASS.

Spikelets 3–5 flowered; florets 2–$2\frac{3}{4}$ mm., rarely 3 mm., long, lanceolate or fusiform as viewed from the back, lanceolate or ovate-lanceolate as viewed from the side, mostly acute or the terminal floret sometimes acuminate at the apex, glabrous between the veins, varying from light brown to dark brown, sometimes tinged with purple, sterile florets lighter; glume usually sharply keeled quite to the apex and often strongly arched, particularly at the base; its marginal folds comparatively broad, extending from the base nearly or quite to the apex, becoming hyaline-edged above the middle in the lower florets, usually not expanded or flaring at the apex, the edges nearly meeting in sterile florets, separated and usually distended forward in fertile lower florets, often scarcely covering the palea keels of fertile terminal florets, the hyaline edge more or less torn away and the margins jagged at the apex in rubbed commercial seed; intermediate veins distinct and glabrous; keel and marginal veins silky pubescent below the middle or somewhat higher on the keel; basal web well developed; pubescence and web wanting, except occasional traces of the former, in well-rubbed commercial seed; palea nearly or quite as long as the glume, its keels finely hispid-ciliate and usually covered for the greater part of their length by the margins of the glume; rachilla segment slender, glabrous, varying from about one-sixth of the length of the glume in the lower florets to one-half its length in the terminal one; aborted floret of the sterile rachilla segment minute; grain $1\frac{1}{2}$ mm. long, somewhat keeled and grooved, often broadest below the middle, reddish brown or darker about the embryo, and semitranslucent. (Fig. 4.)

FIG. 4.—Different forms of commercial seeds of Kentucky bluegrass (*Poa pratensis*): *a* and *b*, back views; *c–f*, side views; *g–j*, front views; *j*, a terminal floret.

Commercial Kentucky bluegrass seed is mostly free from the silky and webby hairs present in hand-gathered samples, owing to the rubbing process to which it is subjected before being marketed. The severe rubbing results in more or less injury to the thin margins of the glume, particularly at the apex, which is usually found to be more or less torn when examined with a lens. Seeds of a well-rubbed sample do not tend to cling in small bunches as do those which are unrubbed or hand-gathered. Well-developed seeds are rather robust and have the glume margins well separated and evidently distended forward. Sterile seeds, or such as have the grain wanting or poorly developed, are generally lighter colored, slenderer, and more compressed, while the glume margins more nearly meet and are but slightly or scarcely distended. Such are much lighter in weight than well-developed seeds and consequently are mostly blown out with other chaff in well-cleaned seed.

Kentucky bluegrass seed is most readily confounded with that of Canada bluegrass (*Poa compressa*) and rough-stalked meadow grass (*Poa trivialis*). Owing to the difference in cost, *Poa compressa* is sometimes mixed with or substituted for Kentucky bluegrass, while the latter is sometimes similarly employed with respect to *Poa trivialis.*

The characteristic differences between Kentucky bluegrass seed and that of Canada bluegrass, as exhibited by the bulk samples and by individual seeds under the lens, may be compared as follows:

KENTUCKY BLUEGRASS (*Poa pratensis*).	CANADA BLUEGRASS (*Poa compressa*).
The usual, well-cleaned bulk samples are brown in color.	Average samples lighter colored than those of Kentucky bluegrass.
Individual, well-matured seeds exhibit the same brown color of the bulk sample.	The lighter color of individual seeds affords the principal character for the preliminary recognition of these seeds in mixtures.
Nearly all the seeds taper from the center to both ends and are not broader at the apex than at the base.	Most of the seeds are broader at the apex than at the base, often distinctly broader at the apex than at the middle.
The apex of commercial seeds is usually torn, obtusely pointed, keeled, and scarcely hyaline.	Apex of commercial seeds often torn, mostly expanded or flaring, often but slightly keeled.
The intermediate veins are almost invariably distinct.	The intermediate veins are very indistinct or apparently wanting.

A number of the samples of Kentucky bluegrass seed examined contained seed of the Canada bluegrass. As the latter seed found in commerce usually contains the prickles or even the seeds of Canada thistle (*Carduus arvensis*), these are often found in samples of Kentucky bluegrass seed containing the Canada bluegrass seed. Their presence indicates the admixture, since the Canada thistle does not grow in the seed-producing localities of Kentucky, while it is abundant in Canada, where the Canada bluegrass is produced. Samples of pure Kentucky bluegrass seed are apt to contain the prickles of horse nettle (*Solanum carolinense*), sometimes wrongly called bull thistle, a prickly plant common in the bluegrass region of Kentucky. These prickles are similar to those of the Canada thistle, but may be distinguished, as shown hereafter in this paper in describing the impurities of the bluegrass seeds. The fact that Canada bluegrass only begins to flower at the time Kentucky bluegrass is ripe precludes the possibility of the mixture of the two kinds of seed owing to the fact of growth together. Such mixture can occur only after the seed is gathered, through accident or intent.

Poa compressa L.

CANADA BLUEGRASS, FLAT-STEMMED BLUEGRASS.

Spikelets 3–9 flowered; florets 2–2½ mm. long, oblong-obovate or the terminal one lanceolate as viewed from the back, somewhat narrowly oblong as viewed from the side, obtuse or the terminal one acute, smooth between the veins, straw colored or light brown; glume somewhat arched, especially at the base, and strongly keeled at the back, the keel often less pronounced at the apex than at the base; margins infolded from the base for about three-fourths the length of the floret in the lower florets and nearly to the apex in the upper ones, hyaline-edged above the middle, often broadly so at the apex, which is more or less flaring in the lower florets, the thin apex often torn and jagged in commercial seed; intermediate veins very indistinct or not evident, glabrous; keel and marginal veins silky pubescent below the middle; basal web present, slight; palea nearly or quite equaling the glume, finely hispid-ciliate on the keels, which are usually more or less exposed above the middle, sometimes from the base; rachilla segment glabrous, varying from about one-fifth the length of the glume in the lower florets to one-half its length in the terminal one; aborted floret of the sterile rachilla segment minute; grain 1–1½ mm. long, keeled and slightly grooved, semitranslucent. (Fig. 5.)

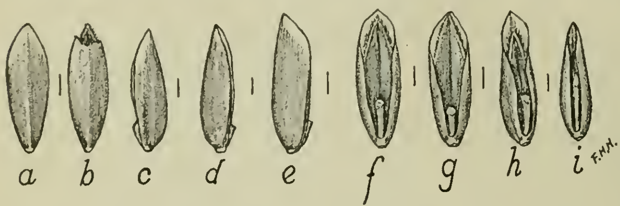

FIG. 5.—Commercial seeds of Canada bluegrass (*Poa compressa*): *a* and *b*, back views; *c–e*, side views; *f–i*, front views of florets; *i*, a terminal floret.

The seed of Canada bluegrass is the cheapest of the bluegrass seeds, and is therefore not adulterated with other Poas, although it is itself used as an adulterant to a considerable extent.

Pure samples of Canada bluegrass seed almost always contain the prickles and sometimes the seeds of Canada thistle (*Carduus arvensis*); therefore, the occurrence of these prickles with other kinds indicates the use of this species as an adulterant. Their occurrence with seed of *Poa trivialis* without evidence of the presence of Canada bluegrass seed is noted under the discussion of *P. trivialis*.

Poa trivialis L.

ROUGH-STALKED MEADOW GRASS.

Spikelets 2 or 3 flowered; florets 2–2½ mm., rarely 3 mm., long, narrowly lanceolate or the fertile terminal one ovate-lanceolate as viewed from the back, usually lanceolate and curved as viewed from the side, laterally compressed as compared with other species, straw colored or light brown and sometimes purplish, sharply keeled, the keel somewhat arched; margins of the glume scarcely or but slightly distended, narrowly and rather sharply infolded nearly or quite to the apex, which is hyaline-edged, very acute and rarely expanded; intermediate veins very distinct as narrow and sharply defined ridges; keel slightly pubescent below the middle, or rarely smooth; marginal veins smooth or sometimes pubescent, basal web present; palea nearly equal to the glume, its keels smooth or finely hispid-ciliate near the apex and mostly covered by the margins of the glume except in the larger terminal florets; rachilla segment very slender, glabrous, varying from one-fourth to one-half the length of the glume; grain 1–1½ mm. long, keeled and grooved, semitranslucent, reddish brown. (Fig. 6.)

Rough-stalked meadow grass is chiefly hand gathered; consequently the commercial seed is apt to bear more or less of the web as well as the silky pubescence on the keel. In many samples, however, both are rubbed away.

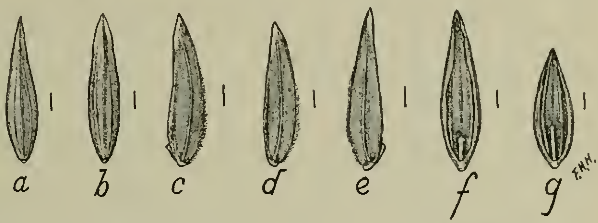

FIG. 6.—Seeds of rough-stalked meadow grass (*Poa trivialis*): *a* and *b*, back views; *c–e*, side views; *f* and *g*, front views; *g*, a terminal floret.

This seed resembles that of *Poa pratensis* and that of *Poa compressa* so closely that both are employed as adulterants, the former apparently to considerable extent, since it has frequently been found to constitute a considerable part of samples of so-called rough-stalked meadow grass. One sample examined marked "*Poa trivialis*" from Europe consisted almost wholly of *Poa compressa*. Several samples from Europe contained prickles of Canada thistle, but no seeds of Canada bluegrass were found.

The principal distinguishing characters of the three species may be compared as follows:

<table>
<tr><th>ROUGH-STALKED MEADOW GRASS
(Poa trivialis).</th><th>KENTUCKY BLUEGRASS
(Poa pratensis).</th><th>CANADA BLUEGRASS
(Poa compressa).</th></tr>
<tr><td>Commercial seeds are usually pubescent on the keel vein, usually smooth on the marginal veins and bear more or less of the webby hairs, consequently cling together in masses.</td><td colspan="2">Commercial seeds rarely pubescent on the veins and the webby hairs wanting; consequently mobile in bulk, not clinging in masses; unrubbed seed pubescent on the marginal and keel veins.</td></tr>
<tr><td>As viewed from the side, the seeds are somewhat curved, much narrower than the others, the glume margins usually only slightly evident.</td><td>Seeds mostly straight as viewed from the side, glume margins often strongly distended.</td><td>Seeds straight, the glume margins somewhat evident from the side.</td></tr>
<tr><td>Apex of the glume usually uninjured, strongly keeled, acute, slightly hyaline-margined, often curved.</td><td>Apex of the glume more or less torn in commercial seed; keeled, sharply pointed, hyaline-edged and not curved in unrubbed seed.</td><td>Apex of the glume often torn, otherwise somewhat keeled, obtusely pointed, broader than the base, hyaline-edged.</td></tr>
<tr><td>Intermediate veins sharply defined as narrow ridges.</td><td>Intermediate veins distinct as rather coarse ridges.</td><td>Intermediate veins indistinct or apparently wanting.</td></tr>
<tr><td>Rachilla segment very slender and less variable in length than in P. pratensis or P. compressa.</td><td colspan="2">Rachilla segment coarser than in P. trivialis and often very short.</td></tr>
</table>

Poa nemoralis L.

WOOD MEADOW GRASS.

Spikelets 2 or 3 flowered; florets 2½–3 mm. long, lanceolate or ovate-lanceolate, mostly acute at the apex, light brown, sometimes yellowish tinged near the apex; glume rather broadly keeled and somewhat arched at the back; margins of the glume narrowly infolded quite to the apex or hyaline-edged and often flaring above the middle; intermediate veins very indistinct; keel and marginal veins silky pubescent below the middle; basal web slight; surface between the veins glabrous; palea nearly equal to the glume, evidently shorter in florets having a flaring apex, its keels hispid-ciliate and usually covered by the margins of the glume; rachilla segment varying from one-fourth to three-fourths of the length of the glume, the sterile rachilla segment very uniformly much longer than the others, more or less appressed pubescent, the pubescence somewhat variable and sometimes nearly wanting; aborted floret of the sterile rachilla segment often one-half as long as the segment; grain 1½ mm. long, rather slender, semitranslucent. (Fig. 7.)

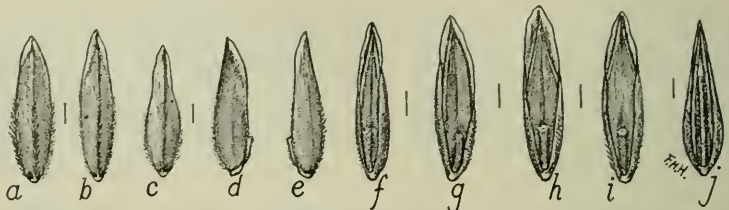

FIG. 7.—Seeds of wood meadow grass (*Poa nemoralis*): *a–c*, back views; *d* and *e*, side views; *f–j*, front views; *j*, a terminal floret.

Commercial wood meadow grass seed is not rubbed in preparation for market, and therefore possesses much of its rather persistent and prominent silky pubescence, and the thin tips of the florets are mostly uninjured. The pubescence of the rachilla segment is persistent and present in most of the seeds of all pure samples of this species. It affords the most marked characteristic by which the seeds of *P. nemoralis* may be distinguished from those of other commercial species of Poa. The conspicuously longer rachilla segments of the terminal florets are noticeably abundant in samples of this species, since these florets constitute from one-third to one-half of all the seed. The abundance of the long rachilla segments is helpful in distinguishing these seeds from those of other Poas.

Commercial seed of *P. nemoralis* is apt to be very much adulterated with other species of Poa. Of a number of samples examined less than half were true to name. One was nearly pure Canada bluegrass seed, and the rest consisted in part of one or all of the following species: *P. pratensis*, *P. compressa*, and *P. trivialis*.

The following comparison of characters should render it comparatively easy to distinguish the seeds of *P. nemoralis* from those of the other species.

Wood meadow grass (*Poa nemoralis*).	Kentucky bluegrass (*Poa pratensis*); Rough-stalked meadow grass (*Poa trivialis*).	Canada bluegrass (*Poa compressa*).
Silky pubescence of the veins mostly present and prominent.	Silky pubescence of the veins wanting or but slight.	
Apex of the glume slenderly pointed or narrowly flaring.	Apex of the glume acute.	Apex of the glume broadly flaring.
Intermediate veins indistinct.	Intermediate veins distinct.	Intermediate veins indistinct.
Rachilla segment pubescent, often more than half the length of the glume.	Rachilla segment smooth, not exceeding half the length of the glume.	

Poa triflora Ehrh. (**P. flava** L., **P. serotina** Ehrh.).

FOWL MEADOW GRASS, FALSE REDTOP.

Spikelets 2–4 flowered; florets 2–2½ mm. long, lanceolate or ovate-lanceolate as viewed from the back, broadly keeled and strongly arched at the back, light brown and usually strongly tinged with yellow above the middle, sometimes purplish, margins of the glume narrowly infolded below the middle or quite to the apex, which is hyaline-edged, expanded but scarcely flaring; intermediate veins indistinct; keel and marginal veins silky pubescent below the middle; basal web slight; palea nearly or quite equal to the glume, finely hispid-ciliate on the keels, which are mainly covered by the glume margins in the lower florets; rachilla segment slender, glabrous or sometimes slightly scabrous, from one-fourth to one-half or two-thirds the length of the glume; aborted floret of the sterile rachilla segment often prominent and nearly as long as the rachilla segment; grain 1 mm. long, comparatively robust and smooth, scarcely keeled or grooved, semitranslucent. (Fig. 8.)

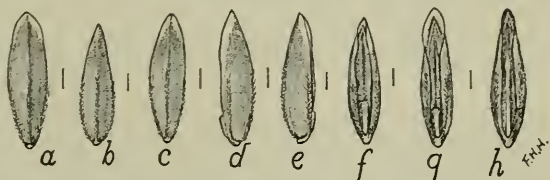

Fig. 8.—Seeds of fowl meadow grass (*Poa triflora*): *a–c*, back views; *d* and *e*, side views; *f–h*, front views; *h*, a terminal floret.

Most, if not all, of the seed of *P. triflora* on the market appears to be of foreign production. The samples examined have proved to be the worst found among the bluegrasses. It is probable that a better grade of seed could be secured from the natural meadows in this country where this species often constitutes the principal grass. The seeds of *P. triflora* are very similar to those of Canada bluegrass and wood meadow grass.

The principal distinguishing characters of the three kinds are as follows:

FOWL MEADOW GRASS (*Poa triflora*).	CANADA BLUEGRASS (*Poa compressa*).	WOOD MEADOW GRASS (*Poa nemoralis*).
Seeds 2–2½ mm. long.	Seeds 2–2½ mm. long.	Seeds 2½–3 mm. long.
Seeds mostly narrower at the apex than at the center.	Seeds mostly broader at the apex than at the center or base.	Seeds narrower or not broader at the apex than at the center.
Seeds usually yellowish at the apex.	Seeds not yellowish at the apex.	Seeds sometimes yellowish at the apex.
Intermediate veins usually evident but indistinct.	Intermediate veins indistinct or more commonly not evident.	Intermediate veins indistinct.
Pubescence of the veins and the web often present in commercial seed.	Pubescence of the veins and the web mostly absent in commercial seed.	Pubescence of the veins usually present in commercial seed.
Rachilla segment mostly smooth, sometimes slightly rough, often two-thirds the length of the glume.	Rachilla segment smooth, not exceeding one-half of the length of the glume.	Rachilla segment pubescent or sometimes only rough, often three-fourths the length of the glume.

The name fowl meadow grass is often applied, both by seedsmen and by writers upon grasses, to *Panicularia nervata*.

Poa arachnifera Torr.

TEXAS BLUEGRASS.

Spikelets 4 or 5 flowered; florets 4–6 mm. long, narrowly lanceolate, acuminate, straw colored or light brown; glume strongly keeled quite to the apex and somewhat arched; margins narrowly infolded below and becoming broadly hyaline above the middle, not widely flaring at the apex; marginal and keel veins strongly pubescent with long, silky hairs; basal web copious, often twice as long as the floret, very persistent; surface between the veins glabrous, the keel hispid-ciliate above the middle; palea from three-fourths to four-fifths the length of the glume, its keels more or less exposed, silky pubescent to the middle and hispid-ciliate at the apex; rachilla segment varying from about one-sixth to one-third the length of the glume, glabrous; aborted floret of the sterile rachilla segment minute; grain slender, 1½–3 mm. long, oblong-fusiform, nearly opaque, distinctly grooved and keeled. (Fig. 9.)

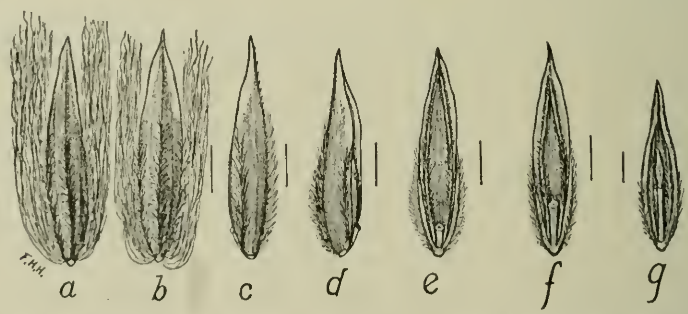

FIG. 9.—Seeds of Texas bluegrass (*Poa arachnifera*): *a* and *b*, back views, seeds showing the long hairs of the web; *c* and *d*, side views; *e*–*g*, front views; *g*, a terminal floret.

Texas bluegrass seed in commerce is unrubbed, and as the silky pubescence and web are very persistent they are always present. The hairs are so long and copious that the seeds cling in loosely matted, woolly bunches, and thus are easily distinguished from all the other commercial Poas. (Fig. 10.)

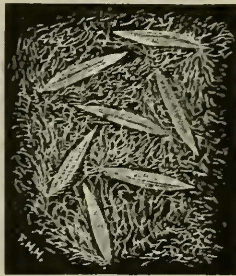

FIG. 10.—A cluster of Texas bluegrass seeds matted by the webby fibers.

Poa annua L.

ANNUAL MEADOW GRASS.

Spikelets 3–5 flowered; florets $1\frac{1}{2}$–3 mm. long, ovate or ovate-lanceolate and relatively robust, strongly keeled and arched at the back, more or less densely pubescent, light brown or dark brown and often purplish or yellowish; margins of the glume very narrowly infolded below the middle, thin and broadly hyaline above the middle in the lower florets, flaring, gaping, or infolded at the apex; intermediate veins usually distinct as narrow ridges extending from the base to the margin of the apex, glabrous or pubescent; marginal veins and keel densely soft-pubescent below the middle; surface between the veins sometimes more or less pubescent at the base; web wanting; palea somewhat shorter than the glume, except in the terminal floret; keels of the palea coarse and prominent, mostly exposed, usually arched forward and exposed to side view in florets having a well-developed grain, often contracted toward the rachilla segment at the base, silky pubescent from near the base nearly to the apex; rachilla segment glabrous, from one-fourth to one-third the length of the glume, aborted floret of the sterile rachilla segment minute; grain 1–$1\frac{1}{2}$ mm. long, robust, distinctly granular, keeled and grooved, slightly translucent. (Fig. 11.)

The seed of *Poa annua* is not in the trade and is not apt to become mixed with the commercial bluegrass seeds. It may be readily distinguished from the common commercial species of Poa by its abundant

FIG. 11.—Seeds of annual meadow grass (*Poa annua*): *a* and *b*, back views; *c–e*, side views; *f–i*, front views; *i*, a terminal floret.

pubescence, arched and silky pubescent keels of the palea, and robust form. The seed most closely resembles that of *Poa alpina*, from which it is distinguished in individual seeds by its distinct intermediate veins and prominent, arched, and silky pubescent but not hispid-ciliate palea keels.

Poa alpina L.

ALPINE MEADOW GRASS.

Spikelets 3–6 flowered; florets $2\frac{1}{2}$–$3\frac{1}{2}$ mm. long, ovate-lanceolate or obovate, the uppermost lanceolate, broadly keeled, arched, acute, or obtuse, light brown, sometimes purplish, and often yellowish tinged at the apex; margins narrowly infolded below the middle and becoming broadly hyaline at the apex; intermediate veins indistinct or evident only below the middle; keel and marginal veins silky pubescent below the middle or higher on the keel, which is hispid at the apex; surface between the marginal veins and keel appressed pubescent at the base; web wanting; palea nearly or quite equal to the glume, its keels not arched as in *Poa annua*, slightly silky pubescent below the middle and hispid-ciliate above; rachilla segment glabrous, varying from no longer than wide to one-third the length of the glume; aborted floret of the sterile rachilla segment minute; grain $1\frac{1}{2}$ mm. long, keeled and grooved, semitranslucent, dark reddish brown, granular. (Fig. 12.)

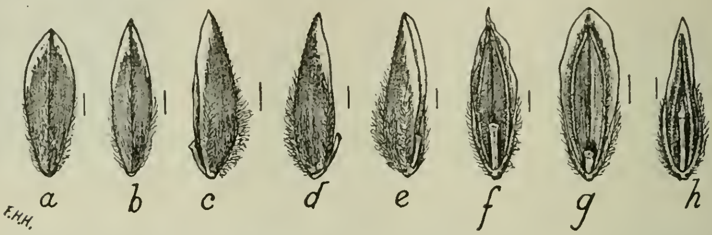

FIG. 12.—Seeds of alpine meadow grass (*Poa alpina*): *a* and *b*, back views; *c–e*, side views; *f–h*, front views; *h*, a terminal floret.

The seed of *Poa alpina* is not on the market and is not likely to be found in commercial seeds. Individual seeds of *P. alpina* closely resemble those of *P. annua*, but are to be distinguished by the indistinct intermediate veins of the glume, the variable rachilla segment, and especially by the keels of the palea, which are slenderer, not arched, less pubescent, and strictly hispid-ciliate above. The plant is alpine and occurs in the northern part of the United States as far west as Colorado, in Canada and Alaska, and in Europe and Asia.

Poa sudetica Haenke.

Spikelets 2 or 3 flowered; florets 3–4 mm. long, lanceolate or ovate-lanceolate; apex acute or acuminate; glume somewhat arched and strongly keeled at the back, light brown or dark brown, sometimes tinged with purple; margins of the glume narrowly infolded below the middle, narrowly hyaline-edged above the middle and not flaring at the apex; all the veins distinct, never silky pubescent, usually hispid;

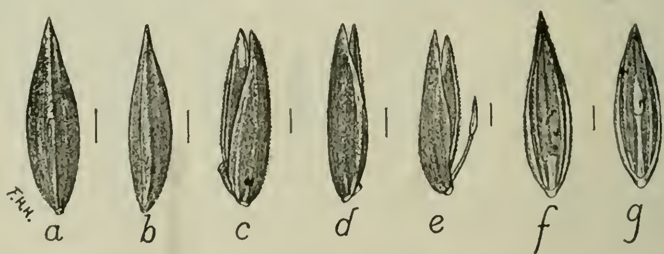

FIG. 13.—Seeds of *Poa sudetica*: *a* and *b*, back views; *c–e*, side views; *f* and *g*, front views; *g*, a terminal floret.

general surface scabrous or sometimes glabrous; web not present; palea equaling or somewhat exceeding the glume and often separated from it at the apex in florets having a well-developed grain; keels of the palea hispid-ciliate, mostly exposed and more or less evident from the side; rachilla segment varying from one-fifth to one-third or even one-half the length of the glume, glabrous or scabrous, sterile rachilla segment tapering to the apex, the aborted floret usually minute, but sometimes conspicuous and nearly equal to the rachilla segment; grain about 2 mm. long, robust, light brown, slightly keeled and grooved, semitranslucent. (Fig. 13.)

This is a European species not found in the American market.

Panicularia spp.

Owing to the fact that *Panicularia nervata* is sometimes sold as fowl meadow grass, a description of its seed is presented. A description of the closely allied *P. americana*, which is often associated with *P. nervata*, is added as an aid in comparing the two species.

Panicularia nervata (Willd.) Kuntze.

NERVED MANNA GRASS, SOMETIMES CALLED FOWL MEADOW GRASS.

Florets 1–1½ mm. long, robust, ovate (obovate with reference to the plant), light brown, purplish and sometimes greenish when immature; glume rounded at the back, prominently seven-veined, its margins somewhat infolded at the base and not flaring at the apex, which is sometimes narrowly hyaline; surface smooth, except the veins, which are sometimes scabrous; palea equal to or sometimes longer than the glume, broad, the keels exposed, prominent and nearly meeting at the rounded and sometimes slightly notched apex, usually scabrous above the middle; rachilla segment one-fifth to one-fourth the length of the glume, subcylindrical and scarcely expanded at the apex, the terminal one somewhat longer than the others and tipped by a minute, aborted floret; grain loosely held by the stiffish glume and palea, obovate, slightly flattened, ¾–1 mm. long, smooth, somewhat polished, very dark brown or black, sometimes slightly translucent. (Fig. 14.)

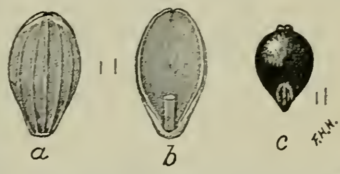

FIG. 14.—Seeds of nerved manna grass (*Panicularia nervata*): *a* and *b*, back and front views; *c*, grain.

Panicularia americana (Torr.) MacM.

REED MEADOW GRASS, WATER MEADOW GRASS, TALL MANNA GRASS.

Florets 3–3½ mm. long, elliptical-oblong as viewed from the front or back, somewhat spindle-shaped as viewed from the side, obtuse at the apex, brown, or purplish before complete maturity; glume rounded at the back, distinctly seven-veined, its margins narrowly infolded at the base and not flaring at the apex; surface smooth between the scabrous veins; palea equal to the glume, concave, its keels exposed, nearly meeting at the apex, very finely hispid-ciliate; rachilla segment one-fifth to one-fourth the length of the glume, subcylindrical, somewhat expanded at the apex, that of the terminal floret slightly longer and tipped by a minute, aborted floret; grain broadly oblong, 1½–2 mm. long, somewhat flattened, very dark brown, slightly translucent, smooth, and somewhat polished when fully developed. (Fig. 15.)

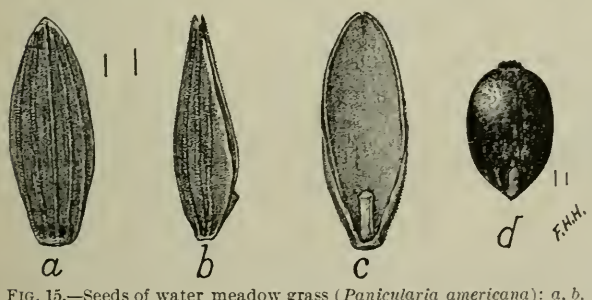

FIG. 15.—Seeds of water meadow grass (*Panicularia americana*): *a*, *b*, and *c*, back, side, and front views of seeds; *d*, grain.

WEED SEEDS COMMONLY FOUND WITH COMMERCIAL BLUEGRASS SEEDS.

The following weed seeds are those most frequently found with the various kinds of bluegrass seed.

Bursa bursa-pastoris (L.) Britton.

SHEPHERD'S-PURSE.

Seeds $\frac{2}{3}$–1 mm. long, oval-oblong, one extremity often pointed by the whitish tissue of the scar, flattened with rounded edges; faces similar and usually presenting two shallow grooves; color yellowish or reddish brown, usually darker near the scar; surface nearly smooth; endosperm absent; embryo curved upon itself, the cotyledons incumbent; seeds developing a coat of transparent mucilage when placed in water. (Fig. 16.)

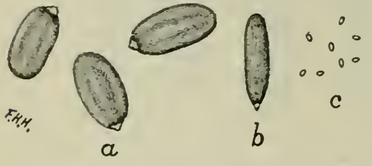

FIG. 16.—Seeds of shepherd's-purse (*Bursa bursa-pastoris*): *a*, side view; *b*, edge view; *c*, natural size of seeds.

Seldom found abundantly, but occurring frequently in all of the commercial bluegrass seeds.

Lepidium virginicum L.

PEPPERGRASS.

Seeds $1\frac{1}{2}$ mm. long, much flattened, ovate with one edge straight and thicker than the other, the curved edge narrowly margined, the margin usually hyaline and broadest at the broad end of the seed; faces similar, each nearly crossed lengthwise by a curved groove; scar at the small extremity, marked by a small, whitish tissue; surface smooth, dull, and reddish yellow; endosperm wanting; embryo curved upon itself, the cotyledons accumbent; seeds developing a copious coat of transparent mucilage when placed in water. (Fig. 17.)

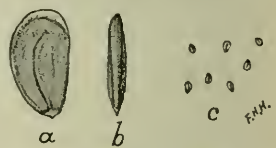

FIG. 17.—Seeds of peppergrass (*Lepidium virginicum*): *a*, side view; *b*, edge view; *c*, natural size of seeds.

Frequently found in home-grown seed and sometimes very abundant, especially in poorly cleaned seed.

Cerastium vulgatum L.

MOUSE-EAR CHICKWEED.

Seeds about $\frac{1}{2}$ mm. long, flattened but not thin, rounded or triangular, the broad edge rounded, the narrow edge notched; surface roughened by small tubercles or very short ridges, dull, and reddish-brown; embryo cylindrical, curved about the endosperm, its extremities nearly meeting at the notch in the seed coat. (Fig. 18.)

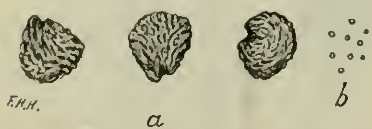

FIG. 18.—Seeds of mouse-ear chickweed (*Cerastium vulgatum*): *a*, side views; *b*, natural size of seeds.

Found frequently; sometimes abundant in poorly cleaned seed.

Alsine media L.

COMMON CHICKWEED.

Seeds circular-ovate, about 1 mm. in diameter with little variation in size, flattened with plane faces and flattened edges; scar in a small notch in the edge; surface dull, slightly tubercled, the tubercles in rows on the edges and in more or less evidently concentric rows on the similar faces; color brown, or reddish in immature seeds: embryo cylindrical, curved about the endosperm, its extremities nearly meeting at the scar. (Fig. 19, *a*.)

Alsine media is very common in the United States, but is so low-growing that the American method of seed stripping prevents the occurrence of its seeds in abundance in commercial bluegrass seeds. Its seeds are common in European bluegrass seeds, particularly those of rough-stalked meadow grass.

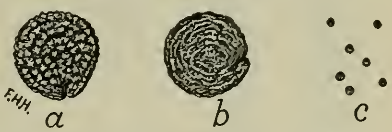

FIG. 19.—Seeds of chickweeds: *a*, *Alsine media; b*, *A. graminea; c*, natural size of seeds.

Alsine graminea (L.) Britton.

Seeds similar to those of *Alsine media*, except in form and surface markings; usually circular or oval; faces and edges somewhat rounded, finely roughened by short, interlacing ridges which are arranged more or less concentrically on the faces and parallel on the edges; surface dull; color grayish-brown, immature seeds reddish. (Fig. 19, *b*.)

Not found in American seed; frequent, although not abundant, in European seed.

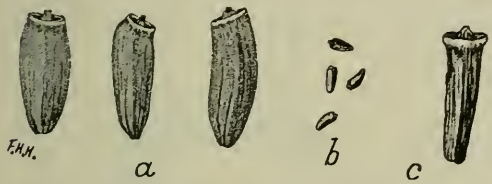

FIG. 20.—Seeds of Canada thistle (*Carduus arvensis*): *a*, well-matured seeds; *b*, natural size of seeds; *c*, a shriveled seed.

Carduus arvensis (L.) Robs.

CANADA THISTLE.

Seeds (akenes) 2–3 mm. long, oblong-lanceolate, flattened with obtuse edges, slightly ridged along each face, straight or curved edgewise, sometimes facewise; apex truncate, often obliquely so, concave with a ring-like border; corolla scar represented by a central, conical projection; surface dull and mostly smooth, sometimes with several narrow, longitudinal grooves; color brown, the apical margin usually lighter and sometimes yellowish. (Fig. 20.)

Prickles of Canada thistle and horse nettle (*Solanum carolinense*) often occur in certain bluegrass seeds. While the presence of the former is significant with respect to adulteration, the two kinds are apt to be confounded.

The prickles of Canada thistle are 2–6 mm. long, very slender, yellowish, usually expanded and laterally flattened at the base, which consists of a portion of the leaf tissue and is darker colored than the rest of the prickle, somewhat rounded or angular in form and jagged-edged. (Fig. 21, *c* and *d*).

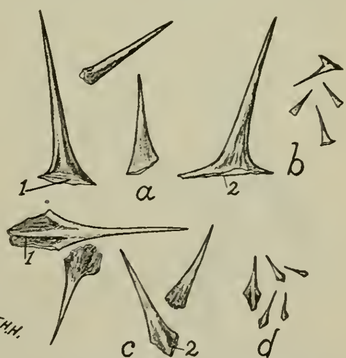

FIG. 21.—Prickles often found with bluegrass seed: *a* and *b*, horse nettle (*Solanum carolinense*) enlarged and natural size; *c* and *d*, Canada thistle (*Carduus arvensis*) enlarged and natural size; 1 and 2, characteristic forms of the bases of the two kinds of prickles.

The prickles of horse nettle (*Solanum carolinense*) are coarser, 4–8 mm. in length, light yellow in color, usually not darker at the base. They are produced on the stems and the coarse midribs of the leaves, and on breaking off have a transversely flattened scar. They occur frequently in samples of Kentucky-grown *Poa pratensis* and are easily mistaken for those of Canada thistle. (Fig. 21, *a* and *b*.)

Matured seeds, shriveled seeds, and prickles from the leaves and stems of Canada thistle are frequently found in Canada bluegrass seed. The presence of the prickles in the more expensive kinds of bluegrass seed indicates the probable use of Canada bluegrass seed as an adulterant. These prickles have been found, however, in rough-stalked meadow grass seed in which no trace of Canada bluegrass seed appeared. Owing to the troublesome nature of Canada thistle, care should be taken not to introduce its seeds with those of the bluegrasses.

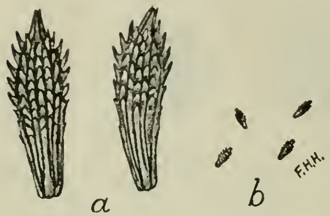

FIG. 22.—Seeds of dandelion (*Taraxacum taraxacum*): *a*, side views; *b*, natural size of seeds.

Taraxacum taraxacum (L.) Karst.

DANDELION.

Seeds (akenes) 3–4 mm. long, including the persistent base of the beak, which forms the pointed apex of the seed, lance-shaped or broadly so, straight or curved, flattened or slightly four-angled with similar faces, barbed in the upper, broader half; teeth directed toward the apex, prominent on the edges and arranged in about five rows on each face, which has two slender grooves with three rows of teeth between them; surface dull; color light brown or dark brown. (Fig. 22.)

Occurring occasionally in both American and European seed, these seeds have appeared most frequently in Kentucky bluegrass and rough-stalked meadow grass seeds.

Matricaria inodora L.

SCENTLESS CAMOMILE.

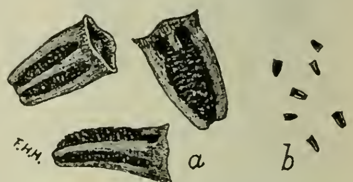

FIG. 23.—Seeds of scentless camomile (*Matricaria inodora*): *a*, back, front, and edge views; *b*, natural size of seeds.

Seeds (akenes) 1½–2 mm. long, slender or robust, oblong with obtuse extremities, tapering somewhat from the truncate apex to the base, slightly flattened; faces dissimilar, one having three prominent, longitudinal ribs joined at the apex, the lateral ribs and a partial one joined to them at the apex appearing on the opposite face, which also presents two small cavities separated by the partial ridge; surface between the ridges transversely roughened, dark brown or black and darker than the brown or yellowish ridges. (Fig. 23.)

Found only in foreign-grown seed, chiefly in rough-stalked meadow grass and wood meadow grass seeds.

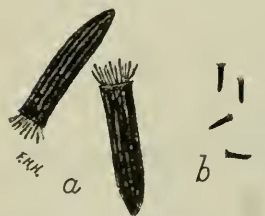

FIG. 24.—Seeds of hawkweed (*Hieracium* sp.): *a*, side views; *b*, natural size of seeds.

Hieracium sp.

HAWKWEED.

Seeds (akenes) 1–3 mm. long, cylindrical, pointed at the base; apex truncate, bearing a small tuft of short, whitish, marginal bristles (the remnants of the pappus bristles); surface lightly ten-ridged lengthwise; color brown or black, reddish in immature seeds. (Fig. 24.)

Found most frequently in wood meadow grass seed. The seeds of several species of hawkweed, occurring in both America and Europe, are practically indistinguishable. Specific determinations can not be made by examination with a lens. The troublesome character of orange hawkweed (*Hieracium aurantiacum*), whose seeds are 1¼–1¾ mm. long, justifies care in the use of seed containing seeds of any species of hawkweed.

Anthemis cotula L.

DOG FENNEL, MAYWEED.

Seeds (akenes) cylindrical, broadly club-shaped, 1½–2 mm. long, straight or curved; surface dull and usually roughened by many small tubercles more or less distinctly arranged in ten rows, indistinctly few-tubercled or nearly smooth, but commonly more or less evidently ten-ribbed; base tipped by the rounded, whitish scar; apex rounded or slightly pointed; color varying from light to dark brown. (Fig. 25.)

Found occasionally, but never abundantly, in both American and European bluegrass seed.

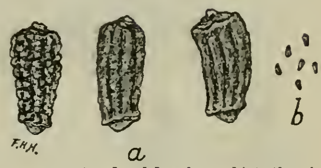

FIG. 25.—Seeds of dog fennel (*Anthemis cotula*): *a*, side views; *b*, natural size of seeds.

Chenopodium album L.

LAMB'S-QUARTERS, PIGWEED.

Seeds nearly circular, lens-shaped, with blunt edges, 1–1½ mm. in diameter, occurring in commercial seeds as free seeds or as fruits, the seeds proper being invested by the thin pericarp; free seeds jet black, smooth or nearly so, and highly polished; scar occupying a curved groove extending from the center to the edge of one face and usually evident as a light-colored line; fruits only slightly larger than the seeds, mostly gray or black and dull; pericarp wall often broken away, exposing the shining black surface of the seed; again, this wall and the seed coat are often broken, exposing the yellowish or whitish embryo and endosperm; embryo cylindrical, occupying the border of the seed and surrounding the endosperm, its extremities almost meeting, the tip of the caulicle occupying an extension of the seed coat at the edge beside the scar. (Fig. 26.)

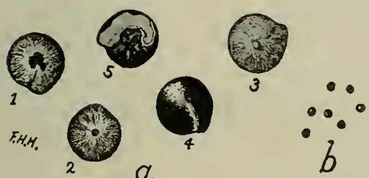

FIG. 26.—Seeds of lamb's-quarters (*Chenopodium album*): *a*, various forms of seeds; *b*, natural size of seeds.

Found chiefly in Kentucky bluegrass and Canada bluegrass seeds, but not frequently and never abundantly.

Plantago lanceolata L.

RIB-GRASS, BUCKHORN, ENGLISH PLANTAIN.

Seeds oval-oblong, 1¾–3 mm. long, flattened, one face convex, the other having a deep groove and rounded, infolded edges which scarcely meet at one end; surface smooth or slightly uneven, shining in fresh seed, brown or somewhat amber-colored; scar situated at the center of the grooved face; embryo straight, in the center of the endosperm, usually evident through the somewhat transparent endosperm and seed coat. When placed in water the seeds develop a coat of transparent mucilage. (Fig. 27.)

FIG. 27.—Seeds of rib-grass (*Plantago lanceolata*): *a*, front and back views of seeds; *b*, natural size of seeds.

Small seeds are found to some extent in both American and European seed; more commonly in Kentucky bluegrass than in Canada bluegrass seed.

Rumex crispus L.

CURLED DOCK.

Seeds (akenes) $1\frac{1}{2}$–$2\frac{1}{2}$ mm. long, triangular with equal faces and broadly ovate-lanceolate; color dark reddish brown; surface smooth, polished; apex acute; base obtuse, contracted, and narrowly truncate at the scar; edges narrowly margined; faces longitudinally concave in poorly developed seeds; true seed coat thin; embryo cylindrical, resting in the center of one face of the endosperm; caulicle pointing to the base of the akene. (Fig. 28.)

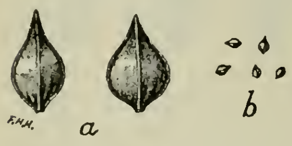

FIG. 28.—Seeds of curled dock (*Rumex crispus*): *a*, broad and narrow forms; *b*, natural size of seeds.

Found occasionally, especially in Kentucky bluegrass and in Canada bluegrass seeds; small, imperfectly developed seed more commonly found than large, heavy seed. Their sharply three-angled, beechnut-like form distinguishes them from other impurities, except one or two other kinds of dock. The docks are destructive weeds, and care should be taken to prevent the sowing of their seeds.

Rumex acetosella L.

SHEEP'S SORREL, SORREL.

Seeds (fruits) acutely oval, three-angled, with equal faces, 1–$1\frac{1}{2}$ mm. long; represented in commercial seed by the seed-like akene only or by the akene covered by the thin, closely fitting perianth segments, which are six in number, three broad ones covering the sides of the akene and three small ones covering the angles at the base; covered by the perianth, the seeds are finely roughened, dull, and reddish brown; venation of the three broad segments evident; small segments at the basal angles often broken away; akenes but slightly smaller than when covered by the perianth, bluntly three-angled; surface smooth, somewhat polished, reddish brown or wine colored, often semitranslucent; angles dark at the apex; internal structure essentially the same as in *Rumex crispus*. (Fig. 29.)

FIG. 29.—Seeds of sorrel (*Rumex acetosella*): *a*, *b*, and *c*, seed enveloped by the perianth; *d*, seed with perianth removed; *e*, natural size of seeds.

One of the commonest impurities in commercial seed, found in all seed of the cultivated bluegrasses.

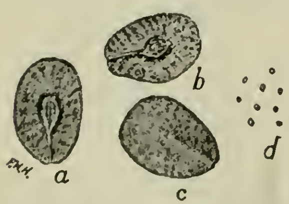

FIG. 30.—Seeds of corn speedwell (*Veronica arvensis*): *a* and *b*, front views, *c*, back view; *d*, natural size of seeds.

Veronica arvensis L.

CORN SPEEDWELL.

Seeds $\frac{1}{2}$–$\frac{3}{4}$ mm. long, flattened and thin, more or less regularly oval, plane or sometimes curved facewise; center of the inner face marked by the relatively large, raised chalaza, which is united by a narrow ridge (the raphe) to the scar on the edge of the smaller extremity of the seed; external face slightly ridged longitudinally, indicating the position of the embryo, which is surrounded by the endosperm; surface dull, finely roughened by somewhat radially-disposed ridges, and reddish yellow. (Fig. 30.)

Found in bluegrass seed of various species, especially common in seed of Kentucky bluegrass. The relatively prominent chalaza and the radially uneven surface distinguish them from the seed of the closely allied *Veronica peregrina*, which sometimes occurs in commercial seed.

Juncus tenuis Willd.

SLENDER RUSH.

FIG. 31.—Seeds of slender rush (*Juncus tenuis*): *a*, seeds enlarged; *b*, natural size of seeds.

Seeds very minute, about $\frac{1}{3}$ mm. long, broadly spindle-shaped, the extremities usually slightly curved; surface (as seen under a lens) nearly smooth; color reddish yellow, darker at the extremities, which sometimes bear a small white tissue. (Fig. 31.)

Often quite abundant in poorly cleaned Kentucky bluegrass seed, sometimes clinging in bunches of several seeds each.

FIG. 32.—Seeds of field rush (*Juncoides campestre*): *a*, different views; *b*, natural size of seeds.

Juncoides campestre (L.) Kuntze.

FIELD RUSH.

Seeds $1\frac{1}{4}$–$1\frac{1}{2}$ mm. long, oval, not flattened, the extremities unequally pointed, the basal extremity turned slightly to one side and consisting of soft white or yellowish tissue; a narrow and often indistinctly defined whitish ridge extends from the base to the apex; body of the seed wine-colored and semitranslucent or grayish. (Fig. 32.)

Found frequently in the seed of wood meadow grass and of the *Poa sudetica* of European origin.

Juncoides albida DC

WOOD RUSH.

Seeds 1–$1\frac{1}{4}$ mm. long, narrowly oval, not flattened; base without an appendage of soft tissue; apex more acutely pointed than the base; a distinct brown or reddish brown ridge joins the base and apex; body of the seed reddish brown or wine-colored, often semitranslucent. (Fig. 33.)

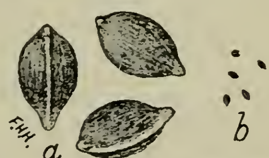

FIG. 33.—Seeds of wood rush (*Juncoides albida*): *a*, different views; *b*, natural size of seeds.

Found in various species of European-grown bluegrass seed. The usually smaller size, absence of the basal appendage, and more distinct and constant reddish-brown lateral ridge serve to distinguish these from the seeds of *Juncoides campestre*.

Carex cephalophora Muhl.

OVAL-HEADED SEDGE.

Seeds (akenes) $1\frac{1}{2}$–2 mm. long, lens-shaped and broadly ovate, contracted at the base and tipped at the apex by a conical appendage (the base of the style); surface smooth and dull; color varying from light to dark brown; apical appendage often broken away in seeds found in commercial samples; perigynium broadly ovate-lanceolate, plano-convex, the tapering extremity usually rough-edged and notched at the apex; surface sometimes slightly grooved or ridged lengthwise, otherwise smooth; color varying from light brown to greenish or dark brown. (Fig. 34.)

FIG. 34.—Seeds of sedge (*Carex cephalophora*): *a*, seeds inclosed by the perigynium; *b* and *c*, seeds with perigynium removed; *d*, natural size of seeds.

Seeds of sedge (Carex) are found in both American and European bluegrass seed. Owing to the wide area of their production, the seeds of various species of Carex occur in commercial bluegrass seed. The seeds of Carex are fruits (akenes) and occur free or inclosed within a sac-like covering (the perigynium). *Carex cephalophora* is the species most commonly found in Kentucky bluegrass seed.

ERGOT OCCASIONALLY FOUND IN COMMERCIAL BLUEGRASS SEED.

Claviceps purpurea (Fr.) Tul.

ERGOT.

This is a fungus growth affecting the grain (caryopsis) of many grasses. It is very common in the seed of redtop and other species of Agrostis, and occasionally occurs in bluegrass seed. The grain of the seed becomes elongated, extending beyond the glume and palea, attains about twice the length of the glume, and is club-shaped, straight, or, more commonly, somewhat curved. It is black, dull, and somewhat grooved lengthwise. (Fig. 35.)

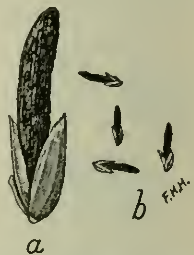

FIG. 35.—Ergot (*Claviceps purpurea*) of Kentucky bluegrass: *a*, enlarged; *b*, natural size.

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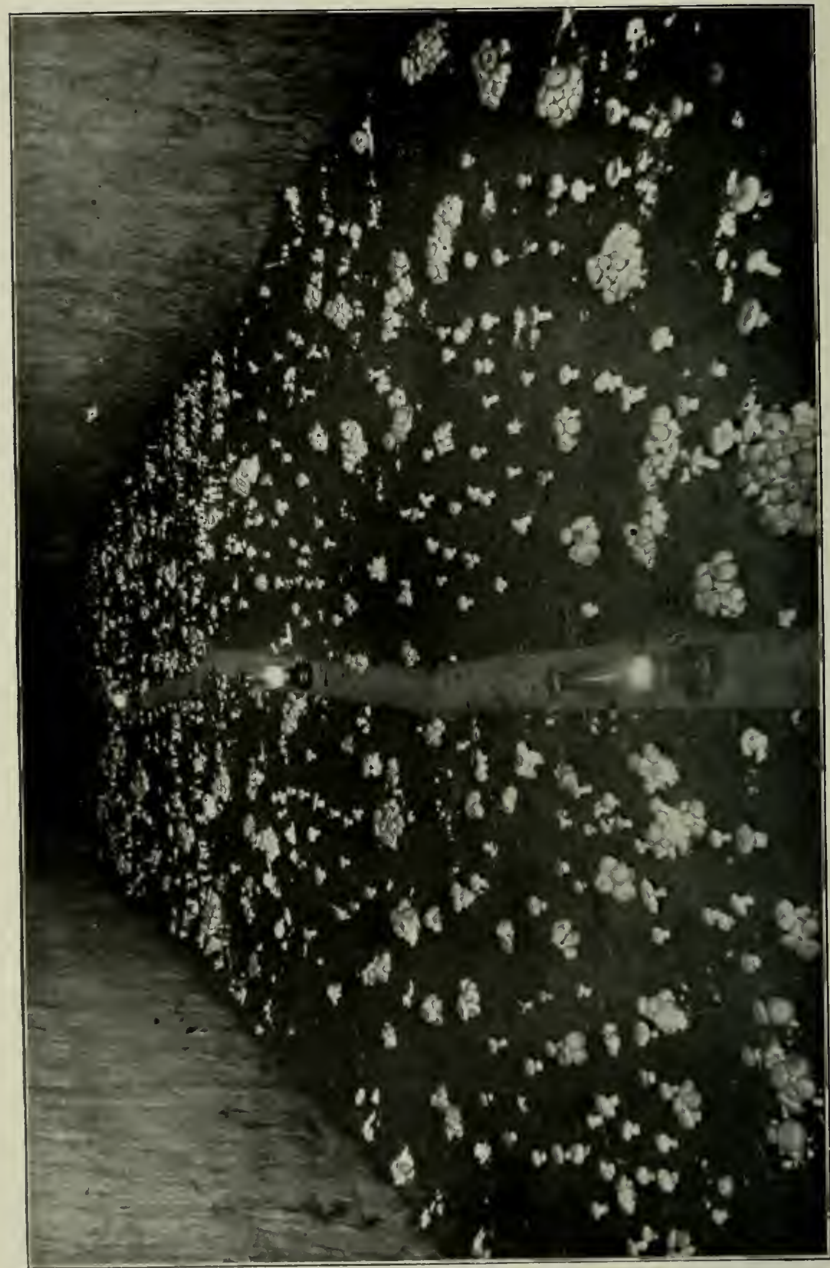

A FINE BED OF MUSHROOMS GROWN FROM SPAWN OF PURE-CULTURE ORIGIN.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 85.

B. T. GALLOWAY, *Chief of Bureau.*

THE PRINCIPLES OF MUSHROOM GROWING AND MUSHROOM SPAWN MAKING.

BY

B. M. DUGGAR,
Professor of Botany in the University of Missouri, and
Collaborator of the Bureau of Plant Industry.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

Issued November 15, 1905.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

BUREAU OF PLANT INDUSTRY.

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Pathologist and Physiologist, and Chief of Bureau.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., August 21, 1905.

Sir: I have the honor to transmit herewith a paper entitled "The Principles of Mushroom Growing and Mushroom Spawn Making," and to recommend that it be published as Bulletin No. 85 of the series of this Bureau.

This paper was prepared by Dr. B. M. Duggar, Professor of Botany in the University of Missouri and Collaborator with the Office of Vegetable Pathological and Physiological Investigations of this Bureau. Under the direction of the Pathologist and Physiologist, Doctor Duggar has been engaged for several years in the investigation of mushroom culture in all of its phases, and great advances have been made, especially in the production of purer and better spawns.

The accompanying illustrations are necessary to a complete understanding of the text of this bulletin.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The bulletin submitted herewith presents the results of the work up to the present time on the problems of mushroom culture and spawn making. The first publication on the subject from the standpoint of pure culture was Bulletin No. 16 of the Bureau of Plant Industry. This was followed by a Farmers' Bulletin (No. 204) on mushroom culture, presenting the results of our work for the use of the practical grower. As an outcome of the work Doctor Duggar has already accomplished, spawn of pure-culture origin is now being produced on a very large scale by several growers and is giving excellent results. This method enables the grower to improve and maintain the most desirable varieties of mushrooms in the same manner as is possible with other plants propagated from cuttings or buds. Information which would enable a grower to accomplish this has not been up to this time available. The general method of securing pure cultures as here described will enable the experimenter to cultivate spawn of other edible species of mushrooms in case it should be found desirable to cultivate them. The methods described differ radically from any hitherto used. They are of more general application and give far better results.

For the past three years this work has been carried on in cooperation with the University of Missouri, Doctor Duggar having left the Department to accept the professorship of botany in that institution. We wish to express our appreciation of the facilities furnished by the university for continuing this work.

Albert F. Woods,
Pathologist and Physiologist.

Office of Vegetable Pathological
and Physiological Investigations.
Washington, D. C., June 16, 1905.

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INTRODUCTION.

For a number of years there has been an increasing demand in the United States for information concerning mushroom growing. In the horticultural and agricultural press many individual practices have been presented; but in order to give rational encouragement to mushroom growing in favorable sections of this country it was recognized at the outset of the investigations undertaken by the writer that much experimental work would be required. Bearing upon the culture of *Agaricus campestris*[a] a number of physiological questions were demanding attention, for it was desirable to ascertain (1) the conditions of spore germination, in order that "virgin" spawn might be propagated and the principle of selection attempted; (2) the relation of this fungus to nutrients, or a determination of the substances or compounds which might best serve as food materials; and (3) the relation of the growing mycelium and of mushroom production to temperature, moisture, and other conditions of the environment. In the next place it would be necessary to determine the application of any physiological principles established to the practice of mushroom growing and mushroom spawn making.

In connection with a presentation of the results of the experimental work[b] it seems desirable to include also a more or less comprehensive account of the present status of mushroom growing at home and abroad.

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[a] Throughout this paper the writer has employed the generic name *Agaricus* in the sense in which it is usually understood by those interested in the practical side of the work.

[b] During 1903–4 the writer was assisted in the experimental work by Mr. A. M. Ferguson, instructor in botany in the University of Texas, at that time special agent of the Department of Agriculture, and during 1904–5 similar assistance has been rendered by Mr. L. F. Childers, student assistant. Through the assistance thus given it has been possible to complete an unusual amount of experimental work, only a portion of which can be described in detail, although it has all been taken into consideration in the conclusions drawn.

It is not possible at this time to give more than a few brief suggestions concerning the possibility of cultivating other edible species than *Agaricus campestris*. The determination of the fundamental needs of diverse species will require study during a term of years.

GENERAL CONSIDERATIONS.

The propagation of *Agaricus campestris* does not seem to have been undertaken to any extent by the ancient Greeks or Romans. The occasional references to mushrooms in the classics are very general, as a rule, and do not suggest that artificial propagation was attempted. In the vicinity of Paris *Agaricus campestris* has been cultivated for several centuries, and the plants have certainly been sold on the open market quite as long.[a] It has not been possible to ascertain whether the methods now in vogue are essentially the same as those employed a few centuries ago. It is very probable, however, that the methods have been gradually improved. It would appear that the cultivation in caves is comparatively recent. The earliest records obtainable concerning the cultivation of mushrooms in the underground quarries indicate that this practice was not common previous to the nineteenth century.

Mushrooms are to-day extensively grown in England and France, and to a limited extent in Belgium, in Germany, and in many other countries. Paris remains, however, the center of commercial production. In the vicinity of that city the culture of mushrooms is now almost entirely confined to the underground limestone quarries or cement mines. The caves used for this purpose are termed " carrières " or " champignonières." These caves may consist of a labyrinth of galleries, or halls, ranging from 5 to 50 feet in width and from 5 to 30 feet in height. In some regions the earth is practically honeycombed by them, and the extent of the cave space used by the larger growers may be measured by miles. For the most part the ventilating system is perfect, every cave system possessing numerous air shafts, protected at the surface by wooden towers. Artificial partitions in the caves themselves enable the operator to control the ventilation. Until recent times the cultural methods have been more or less sacredly guarded by the growers, and even to-day it is not easy to get permission to make a casual visit to the champignonières. In many cases the work has been followed from generation to generation within the same family. There are at present, however, large corporations in control of some of the most famous caves.

[a] In a painting of the early seventeenth century (that of a Fishmonger's and Poulterer's Shop, by Jordaens and Van Utrecht, in the Gallery of Old Pictures, Brussels) *Agaricus campestris* and Boletus are shown on sale as a conspicuous part of a market scene.

In the United States fresh mushrooms have only recently been of any importance commercially, although florists and gardeners of English and French training have long been successful growers on a small scale. Nevertheless, during the past decade or so, the record of failures has been most conspicuous, and it is certain that of the many who attempted this work only a few, relatively, were uniformly successful.

The conditions under which mushrooms may be successfully grown are limited, and intelligent attention is therefore essential. It must be said, moreover, that the majority of failures may be directly traced to erroneous ideas as to the cultural requisites, or to a reckless disregard of conditions. The essential conditions will be subsequently defined in detail, but it may be stated here that failures are usually due to one or more of the following causes: (1) Poor spawn; (2) very poor manure; (3) unfavorable temperature; and (4) heavy watering during the early stages of growth.

Under suitable conditions mushrooms may be grown with assurance of success. Ordinarily they are grown only where the conditions may be controlled, and success should therefore be invariable.

MARKET CONDITIONS.

In the vicinity of Paris the mushroom industry has been remarkably developed during the past eight or ten years. The total product sold through the central market of Paris in 1898 was nearly 4,000,000 pounds; the quantity for 1900 is given as approximately 8,500,000 pounds, and for 1901 nearly 10,000,000 pounds. These figures show most convincingly the present status of the mushroom industry in France. It may be safely assumed that more than one-third of this quantity is consumed in a fresh state in and about the city. The growth of the canning industry during this period has also been remarkable. In 1898 about 1,800,000 pounds were preserved, while in 1901 the canned product amounted to nearly 6,200,000 pounds. During 1901 the approximate monthly production of mushrooms ranged from 651,000 pounds to 985,000 pounds, from which it is evident that these caves yield heavily throughout the year. In some instances growers are able to get a crop every four or five months.

It is extremely difficult to estimate the quantity of mushrooms grown in the United States. It is certain, however, that the production has increased very greatly, and particularly within the last four or five years. In the vicinity of several of our larger cities there are to-day individual growers who produce more than the total commercial output in the neighborhood of those cities ten years ago.

There is now a very good open market for fresh mushrooms in a few of the larger cities, although many large growers continue to sell entirely by contract or by special orders to hotels and restaurants. With such an enormous comparative consumption of the canned product, there is every reason to believe that fresh mushrooms can be sold in much greater quantity as soon as this product becomes a certain factor in the market. With canning factories to take the surplus product, growers could afford to accept a smaller margin of profit, and this would place mushrooms within reach of many who may not be able to purchase them at present average prices. *Agaricus campestris* and its varieties and allied species are perhaps the only fresh mushrooms commonly salable in the markets of American cities. Throughout practically the whole of Europe several other species are legitimate market products. The more delicate or fleshy forms of the latter are sold as fresh mushrooms; others are dried, and some of these, being tougher, are used only for soups, sauces, and gravies. Besides the various species of truffle and morel, any special mention of which will be omitted here, the French market to-day legalizes the sale of five or six other species of mushrooms.

GERMINATION STUDIES.

Review of earlier work.—In a small way the germination of the spores of Basidiomycetes has received attention from the earliest times. A complete historical review of the literature dealing with spore germination will be found in Bulletin No. 16 of the Bureau of Plant Industry. It will be seen that most of the early work furnishes only incidental references to spore germination. By far the most important contributions made by early workers to this particular subject were several papers by Hoffmann.[a] It is not to be expected that the method employed by him would yield accurate results. Nevertheless, the work of Hoffmann is comprehensive for that time. Brefeld,[b] in his extensive reports upon the Basidiomycetes, gives the results of germination studies with a large number of the fleshy fungi. More than 200 species were used in his various experiments, and successful germination is recorded for about 160 species.

In 1898 the writer became interested in some attempts to germinate the spores of certain Basidiomycetes. Subsequently the problem received incidental attention in connection with some general studies on the physiology of spore germination.[c] The work progressed only

[a] Hoffmann, H. Ueber Pilzkeimungen. Botan. Zeitg., 19: 209–214, 217–219. 1859. Beiträge zur Entwickelungsgeschichte und Anatomie der Agaricineen. Botan. Zeitg., 18: 389–395, 397–404. 1860. Untersuchungen über die Keimung der Pilzsporen. Jahrb. f. wiss. Botanik, 2: 267–337. 1860.

[b] Brefeld, O. Botanische Untersuchungen über Schimmelpilze. Basidiomyceten, I, Bd. I, H. 3. 1877. Untersuch. a. d. Gesammtgebiete der Mykologie. Basidiomyceten, II, H. 7; III, H. 8. 1888–89.

[c] Duggar, B. M. Physiological Studies with Reference to the Germination of Certain Fungous Spores. Bot. Gaz., 31: 38–66.

far enough to suggest that an investigation of the factors influencing germination might yield studies of special interest. During 1900–1901 Dr. Margaret C. Ferguson undertook a systematic investigation of the relation of stimuli to germination in certain species. The results[a] have made it evident that the problems involved are not the well-known simple nutrient or physical factors. Miss Ferguson spent much time in experimenting with a great variety of nutrient media and special stimuli. Several thousand cultures were made. In the majority of these cultures *Agaricus campestris* was used, and it is shown that from the known ecological relationships of this fungus one could not possibly predicate the probable stimulus for germination. In fact, with no known nutrient medium or special chemical stimulus employed, was there anything more than erratic germination. Nevertheless, the work was finally very successful in the discovery that almost a perfect percentage of germination could be secured by the influence of the living hyphæ of *Agaricus campestris* upon the spores, as announced in the statement that "if a few spores are able to germinate under the cultural conditions, or if a bit of the mycelium of *Agaricus campestris* be introduced into the culture, the growth resulting will in either case cause or make possible the germination of nearly all the spores of the culture, provided, of course, that the other conditions are not such as to inhibit germination."

The stimulus would seem to be of enzymatic nature. No other mycelium tested produced a similar effect. This was a distinct advance in our knowledge of factors influencing germination. The stimulus, however, could only be looked upon as perhaps a substitution stimulus. It did not seem possible that it could obtain in nature, nor could it be looked upon as wholly satisfactory from a practical point of view.

Miss Ferguson's results offered encouragement; but, nevertheless, the problems with *Agaricus campestris* and related species were left open for further investigation. It should, perhaps, be emphasized that prior to 1902 no method had been published, so far as can be learned, whereby one might be able to obtain with uniformity the germination of *Agaricus campestris*. It is quite certain that Chevreul and others obtained at best only erratic results. Nevertheless, as early as 1893 Costantin and Matruchot[b] announced that a method had been developed by them whereby they were able to germinate the

[a] Ferguson, M. C. A Preliminary Study of the Germination of the Spores of Agaricus Campestris and Other Basidiomycetous Fungi. Bulletin No. 16, Bureau of Plant Industry, U. S. Dept. Agriculture, pp. 1–43. 1902.

[b] Costantin and Matruchot. Nouveau procédé de culture du champignon de couche. Compt. Rend. de l'Acad. des Sci., 117 (2): 70–72. (Compare, also, Bul. Soc. de Biol., 2 December, 1893.)

spores and to grow in pure culture the mycelium of *Agaricus campestris*. Information concerning the details of the method employed was avoided in the reports of this announcement and in subsequent references to the process.[a] In the first announcement the method is stated as follows:

Method followed.—The spores are collected free from contaminations, and in order to preserve them in that condition are sown on a certain sterilized nutritive medium. We obtain in this manner a twisted mycelium which constitutes pure spawn. By repeated cultures on an identical substratum the spawn can be multiplied indefinitely, and is transferred at a proper time to sterilized manure, where it develops abundantly in several weeks. At that stage it possesses the characteristic appearance and odor of natural spawn. It can then be sown in a bed of ordinary manure, to which it adheres and where it grows and fruits normally.

In the later paper cited, writing of the recent improvements in mushroom culture, Costantin expresses himself as follows:

We have succeeded in manufacturing an artificial spawn obtained from the spore germinated on a medium free from contamination. It is then pure spawn. We can state further that it is virgin spawn.

In 1897 Répin [b] claimed to have independently arrived at results similar to those obtained by Costantin and Matruchot. Concerning his germination studies he says:

It is only recently that the study of this question has been renewed, independently and simultaneously by Costantin and Matruchot.

There is nothing unusual in the germination of the spores of Agaricus. Spores can be germinated on media such as used in bacteriology, on wet sand, or in moist air as well as on manure. Without doubt, germination is not produced with the same spontaneity and rapidity as in the case of the spores of lower fungi, which fact makes it necessary to promote the process by some artifices, but they are only sleight-of-hand tricks, variable according to the operators, and which are acquired after some unsuccessful attempts. The spores which should germinate (and these are always in the minority) begin by swelling. This very simple method makes it possible to obtain virgin spawn at pleasure. It is applied industrially in the manufacture of spawn of Agaricus from cultures which I have made.

So far as the writer has been able to ascertain, therefore, no description of the method employed by the above writers is to be found. The report of Miss Ferguson's work is accordingly the only available scientific record defining the conditions under which germination had been constantly obtained up to this time.

Experimental work.—The writer has been able to confirm Miss Ferguson's work repeatedly, and at the same time numerous series of experiments have been made to test further the possibility of influenc-

[a] Costantin, J. La culture du champignon de couche et ses récent perfectionnements. Extrait du Revue Scientifique. April, 1894.

[b] Répin, C. Le blanc vierge de semis pour la culture du champignon de couche. Revue Générale des Sciences. (September 15, 1897.)

ing germination by chemical stimuli. In distilled water, on the one hand, and in plant decoctions (such as decoctions of beans, sugar beets, mushrooms, potatoes, etc.) and in bouillon, on the other hand, there have been tested a large number of inorganic and organic salts, carbohydrates, nitrogenous compounds, and active enzymes.

The results of one series of experiments are tabulated in detail. In general, it has been found that dulcite, monobasic magnesium phosphate, magnesium phosphite, magnesium potassium ammonium phosphate, ammonium molybdate, magnesium lactophosphate, dibasic calcium phosphate, and other salts, especially phosphates, have in one medium or another been more or less effective as stimuli for germination. Unfortunately, none of the substances mentioned, apparently, are very strong stimuli; they are unable to cause invariable germination in all nutrient media. Moreover, in subsequent series, where the conditions have been the same, within experimental possibilities, wholly analogous results have not always been obtained. No account has been taken, however, of the particular variety of *Agaricus campestris* from which the spores were obtained, and it may be that this will influence the results.

It is to be noted from the following table that Miss Ferguson's method of employing living bits of mycelium was modified by the use of small pieces of the inner tissue of a young mushroom taken under sterile conditions. It was found that often a new growth of mycelium was developed from this tissue. Whenever this growth appeared, the influence upon spores in the drop culture was, as might be expected, the same as had been demonstrated for the living mycelium. Frequently a few spores germinated within from three to five days. The most interesting conclusion, however, which could be drawn from the cultures in which small bits of tissue were used was the following: Under favorable conditions a small piece of the inner growing tissue of a mushroom is capable of producing a mycelium with great readiness. This fact has been utilized, as shown in detail later, in the development of a new and effective method of securing pure cultures of fleshy fungi in general.

TABLE I.—*Extent of germination.*

No.	Media.	After 3 days.	After 5 days.
1	Distilled water	*a*—5 spores	As before.
		b—None	Do.
2	Bouillon	None	None.
3	½ per cent KH_2PO_4	do	Do.
4	½ per cent KH_2PO_4 in bouillon	do	Do.
5	½ per cent K_2HPO_4	do	Do.
6	½ per cent K_2HPO_4 in bouillon	do	Do.
7	½ per cent Na_2HPO_4	do	Do.
8	½ per cent Na_2HPO_4 in bouillon	do	Do.
9	½ per cent $(NH_4)_2HPO_4$	do	Do.
10	½ per cent $(NH_4)_2HPO_4$ in bouillon.	do	Do.

TABLE I.—*Extent of germination*—Continued.

No.	Media.	After 3 days	After 5 days.
11	½ per cent $MgH_4(PO_4)_2$	10 spores	50 per cent.
12	½ per cent $MgH_4(PO_4)_2$ with bouillon.	*a*—1 spore *b*—None	3 per cent. None.
13	½ per cent $MgHPO_4$	None	Do. 1 per cent.
14	½ per cent $MgHPO_4$ in bouillon	*a*—10 spores	Germinated spores badly injured.
15	½ per cent $Mg(NH_4)PO_4$	None	None.
16	½ per cent $Mg(NH_4)PO_4$ in bouillon.	2 spores	As before; injured.
17	½ per cent $MgK(NH_4)PO_4$	Few spores	5 per cent.
18	½ per cent $MgK(NH_4)H_2(PO_4)_2$ in bouillon.	do	Do.
19	½ per cent $(NH_4)_2C_4H_4O_6$	*a*—None *b*—None	Few spores. 10 per cent.
20	½ per cent $(NH_4)_2C_4H_4O_6$ in bouillon.	10 spores	As before: injured.
21	½ per cent magnesium lactophosphate.	do	5-10 per cent.
22	½ per cent magnesium lactophosphate in bouillon.	do	2-5 per cent.
23	½ per cent $Ca_2H_2(PO_4)_2$	None	1-2 per cent.
24	½ per cent $Ca_2H_2(PO_4)_2$ in bouillon	10 spores	Injured.
25	½ per cent $KCHO_2$	None	1-2 per cent.
26	½ per cent $MgHPO_3$	10 spores	10-50 per cent.
27	½ per cent $MgHPO_3$ in bouillon	do	1 per cent.
28	½ per cent $MgK(NH_4)H_2(PO_4)_2$ in mushroom decoction.	do	1-2 per cent.
29	½ per cent KH_2PO_4 in mushroom decoction.	None	None.
30	½ per cent K_2HPO_4 in mushroom decoction.	do	Do.
31	½ per cent Na_2HPO_4 in mushroom decoction.	Few spores	Injured.
32	½ per cent $(NH_4)_2HPO_4$ in mushroom decoction.	1 or 2 spores	Few spores.
33	½ per cent $MgHPO_4$ in mushroom decoction.	Few spores	2-5 per cent.
34	do	10-50 per cent	10-20 per cent.
35	½ per cent $Mg(NH_4)PO_4$ in mushroom decoction.	Few spores	Contaminated.
36	½ per cent $(NH_4)_2C_4H_4O_6$ in mushroom decoction.	2 per cent	Contaminated: 50 per cent, but injured.
37	½ per cent magnesium lactophosphate in mushroom decoction.	10 spores	3-5 per cent: injured.
38	½ per cent $Ca_2H_2(PO_4)_2$ in mushroom decoction.	5-8 per cent	10 per cent.
39	½ per cent $KCHO_2$ in mushroom decoction.	2-3 per cent	10-20 per cent.
40	½ per cent $MgHPO_3$ in mushroom decoction.	1-2 per cent	*a*—5 per cent. *b*—Contaminated
41	Decoction of mushrooms	*a*—2 per cent *b*—Very few spores	2 per cent. 1-2 per cent.
42	Living tissue of mushroom in mushroom decoction.	*a*—Few spores [a] *b*—None [b]	12 spores.
43	do	*a*—Few spores [a] *b*—None [b]	As before. None.

[a] In this cell the tissue developed a new growth.
[b] No growth from tissue introduced.

On account of the fact that magnesium phosphite and magnesium potassium ammonium phosphate had in most cases proved to be stimuli for germination, experiments were next made to determine the efficiency of these salts on various media, as indicated in the table on the following page.

TABLE II.—*Efficiency of salts on various media.*

Nature of compost.	Appearance after 25 days.	Nature of compost.	Appearance after 25 days.
Well-rotted stable manure.[a]	No growth.	Well-rotted cow manure.[b]	Good growth.
Do.[b]	Fine growth.	Peaty mold[a]	No growth.
Half-rotted stable manure.[a]	One, fair growth: one, good growth.	Do.[b]	Do.
		Maryland peat[a]	Do.
Do.[b]	No growth.	Do.[b]	Do.
		Well-rotted Ginkgo leaf mold.[a]	Do.
Fresh stable manure[a]	One, good growth; one, slight growth.	Do.[b]	Do.
Do.[b]	One, good growth; one, fine growth.	Cotton-seed motes[a]	One. no growth; one, fine growth.
Well-rotted cow manure.[a]	One, good growth; one, slight growth.	Do.[b]	Fine growth.

[a] Watered with concentrated solution of magnesium phosphite.
[b] Watered with strong solution of magnesium potassium ammonium phosphate.

Large test tubes were used in these experiments, and duplicate cultures were made in every instance. From these and from numerous other cultures it was ascertained that germination could not be obtained invariably, even on favorable media and under pure-culture conditions, by the use of these partial stimuli. Nevertheless, the percentage of failures has usually been small. By means of the stimulus given by magnesium phosphite it has also been possible to get growth from the spores in test-tube cultures with gray filter paper as the solid substratum and various plant decoctions and culture solutions as the nutrients. Details of these results, however, may be omitted.

In many cases it has been possible to obtain growth from the spores by the use of the stimulating salts which have been mentioned in connection with the germination studies. Where it is desired to make experiments along this line the writer has found it more practicable to use spores from a mushroom as young as possible. If one takes a mushroom just at the time that the veil is breaking, inoculations may be readily made from the spores and few contaminations will result. In this case, by means of a sterile needle, or scalpel, a few spores may be removed from the spore-bearing, or gill, surface and these may be transferred to the tubes in the same way as were bits of the fresh tissue. It is also possible to secure a spore print from a mushroom the gill surface of which has not been exposed to germs of the atmosphere. In the latter case it is desirable to remove stem and partial veil, peel off the incurved edges of the cap which have been in contact with the soil, and place the cap, gill surface downward, in a sterilized dish or on sterile paper. If this is then kept free from dust, a spore print may be obtained, which should not be contaminated by foreign germs. This print may then be used in making a large number of spore cultures.

Experiments were also made in which pots of unsterile composts and manures were inoculated, on the one hand, with spores, and, on the other hand, for control purposes, with spawn from pure cultures. The duration of the experiments was two months. Some of these pots were watered with a mineral nutrient solution including as one constituent magnesium phosphite, designated *X*, others with the same solution to which was also added a small quantity of dried blood, designated *Y*, and the remainder with pure water. The results are tabulated as follows:

TABLE III.—*Extent of growth of spores and spawn in pots.*

	Cattle manure, old.	Fresh stable manure and sand.	Stable manure.	Old stable manure and sand.	Old stable manure.	Fertilizer.
Spores	*a*—Good	None	Slight	None	None	*Y.*
	b—None	do	do	do	do	*Y.*
Spores	*a*—Good	Very good	do	do	do	*X.*
	b— Do.	do	do	do	do	*X.*
Spawn	*a*—Slight	Slight	None	do	do	*Y.*
	b— Do.	do	Slight	do	do	*Y.*
Spawn	*a*—None	None	Good	do	do	*X.*
	b— Do.	do	Slight	do	do	*X.*
Spawn	*a*—None	Slight	do	do	do	None.
	b— Do.	do	None	do	do	Do.

TISSUE CULTURES.

The suggestion which had presented itself of using bits of living tissue from a sporophore instead of spores seemed also, from general observations, to be of sufficient importance to warrant a thorough trial. During moist weather, or in a moist cellar where mushrooms are being grown, one will frequently find that an injury in a young mushroom is rapidly healed by a growth of hyphæ from the edges of the injured area. The same thing had been noted in the open in the case of puffballs. In many instances, moreover, pure cultures of fungi in other groups have been obtained by the use of small bits of a sclerotial mass of tissue. Accordingly, a young sporophore of *Agaricus campestris* was obtained, and after breaking it open longitudinally a number of pieces of tissue from within were carefully removed with a sterile scalpel to a sterile Petri dish. A number of cultures were then made by this tissue-culture method on a variety of nutrient media, such as bean pods, manure, leaf mold, etc. From this and from numerous other similar tests it was ascertained that when the mushrooms, from which the nocules of tissue are taken, are young and healthy, there is seldom an instance in which growth does not result. It was easily shown that failure to grow was generally due to the advanced age of the mushroom used, to an unfavorable medium, or to bacterial contamination.

The first successful pure cultures were made by this method during the early spring of 1902 from mushrooms grown indoors. During the following summer, or as other fleshy fungi appeared in the open, cultures were made from other forms in order to determine the general applicability of the method. The experiments were successful in most cases, although it was found almost impossible to obtain certain species of fungi in a condition young enough to be free from bacterial infestation. In general, the method seemed to commend itself strongly as a means of procuring pure cultures of desirable edible species, particularly of those species the spores of which could not be obtained pure or which could not be readily germinated.

During the two subsequent seasons this method has been employed with a great variety of fungi representing many natural orders. No systematic endeavor has been made to determine the limitations of the tissue-culture method as applied to Basidiomycetes, but, incidental to the general studies, cultures have been made from forms differing very widely, not only in relationship but also in texture and in habitat.

In all there is a record of 69 species having been tested upon one or another medium. In a few cases the cultures have invariably been contaminated, and it is to be supposed, perhaps, that the plants were collected in a condition too old for the purpose in hand. In only about ten forms has it seemed that there is no evident reason for the failure to develop mycelium. Of the remainder fully 40 have grown promptly on the media employed. The table following indicates the names of the species employed and the results obtained. It must be said, however, that cultures of a number of species were made of which no record was kept; among these, also, some grew and some failed.

TABLE IV.—*Results obtained from different species.*

Fungus.	Number of cultures.[a]	Substratum.	Result.
Agaricus arvensis	Few.	Beans, manure, leaves, etc	Rapid growth.
Agaricus augustus	1	Beans	Contaminated.
Agaricus campestris (various varieties).	∞	Beans, manure, leaves, etc	Rapid growth.
Agaricus fabaceus	∞	do	Do.
Agaricus fabaceus var	∞	do	Do.
Agaricus placomyces	1	Beans	Some growth.
Agaricus villaticus	Few.	Manure, leaves, etc	Rapid growth.
Amanita frostiana	1	Leaves	Contaminated.
Amanita muscaria	2	Beans	Do.
Amanita verna	2	do	Do.
Amanitopsis vaginata	2	do	Do.
Armillaria mellea	∞	Beans, leaves, dead wood, etc	Rapid growth.
Boletinus porosus	2	Beans	Slow growth.
Boletus felleus	2	do	No growth.
Boletus miniato-violaceus	1	do	Do.
Boletus peckii	2	do	Contaminated.
Bovistella ohiensis	Few.	Beans, leaves, etc	Rapid growth.
Calvatia craniiformis	Few.	do	Do.
Calvatia cyathiforme	∞	Beans, leaves, soil, etc	Do.
Calvatia rubro-flava	Few.	Beans, leaves, etc	Do.
Cantharellus cibarius	1	Beans	No growth.
Clavaria formosa	1	do	Do.

[a] ∞ indicates an indefinite number.

TABLE IV.—*Results obtained from different species*—Continued.

Fungus.	Number of cultures.	Substratum.	Result.
Clitocybe illudens	2	Beans	Some growth.
Clitocybe sp.?	2	do	Rapid growth.
Clitopilus prunulus	Few.	Beans, manure, etc	Some grew well.
Collybia platyphylla	1	Beans	No growth.
Collybia radicata	Few.	do	Good growth.
Collybia velutipes	1	do	Do.
Coprinus atramentarius	∝	Beans, leaves, manure, etc	Rapid growth.
Coprinus comatus	∝	Beans, manure, leaves, etc	Do.
Coprinus fimetarius	Few.	Beans, leaves	Do.
Coprinus micaceus	∝	Beans, leaves, manure, etc	Do.
Cortinarius armillatus	1	Beans	Contaminated.
Cortinarius castaneus	1	do	Do.
Cortinarius sp.?	Few.	Beans, leaves, manure	Good growth.
Daedalia quercina	Few.	Beans, leaves, manure, etc	Rapid growth.
Hydnum caput medusae	1	Beans	Good growth.
Hydnum coralloides	2	do	Do.
Hydnum erinaceum	2	do	Do.
Lactarius corrugis (?)	Few.	Beans and leaves	Slight growth, one.
Lactarius piperatus	∝	do	No growth.
Lactarius volemus	1	Acid beans	Some growth.
Do	∝	Beans	No growth.
Lepiota americana	1	do	Do.
Lepiota morgani	2	do	Some growth.
Lepiota procera	∝	Beans, leaves, etc	Rapid growth.
Lepiota rhacodes	Few.	do	Do.
Lycoperdon gemmatum	2	Beans	Good growth.
Lycoperdon wrightii	1	Sod	Do.
Morchella esculenta	2	Beans and leaves	Do.
Pluteus cervinus	Few.	do	Some growth.
Pleurotus ostreatus	∝	Beans, leaves, manure, etc	Rapid growth.
Pleurotus ulmarius	1	Beans	Do.
Pholiota adiposa	1	Beans and leaves	No growth.
Polyporus betulinus	1	Beans	Slow growth.
Polyporus intybaceus	1	do	Do.
Polyporus sulphureus	2	Beans and leaves	Rapid growth.
Polystictus cinnabarinus	2	do	Good growth.
Russula adusta	1	Beans	No growth.
Russula emetica	∝	Beans, etc	Often contaminated but some grew.
Russula sp	Few.	Beans	No growth.
Russula sordida	1	do	Do.
Russula virescens	Few.	do	Do.
Secotium acuminatum	2	do	Slow growth.
Strobilomyces strobilaceus	1	do	No growth.
Stropharia sp	1	do	Contaminated.
Tremella mycetophila	1	do	No growth.
Tricholoma personatum	1	Beans and manure	Good growth.
Tricholoma russula	2	Beans and leaves	Do.

It is not to be understood that the failures recorded in the foregoing table indicate that these species will not grow. The evidence is that they did not grow upon the media used, and it is very probable that most of these could be propagated in culture by this method if a systematic attempt were made to determine what substrata are desirable. The writer believes that this statement holds true particularly in the case of certain species of Boletus. No attempt was made to cultivate Boleti in any other way than upon bean pods. A few mycelial threads were developed in such cases, but these failed to grow upon the bean, apparently dying before even the nutrients in the fragment of tissue were exhausted.

It is interesting to note that many of the fungi which have given good growth have not hitherto been grown in pure culture. According to Costantin and Matruchot,[a] Van Tieghem (1876) produced the

[a] Costantin and Matruchot. Sur la production du mycelium des champignon supérieurs. Extrait Compt. Rend. d. Séances de la Soc. de Biologie. January, 1896.

mycelium of Coprinus in pure culture. Later, Brefeld[a] accomplished the same result with many species of Coprinus, and also with *Armillaria mellea.* Costantin has also published a number of brief papers, or announcements, of successful cultures upon artificial media of the mycelium of several fleshy fungi. Besides *Agaricus campestris*, he has grown the mycelium of *Amanita rubescens*, *Armillaria mellea*, *Collybia velutipes*, *Lepiota procera*, *Marasmius oreades*, *Tricholoma nudum*, *Pleurotus ostreatus*, *Pholiota aegerita*, *Coprinus comatus*, *Polyporus tuberaster*, *P. frondosus*, *Hydnum coralloides*, *Morchella esculenta*, and perhaps a few others. He has also grown to maturity sporophores of *Agaricus campestris*, *Coprinus comatus*, and *Tricholoma nudum.* Unfortunately, Costantin seldom indicates the substratum upon which his cultures were made. Falck[b] reports having produced in culture the sporophores of *Collybia velutipes*, *Phlebia merismoides*, *Hypholoma fasciculare*, *Chalymotta campanulata*, and *Coprinus ephemerus* in his studies upon the connection of oidial stages with perfect forms of the Basidiomycetes. In the work of the writer so far no special attempt has been made to obtain the sporophores of the fungi cultivated except in the case of *Agaricus campestris.* Nevertheless, the following species have fruited in pure culture upon the media indicated:

	Medium.
Agaricus campestris	Manure.
Agaricus fabaceus	Manure.
Agaricus amygdalinus	Manure.
Armillaria mellea	Beans.
Bovistella ohiensis	Soil.
Calvatia cyathiforme	Soil.
Calvatia rubro-flava	Soil.
Cortinarius sp	Soil.
Coprinus comatus	Leaves.
Coprinus fimetarius	Leaves.
Coprinus solstitialis (?)	Leaves, etc.
Daedalia quercina	Leaves, etc.
Hydnum coralloides	Beans.
Lycoperdon wrightii	Soil.
Pleurotus ostreatus	Beans and manure.
Pleurotus ulmarius	Manure.

In some instances the sporophores have been minute, owing to the small quantity of the culture medium.

[a] Brefeld. O. Unters. aus d. Gesammtgebiete d. Mykologie. S. 9. 10.

[b] Falck, R. Die Cultur der Oidien und die Rückführung in die höhere Fruchtform bei den Basidiomyceten. Cohn's Beiträge zur Biologie der Pflanzen. 8: 307–346 (Pls. 12–17).

From the standpoint of obtaining pure cultures, the tissue-culture method is capable of very general application. Three considerations render it particularly important, as follows: (1) When a suitable culture medium is at hand, a pure culture may be obtained almost invariably from a young, healthy plant. (2) Cultures may be made from fungi the spores of which have never been brought to germination. (3) Pure cultures are made by direct inoculation; that is, dilution cultures are rendered wholly superfluous. In the case of *Agaricus campestris* and other Basidiomycetes, in which the gill-bearing surface is protected until the spores are produced, it is possible, with the precautions previously mentioned, to obtain the spores pure, or practically pure, and at the same time in considerable quantity. This is not possible with the great majority of fleshy fungi, which are truly gymnocarpous. Again, members of the genus Coprinus are deliquescent, and here it is impracticable to secure spores by the spore-print method. In the Lycoperdaceæ and other Gasteromycetes it has been found that bacteria are frequently present in the tissues by the time the spores are formed, and, even if the spores could be germinated, direct cultures would perhaps be seldom possible. By the tissue method it is only necessary that the plant shall be so young that the cells of the tissue are capable of growth and that there are no foreign organisms present in the tissue. In this connection it may be stated that in the Phallineæ, Hymenogastrineæ, and Lycoperdineæ no representative has been germinated, while in the Plectobasidineæ germination is known only in the case of *Sphaerobolus stellatus and Pisolithus crassipes.*

When the natural conditions of germination shall have been more definitely ascertained, direct spore-culture methods should in practice, perhaps, replace the pure tissue-culture methods in making virgin spawn. This would render unnecessary a tedious portion of the work, and the process of spawn making would be thereby made less expensive.

A discussion of the respective practical merits of the spore and tissue methods would not be complete without reference to the comparative vigor, or productive power, of the resulting mycelium. In the growth of the mycelium no difference could be detected. The writer has also grown mushrooms from spawn produced by both of these methods; but the results do not indicate that there is any advantage for the one over the other. It is believed, therefore, that the processes of basidial and spore formation are in this regard relatively unessential, or at least do not intensify whatever invigoration may, in general, result from mere sporophore production. It is to be expected, perhaps, that any and all cells of the sporophore may be invigorated by whatever is to be gained by the assemblage, or concentration, in the differentiated sporophore, of food products collected by a ramifying mycelium. According to the studies of Harper,[a] Maire,[b] and others, there is no sexual fusion in the case of the Basidiomycetes which have been studied. Two nuclei are present in the cells of the sporophore, but these are associated conjugate nuclei, and the fusion of these in the basidium is generally considered in no sense an act of fertilization, but rather a form of nuclear reduction. Maire states that the cells of the mycelium obtained by the germination of the basidiospore are uninucleate. It has not yet been ascertained when or how the binucleate condition arises.

NUTRITION.

Although *Agaricus campestris* has been cultivated for so long a time, it does not seem that it has previously been subjected to careful experimentation from the point of view of nutrition. The belief generally prevalent is that the most essential factor in the nutrition of the mushroom is the "ammonia" of the manure or compost. Again, it is claimed that organic waste products, such as those indicated, must undergo a process of fermentation, or "preparation," in order to furnish the necessary nutrients for the growing mycelium. This idea, as will be seen later, is merely based upon casual observations "in nature," and it is found wholly erroneous when tested for its fundamental worth by the elimination of other factors of the compost environment.

Growth on manure and other complex media.—Early in this investigation it was ascertained that the mycelium of *Agaricus campestris* in pure cultures would grow luxuriantly on fresh stable manure, and as a rule upon the same product in any stage of fermentation or decomposition. In some instances, undoubtedly, fresh manure may contain injurious compounds; somewhat oftener the same is true for the fermented product. In some instances it is desirable to dry or thoroughly air the fresh manure before use. Fresh manure from grass-fed animals is not to be recommended. The mycelium also grows luxuriantly on bean stems or pods, on half-rotted leaves of deciduous trees, on rich soil, on well-rotted sawdust, and on a variety of other substances. It does not grow readily upon peaty products.

Some of the more promising edible species were cultivated in various media in order to obtain an idea of the comparative value of these media in furnishing a nutrient to particular forms. It is not possible, of course, to base definite conclusions upon results obtained

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[a] Harper, R. A. Binucleate cells in certain Hymenomycetes. Bot. Gaz., 33: 1–25. 1902.

[b] Maire, R. Recherches cytologiques et taxonomiques sur les Basidiomycetes. Bul. Soc. Myc. de France, 18: 1–209. 1902.

from pure cultures, since the presence of particular foreign organisms in the substratum under natural conditions is perhaps quite as important a consideration as that of the specific nutrient value of the substratum. The following results are, however, suggestive:

1. Agaricus campestris.
   Leaves—good growth throughout.
   Soil—fair growth, with tendency to become threaded early.
   Manure—good growth throughout.
   Beans—good growth throughout.
   Sugar beet—fair growth, spreading very slowly.
   Potato—slight growth, spreading very slowly.
   Corn meal—slight growth, spreading slowly, soon becoming brown.
2. Agaricus fabaceus.
   Leaves—very good growth, rapidly filling tube.
   Soil—good growth, but slower than the above.
   Manure—good growth, but slower than the above.
   Beans—very dense growth, soon filling whole tube.
   Sugar beet—good growth; somewhat less rapid and abundant than the above.
3. Agaricus villaticus.
   Practically the same as *Agaricus campestris.*
4. Agaricus fabaceus var.
   Practically the same as *Agaricus fabaceus.*
5. Bovistella ohiensis.
   Leaves—good growth throughout.
   Soil—growth throughout, but sparse and threadlike.
   Manure—good growth throughout.
   Beans—good growth; appressed.
   Sugar beet—very slight growth.
6. Calvatia cyathiforme.
   Leaves—very good growth throughout.
   Soil—good growth; quite as rapid as above.
   Manure—practically no growth.
   Beans—good growth, but spreads very slowly.
   Sugar beet—slight growth.
7. Calvatia craniiformis.
   Practically the same as above.
8. Calvatia rubro-flava.
   Practically the same as in the other species of this genus, but spreads somewhat more slowly on soil.
9. Coprinus atramentarius.
   Leaves—very good growth throughout.
   Soil—slight growth.
   Manure—fair growth, but very slow.
   Beans—very good growth.
10. Coprinus comatus.
   Leaves—very good growth throughout; rapid.
   Soil—good growth.
   Manure—very good growth throughout; rapid.
   Beans—very good growth throughout; rapid.
   Sugar beet—very slow growth.

11. Lepiota rhacodes.
    - Leaves—very good growth.
    - Soil—slight growth.
    - Manure—slight growth.
    - Beans—very good growth throughout.
    - Sugar beet—very good growth throughout.

12. Morchella esculenta.
    - Leaves—very good growth; mycelium never dense.
    - Soil—very little growth.
    - Manure—very slight growth.
    - Beans—very good growth.
    - Sugar beet—good growth, but slower than above.

13. Pleurotus ostreatus.
    - Leaves—very good growth; rapid.
    - Soil—fair growth.
    - Manure—good growth.
    - Beans—very good growth; rapid.
    - Sugar beet—slight growth; very slow.

14. Pleurotus ulmarius.
    - Practically the same as Pleurotus ostreatus.

15. Polyporus sulphureus.
    - Leaves—fair growth; abundant, filling tube.
    - Soil—fair growth.
    - Manure—fair growth, but very slow.
    - Beans—very good growth, rapidly filling tube.
    - Sugar beet—fair growth; much lighter mycelium than the above, with prompt oidial development.

16. Tricholoma personatum.
    - Leaves—very good growth throughout.
    - Soil—very good growth throughout.
    - Manure—growth slow, but eventually good.
    - Beans—good growth throughout.

Plates II, III, and IV show some of the more important of these species.

Taking into consideration the variable quality of the stable manure which may be obtained at all seasons, the value of half-rotted deciduous leaves as a substratum for Basidiomycetes is worthy of special emphasis. The writer has found such material more readily sterilized than manure, and usually more prompt than the latter to give growth.

In order to test in pure cultures the probable effect of fertilizers as indicated by any marked increase in the rapidity of growth of the mycelium, experiments were made by adding a small quantity of ordinary nutrient salts to test tubes containing manure. A chlorid and a nitrate of the following salts were employed, viz. ammonium, calcium, magnesium, and potassium. In addition, dibasic potassium phosphate and also sodium chlorid, as well as control cultures, were used. Three tubes were employed with each of the compounds mentioned. There was no marked difference in the amount or rapidity of the growth noted, as found by comparing the averages of growth.

It seemed possible, however, that some slight advantage resulted from the calcium compounds, but there was no pronounced benefit in any tube. Further reference is made to the use of nutrient salts in mushroom growing in another chapter.

Growth on chemically known media.—In an attempt to determine somewhat more accurately the value of different compounds as nutrients, particularly carbohydrate and nitrogenous substances, several series of extensive tests have been made with *Agaricus campestris*, and also with *Agaricus fabaceus* and *Coprinus comatus*. These fungi do not grow readily in liquid media, and it has been difficult to obtain a wholly reliable and satisfactory substratum, one which would itself be practically pure, or well known, chemically, and at the same time effective for its purpose. After unsatisfactory attempts with various gelatinous solid media, with charcoal, etc., it was decided that the commercial gray filter paper had more to recommend it than any other substance suggested. Accordingly, all experiments were made in Erlenmeyer flasks of 150 c. c. capacity, and in each flask was placed about 6 grams of this paper wadded into pellets. The latter was moistened in each case with the nutrient solution used. The flasks were subsequently sterilized in the autoclave and then inoculated with a very minute fragment of straw with the fresh mycelium from a pure culture on manure.

Tabulation of special results.—In the following tables are given the results of two out of several series of experiments, which have been conducted in order to throw some light on the point just discussed. These tables include, also, many cultures on media of unknown composition.

TABLE V.—*Results of growth on media—First series of experiments.*

No.	Medium.	Extent of growth.
1a 1b	Dt. H_2O	Very slight. Do.
2a 2b	Solution A[a]	Do. Do.
3a 3b	Solution A and cane sugar, 1½ per cent	Do. Do.
4a 4b	Cane sugar, 1½ per cent	Do. Do.
5a 5b	Solution A and lactose, 1½ per cent	Do. Do.
6a 6b	Lactose, 1½ per cent	Do. Do.
7a 7b	Solution A and glycerin, 1½ per cent	Do. Do.
8a 8b	Glycerin, 1½ per cent	Do. Do.
9a 9b	Solution A and starch paste, ½ per cent	Fair growth Do.
10a 10b	Starch paste, ½ per cent	Do. Do.
11a 11b	Solution A and starch, ½ per cent, and diastase, trace	Contaminated, discarded. Fair.
12a 12b	Starch, ½ per cent, and diastase, trace	Good. Do.
13a 13b	Solution A and dextrose, 1½ per cent	Very slight. Good.

[a] *Solution A.*—Water, 2,000 cubic centimeters; $MgSO_4$, 5 grams; K_2HPO_4, 10 grams; NaCl, 1 gram; $CaCl_2$, 0.25 gram; KNO_3, 20 grams; $FeCl_3$, trace.

TABLE V.—*Results of growth on media—First series of experiments*—Continued.

No.	Medium.	Extent of growth.
14a 14b	Dextrose, 1½ per cent	Slight. Do.
15a 15b	Solution A and mannite, 1½ per cent	Very slight.
16a 16b	Mannite, 1½ per cent	Lost.
17a 17b	Solution A and maltose, 1½ per cent	Contaminated with Aspergillus. Fair growth, yellowish in color.
18a 18b	Maltose, 1½ per cent	Fair. Do.
19a 19b	Solution A and potassium tartrate, ½ per cent	Slight. Do.
20a 20b	Potassium tartrate, ½ per cent	Do. Do.
21a 21b	Solution A and magnesium tartrate, ½ per cent	Do. Do.
22a 22b	Magnesium tartrate, ½ per cent	Do. Do.
23a 23b	Solution A and ammonium tartrate, ½ per cent	Do. Do.
24a 24b	Ammonium tartrate, ½ per cent	Do. Do.
25a 25b	Solution A and potassium lactate, ½ per cent	Do. Do.
26a 26b	Potassium lactate, ½ per cent	Do. Slight to fair.
27a 27b	Solution A and magnesium lactate, ½ per cent	Slight. Do.
28a 28b	Magnesium lactate, ½ per cent	Do. Do.
29a 29b	Solution A and ammonium lactate, ½ per cent	Fair to good. Do.
30a 30b	Ammonium lactate, ½ per cent	Slight. Do.
31a 31b	Solution A and calcium hippurate, ½ per cent	Very good. Do.
32a 32b	Calcium hippurate, ½ per cent	Slight. Do.
33a 33b	Solution A and asparagin, ½ per cent	Do. Do.
34a 34b	Asparagin, ½ per cent	Do. Do.
35a 35b	Solution A and peptone, ½ per cent	Good. Do.
36a 36b	Peptone, ½ per cent	Very slight. Do.
37a 37b	Solution A and casein, ½ per cent	Very good. Do.
38a 38b	Casein, ½ per cent	Do. Do.
39a 39b	Solution A and pepsin, ½ per cent	Slight to fair. Do.
40a 40b	Pepsin, ½ per cent	Do. Do.
41a 41b	Solution B[a]	Do. Do.
42a 42b	Solution B and asparagin, ½ per cent	Slight. Do.
43a 43b	Solution B and peptone, ½ per cent	Very slight. Do.
44a 44b	Solution B and casein, ½ per cent	Very good. Do.
45a 45b	Solution B and pepsin, ½ per cent	Culture lost. Do.
46a 46b	Bouillon	Slight to fair. Do.
47a 47b	Bean decoction	Very good. Do.
48a 48b	Beet decoction	Good to very good. Do.
49a 49b	Manure decoction	Very good. Do.
50a 50b	Manure	Do. Do.
51a	Wheat straw	Lost.
52a 52b	Solution A and wheat straw	Do. Do.
53a 53b	Solution B and wheat straw	Do. Do.
54a 54b	Solution B and NH_4NO_3 and cane sugar	Slight to fair. Do.
55a 55b	Solution B and cane sugar and $Ca(NO_3)_2$, ½ per cent	Very slight. Do.

[a] *Solution B.*—Water, 1,000 cubic centimeters; $MgSO_4$, 2.5 grams; K_2HPO_4, 5 grams; $CaCl_2$, 0.25 gram; NaCl, 0.5 gram.

TABLE V.—*Results of growth on media—First series of experiments*—Continued.

No.	Medium.	Extent of growth.
56a 56b	Solution B and sugar and $Mg(NO_3)_2$, ¼ per cent	Very slight. Do.
57a 57b	Solution B and sugar and NH_4Cl, ¼ per cent	Do. Do.
58a 58b	Solution B and NH_4NO_3, ¼ per cent	Do. Do.
59a 59b	Solution B and $Ca(NO_3)_2$, ¼ per cent	Do. Do.
60a 60b	Solution B and $Mg(NO_3)_2$, ¼ per cent	Do. Do.
61a 61b	Solution B and NH_4Cl, ¼ per cent	Slight to fair Do.
62a 62b	Mushroom decoction	Do. Do.

TABLE VI.—*Results of growth on media—Second series of experiments.*

No.	Medium.	Extent of growth.
1a 1b	Fresh horse manure (grass-fed animals)	None. Slight.
2a 2b	Fresh horse manure, thoroughly washed, residue only used	Contaminated. Good.
3a 3b	Filtrate, or liquid resulting from washing No. 2	Good. Contaminated.
4a 4b	Decoction of fresh horse manure, as in No. 1	Fair. Do.
5a 5b	Fermented horse manure, thoroughly washed	Very good. Do.
6a 6b	Filtrate or washing from No. 5	Slight. Do
7a 7b	Rotted stable manure	Good. Contaminated
8a 8b	Decoction of green timothy hay	Good. Do.
9a 9b	Residue from decoction in No. 8	None. Do.
10a 10b	Strong bean juice	Slight. Contaminated.
11a 11b	Weak bean juice	Good. Do.
12a 12b	Strong decoction of mushrooms	Slight. Do.
13a 13b	One-half strength decoction of mushrooms	Slight. Contaminated.
14a 14b	Weak decoction of mushrooms	Slight. Do.
15a 15b	Oat straw	Contaminated. Slight.
16a 16b	Wheat straw	Good. Do.
17a 17b	Corn meal	Fair. Do.
18a 18b	¼ gram cane sugar in 25 c. c. solution A	Slight. Confined to nocules.
19a 19b	¼ gram milk sugar in 25 c. c. solution A	Do. Slight throughout.
20a 20b	¼ gram galactose in 25 c. c. solution A	Do. Slight, but contaminated.
21a 21b	¼ gram cornstarch in 25 c. c. solution A	Slight at top. Lost.
22a	½ strength albumen (egg)	Confined to nocules.
23a 23b	¼ gram glucose in 25 c. c. solution A	Slight at top. Do.
24a 24b	¼ gram dextrose in 25 c. c. solution A	Fair throughout. Do.
25a 25b	¼ gram mannite in 25 c. c. solution A	Fair. Contaminated
26a 26b	¼ gram glycogen in 25 c. c. solution A	Slight; contaminated. Fair.
27a 27b	¼ gram maltose in 25 c. c. solution A	Slight at top. Do.
28a 28b	¼ gram levulose in 25 c. c. solution A	Slight. Slight at top.
29a 29b	¼ gram glycerin in 25 c. c. solution A	Confined to nocules.

TABLE VI.—*Results of growth on media—Second series of experiments*—Cont'd.

No.	Medium.	Extent of growth.
30a	¼ gram potassium tartrate in 25 c. c. solution A	Very slight; contaminated.
30b		Do.
31a	¼ gram magnesium tartrate in 25 c. c. solution A	Confined to nocules.
31b		Do.
32a	¼ gram potassium lactate in 25 c. c. solution A	Do.
32b		Do.
33a	¼ gram potassium lactophosphate in 25 c. c. solution A	Slight at top.
33b		Do.
34a	¼ gram magnesium citrate in 25 c. c. solution A	Do.
34b		Do.
35a	¼ gram magnesium malate in 25 c. c. solution A	Do.
35b		Do.
36a	¼ gram calcium hippurate in 25 c. c. solution A	Good top.
36b		Do.
37a	¼ gram asparagin in solution A	Slight.
37b		Do.
38a	¼ gram urea in solution A	Confined to nocules.
38b		Do.
39a	¼ gram peptone in solution A	Fair at top.
39b		Do.
40a	¼ gram casein in solution A	Fair throughout.
40b		Do.
41a	½ gram benzoic acid in solution A	None.
41b		Do.
42a	⅛ gram benzoic acid in solution A	Do.
42b		Do.
43a	Solution A	Confined to nocules.
43b		Do.
44a	Solution B	Do.
44b		Do.
45a	Distilled HO	Do.
45b		Do.
46a	Decoction from productive old bed	Fair throughout.
46b		Do.
47a	Oak sawdust, only slightly rotted	Confined to nocules.
47b		Do.
48a	Gluten meal and water	Good throughout.
48b		Do.
49a	Cotton-seed meal and water	Contaminated.
49b		Do.
50a	Cotton-seed meal	Slight at top.
50b		Contaminated.
51a	½ gram asparagin in solution B	Slight at top.
51b		Do.
52a	¼ gram asparagin in solution B	Fair.
52b		Do.
53a	½ gram urea in solution B	None.
53b		Do.
54a	¼ gram urea in solution B	Slight at top.
54b		Do.
55a	⅛ gram urea in solution B	Slight throughout.
55b		Do.
56a	½ gram peptone in 25 c. c. solution B	Slight at top.
56b		Do.
57a	¼ gram peptone in 25 c. c. solution B	Do.
57b		Do.
58a	⅛ gram peptone in 25 c. c. solution B	Fair at top.
58b		Do.
59a	¼ gram peptone and $\frac{1}{16}$ gram $NaNO_3$ in solution B	Fair throughout.
59b		Slight.
60a	½ gram casein in 25 c. c. solution B	Very slight.
60b		Do.
61a	¼ gram casein in 25 c. c. solution B	Fair at top.
61b		Slight at top.
62a	$\frac{1}{16}$ gram casein in 25 c. c. solution B	Fair throughout.
62b		Do.
63a	¼ strength albumen (egg)	Slight at top.
63b		Do.
64a	Oil meal and water	Good throughout.
64b		Do.
65a	White pine shavings	Very small area, but copious.
65b		Do.
66a	White pine shavings with bean decoction	Do.
66b		Do.
67a	Asbestos with bean decoction	Confined to nocules.
67b		Do.
68a	Old flake spawn	Very good.
68b		Do.

It is not possible here to enter into a detailed discussion of the results, but attention is directed to the fact that under ordinary conditions *Agaricus campestris* does not give a copious growth when nitrogen is furnished from an inorganic salt and carbon in the form of the well-known sugars. Calcium hippurate in a solution of the necessary salts has almost invariably given better growth than other organic salts and carbohydrates. In general, casein has been a better source of carbon, or of carbon and nitrogen, than other proteids.

When the manure is of good quality it furnishes, in pure cultures, a source of necessary nutrients, whether fresh or fermented, whether as a decoction or an infusion (a cold aqueous extract).

Acid and alkaline media.—Manure which has undergone fermentation for a few weeks is usually slightly acid in reaction. Under certain conditions of fermentation the acidity is increased, and this is probably an important factor in making the manure from animals fed with green foods less valuable for mushroom work. Some acid tests were made of beds which had failed to yield satisfactory results, and in many instances it was found that the acid content was much above the normal. A small series of experiments was therefore instituted to determine the relative amount of acidity or of alkalinity most favorable for the growth of the spawn under pure-culture conditions. In this test there were also included several other edible fungi, the results of all of which are included in the table below. These experiments were made in large test tubes, and in such a test it was impracticable to determine absolute acidity or alkalinity, and from the results only a rough qualitative comparison could be anticipated. Potassium hydrate and lactic acid were used as reagents. The duration of the experiments was one month, and duplicate cultures were used in every instance.

Although the results are not wholly uniform, it may be inferred that in the case of *Agaricus campestris* a marked acidity of the medium would be unfortunate; *Calvatia cyathiforme*, on the other hand, seems to have grown somewhat better, in general, in the more acid media; *Coprinus comatus* grows under a wider range of conditions; and *Coprinus atramentarius*, in this instance, thrives in an alkaline medium. Further tests on a quantitative basis are required before definite conclusions may be drawn. This matter will also receive further attention when facilities are at hand for undertaking to better advantage than has yet been possible the practical growing of the other species, besides *Agaricus campestris*, included in this test.

TABLE VII.—*Results of tests of acidity and alkalinity.*

Medium.	Nature of stable compost.	Extent of growth.			
		Agaricus campestris.	Calvatia cyathiforme.	Coprinus comatus.	Coprinus atramentarius.
4 drops KHO	Fresh	Very slight	Very slight	Slight	1 good, 1 very slight.
	Rotted	Slight	do	Very slight	Contaminated.
2 drops KHO	Fresh	1 good, 1 fair.	1 none, 1 slight.	1 very good, 1 excellent.	Very slight.
	Rotted	Very good	None	Very good	Good.
1 drop KHO	Fresh	Good	Very slight	Excellent	Very good.
	Rotted	Very good	None	do	Excellent.
Control	Fresh	1 very good, 1 fair.	1 good, 1 none	do	Very slight.
	Rotted	Very slight	Contaminated.	None	None.
1 drop acid	Fresh	1 contaminated, 1 very good.	1 slight, 1 good.	Excellent	Very slight.
	Rotted	Very slight	Very slight	do	Do.
2 drops acid	Fresh	do	do	do	Do.
	Rotted	do	Very good	None	Do.

TEMPERATURE AND MOISTURE.

The temperature factor is, next to that of good spawn, perhaps the most important in mushroom growing. It has been frequently stated that mushroom growing is not profitable when the temperature may not be maintained more or less continuously at from 50° to 60° F. It is very probable that the exact temperature which may be considered an optimum will vary somewhat in different sections of the country. It will be noted later in detail that the temperature factor acts not so directly upon the growth of the spawn or the production of mushrooms as indirectly to render some other conditions of the environment injurious. It is best to consider that in practice the optimum temperature for mushroom growing varies from 53° to 58° F.

When the matter of temperature was first under consideration, a series of pure cultures of *Agaricus campestris* was placed at different temperatures in the laboratory in order to determine the rapidity of growth. It was soon found that a temperature above 60° F. and, indeed, as high as from 80° to 85° F., was much more favorable to rapid growth than a lower temperature, provided, of course, that the higher temperature did not encourage a too rapid drying out of the culture. It was soon definitely ascertained that the conditions of pure-culture growth are essentially different from those attending the growth of mushroom spawn in the bed. This was perhaps best indicated by comparing spawn grown in pots at 85° F. under impure conditions with similar spawn grown at 50° F. At the former temperature, even though the conditions of moisture were properly maintained, there was little or no growth. Foreign fungi, molds, and bacteria, as well as insects, were, however, abundant. At the lower temperature there was little or no evident appearance of other fungi, molds, or insects;

yet the mushroom spawn grows slowly and continuously so long as other conditions are maintained. From numerous experiments of this nature it is apparent that the temperature relation is one which is governed by the competition to which the mushroom spawn is subject in the bed. This is, of course, wholly in accord with the results obtained from the study of the relative growth made by mushroom spawn in fresh and composted manures.

The statement previously made, therefore, that the optimum temperature may vary slightly in different localities is true on account of the fact that the mites, insects, and other animal pests of mushroom growing may vary considerably in different localities, or under different conditions, even though there may not be a great variation, perhaps, in the bacterial and fungus flora of the compost upon which the mushrooms are grown. Certain insects, for example, are more abundant in a moist climate, but if special precautions can be taken to eliminate all such pests, the growth problem is confined to the interrelation existing between the mushroom spawn and the microscopic flora of the compost. Mushrooms grown in the open will probably show greater variation with reference to the temperature factor than those grown in caves or cellars.

While a number of interesting problems would be presented by a study of the interrelation of the mushroom mycelium with that of other microscopic fungi present in the compost, these are matters of detail; and it has been wholly impossible thus far to give any attention to suggestions which have been furnished by the experimental data. It may be possible that other species of mushrooms are more independent of insects and other microscopic fungi, and such fungi may therefore be more suitable for cultivation at high temperatures than is *Agaricus campestris* or any of its close allies. A considerable effort is being made to obtain spawn of certain species of Agaricus, and also of other edible mushrooms which make their appearance during the warm weather. At this time, however, it is not possible to say what results of value may be anticipated from this line of work.

The direct effect of a temperature above the optimum upon the sporophores is manifest through lengthening of the stipes and rapid expansion of the caps, ordinarily accompanied by toughness and decreased size. In other words, the lower grade market product is produced at the higher temperature.

The moisture factor is also one of importance. It is undesirable that the place in which mushrooms are grown should be very damp, or dripping with water. Nevertheless, a fairly moist condition of the atmosphere should be maintained throughout the growing and productive period. There should be a gradual but slight evaporation from the surface of the beds, and sufficient ventilation to insure this is believed to be essential. It is certain that in poorly ventilated caves mushrooms do not succeed. On the other hand, in a dry atmosphere, or exposed to drying winds, mushroom beds soon cease to bear, while such sporophores as are developing may have their caps cracked and torn.

Mushrooms are grown in cellars, caves, or specially constructed houses largely on account of the fact that temperature and moisture are then practically under control. The nature of the structure or cellar which is constructed for mushroom growing must be determined, therefore, not merely by its expense, but by the effectiveness of the structure in regulating the factors indicated under the particular climatic conditions.

It is not possible at this time to discuss cellar or house construction, and the accompanying illustration of mushroom houses (Plate VI, fig. 1) must suffice to give an idea of the types which are in use.

PREPARATION OF THE COMPOST.

It is not to be understood that there is one and only one method of preparing compost for mushroom growing. Nor is it always necessary that the compost shall be in one particular stage of fermentation or decay. In fact, every change of condition elsewhere may necessitate a similar change in the amount of fermentation which may be most desirable. At the outset it should be understood that it is not the "fermentation" which is absolutely essential.[a] The

[a] Répin, l. c. (See translation in The Garden (London), February 5, 1898. Special reprint, pp. 10–16.) Here it is stated that "manure is rendered capable of supplying nutriment suitable for mushrooms only by means of fermentation;" further, that "all the higher orders of mushrooms, the spores of which I have succeeded in causing to germinate, have a sterile spawn of a similar nature." Again, the conclusion is expressed somewhat indefinitely that manure is "rendered suitable" by means of chemical combustion, which is said to proceed rapidly only at a temperature above 178° F.; that it is not the soluble substances in the manure which are valuable, but rather the cellulose matter, together with the necessary salts.

In this connection it is of interest to note that the material constituting many of the beds in the experimental cellar at Columbia, Mo., were fermented at comparatively low temperatures. A complete temperature record was kept of 18 small compost piles in which special kinds of manure were prepared, and in only one instance was the temperature in any pile more than 140° F. In some cases 120° F. was the maximum attained.

Répin implies that mushrooms will not grow in manure until there has been effected "the destruction of all the soluble organic matters, which disappear through the agency of bacteria or are consumed in the process of oxidation." Very simple nutrition experiments clearly demonstrate that these conclusions are erroneous.

It may be stated, however, that peculiarities appear when the fresh manure contains certain compounds which render it injurious; for example, the mycelium does not grow readily in pure culture upon fresh manure from animals fed almost wholly on green forage. Such manure is improved by fermentation.

"fermentation" is of itself a minor matter. In pure cultures, where sterile media are employed, mushroom spawn starts slowly, but finally grows best, in general, upon fresh (wholly unfermented) manure. It grows least well, or, rather, less densely, so far as tested, on very well fermented manure. This certainly indicates that it is not fermentation which is ordinarily advantageous. In practical mushroom growing, however, it is not possible to deal with pure cultures; and, therefore, other conditions of the environment must be correspondingly changed. The rapid oxidation action of bacteria, and perhaps of independent ferments, upon manure causes a considerable rise of temperature. At the higher temperatures (which may be maintained as long as there are present rapidly oxidizable food products) bacterial action is vigorous, and is unquestionably injurious to mycelial development. Wholly aside from the rise of temperature accompanying their activities, bacteria are otherwise injurious. In fact, manure which is put to ferment in a small test tube shows little or no rise of temperature above that of the place in which it is incubated. Nevertheless, the mycelium of the mushroom will not grow under such conditions. Rapid bacterial action is therefore prejudicial. Under those conditions where bacterial action is not rapid, fresh manure might be used to advantage; in other words, if the beds are so constructed that the manure ferments very gradually, without either excessive bacterial action or rise of temperature, then spawning might be made in fresh manure.

The old belief that rotten manure does not have the necessary strength—that is, does not produce so vigorous a mushroom growth as that which has been less transformed by bacterial action—has been confirmed by practical experiments. This loss of effectiveness is probably due, in part, to a change in texture or to other physical changes. In well-rotted manure there is ample food material to support a very good growth of mycelium in pure cultures. This has been chemically proved by sterilizing such manure and growing mushroom spawn upon it in pure culture. Nevertheless, by comparing (in Table VIII) No. 12 with Nos. 13, 14, and 15, it will be seen that beds prepared with well-fermented manure and left for some time before spawning do not yield so well. It is believed that here the physical condition has much to do with the result.

The latter does not by any means invalidate the following practice, which has commended itself to some very successful growers: The manure is piled in very large compost heaps, where it is kept moist and is turned only once or twice. It ferments very slowly. Then it is carted into the cave, or mushroom house, long before it could be considered in proper condition to be spawned. The beds (usually flat when this is the procedure) are made immediately. These are fairly well moistened and compressed, then left to undergo a gradual fermentation, which may require a month. When the manure shows a tendency to fall to the temperature of the room it is spawned. Meanwhile, it will doubtless be found that a heavy crop of some small species of Coprinus will have appeared. The presence of this fungus is not injurious, but rather it may be taken as an indication that the conditions are favorable.

Ordinarily the manure is obtained as fresh as possible. It should include the straw used in bedding the animals, and the quality of the straw will determine to some extent the value of the manure. The straw of cereals is far better than that of most other grasses. The more resistant straws seem greatly to improve the texture of the compost for mushroom purposes. Commercially it is a mistake to attempt to get the manure free from straw. If fresh manure is not obtainable, that which has been trampled by the animals is ordinarily rich, well preserved, and desirable. It ferments best in large piles, and these may be of considerable extent, about 3 or 4 feet deep throughout. If not uniformly moist the material should be sprinkled. At no time is a very heavy watering desirable. In from four days to a week or more the compost should be turned, or forked over, and a second turning will be required a week or ten days later. Water should be added only when necessary to maintain a moist (but not a wet) condition. With this amount of moisture, and with the piles deep enough to become fairly compact as a result of their own weight, there will be little danger of any injurious fermentation. During the normal fermentation the temperature may rise higher than 150° F. In from fifteen to twenty-one days or more, depending upon the conditions, the temperature will begin to fall, and the compost may be used in the construction of the beds. When used in the beds, it has ordinarily lost all objectionable odor, and the color of the straw has changed from yellow to brown. In figure 2 on Plate V is shown a shed in which the manure is composted during the summer.

As stated in Farmers' Bulletin No. 204:

> It is the custom with some growers to mix a small quantity of loam, about one-fourth, with the manure. This enables one to use the manure earlier; and, indeed, under such circumstances it may sometimes be used with but little or no composting. Nevertheless, the majority of growers have obtained greater success by the use of the manure alone, and this is also the writer's experience. Very well-rotted compost should not be used in mushroom growing if large and solid mushrooms are desired. When sawdust or shavings are employed for bedding the animals, the composting may require a somewhat longer period.

It has been the experience of some of the most successful growers that the use of shavings for bedding material in the stables does not injure the value of the product for mushroom work. The presence of a large amount of sawdust is, however, objectionable so far as the writer's experience goes. Compost containing much sawdust is necessarily very "short," and therefore the physical condition is not the most favorable for *Agaricus campestris.*

In another chapter attention is called to the fact that the value of the manure depends to a considerable extent upon the feed given the animals. It would not be wise to depend upon that obtained from stables in which hay and green foods are used to too great an extent. Moreover, it is not believed that compost made from the manure of cattle barns is in mushroom growing as desirable as stable manure.

In some cities the municipal ordinances require that the manure shall be promptly removed from the feeding stables or that it shall be disinfected. In the latter case crude carbolic acid, or even corrosive sublimate, may be used to secure this end. Manure thus disinfected is, of course, undesirable for mushroom work. For the same reason the manure of veterinary hospitals is of questionable value.

It is not wholly improbable that some other waste products of the farm, field, and forest may be utilized in mushroom growing; nevertheless, no such product has yet been found which, under the conditions of the experiment, has yielded sufficiently to make it of special interest in growing *Agaricus campestris.* Among the products which have been tested, either alone or in conjunction with some commercial fertilizer, are the following:. Leaves of deciduous trees, needles of conifers, sawdust, cotton-seed hulls, cotton seed, corn stover, sorghum stover (or bagasse), rotten hay, sphagnum, and yeddo fiber. The writer is convinced that greater profit may be anticipated, for the present, at least, if the culture of *Agaricus campestris* is confined to manure; and if other edible forms which grow in the woods are used in beds of leaves, etc., as indicated elsewhere in these pages, it is quite possible that such a fungus as *Coprinus comatus* may be grown successfully in this latter way. It may, however, be too much to hope that the morel may also be thus made amenable to culture, although leaf mold is in nature the favorite habitat of this fungus.

From the prompt and abundant growth of *Agaricus campestris* on half-rotted leaf mold in pure cultures, it was thought that mushrooms might be grown to advantage upon this product. The practical experiments made to test this point are distinctly discouraging, as shown by reference to No. 17, Table VIII; Nos. 3 and 4, Table IX, and No. 11, Table X.

For the most part manure may be composted in the open air. It may, however, be prepared with greater uniformity under cover. During midsummer, protection may be desirable on account of drying out, while in the winter it is more important in case of excessive cold. If it is necessary to compost manure during the winter, moreover, the piles should be of considerable depth.

INSTALLATION OF BEDS.

In making the beds, as well as in other phases of mushroom work, regard must be had for all environmental conditions. The type of bed should be determined by convenience, and the size, to a certain extent, by the temperature to which the beds may be exposed. The flat bed, frequently referred to as the English type, is more commonly employed in the indoor work in England and America. With this type merely the entire floor space may be utilized, as illustrated in the frontispiece, Plate I, or the beds may be arranged in tiers of shelves. In figure 1 on Plate V a view may be had of the supports for shelf beds in a large commercial house. In this house there is the greatest economy of space. The shelf system gives the greatest amount of bed space and is certainly most economical where the floor space is an important factor. Such beds do not require great depth, but merely sufficient to insure an ample development of spawn. They should be from 8 to 10 inches deep after being firmed or compressed.

The ridge-bed system is employed almost exclusively in the caves about Paris. This system is also in use in open-air culture. It may be used to advantage in low cellars, caves, or houses when labor is not too expensive. Ridge beds increase slightly the surface area and permit of easy passage from one part of the cave to another. The size of such beds in caves, or under other conditions where the temperature remains practically uniform, should be not more than 2 feet wide at the base and 15 inches high, tapering gradually to the top when compressed. Slanting beds are commonly employed next to the walls. Large beds are desirable under changeable open-air conditions.

The prevalent opinion among amateurs that the bed should always be deep enough to maintain a considerable heat is believed to be erroneous. Grown under more or less uniform conditions, mushrooms seem to require no bottom heat, and the bed should fall to the temperature of the room some time after spawning. Bottom heat, and hence large beds, are, however, desirable when sudden changes of weather would so reduce the temperature of the bed as to delay growth. Under similar conditions, as well as in dry air, mulching may be required.

As previously stated by the writer in Farmers' Bulletin No. 204 of the Department of Agriculture—

> In any case, the manure is made up in the form of the bed desired and should be firmed, or compressed, to some extent immediately, in order to prevent drying out and burning when the secondary fermentation takes place. At this time the manure should be neither wet nor dry, but merely moist. The only practical test of the proper moisture content of the manure which can be relied upon is when, upon compression, water can not readily be squeezed out of it.

SPAWNING AND CASING THE BEDS.

From what has been said concerning the temperature requirements, it will be evident that spawn should not be inserted in the beds until the temperature has fallen low enough to insure successful competition on the part of the mycelium with other organisms. In many articles on mushroom growing it has been suggested that beds may be spawned when the temperature has fallen to about 90° F. From experience and observation, the writer can only conclude that such a temperature is frequently fatal, and it is believed that the temperature of the beds should be permitted to fall to 70° F. before being spawned. In fact, the most successful results have been obtained at temperatures from 65° to 70° F. It was formerly believed that if the spawn were inserted at 90° F. this higher temperature incited the rather dormant mycelium to rapid and vigorous growth. It is clear, however, that the rapid development of new mycelium from the pieces of spawn brick inserted is not so important a factor as suitable conditions for continued growth. If the temperature falls rapidly from 90° F. after spawning, however, no injury may result. Nevertheless, it is to be considered an unfortunate condition.

The bricks of spawn may be broken into from ten to twelve pieces, from 1½ to 2 inches square. These pieces may be inserted about 1 inch beneath the surface of the manure. In flat beds they may be placed from 10 to 12 inches apart throughout the bed, and in ridge beds the pieces should be inserted on each side alternately, one near the top and the next near the bottom. It is well to insert the pieces vertically, as the mycelium does not then seem so readily to suffer damping off. After spawning, the beds should again be firmed, and they are then ready to be cased or loamed whenever this process may seem most desirable. At the time of spawning the beds should be in the best condition possible for the growth of the mycelium. Delay in growth at this time is one of the surest indications of a light yield. If the bed contains the proper amount of moisture, and if the walls and floors of the house or cellar are sprinkled occasionally, so as to maintain a moist condition of the atmosphere, it is possible to avoid wholly the use of water upon the beds immediately after spawning. In no case should a bed recently spawned be heavily watered. The surface may be sprinkled, if there is a tendency toward drying out. The same test for moisture content as has been outlined previously in these pages in the chapter on preparing the manure should be followed. The beds should become gradually somewhat drier, however, during the growth of the spawn.

The absolute water content for the bed at the time of spawning should be about 40 per cent, although this will vary considerably, according to the conditions, and especially with relation to the quantity of straw in the manure.

If the spawn grows rapidly at first and spreads throughout the bed, it will not be injured by a slight drying out, or by a temperature even as low as 32° F. On the other hand, a continuous high temperature for several days, or excessive watering, is sure to result in an irreparable injury. In several instances where the experimental beds of the writer have been made during the late autumn, and where a vigorous growth of spawn has been secured before the advent of the coldest weather, the beds have remained unproductive throughout the winter months, or so long as the temperature remained intermittently below 40° or 50° F. With warmer weather, these beds have come into bearing several months later, and where the temperature has then remained favorable for some time a good yield has been obtained. In this case, moreover, the bed will bear much longer at a temperature of 60° F., or above, than if the temperature has been constantly in the neighborhood of 60° F. throughout the growing season of the spawn. As a rule, beds thus filled with spawn and then subjected for a time to cold conditions yield at the outset much larger mushrooms than beds exposed to a more constant temperature, even if this constant temperature may be the optimum.

At any rate, the beds must be "cased" as soon as convenient after the spawn is inserted. As a rule, one should wait from one to two weeks in order to be sure that the spawn is growing. Casing consists in applying to the bed a layer of loam from 1 to 1½ inches deep. In France the casing soil consists usually of calcareous earth, sometimes mixed with loam. Ordinary loam of almost any quality will suffice. This should be secured in advance, and it is well to protect it from the weather, so that at a convenient time it may be worked over and, if necessary, screened, in order to free it from large pebbles or trash. When the loam is applied, it should, on ridge beds, be carefully firmed. When cased a bed should require watering for the most part merely to maintain a moist surface.

MUSHROOM GROWING.

EXPERIMENTS AT COLUMBIA, MO.

The practical experiments in mushroom growing which have been undertaken at Columbia, Mo., were designed, in the first place, to determine the exact effect of conditions upon the growth of mushrooms, and in the second place to test or immediately apply the results obtained or suggested by the laboratory work. The effects of temperature, moisture, etc., have already been discussed, and the conclusions drawn have been based upon the most careful observations of the experimental beds, as well as upon the evidence which has been obtained by a personal study of the conditions in commercial mushroom houses and caves both at home and abroad. It is needless to give in detail the record of all failures or of poor yields invariably obtained when the conditions were unfavorable—that is, when they were beyond the limits which have been more or less definitely stated as requisite. On the other hand, the results which are given do not represent the best yields obtained; they are those which seem to be most instructive.

The experimental work has been seriously handicapped in one particular. With only one set of experiments (those recorded in Table VIII) has it been possible to maintain a temperature constantly between 50° and 60° F. Unfortunately a north basement room which gave those results during the winter of 1903–4 has not since been available for the work. The results are, however, comparative when not absolute.

The results given in Table VIII are referred to in various parts of this bulletin. Attention should be directed to the fact that many of these beds were yielding well when the experiment was necessarily closed to make room for a second series of experiments planned during the same winter. Beds Nos. 6, 9, 13, 25, and 40, for instance, each yielded between 8 and 15 ounces the day the experiment was closed, while beds Nos. 2, 10, 14, 23, 26, 30, and 37 each yielded 1 pound or more on the same day.

It is to be noted that a considerable number of beds in this series produced more than 1 pound per square foot, and some nearly 2 pounds for a similar area. It is certain that some beds would have yielded more than 2 pounds if they could have been permitted to produce longer.

TABLE VIII.—*Yields of experimental mushroom beds.*

Number of the experimental bed.	Material used in the bed.	Source of the spawn.	Number of days to produce mushrooms.	Yield in ounces first 30 days.	Yield in ounces second 30 days.	Total yield in ounces at close of experiments.	Area in square feet per bed.	Yield in ounces per square foot.
1	Fermented horse manure.	Alaska, old	27	53	54	107	6	18.0
2	...do	Old American made	104	20	......	20	6	3.6
3	...do	English, current year market product.	51	7	......	7	6	1.0
4	...do	English, 2 years old	......	......	......	0	6	0.0
5	...do	English, 1 year old	......	......	......	0	6	0.0
6	...do	Alaska, U. S. Department of Agriculture.	51	47	68	115	6	18.8
7	...do	Bohemia, U. S. Department of Agriculture.	53	48	17	65	5	13.0
8	...do	Mixed varieties, U. S. Department of Agriculture.	51	78	34	112	6	18.6
9	...do	Bohemia, U. S. Department of Agriculture, light spawning.	68	102	......	102	6	17.0
10	...do	Bohemia, U. S. Department of Agriculture, heavy spawning.	46	71	65	136	6	22.6
11	...do	*Agaricus amygdalinus*, old	......	......	......	0	6	0.0
12	Fermented horse manure (bed left for 2 months before being spawned)	Bohemia, U. S. Department of Agriculture.	61	5	......	5	6	0.8

TABLE VIII.—*Yields of experimental mushroom beds*—Continued.

Number of the experimental bed.	Material used in the bed.	Source of the spawn.	Number of days to produce mushrooms.	Yield in ounces first 30 days.	Yield in ounces second 30 days.	Total yield in ounces at close of experiments.	Area in square feet per bed.	Yield in ounces per square foot.
13	Fermented horse manure.	Bohemia, U. S. Department of Agriculture.	49	110	50	160	6	27.7
14, 15	....do	....do	61	241	40	281	12	23.4
16	Leaf mold	*Calvatia cyathiforme*	......	......	......	0	6	0.0
17	....do	Bohemia, U. S. Department of Agriculture.	......	......	......	0	6	0.0
18	Fermented stable manure; bed fairly compact.	Alaska, U. S. Department of Agriculture.	48	118	71	189	9	21.0
19	Fermented stable manure.	....do	53	93	30	123	6	20.5
20	....do	Bohemia, U. S. Department of Agriculture.	48	101	39	140	6	23.3
21	....do	Var.?, U. S. Department of Agriculture.	53	96	37	133	6	22.2
22	....do	American commercial more than 1 year old.	......	......	......	0	6	0.0
23	....do	American commercial, Bohemia	53	111	53	164	8	20.5
24	....do	....do	51	46	67	113	9	15.2
25	....do	Bohemia, U. S. Department of Agriculture. Loose cakes; dried.	46	22	50	72	6	12.0
26	....do	Bohemia, U. S. Department of Agriculture. Watered freely late.	49	74	75	159	6	26.6
27	....do	Bohemia, U. S. Department of Agriculture. Watered freely.	49	42	51	93	6	15.5
28	....do	Bohemia, U. S. Department of Agriculture.	46	89	30	119	6	19.8
29	....do	....do	55	90	55	145	8	18.1
30	Fermented stable manure and 5 pounds cotton-seed meal.	....do	51	129	146	275	9	30.5
31	Fermented stable manure.	English commercial, St. Louis	......	......	......	0	6	0.0
32	....do	English commercial, New York	......	......	......	0	6	0.0
33	....do	Bohemia, Americal commercial	42	70	32	102	6	17.0
34	....do	Alaska, American commercial	46	70	31	101	6	16.7
35	....do	French, commercial flake	......	......	......	0	8	0.0
36	Fermented stable manure and cotton-seed hulls.	Bohemia, U. S. Department of Agriculture.	53	47	96	143	9	15.9
37	Fermented stable manure; bed heavily compressed.	....do	61	......	......	104	6	17.3
38	....do	Var.?, U. S. Department of Agriculture.	46	58	46	104	6	17.3
39	Fermented stable manure and sphagnum.	....do	46	11	11	22	6	3.7
40	Fermented sheep manure.	....do	50	44	......	44	6	7.3
41	Fermented stable manure, cotton-seed hulls, and cotton-seed meal.	....do	46	18	39	57	8	7.1
42	Fermented cotton-seed hulls and cotton-seed meal.	Bohemia, U. S. Department of Agriculture.	55	......	......	5	9	0.6
43	Manure mold	....do	......	......	......	2	6	......
43	Sod	*Calvatia cyathiforme.* Pure cultures.	......	......	......	0	6	0.0
45	Old compost, left 2 months before spawning.	Bohemia, U. S. Department of Agriculture.	52	......	......	5	9	0.6

The series of experiments outlined in Table IX followed directly upon the series given in Table VIII. The beds in the first series were made in midwinter, and as the manure had been well fermented there was little or no rise of temperature after the beds were made. The spawn was therefore inserted at an unusually low temperature. During thaws in the late winter there was considerable seepage through the walls of the room. Some of the wall beds—Nos. 14 to 21—were seriously damaged, but although beds Nos. 7 to 13 were also wall beds seepage was not evident in this region. Within about thirty days after vigorous mushroom production began in this series the basement was flooded, and the work was therefore brought to an abrupt close. The yield up to that time is given, however, since in this series there are included many fertilizer tests.

TABLE IX.—*Yields of experimental mushroom beds in a north basement room, 1904.*

Number of the experimental bed.	Bedding material and fertilizer.	Spawn used.	Number of days to first picking.	Yield, in ounces, per bed.	Area of bed in square feet.
1	Stable manure and cotton-seed hulls.	Bohemia, U. S. Department of Agriculture.	48	33	6
2	.....do	.....do	48	9¼	6
3	Leaf mold and stable manure	.....do	48	38	6
4	.....do	.....do	48	36	6
5	Stable manure and sphagnum	.....do	61	4	6
6	Stable manure and cotton-seed meal.	.....do	61	64	6
7	.....do	.....do	66	73	6
8	Stable manure, timothy fed	.....do	73	2	6
9	.....do	.....do	......	0	6
10	Stable manure, clover fed	.....do	......	1	6
11	.....do	.....do	......	3	6
12	Stable manure, bran fed	.....do	66	84	6
13	.....do	.....do	54	109	6
14[a]	Stable manure, corn fed	.....do	71	12	6
15[a]	.....do	.....do	68	8	6
16[a]	Stable manure, oats fed	.....do	......	3	6
17[a]	.....do	.....do	80	14	6
18[a]	Stable manure	.....do	71	24	6
19[a]	.....do	.....do	66	40	6
20[a]	.....do	.....do	71	17	6
21[a]	.....do	.....do	68	55	6
22	.....do	.....do	48	61	6
23	Stable manure and complete fertilizer: KCl, 1 ounce; KNO_3, 1 ounce; bone meal, 7 ounces.	.....do	64	55	6
24	Stable manure and incomplete fertilizer: $NaNO_3$, 1 ounce; bone meal, 7 ounces.	.....do	64	30	6
25	Stable manure and NaCl, 2 ounces.	.....do	66	41	6
26	Stable manure and $NaNO_3$, 2 ounces.	.....do	48	42	6
27	Stable manure and $MgSO_4$, 2 ounces.	.....do	66	39	6
28	Stable manure and K_2SO_4, 2 ounces.	.....do	64	46	6
29	Stable manure and kainit, 4 ounces.	.....do	64	62	6
30	Stable manure and $CaCl_2$, 2 ounces.	.....do	64	48	6
31	Stable manure and Na_2HPO_4, 2 ounces.	.....do	64	65	6
32	Stable manure and $(NH_4)_2SO_4$, 2 ounces.	.....do	54	41	6
33	Stable manure and $NaNO_3$, 1 ounce; kainit, 2 ounces.	.....do	68	30	6

[a] Some of the beds in this block—Nos. 14-21—were seriously injured by seepage water, and the results are untrustworthy.

TABLE IX.—*Yields of experimental mushroom beds in a north basement room, 1904*—Continued.

Number of the experimental bed.	Bedding material and fertilizer.	Spawn used.	Number of days to first picking.	Yield, in ounces, per bed.	Area of bed in square foot.
34	Stable manure	English commercial (ordered as fresh).	68	34	6
35	do	Spawn from bed in full bearing	66	12	6
36	Stable manure, lime dressing	Bohemia, U. S. Department of Agriculture.	68	8	6
37	Stable manure, ammonium molybdate, ½ ounce.	do		(?)	6
38	Stable manure, $ZnNO_3$, 1 gram	do		(?)	6
39	Stable manure	*Agaricus amygdalinus*	68	7	6
40	do	Bohemia, U. S. Department of Agriculture.	64	77	6
41	do	English commercial (New York)	77	4	6
42	do	Bohemia, U. S. Department of Agriculture.	64	33	6
43	do	Spawn from old bearing bed		0	6
44	do	*Pleurotus ostreatus*		0	6
45	do	English commercial (Philadelphia)		0	6
46	Stable manure and sawdust	Bohemia, U. S. Department of Agriculture.		0	6
47	Stable manure	Var.?, American commercial	48	60	6
48	do	Alaska, American commercial	64	22	6

From the experiments given in the foregoing table further proof is furnished of the fact that stable manure alone, when of good quality, is sufficient for the growth of mushrooms. The addition of nutrient salts as fertilizers has not, on an average, given any marked increase in yield, but rather the contrary. It is hardly possible that the quantity of salts used on the beds was too little to make the effect felt. On the other hand, it was not sufficient to be injurious. It is evident from the experiment in bed No. 29, for instance, that the addition of 4 ounces of kainit could not have been injurious. In some instances the results obtained by the use of fertilizers were poorer than where the manure alone was used. This, however, the writer believes to be due largely to differences in the spawn used, or the differences in condition owing to the location of the bed, for subsequent experiments with some of the salts which seemed to be either injurious or beneficial have not wholly confirmed these results. It is to be noted, however, from the experiment in bed No. 6 of this series and also from bed No. 30, in Table VIII, that the beds treated with cotton-seed meal have invariably yielded somewhat above the average. These beds do not come into bearing quite so rapidly as those in which manure alone is used. It is thought that this is due to the fact that bacterial action is at the beginning more rapid in beds containing cotton-seed meal, and that, consequently, when this wave of bacterial growth has passed the nutrition of the spawn is favorably affected. Experiments had already indicated that manure from animals which were fed a poor diet, such, for instance, as grass or hay alone, is much less valuable than where the animals are well fed. The experiments in beds Nos. 10 to 22 were designed to test the value of some different feeds. The writer was fortunate in being able to secure manure from work animals which were being used in feeding tests where very different foods were employed. Unfortunately, however, the mushroom beds were located next to a basement wall, and in beds Nos. 14 to 21 the results were vitiated by the fact that there was considerable seepage water in that region during the thaws and heavy rains of the spring. Nevertheless, it is believed that the experiments in beds Nos. 8 to 13 are trustworthy. An attempt was made to check these results by using some of this manure in tube cultures, and it was found that the manure used in beds Nos. 8, 9, 10, and 11 particularly was unfavorable for the growth of the mycelium even in the pure cultures.

On account of its stimulating action upon the spores of *Agaricus campestris* a small quantity of ammonium molybdate was applied to one bed, No. 37, in order to test its effect upon the growing mycelium. Moreover, since certain salts of zinc at considerable dilution have been found to increase greatly the quantity of mycelium produced by other fungi, zinc nitrate was employed in an adjacent experiment. The results of these two tests were the same. There was a profuse mycelial development and an abundant production of small deformed sporophores.

Table X also summarizes a series of some interest. These beds were spawned early in November, 1904. Soon after the spawn began to spread throughout the beds—about December 15—the temperature of the room fell to 40° F. From that time on until March 1, 1905, the temperature was constantly below 52°, and on several occasions as low as 32° F. After two or three weeks of warmer weather the beds began to bear vigorously, and the mushrooms, particularly the first ones, were of unusual size and of excellent flavor. Numerous individuals weighed from 6 to 8 ounces immediately after the separation of the ring, and a few mature specimens ranged from 10 to 14 ounces.

TABLE X.—*Yields of experimental mushroom beds—Third series.*

Bed No.	Material constituting bed.	Spawn used.	Comparative yield per bed, in ounces.
1	Stable manure	English commercial, 2 years old	0
2	do	Columbia, "green" spawn, U. S. Department of Agriculture.	70
3	do	Poor grade English commercial, recent importation.	16
4	do	Good grade English commercial, recent importation.	49
5	do	Good grade English commercial, 6 months old.	40
6	do	American commercial	57
7	do	do	34
8	do	do	54
9	do	U. S. Department of Agriculture, Columbia.	56
10	Rotted sawdust and stable manure	do	31
11	Leaves and stable manure	do	30
12	Sawdust	do	3
13	Leaves	do	6
14	Stable manure	American commercial, probably *A. arvensis*, var.	60
15	do	American, *A. villaticus*	68

In some publications on mushroom growing the claim is made that old or practically exhausted beds may be brought into bearing again by heavy fertilization with liquid manure or with a weak solution of potassium nitrate. From a commercial point of view, no measurable success has resulted from any trials of this nature made by the writer; consequently, it is believed that exhausted beds should be immediately discarded. From the standpoint of mushroom sanitation, this is also particularly desirable.

VARIABILITY IN MUSHROOMS GROWN UNDER DIFFERENT CONDITIONS.

The writer does not intend to discuss even in a general way the relationships of the various forms of Agaricus—that is, those that may be considered allies of *A. campestris*—which he has cultivated or studied in the field. Some reference to the variability of common forms should, however, be made. For a comprehensive study of species and varieties, a knowledge of European forms as well as of those found in America is essential. Authors differ so widely in their descriptions of species, as well as in their conceptions of them, perhaps, that in the absence of unlimited material nothing short of confusion results from any attempt to harmonize opinions. It is sufficiently difficult to separate what many would regard as varieties of *A. campestris* from those of *A. arvensis*. When specific rank is bestowed also upon such forms as *A. pratensis*, *A. villaticus*, *A. magnificus*, *A. rodmani*, etc., the difficulties are greatly increased. The writer has grown many forms of Agaricus, and, as might be expected, there seems to be no form which will remain practically constant under variable conditions. Besides general size, size of spores, etc., some of the characters used in separating the common forms are color of gills; character of ring, particularly as to whether single or double; shape of stipe; color and markings of pileus; color of flesh, etc. In following the development of these characters in different forms, many variations will be found. *Agaricus campestris* grown on composted leaves shows very little pink in the gills. The color changes rapidly from dull pinkish-brown, or almost white, to a leaden hue. Several brown-capped forms, usually considered varieties of *A. campestris*, never show a bright-pink surface unless produced under exceptionally favorable conditions, moist air being a sine qua non. The ring is naturally variable. In any variety of *A. campestris* it is not uncommon for an edge of the partial veil to remain attached to the base of the stem as a volvate line, or this line may be left at any stage during the elongation of the stem. Again, if the lower margin of the partial veil on the stipe separates slightly from the stipe, and upon drying curves slightly upward, there is an indication of a double ring. A very good double ring appeared on a number of very vigorous specimens of an undoubted variety of *A. campestris* during the present season. It is possible that there is a greater tendency to produce a double ring when conditions are favorable for the production of the most vigorous mushrooms. *Agaricus arvensis* is also very variable with respect to the formation of a double ring, as also in the persistence of the partial veil.

The shape of the stipe is in many forms dependent upon the conditions. Under favorable conditions a brown variety of *A. campestris* may have a very short, thickened, equal stem, when grown on manure, and practically uniform at maturity, while the same form grown on decayed leaves may show in the main a stipe with thickened base, gradually tapering to the top. The color of the cap is of undoubted value as a varietal or specific character, yet it must be remembered that whether the surface be smooth or rough, merely fibrillose, or broken into scales of definite form, may depend entirely upon whether produced in moist air or in dry air, subjected to drying after being wet, etc. The color of the flesh is also dependent, to a considerable extent, upon the conditions. A specimen grown in even fairly unfavorable conditions will show the flesh somewhat darkened, and on exposure the characteristic pink tint will not be even momentarily visible. In other words, a considerable range of variation must be anticipated, and in comparisons there should be stated very clearly the conditions under which the particular forms are produced.

THE CULTIVATION OF VARIOUS SPECIES OF MUSHROOMS.

In Table X are given the results of a single test with *Agaricus arvensis*, or what is supposedly a brown variety of this species, and also of a single experiment with *A. villaticus.* In both cases the yield was excellent. It is not well to draw definite conclusions from individual tests, but it is believed that both of these forms will yield profitably in general culture under conditions similar to those required for *A. campestris.* Plate III, figure 2, indicates the size and compactness of the mature sporophore of *A. villaticus.* Moreover, both of the species above referred to are to be recommended for texture and flavor. Two forms of *Agaricus fabaceus* (see Pl. III, fig. 1), both with amygdaline odor and flavor, have been tried in relatively few experiments. In no case has the yield been very good, and further experiments will be required before it will be possible to state under what conditions these forms may be most successfully grown. At the Missouri Botanical Garden Prof. William Trelease has for some time grown successfully one of these varieties.

Owing to the profuse and rapid growth of the mycelium of *Coprinus comatus* in pure cultures, it was anticipated that it might easily be grown in beds. The few experiments thus far made indicate that in impure cultures (beds) of leaf mold the mycelium grows and spreads very slowly. Hot weather prevented the maturity of the tests, but no sporophores were produced during a considerable period. In similar experiments *Lepiota rhacodes* and *Tricholoma personatum* were used. The former has given unsatisfactory results thus far, but the latter is promising.

It is not yet time to report on the possibility of growing the better and larger species of puffballs and the morel. It has already been indicated that the mycelium of these fungi grows well in pure cultures. From the pure cultures it has also been demonstrated that spawn may be made, but it has not been determined under what conditions the fruit may be produced. Figure 1 on Plate IV shows a young specimen of one of the puffballs, *Calvatia craniiformis*, the spawn of which is produced with the least difficulty.

COOPERATIVE EXPERIMENTS.

During the winter of 1902–3 a small quantity of experimental spawn made by the writer was sent out to mushroom growers for trial; in 1903–4 this spawn was made in large quantity, and trial packages were sent to more than 100 growers or interested persons. At that time Farmers' Bulletin No. 204 had not been issued, and the instructions which could be furnished inexperienced growers were inadequate. Nevertheless, an attempt was made to obtain reports from all persons receiving the experimental spawn, even from those who had applied for and received spawn when the season was too far advanced for successful work except in caves and cool cellars. A number of reports were received, but, as might be expected, fully 50 per cent of these indicated that the conditions under which the experiments were made were wholly unsatisfactory, and that, therefore, no favorable results could be anticipated. Among those whose reports indicated that the conditions were favorable, or fairly favorable, only a small percentage reported failures, while four-fifths of those claiming success secured yields of more than one-half pound per square foot of bed space, many obtaining more than 1 pound per square foot. In two instances a yield of nearly 2 pounds to the square foot was reported. The frontispiece, Plate I, a bed in full bearing, and Plate VII, figure 1, showing the mushrooms as prepared for market, are photographs furnished by cooperating growers who are now also making spawn of pure-culture origin. It was suggested to growers who received the experimental spawn that a comparative test of the English or other commercial spawns with that received from the Department of Agriculture would be of interest. Comparative tests were made and reported by 10 growers. In most cases the English spawn, obtained at random on the market, failed to grow. In only one case did the English spawn prove better than the pure-culture product, and in this instance the spawn furnished by the Department when used was nearly one year old.

Failures may always be anticipated when attempts are made to grow mushrooms under adverse conditions, and it must be said that greater success was obtained from the cooperative work than could have been hoped for, considering the fact that many of the persons who sent in reports were wholly inexperienced and were practically unguided.

During the present year experimental mushroom spawn has been sent to more than 200 interested persons, and this will doubtless be the last general distribution of this product by the Department of Agriculture. Representing the varieties of *Agaricus campestris* commonly grown, mushroom spawn of pure-culture origin is now an established market product. In order that the standard of the American spawn may be maintained, spawn makers, dealers, and growers should see to it that only the fresh, recently dried product is used.

Nevertheless, it is hoped that this cooperative work may be carried forward, looking toward the development of better varieties or the bringing into culture and the testing of new species.

CAVE FACILITIES IN THE UNITED STATES.

Cave facilities in the United States are by no means so meager as has been supposed. There are in some sections caves from which rock for Portland cement has been mined. Some of these have been utilized for mushroom growing. There are also natural caves of great extent in many of the States of the Central West—especially in Indiana, Missouri, Kentucky, and Arkansas—as well as in Virginia.[a] The difficulty is to obtain caves within a convenient distance from cities, for stable manure becomes expensive if it must be hauled many miles or transported long distances by the carload. Again, caves should be easy of access, since after each crop every vestige of soil, manure, etc., of the preceding crop must be removed as a sanitary precaution. This is especially necessary since there is much waste space in most natural caves, and it becomes a very difficult or expensive matter to fumigate. If the cave system is extensive, it must also be possible to give it thorough ventilation. Many natural caves are the courses of subterranean streams. The latter are by no means objectionable if there is no danger from overflow. In many caves the stream has long since found a new channel and the cave is dry. Seepage water, usually accompanied by continuous stalactite and stalagmite formation, is undesirable. In some of the Eastern States coalpits or coal mines may be important for mushroom purposes. Where the coal mine is not too deep, or where perfect ventilation may be given, there is no reason why it is not entirely suitable for mushroom growing.

OPEN-AIR CULTURE.

In some sections of England and France open-air culture of mushrooms in beds is practicable during the late autumn and winter months, in which case the productive period may extend into the spring. The difficulties in the way of open-air culture are not merely those of maintaining a more or less uniform temperature, but also of maintaining practically constant conditions of moisture. For these reasons it is necessary to mulch the beds heavily with clean straw. In some instances a light mulch of straw is permitted to remain even during the period of production, for a rapid drying out of the surface would be hazardous or fatal. It is better, perhaps, to put the beds under some form of protection, such as an improvised cold frame.

In regions where the climatic changes are marked, open-air culture is probably not to be recommended during any season for commercial purposes. It is probable that there are some areas in the United States in which open-air culture might be practiced with profit. It has seemed that certain sections of California might be favorable for this phase of the work. In the interest of experiments

[a] The writer is indebted to Prof. C. F. Marbut for the information that caves are to be expected in the Silurian limestone, which occurs particularly in the extension of the Shenandoah Valley, in the bluegrass region of Kentucky, and in the Ozark region of Missouri and Arkansas; also in the Lower Carboniferous limestone, which extends into Indiana, Kentucky, Tennessee, and Missouri.

along this line the writer has made a special attempt to acquaint himself with the conditions in that section of the country. This has seemed particularly desirable, inasmuch as fresh mushrooms could not be shipped to the far West from sections in which they are at present grown in quantity. From the information obtained it is thought that successful open-air mushroom growing might be anticipated in those sections where the average temperature is between 48° and 55° F., provided there are relatively few days when the temperature falls as low as 32° F. At the same time, open-air culture can not be recommended for those sections in which dry winds are prevalent. As a rule, during the wet or winter season the rainfall is so light that heavy mulching would probably suffice to prevent injury from excessive wetting. Nevertheless, it seems apparent that even in regions most favorable for open-air culture some inexpensive partial protection against the changes of temperature due to direct sunlight, or against heavy rainfall, would be desirable.

It was also ascertained that *Agaricus campestris* appears naturally in some quantity during the months of January and February, or longer, during the rainy season. This, however, is also true of other species of fleshy fungi. The large size of some of the specimens of *Agaricus campestris* and *A. arvensis* found would seem to suggest that they were produced from an unusually vigorous mycelium. This may be the result of a condition analogous to that previously mentioned, where, on account of the low temperature of the atmosphere, the spawn may develop slowly through a considerable period, and finally, under favorable conditions, sporophores of unusual size are produced.

In the following table are given the monthly mean temperatures from several representative stations in California during the years 1899 and 1900. From this table it will be seen that so far as the mean temperature is concerned Eureka and San Francisco would be especially favorable during a large portion of the year. Independence and Red Bluff are likewise satisfactory, while San Luis Obispo, Santa Barbara, Los Angeles, and San Diego show a mean which is perhaps rather too high. The moisture of the atmosphere, the prevalence of hot winds, the variation in the daily temperature, and the number of hot or cold days must all be considered. From the data obtained, the general conclusion seems to be that the most favorable regions are those where conditions correspond closely to those of Eureka and San Francisco. This, however, represents a large region, including a considerable portion of the San Joaquin and of the Sacramento valleys. In a few places experiments have already been undertaken to determine the possibilities for the development of this work, but no definite recommendations can be made until the experimental evidence is at hand. It may be said, moreover, that some of the regions which seem to be too warm for open-air culture may be especially favorable during several months at a time for mushroom growing in ordinary cellars, or in very simply constructed mushroom houses. In those sections the winter and early spring months would doubtless give the most satisfactory conditions; and this period, fortunately, corresponds with the tourist season—a season when the market demands are greatest. It is also possible that with mulching and with simple protection, mushroom growing may be successful in some of the Eastern States.

TABLE XI.—*Mean monthly temperatures at points in California, in degrees Fahrenheit.*

Month.	Eureka.		San Francisco.		San Luis Obispo.		Santa Barbara.	
	1899.	1900.	1899.	1900.	1899.	1900.	City.	F.H.S.[a]
January	47.5	50.4	53.0	50.7	54.2	56.2	53.0	55.4
February	44.4	48.6	51.6	53.6	54.4	56.2	54.6	58.0
March	48.0	50.5	52.2	55.2	54.0	58.2	55.3	57.4
April	48.2	50.0	54.6	54.0	56.4	54.2	57.9	59.3
May	49.6	54.4	52.6	57.0	54.0	61.6	59.4	59.4
June	52.0	56.2	56.9	57.6	62.4	63.9	62.6	64.4
July	54.8	56.4	55.9	58.2	64.4	64.2	65.5	68.1
August	55.9	57.0	58.3	59.7	64.0	64.9	66.9	68.9
September	54.8	56.6	58.2	63.3	65.5	64.4	66.1	69.9
October	52.0	53.8	59.3	58.8	59.6	62.8	62.6	64.8
November	55.9	53.3	56.8	56.3	57.4	59.8	59.1	64.7
December	48.0	50.8	49.6	50.2	54.3	55.6	55.6	58.4
Year	50.9	53.2	54.9	56.2	58.4	60.2	59.9	62.3

Month.	Los Angeles.		San Diego.		Independence.		Red Bluff.	
	1899.	1900.	1899.	1900.	1899.	1900.	1899.	1900.
January	56	58	56.0	57.1	40.2	46.6	48.8	48.8
February	54	58	53.4	57.2	46.5	48.1	51.6	51.1
March	57	60	56.4	59.1	50.5	54.9	52.2	58.6
April	60	57	58.0	57.1	59.4	52.0	60.8	57.6
May	60	64	58.0	60.6	60.0	65.8	63.2	67.0
June	65	67	61.4	63.9	74.2	75.4	77.9	76.8
July	70	71	65.6	67.1	80.4	79.4	82.0	82.6
August	69	68	65.8	65.7	72.6	72.4	73.8	77.0
September	70	67	65.5	65.3	74.6	63.5	78.0	69.9
October	63	64	62.7	62.8	55.4	58.8	61.0	60.0
November	62	66	61.0	63.7	49.4	50.4	54.4	54.8
December	58	60	58.7	59.7	43.1	43.4	45.5	45.4
Year	62	64	60.2	61.6	58.9	59.2	62.4	62.5

[a] Foothills or suburbs of Santa Barbara, at an elevation of 750 feet above the city.

Occasionally one reads of successful natural cultures of mushrooms; that is, the production of this plant in pastures, lawns, etc., under more or less natural conditions. At Columbia, Mo., the writer has made numerous attempts to spawn plats in pastures and lawns; but thus far failure has attended every attempt. The spawning has, moreover, been tried at every season of the year. It is believed that in the section of the country mentioned only exceptionally favorable seasons will permit any success in this phase of open-air culture.

MUSHROOM SPAWN MAKING.

The mycelium of the cultivated mushroom has long been known commercially as "spawn." From early times it has been recognized that mushrooms may be grown from spawn, and it is quite certain that in all attempts to propagate mushrooms spawn has been used for the purpose.

In France, in England, and in other countries in which the mushroom has long been grown it is recognized that it is not profitable continually to take growing spawn from one bed to be preserved as "seedage" for the next crop. The common expression is that the spawn "runs out" in about three years. There seem to be few or no definite experiments indicating the exact conditions under which the spawn in two or three years loses the power of vigorous mushroom production. Nevertheless, it is the almost unanimous opinion of all extensive growers that there is a marked diminution in the yield after several successive propagations from the spawn in the mushroom bed. This has seemed to be true in the writer's experiments, although it must be said that accidents to experiments undertaken have made it impossible to report at this time upon the nature of this running out. That deterioration does result is apparently a fact accepted by all scientific men who have given attention to mushroom growing. It is possible, however, that under certain conditions the spawn might be repeatedly propagated without loss of prolificness. It is not necessary to enter here into a discussion of possibilities or to attempt to explain why weakening might be evident under ordinary conditions.

A "chance" method.—For practical purposes it is necessary to renew the spawn and to secure, if possible, spawn which has not previously weakened itself by the production of mushrooms—known as virgin spawn. Natural virgin spawn may be found wherever "in nature" it has been possible for the spores to germinate and to produce a mycelium. Ordinarily such so-called "spontaneous" appearances of spawn may be anticipated in compost heaps, rich garden beds, pastures near the feeding places of animals, etc.

Many attempts have been made by practical growers to develop spawn from spores, sowing the gill portions of mature mushrooms in specially constructed beds; but the results, so far as the writer is aware, have not been satisfactory. As a rule, therefore, growers have been compelled to rely wholly upon a virgin spawn which has been obtained by chance. It is said that in the vicinity of Paris some persons make a business of searching for this virgin spawn, which they sell to the growers at a high figure. It is claimed that they become so adept in detecting the differences in the character of growth, the quality of odors, etc., that they can distinguish not only

Agaricus campestris, but also some of its varieties. In England much of the virgin spawn has been obtained from pastures. Where a "spontaneous" growth of spawn is observed, trenches are dug, and these are filled with good stable manure. The latter in time becomes penetrated, and it is highly prized for cultural purposes. As a rule, the virgin spawn is used in spawning beds, which, when well penetrated, are torn down, and the whole bed used as flake spawn in spawning the general crop. Again, the virgin spawn may be used in spawning the brick, or cakes, this being the form in which English spawn is usually made. However adept persons may become in the identification of various varieties of spawn by odor, etc., this must be considered essentially a chance method.

A "selective" method.—From what has been said it will be perceived that very little advancement could be made in the selection of desirable varieties of mushrooms, in varietal improvement and the like, so long as the chance method of securing spawn should prevail. The studies in the germination of mushroom spores previously referred to were encouraged by the apparent necessity of beginning with spores from mushrooms of known qualities in order to effect improvement. In recent years the investigations of Costantin [a] upon spore germination have found application in a department of the Pasteur Institute. By a secret method, mycelium is grown from the spores in pure cultures. These cultures, which are, of course, pure virgin spawn, are then offered for sale to the growers. This spawn does not seem to have received deserved consideration on the part of the growers. The secret method of effecting spore germination referred to by Répin [b] has also been practically applied by one of the largest seed firms in Paris. In general, however, French growers have not profited so much by the new methods, perhaps partially on account of the fact that these methods are not known and partially because of the expense of the new virgin spawn. It is to be noted that these methods imply pure cultures to begin with.

The successful germination studies with chemical stimulation mentioned in this paper were soon overshadowed by the discovery of the ease of making tissue cultures. The use of the latter method has been the means of a sudden advancement in spawn making in this country during the past two years, for many practical men have been quick to see the advantages which it offers.

Pure-culture precautions.—It has already been stated that the pure-culture method of making virgin spawn is not one which will prove successful in the hands of wholly inexperienced persons, or of those who are unwilling to spend time and use the utmost care in the manipulation of the cultures and the culture material. The use of

[a] Costantin, J., loc. cit. [b] Répin, C., loc. cit.

pure-culture methods necessitates to a considerable extent a knowledge of the bacteria and molds which are everywhere present in the air and which are especially abundant wherever there are dusty or damp, moldy conditions. The principle of making pure cultures is briefly this: The materials, or media, and all the vessels employed must be sterilized, which implies being heated at a temperature sufficient to kill all germs present in the vessels or materials used. If the vessels used are test tubes or other pieces of glassware with small mouths, they should, previous to sterilization, be plugged with cotton batting. This cotton batting prevents, when carefully manipulated, the entrance of germs from the air, and therefore keeps the vessel or medium in a pure or sterile condition. If such a vessel is opened, this should be done in a room free from currents of air or falling dust particles; and, while open, tubes and other apparatus should be held in a more or less horizontal position, so that they will be less liable to contamination. It follows, of course, that the cotton plug, if removed, should not come in contact with any unsterilized substances. If, now, a small quantity of the growing mycelium of a mushroom from a pure culture is transferred to such a sterilized tube, using for this transfer sterile needles, or scalpels, there will be little danger from foreign organisms, and the piece of mycelium inserted will therefore grow as a pure culture free from all other fungi or bacteria.

The tissue-culture method.—In making pure cultures of mushrooms, large test tubes or wide-mouthed bottles may be used. These should be carefully cleaned, and, if possible, a sterilization should be given by means of dry heat as a preliminary precaution. In this event the tubes are plugged with cotton plugs and placed in a dry oven made for the purpose. They are heated to a temperature of about 150° C., and this temperature should be maintained for nearly an hour. Ordinarily, however, in rough work it is not essential to employ this preliminary sterilization. In either case the tubes are next partially filled (about two-thirds) with the manure, or half-decayed leaves, upon which it is desired to grow the virgin spawn. A plug is inserted in each tube, and the tubes are then sterilized in a steam boiler or under pressure. If sterilized under steam pressure, as in an autoclave, it is necessary to use about 15 pounds pressure and to allow the tubes to remain at this pressure for from fifteen minutes to half an hour. If the sterilization must be effected in a boiler or in an open water bath, it can only be done at 100° C., of course; and it is then desirable to boil the tubes for at least one hour on each of two or three successive days.

With the tubes thoroughly sterile, the next step is to make the cultures or inoculations. By the tissue-culture method it is implied that the inoculations are made from pieces of the tissue of a living mushroom. It is at this stage that selection may be made. One should procure from a bed of mushrooms in full bearing a mushroom which represents the most desirable qualities that are to be found. Size, quality, and general prolificness must all be considered, as well, also, as other characteristics in any special selections. One may desire, for instance, to select from a variety which yields throughout a long period—one which is resistant to higher temperatures, etc. Having found the mushroom from which it is desired to propagate, plants as young as possible may be used, and those which show the veil still intact are especially desirable. With a scalpel, or a pair of forceps, which has been sterilized by passing the blade through a gas flame, or even the flame from an alcohol or ordinary lamp, small pieces of the internal tissue may be removed, and these pieces transferred to the tubes, without, of course, coming in contact with any object whatever which has not previously been sterilized. It is a good idea to wash the mushroom first, so that no dust will be made. The plant may then be broken open longitudinally and bits of the internal tissue readily removed without fear of contamination when one becomes adept in this kind of manipulation. Immediately upon inoculation the cotton plug is replaced in the tube, and after all the tubes are inoculated they should be put out of the dust, preferably in a situation where the temperature is about that of an ordinary living room. In the course of several days a slight growth may be evident from the tissue if the conditions have been perfectly sterile. In the course of a week or more the growth should become very evident, and in three weeks the moldlike development of mycelium should spread to practically all parts of the medium in the tube. The method of making pure cultures and the laboratory apparatus usually involved are shown in Plate VI, figure 2.

When the tubes are thoroughly "run" the contents may be removed and used in spawning brick. The contents of a single tube may spawn several bricks when carefully employed. If no transfers are made of the growing mycelium from one lot of tubes to another, the writer has not found it at all impracticable or unfavorable to utilize this first lot of bricks later in spawning others. No further transfers, however, should be made from these bricks to others under any circumstances in spawn making. As elsewhere indicated, such a continuous transference is injurious to the vigor of the spawn and diminishes the quantity of mushrooms produced.

The commercial process.—The essentials in spawn making are (1) a uniform, compact manure brick; (2) vigorous and well-selected virgin spawn to be used in inoculating the bricks, and (3) favorable conditions for the storage of the bricks during the growth of the spawn.

It should be indicated that there is no one method of making brick spawn. The process may and will be varied by each spawn maker. Any skill or mechanical devices which will simplify or improve the process in any particular are to be recommended.

The materials entering into the composition of the brick are fermented stable manure, cow manure, and sometimes a small quantity of well-selected loam. Perhaps the chief value of these different constituents is as follows:

In the horse manure the mycelium grows most readily. The cow manure binds the materials together into compact brick. The loam, which is perhaps least essential, is supposed to prevent cracking or hardening of the surface, and therefore contributes to the appearance of the finished brick, at the same time tending to prevent rapid fermentation during growth. It also in some cases facilitates the uniform spread of the mycelium. If fresh manure is used, the necessity of using loam is perhaps to be emphasized.

In the experiments which have been made under the auspices of the Department of Agriculture these materials have been used singly and in various combinations, and it is beyond doubt that the relative proportions of these should be determined by the special conditions under which the spawn is made. Excellent results have been obtained by using a mixture of from two-thirds to three-fourths stable manure and the remainder cow manure. In this case the compost for the brick is subjected to fermentation previous to its use. When loam is employed it may be used in more or less equal proportion to the cow manure; and the quantity of stable manure should about equal that of the other two ingredients. If the straw present does not become sufficiently disintegrated during the preparation of the manure to enable one to make a smooth brick, it should be removed, in part at least.

The dry bricks ordinarily measure about $5\frac{1}{2}$ by $8\frac{1}{4}$ by $1\frac{1}{4}$ (to $1\frac{1}{2}$) inches. They should therefore be molded of somewhat larger size, perhaps 6 by 9 by 2 inches, since there is considerable contraction during drying. The mold consists merely of an oak frame of four pieces strongly riveted together. It may also be profitably lined with thin steel plates. In molding the brick one of two methods may be followed: (1) The compost may be thoroughly wet or puddled; then, with the mold upon a board of suitable width, the manure is compressed into it, the mold removed from the brick then formed, and the board pushed along for a succession of such impressions. The boards supporting the bricks are then disposed in racks and the bricks dried for a few days, or until they may be turned on edge for further drying out. (2) The compost may be used in a condition which is merely moist. It is compressed into the brick with some force, a mallet being often employed. The brick thus obtained is sufficiently rigid to be immediately handled if necessary. By this method, unless the compost has been in excellent condition, the bricks are not so smooth as might be desired for commercial purposes. In some instances they have then been subjected to a repress process, an old repress brick machine being adapted for the purpose. In such cases the bricks are made thicker to begin with. The second method has been discontinued by some who at first employed it.

Two methods are also employed in spawning: (1) The more common method is to insert into the brick near both ends a piece of the virgin spawn obtained for the purpose. A cut is made with the knife, the spawn inserted, and a stroke of the knife effectively closes the surface. This must be done as soon as the brick can be readily handled. (2) The bricks are dried until merely moist throughout; then, on being piled, nocules of spawn are placed between successive bricks, a piece at each end. In either case the bricks are not piled for the growth of the spawn until in good condition as to moisture content. This should be determined not by the surface, but by the interior of the brick. In the pile the surface will soon become moist. When the first method is employed it is sometimes customary to spread between the layers of brick in the pile a little moist manure or sawdust. It has been determined, also, that the absolute moisture content of the brick should be about 40 per cent, which is the same as for the mushroom bed. Tests of the moisture content of bricks growing well have varied from 35 to 47½ per cent.

Occasional examination should be made to determine the temperature and the extent of growth. In order that the bricks may become thoroughly penetrated, more than a month will usually be required.

The most favorable conditions for the growth of the spawn are practically the same as for mushroom growing. A fairly moist atmosphere, maintained, if necessary, by spraying, and a more or less uniform temperature (55° to 60° F.) are to be preferred. The size of the piles will depend upon the other conditions; but if there is any danger of considerable fermentative activity the bricks should be so disposed as to permit perfect ventilation between two or more adjacent rows.

When the bricks are thoroughly "run" they are dried under cover before being shipped or stored in bulk, since in a moist brick the spawn would continue to grow and would soon produce small mushrooms or else would become moldy. Well-penetrated bricks of spawn are shown in Plate VII, figure 2. The areas of mycelial growth should be evident to the eye. The growth should be moldlike, however, rather than composed of very large threads or fibers.

The suggestion made in a previous publication that mushroom spawn should be sold by the brick (with a uniform standard of size) seems to have been adopted by American makers. The trade names suggested for the common types of *Agaricus campestris* in culture have also come into use. It is certain that these names, Alaska, Bohemia, and Columbia, designating respectively a white, a brown, and a more or less cream-gray form, do not include all forms in cultivation. Until a careful study has been made of varieties, however, this nomenclature will enable spawn makers to keep in mind certain types, and will make it possible for growers to ask for a spawn yielding a color demanded by their special markets.

THE VITALITY OF MUSHROOM SPAWN.

Many of the early experiments in mushroom growing undertaken by the writer were made in the hope of being able to ascertain the more frequent causes of failure and some of the chief difficulties encountered by American mushroom growers. The ordinary commercial spawn used by amateurs, that is, such as is obtainable upon the market during the winter months, was purchased wherever possible. Samples of this spawn were placed under conditions which were supposed to be most favorable for growth. Nevertheless, in the majority of cases there was no indication of the development of a new mycelium from the bricks of spawn thus obtained. From these results it was suspected that much of the spawn which reaches the amateur grower may be considerably injured, or even killed, by transportation or improper conditions of storage; for it must be supposed that most of this spawn is in good or at least fair condition when exported from Europe.

Subsequently the writer was able to look into the matter of spawn making in Europe and France, and he was convinced that the difficulty of securing good spawn in England is not a very serious factor. The same is true with reference to the material which is obtained by both extensive and small growers in France.

Special importations of some of the commercial English and French spawns were made, and this was packed, shipped, and stored under conditions as favorable as may ordinarily obtain. This spawn was imported during midwinter and stored until March or early April, when it was used in spawning some experimental beds. The conditions of the experiments were practically the same throughout, yet in not more than half the beds was there a favorable development of mushroom spawn. A distribution of the French spawn, both the commercial flake and the improved cake spawn, was made to several prominent American growers. Some of these growers experienced entire failure, while others reported that, after a slow beginning, beds spawned with this material made a good yield. The general conclusion, reenforced by observation and by the experience of practical growers, could only be that a large percentage of loss in mushroom growing is attributable to the injury suffered by the spawn after its preparation. This conclusion has been further strengthened by the experience of the past three years. From Table VIII, beds Nos. 1, 2, 4, 5, and 30, it will be seen that, under conditions where fresh spawn has invariably made a good yield, the spawn which is more than a year old is, for the most part, seriously injured or killed. To be exact, in only one case was there any production of mushrooms by spawn which had been kept for a year or longer. It must be said that no attempt was made to keep these spawns under similar conditions or under the most favorable conditions. For the most part the spawn was stored in the dry laboratory room, in which the temperature was more or less variable, but never extreme. The old American spawn which was used in experimental bed No. 1, in Table VIII, was stored in a basement room where the average temperature was undoubtedly cooler than that of the laboratory room.

From experimental beds Nos. 1, 3, 4, and 5, in Table X, it is again seen that old spawn is unreliable. In this particular case the material was furnished by a prominent mushroom grower—an English spawn importer. This spawn had been stored in a dry house and was therefore subject to similar conditions. In Table VIII, beds Nos. 31, 32, 35, and in Table IX, Nos. 34, 41, and 45, there is further proof of the loss of vitality in the imported spawn ordinarily offered for sale in many of our cities. In these cases spawn was bought on the market just as offered for sale to the amateur buyer; "best on hand" was asked for, but no stipulation was made that is should be of recent importation, and no guaranty was asked. The tests were not, therefore, to compare the very best English with the best American spawn, but merely to secure an indication of some of the causes of failure by the purchase at random of English and French spawn on the market. Even in times past the extensive mushroom growers have either imported their spawn direct, or made sure that they were obtaining the best product that the market could furnish. Unfortunately, it has not been possible to compare, in any experiments thus far concluded, the best English with the best American spawn.

The results seem also to indicate that brick spawn maintains its vitality longer than the flake material, and that brick spawn made of loose, light material is less retentive of vitality than that made after the formula commonly followed in England. This proves to be an unfortunate factor to be dealt with in the attempt to reduce by all means the weight of the brick. The reduction in weight would be most desirable, since freight upon this material adds considerably to the price of market spawn. To the poor keeping qualities of loose spawn is perhaps due the large number of failures with French flake spawn, and perhaps also some of the failures with the newer form of French brick spawn. The latter is made in the form of very small, thin bricks, which are unquestionably more affected by weather conditions than the larger English bricks.

These results have seemed to demand that special attention should be given to methods of spawn making in the United States in order that growers might be able to secure this product as fresh as possible. Moreover, it was desirable, as previously indicated, to attempt work leading to the selection and improvement of varieties. The success of the work in spawn making has been almost all that could have been anticipated. By the pure-culture methods described, several firms are now making grades of brick spawn which have yielded remarkably well. This fact is now thoroughly recognized by a large number of the best growers throughout the country. Probably as many as 50,000 bricks were sold during 1904, and it is perhaps to be expected that several hundred thousand will be sold during the present year.

It is to be regretted that it has not yet been possible to abandon the pure-culture process by means of which the virgin spawn is made while retaining the advantages of selection. Nevertheless, it should be remembered that the very difficulties of this process insure its use only by those who are able to give it their best attention and who will doubtless develop it to the fullest commercial extent. It has not been supposed by the writer that the work thus far accomplished will enable all mushroom growers to manufacture their own spawn with comparative ease. In other phases of horticultural work it is not so much to individual growers as to progressive seedsmen that we look for the best seed of improved varieties. The same thing apparently must be anticipated in the development of the mushroom industry. The growing of selected spawn may, in general, become a specialized process.

Nevertheless, it is believed that in time a method of spawn production from spores without pure-culture precautions will be developed. The necessity of developing immediately, or placing on a practical basis, the pure-culture process has temporarily directed the experimental work along other lines.

O

FIG. 1.—A FINE CLUSTER OF AGARICUS CAMPESTRIS, THE HORTICULTURAL VARIETY COLUMBIA.

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FIG. 2.—THE METHOD OF MAKING PURE CULTURES, SHOWING THE APPARATUS AND MATERIALS.

FIG. 1.—MUSHROOMS PREPARED FOR THE AMERICAN MARKET.

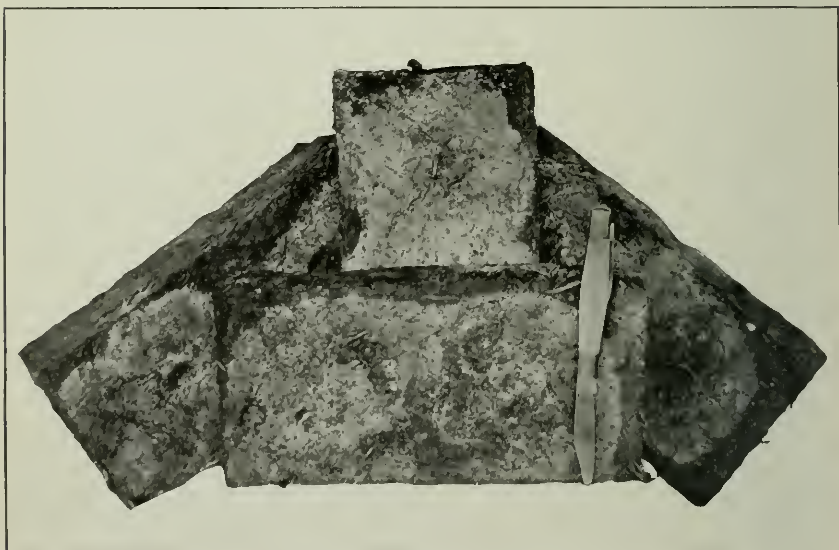

FIG. 2.—GOOD ("WELL-RUN") MUSHROOM SPAWN, BRICK FORM.

A

GENERAL VIEW OF THE OUED SOUF REGION FROM THE TOWN OF EL OUED, SHOWING SAND DUNES AND SUNKEN GARDENS OF DATE PALMS.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 86.

B. T. GALLOWAY, *Chief of Bureau.*

AGRICULTURE WITHOUT IRRIGATION IN THE SAHARA DESERT.

BY

THOMAS H. KEARNEY,
PHYSIOLOGIST.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

ISSUED NOVEMBER 16, 1905.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

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Pathologist and Physiologist, and Chief of Bureau.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., September 6, 1905.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 86 of the series of this Bureau the accompanying paper, entitled "Agriculture without Irrigation in the Sahara Desert."

This paper was prepared by Mr. Thomas H. Kearney, one of the physiologists of this Bureau, and the data for it were obtained on a trip which he made to northern Africa for the Office of Seed and Plant Introduction and Distribution, primarily for the importation into the United States of offshoots of valuable Tunisian date varieties. It is believed that the methods described may be useful in some cases in our southwestern desert regions where date culture is being introduced.

The accompanying illustrations are necessary to a clear understanding of the text of this bulletin.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

In view of the interest in farming without irrigation that is now being manifested in the arid portion of the United States, an account of a region where agriculture is carried on under extremely adverse natural conditions is particularly timely. The present paper deals with a highly developed system of date-palm culture in the Oued Souf, a remarkable and little-known part of the Sahara Desert in northern Africa. Strictly speaking, it is not dry-land agriculture with which we have to do in the Souf region, for while the rainfall is practically nothing and irrigation is impracticable, the roots of the trees quickly find their way to ground water. However, it is quite possible that similar conditions may be found to exist in this country in some parts of the desert region of the Southwest, and that the Souf system, with or without irrigation, can be utilized there on a small scale in growing certain orchard crops with a view to forcing fruit to early maturity, so that it can be put upon the market much in advance of the bulk of the crop.

The Oued Souf was visited by Mr. Kearney at the end of November, 1904, the journey having been made from Nefta, in southwestern Tunis, where he had spent several weeks in a study of the date palm. This expedition to northern Africa was made under the auspices of the Office of Seed and Plant Introduction and Distribution of the Bureau of Plant Industry.

Acknowledgment is here made to Captain Bussy, Chef du Bureau Arabe at El Oued, for the cordial assistance rendered by him to Mr. Kearney during the latter's stay in the Souf region.

A. F. Woods,
Pathologist and Physiologist.

Office of Vegetable Pathological
and Physiological Investigations,
Washington, D. C., August 22, 1905.

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AGRICULTURE WITHOUT IRRIGATION IN THE SAHARA DESERT.

INTRODUCTION.

In the great desert of northern Africa, stretching across in a belt from southeastern Algeria to the borders of Tripoli, is the region known as the "Erg." It is a land of enormous sand hills, some of which reach a height of 500 feet. Chain after chain of these great dunes, with knife-edge summits and steep slopes and trough-like valleys between, extend diagonally northeast and southwest across this part of the Sahara. (Pl. II, fig. 1.) It is like an ocean caught in a raging storm, with its huge billows rising skyward and held fixed and motionless. Not a leaf nor a blade of grass, not a bowlder nor a pebble mars the smoothness of the sand. Never is the least trace of water to be seen on its surface. The few drops of rain that fall at rare intervals are drunk up as soon as they touch the thirsty ground. Pure quartz sand it is, light yellow in color and so fine of grain that the least breath of air sends a little cloud of it curling off the sharp crests of the ridges. When a hard wind blows the air is filled with it, the sun is blotted out at noonday, and the traveler can hardly see his horse's head in front of him. The sharp-cornered particles of sand sting his face and blind and bewilder him. The vague tracks of camels and donkeys, the only roads through this wilderness, are quickly covered up, all landmarks disappear, and without an experienced guide one is sure to be hopelessly lost.

It is a desolate and unfriendly landscape, yet at times not without a weird beauty of its own. When the sun is high the glare is blinding and there is little to attract one in the scene. But in the early morning and the late evening the sand assumes a golden color, and the dense black shadows cast by the dunes bring out their contours in sharp relief. Then their surface is seen to be modeled by series of delicate ripple marks left by the wind, and one finds it hard to believe that when he climbs the next high ridge he will not see the ocean at his feet.

Who would suspect that amid these mountains of bare sand, where even the hardy shrubs and grasses of the desert find no foothold,[a] men can live by the products of the soil? Yet in the very heart of the Erg, two long days' ride east or west from the nearest habitations, there exists one of the most highly developed agricultural communities in the world. This is in the country known as the Oued Souf, situated in extreme southeastern Algeria (see fig. 1), about midway between the oases of southwestern Tunis and the Algerian oases known as the Oued Rirh, in which latter the date palm is grown by

FIG. 1.—Map showing location of the Oued Souf with respect to other localities in Algeria and Tunis.

Europeans upon a commercial scale.[b] From El Oued, the capital of the Souf, it is about 70 miles southwest to Tougourt, the chief town of the Oued Rirh, and about the same distance northeast of El Oued is Nefta, the nearest oasis in Tunis. The elevation of El Oued is about 257 feet above sea level.

[a] Only eight species of flowering plants were found growing wild in the Souf region by Massart. See "Un voyage botanique au Sahara," p. 249 (1898).

[b] See Plate II (map) in Bul. 53, Bureau of Plant Industry, "The Date Palm," by W. T. Swingle.

From the tops of the lofty sand hills that surround El Oued an excellent view can be had, and there one can form a clear idea of the character of this remarkable country. (See Pl. I, frontispiece, and Pl. II, fig. 3.) Assuredly there are few regions where any sort of agriculture is carried on under more extraordinary conditions. As far as the eye can reach it rests upon an expanse of pure sand, heaved up into range after range of dunes.[a] In the hollows among these dunes are the gardens of date palms, sometimes mere pockets containing 10 or 20 trees, sometimes larger basins in which are groves of 50 to 100 palms.

Often the bordering sand hills are much higher than the tallest of the palms, so that many of the gardens can not be seen until one is on the very edge of the basin. In other places, however, the ridges are lower or gaps occur, allowing a cluster of feathery crowns to peep through. These are of such a dark green as to look almost black against the pale sand. A more striking contrast of colors could not be imagined. The trunks are rarely seen until one reaches the brink of the basin or pocket in which the palms are growing.

We have before us, in short, a network[b] of basins or hollows containing small groves of date palms and separated by great hills and ridges of sand. The aspect of the country is wholly different from the Oued Rirh in Algeria and the Djérid in Tunis, where each oasis is a dense continuous forest of date palms, containing often several hundred thousand trees,[c] and situated upon comparatively level land.

Such, then, is the country of the Souf, a land where there is practically no rainfall, where there are no streams nor springs nor flowing wells to furnish water for irrigation, where the soil is a pure hard sand devoid of organic matter and blown about in clouds by every wind, so that unceasing vigilance is needed to keep the gardens free from it, and where the summer heat is almost as great as anywhere in the world. Yet here the date palm grows to perfection, yielding fruit of better quality and in larger quantity than elsewhere in the Sahara. How this has been brought about we shall presently see in these pages; but first we should know what manner of men are they who have developed a flourishing agriculture in a land where Nature seems to frown most severely upon all efforts to win a living from the soil. The race that has succeeded so well in the face of such tremendous obstacles must needs be an interesting one.

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[a] The surface of these dunes is easily moved, even by a light breeze, but the core is said to be stationary and composed of stratified materials.

[b] The Arab word "erg" (plural areg) means "a vein."

[c] In 1899 there were only 192,000 date palms in bearing in the entire Souf region.

POPULATION.

There are about 25,000 people in the Souf region, 5,500 of whom inhabit the capital town, El Oued, and its immediate neighborhood. Several distinct tribes are included in this population, some being chiefly nomadic shepherds, and others more sedentary, devoting most of their time to the care of their gardens. They are for the most part a healthy and strong looking race, and are much more energetic than the inhabitants of other north African oases. This is doubtless partly due to the unceasing labor demanded by the conditions under which they live and partly to the fact that their climate is a healthful one, despite the intense heat of summer. There is no standing water nor even moist surface soil, and mosquitoes are said to be unknown. The dry air and the hot sand are not friendly to the germs of contagious diseases. The conditions are, therefore, very different from those in other oases of the Sahara, which are so overirrigated as to be mere swamps in summer, scourged with malarial fevers.

The inhabitants of the Souf region, who are called "Souafas," depend for a livelihood largely upon the products of their gardens, but they have other resources as well. The more nomadic tribes possess flocks of sheep and goats. They have almost a monopoly of the trade of camel drivers in a large part of the Sahara, guiding caravans eastward into Tunis, westward to Biskra, and far south into the heart of the great desert. Their camels are considered the largest and finest of the Sahara. The men of the Souf are indefatigable walkers, thinking nothing of traveling 20 or 25 miles a day through the loose sand. Their camel's-hair shoes, tightly bound around the ankles, are much better adapted to this sort of travel than the loose-fitting, heelless slippers generally worn by the Arabs.

In building their houses, as in cultivating their palms, the Souafas have many difficulties to contend with that are not experienced by the dwellers in other oases. Elsewhere in the Sahara, sun-dried brick, like the Mexican adobe, is the universal building material. But in the Oued Souf there is no clay to be had. Consequently the town of El Oued and all the villages of the region are constructed with irregular masses of grayish, crystalline, gypseous rock, cemented by plaster made from the same material, which thus furnishes both stone and mortar. Wood being very scarce, the roofs are not flat, wooden ones, but consist of rows of small, flattened cupolas, not unlike old-fashioned beehives, which give a very odd look to the cube-shaped houses. (Pl. II, fig. 2.) In its architecture, as in everything else, the Souf is unique. The immaculate cleanliness of the villages is surprising to the traveler who is familiar with the filthy streets of most Arab towns. The pure, dry sand is constantly drifting among the houses, and quickly buries all refuse.

CLIMATE.

Exact data in regard to the climate of the Oued Souf are not easily obtainable. The observations here given were made chiefly by a medical officer of the French army during the summer of 1884.[a] Unfortunately records covering a period of several years are not available.[b]

The summer temperatures are very high, few hotter localities being known in the Sahara. The monthly maximum shade temperatures observed by Escard in the summer of 1884 are as follows (in degrees Fahrenheit):

April	93	August	116.5
May	100	September	113
June	106	October	91.5
July	122		

In June, 1904, a maximum of 127.5° F. is said to have been reached. The sum total of temperature during the summer, a factor of the greatest importance in the ripening of the finer varieties of dates, is said to be greater in the Oued Souf than in the Oued Rirh and the Djérid. At the time of the writer's visit (November 22–26, 1904) cool, cloudy weather prevailed, and the nights were decidedly cold.

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[a] Escard, Etude médicale et climatologique sur le pays de l'Oued Souf. Archives de Méd. et de Pharm. Milit., 7 : 33 (1886).

[b] Since the above chapter on climate was written the records of observations made at El Oued during the whole of 1904 and parts of 1903 and 1905 have been received, through the courtesy of the Director of the Meteorological Service of Algeria. These observations necessitate some modifications in the previously written discussion of the climate of the Souf. The absolute maximum temperature at El Oued in 1904 was 121.8° F. in May instead of 127.5° F. in June. The absolute minimum in 1904 was 32° F. The mean relative humidity during 1904 at El Oued was 58.8, which is lower than the normal at Tozer, in Tunis (60.8), but higher than the normal at Ouargla and Biskra, Algeria (47.2 and 48.4, respectively), and at Yuma, Ariz. (42.9). The sum of the monthly means of evaporation at El Oued in 1904 is 156 inches, while the normal at Tozer is 94 to 98.5 inches. The total precipitation at El Oued in 1904 was 3.23 inches, while the normal yearly total is 3.61 inches at Ouargla, 6.73 inches at Biskra, 5.1 inches at Tozer, and 2.83 inches at Yuma.

The observations on the prevailing direction of the wind during 1904 and the first half of 1905 do not agree with those made by Escard and quoted in the text, but the data are insufficient for an adequate discussion of this factor.

As the climatic factor which is most important in date growing is probably the effective temperature during the ripening season, a calculation has been made of the sum totals of daily mean and of daily maximum temperatures above 64.4° F. (18° C.) during the months of May to October, 1904, at El Oued, and, for the sake of comparison, of the sums for the same months of the same year at Ouargla and Biskra, Algeria; Tozer, in Tunis, and Mecca, in the Salton Basin, California. Records at Mecca for May and June, 1904, not being available, the records for those months at Imperial, Cal., were substituted in making

Almost every winter freezing temperatures are reached, although probably the minima are higher and frosts are less frequent in the Oued Souf than at Tougourt and at Tozer. In the winter of 1903–4 the absolute minimum was 32° F., and for several preceding winters 27° F.

In respect to atmospheric humidity, the absence of surface water probably tends to keep the air drier than is generally the case in the oases of the Sahara.

The rainfall is said to be even less than in the Oued Rirh, where the average yearly precipitation (at Tougourt) is only 5.3 inches. Most of the rain is divided between two periods—October to November, and February to March. The rains are generally torrential in character and fall during several successive days, with intervals of sunshine.

The sky is nearly always clear in summer. Toward the end of August light clouds appear in the morning and evening, but no rain falls until October. During the writer's four days' visit to the Souf

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the calculations for Mecca, experience having shown that the temperatures recorded at Mecca and at Imperial are very nearly identical.

TABLE I.—*Sum of daily mean temperatures above 64.4° F. (18° C.) from May 1 to October 31, 1904.*

Locality.	Degrees Fahrenheit.	Degrees centigrade.
El Oued, Algeria	3,672.6	2,040.3
Ouargla, Algeria	3,961.3	2,200.7
Biskra, Algeria	3,140.4	1,744.6
Tozer, Tunis	3,831.3	2,128.5
Mecca, Cal	3,591.5	1,995.3

The sum of daily means at Biskra for 1904 is nearly 200° F. lower than the normal, as based upon observations covering a period of 10 years (see W. T. Swingle, Bul. No. 53, Bureau of Plant Industry, p. 66), and the sum at Mecca for that year is about 400° F. lower than the normal for Indio, Cal., a few miles distant.

TABLE II.—*Sum of daily maximum temperatures above 64.4° F. (18° C.) from May 1 to October 31, 1904.*

Locality.	Degrees Fahrenheit.	Degrees centigrade.
El Oued, Algeria	6,325.7	3,514.3
Ouargla, Algeria	6,501.6	3,612.0
Biskra, Algeria	5,219.1	2,899.5
Tozer, Tunis	5,903.6	3,279.8
Mecca, Cal	6,370.1	3,539.0

In calculating the sums of daily maximum temperatures allowance was made for mean monthly minima falling below 64.4° F., in accordance with the practice suggested by Swingle (ibid., p. 67). The sum of daily maximum temperatures at Biskra during May to October, 1904, is about 250° F. lower than the normal for 12 years (Swingle, ibid., p. 68). The sum for Mecca is about 700° F. lower than that for Imperial, Cal., in 1902.

at the end of November the sky was overcast about half of the time, and there were occasional gusts of cold, drizzling rain.

Winds are probably more frequent and more violent in the Oued Souf than in the other groups of oases mentioned. It would appear, in fact, that windiness is the ordinary condition there. During the winter, northwest and northeast winds prevail. From April to October, however, the wind is generally from the south (the sirocco) or the southeast (the simoom). The sirocco is the hottest wind, but is less frequent than the simoom, which is generally more violent and transports more sand. All these are winds that blow more or less steadily for several hours and often days at a time. Cyclonic sand storms also occur, arising suddenly and lasting but a short time. Such storms are never accompanied by rain.

Owing to the lack of natural vegetation (see Pl. II), and the fineness of the sand with which the country is covered, strong winds carry with them a great deal of material, so that the face of the land is being constantly altered. This is shown by the fact that an apparently fresh wagon track noticed by the writer on his journey from Nefta was completely buried in many places by large heaps of sand. During his four days' stay in the Souf country, a strong wind blew constantly, often making travel difficult, as the particles of sand stung the face and made it hard at times to keep the eyes open. The air was frequently so full of sand that one could see but a few rods ahead.

The slopes of the dunes that border the gardens are very steep, so that when a heavy wind is blowing much sand rolls down upon the floor of the garden. Generally there is a fence or palisade along the crest of the dunes, made by sticking palm leaves or pieces of gypsum rock close together (Pl. II, fig. 3; Pl. III, fig. 1; Pl. IV, fig. 1), but this only partly arrests the blowing and drifting sand, and it is necessary to remove it frequently from the gardens. The task is a laborious one, as the sand must be carried up the steep hillside in baskets and dumped on the outer slope of the dunes. But if it were neglected, in a few years the trees would be buried, especially in smaller gardens. The writer saw several little gardens that had been abandoned by their owners where the basin was almost filled and only the crowns and a small part of the trunks of the trees still projected above the soil.

Another injurious effect of the sand-carrying winds is that when harvested the dates always have more or less sand adhering to the skin, and this must be brushed or washed off before they are fit for export. Dates that had been kept for some weeks in the houses of natives, and even those freshly gathered from the trees, were very unpalatable to the writer on this account; although the Souafas themselves do not seem to mind eating a good deal of sand with their dates.

WATER SUPPLY.

There is no surface water in the whole Souf country, excepting, possibly, a small sebka, or salt pond, of which the writer was told, but which he did not see. There are no natural springs, although ground water is everywhere very near the surface in the hollows among the dunes. It is said to occur sometimes in strata of pure quartz sand, sometimes in gypseous sand. The distance to standing water is said to reach as much as 40 feet in different parts of the region, although averaging considerably less; but in the bottoms of the basins in which date palms are grown it is encountered often at a depth of only 2 or 3 feet below the surface of the soil, thanks to the extensive excavation that has been done. In one garden, near the town of El Oued, the writer saw water standing at a depth of 6 feet in a large hole that had been dug to receive manure. The Souf oases are believed to mark the course of a buried Quaternary stream; Oued Souf means "murmuring river."[a]

As we shall presently see, the date palm is not irrigated in the Souf country, receiving at most a few waterings by hand during the first summer after planting. In almost all the gardens, however, shallow wells occur,[b] the water of which is used for household purposes and for irrigating small plats of garden vegetables. (Pl. III, fig. 3.) These are generally situated on the slope of the bordering dunes, 10 feet or less above the bottom of the basin, and water stands in them at a depth of 10 to 16 feet. In the town of El Oued the wells are much deeper than in the gardens, water standing in them at 30 to 40 feet. All this water is under a slight pressure, rising in the wells about 1.5 feet higher than the general water table. Small gardens of vegetables and tobacco,[c] irrigated from deeper wells, are also located in some parts of the region far above the bottoms of the basins. Practically no grain is raised, wheat and barley being brought by caravan from other parts of Algeria and from Tunis, to be exchanged for dates.

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[a] It is difficult to obtain a very satisfactory idea as to the distribution of the ground water in the Souf region, its depth at various points, and the amount of excavation necessary to enable the roots of the palms to reach it easily. The natives themselves give the most conflicting answers to questions upon this subject, and there are serious discrepancies in the accounts that have been published by French authorities upon irrigation. The whole matter evidently needs to be carefully studied by competent hydrographers, a study which is certainly warranted by the rarity of this type of agriculture.

[b] In 1883 Rolland estimated that there were 4,431 wells in the Souf region.

[c] Tobacco growing, which is unrestricted in Algeria, is a profitable industry in the Souf country on account of that region's nearness to the frontier of Tunis, where the growing of this crop is forbidden by law and where the selling of tobacco is controlled by the government. Agents of the Tunisian tobacco monopoly frequently visit the Oued Souf to purchase supplies.

The plats of vegetables that are irrigated from wells in the date gardens are situated on terraces constructed in the side of the sand hills, usually 10 feet or less above the floor of the basin. (Pl. III, figs. 1 and 3.) The well water is raised by hand in a shallow bucket, generally made of basketware covered outside with pitch, but sometimes of goatskin, which is hung on the small end of a slender palm trunk and counterpoised by a piece of rock fastened to the large end. The pole is fastened by its center to a crosspiece that is supported by two vertical posts made of stouter palm logs or of cemented rock. The bucket is emptied into a little cement basin adjoining the well curb, whence the water flows through a system of small conduits into the plats that are to be irrigated. Flood irrigation alone is practiced. As there is no soil in the region from which ditch banks and ridges that will stand up when wet can be made, the conduits and ridges of the plats, as well as the lining and curb of the well, are made of the same dark-gray plaster with which the walls of the houses are cemented. Plugs of wool are used for stopping the conduits at places where water is to be diverted into the plats. Among the vegetables most commonly grown are cabbages, turnips, radishes, carrots, pumpkins, melons, watermelons, onions, tomatoes (a small-fruited sort), and peppers.

In parts of the Souf region, especially east of the capital town, El Oued, the water of the wells is said often to contain enough magnesium and other salts to make it disagreeable for drinking.[a] West of the town, on the other hand, the water is said to be generally very pure. The difference is thought to be sufficiently great to have a marked effect upon the quality of the dates, the most renowned Deglet Noors of the Souf region being produced near the village of El Amiche, where the water is purest. The peculiar character of the water supply of the Oued Souf is not without advantages. Eminent authorities are of the opinion that the underground sheet is abundant and that it is much less liable to exhaustion than in the Oued Rirh, where numerous flowing artesian wells exist.

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[a] Well water in the Souf, according to an analysis cited by Jus (Les oasis du Souf du Département de Constantine. Bul. Acad. d'Hippone, No. 22, p. 67 (1886), has the following contents of solid matter in grams per liter of water:

Sulphates	1.9993
Chlorids	.7769
Carbonates	.2999
Nitrates and dissolved organic matter	.0690
Silicates, etc., in suspension	.0335
Total	3.1786

Schirmer (Le Sahara, p. 261) states that the mean salt content of well water at El Oued is 2.77 grams per liter.

SOILS.

The soil of the whole Oued Souf region is a fine-grained, light-yellow quartz sand, which is practically uniform in character to a considerable depth.[a] Here and there beds of a coarse, rather soft, gypseous rock occur at a depth, it is said, of 10 to 20 feet and in strata 1.5 to 10 feet thick. The crystals of which this rock is composed are very large, often 1 foot long. They are often aggregated into masses which, on account of their shape, are known as "Souf roses."[b] It is therefore a fair inference that the Souf soils are sufficiently rich in lime. They are very poor in organic matter and doubtless in nitrogen. Other data as to their composition are wanting.

In the eastern part of the region the soil of all the gardens is said to be somewhat saline, and the writer was told that there is even a small sebka (salt pond) in that section, although he saw nothing of these conditions. There is said to be nowhere enough salt to injure seriously the palms themselves, but the yields of fruit are diminished by this cause, and the dates are somewhat smaller and of slightly inferior quality. Consequently, palms in full bearing in the gardens west of El Oued are worth from two to ten times as much as those in the gardens east of that town. The Souafas do not pretend to distinguish some varieties of the date palm as being more resistant to salt than others, as do the inhabitants of the Djérid oases, where the salinity of the soil is often very pronounced. Neither have they adopted any special methods of preparing and handling salt land by drainage, flooding, or otherwise, as is the case in the Tunisian oases. It is fortunate for the Souafas that their soils are not saline, or but very slightly so, as it is hard to see how they could possibly reclaim strongly saline lands in view of the conditions of water supply in their country.

THE DATE GARDENS.

Let us now have a closer look at the gardens. (Pl. III, figs. 1 and 2.) The craterlike basins which they occupy are generally circular or nearly so, and from 35 to 50 feet deep. The bottom is entirely given up to the palms. Descending to the floor of the basin,

[a] According to Jus this hard quartz sand extends to a depth of 3.5 to 4.5 feet; next there are from 7 to 8.5 feet of a "reddish gypseous sand;" and then 3 to 3.5 feet of either "a fine quartz sand" or "a yellow gypseous sand."

[b] The composition of this rock, as given by Jus (ibid., p. 69), is:

	Per cent.
Quartz sand	37.00
Clay	5.10
Gypsum	41.40
Carbonate of lime	3.20
Carbonate of magnesia	1.50
Water	11.43

or "ghitan," as the natives term it, we find it to be a practically level expanse of clean, bare sand, checkered with the bright sunlight and the singularly black shadows that are cast by the trunks and leaves. (Pl. V, fig. 1.) The palms stand farther apart than in the gardens owned by natives in the Djérid and the Oued Rirh, but are not planted in rows and at equal intervals, as in the French plantations in the latter region. While native gardens elsewhere in the Sahara are a perfect jungle of various fruit trees, besides garden vegetables, barley, and alfalfa underneath the palms, in the Oued Souf one sees only scattered pomegranate and fig trees, and the groves have an unfamiliarly open and bare look. While in other oases the soil is often rich and black and is almost always moist, here it is quite dry on the surface. One misses, too, the irrigation and drainage ditches by which the gardens of the Djérid and the Oued Rirh are cut up into small plats.

Another feature of the Souf date orchards that immediately attracts attention is the enormous thickness of the trunks of the trees. They sometimes attain 3 feet in diameter. (Pl. V, fig. 2.) This is probably due to the trees being comparatively far apart, thus receiving plenty of light and air from every side, and is, perhaps, also to some extent a reaction to the buffeting of the sand-laden winds. At any rate, it is a useful character, giving the trees power to withstand the winds that prevail here to a greater extent than in the other oases of the northern Sahara. The relatively small height of the palms, which rarely exceed 30 feet in the Oued Souf, gives them a further advantage in this respect. Frequently, when the base of the trunk has become weakened and there is danger of the tree blowing down, the natives make a "dokana," or low, circular mound of soil, plastered on the outside, to strengthen it. (See Pl. V, fig. 1.)

The palms are almost invariably strong and healthy looking. The foliage is extraordinarily well developed, and the leaves commonly measure 15 to 20 feet long. The yields of fruit, as stated by the natives, are very heavy.

So unusual are the conditions under which date palms are grown in the Souf country that further details as to the methods used by the natives can not fail to be interesting.

PLANTING.

As the date palm is a tree that requires a great deal of water, it can evidently be grown in a dry country without surface irrigation only in places where its roots can quickly make their way to ground water. This is exactly the condition obtaining in the Oued Souf, where the palms are artificially watered only during the first summer after the offshoots are planted, and are then left to shift for themselves, so far as water supply is concerned.

As we have seen, the bottoms of the basins where the palms are grown are not only far below the summits of the surrounding sand hills, the height of which is increased by the sand removed in excavating the gardens, but are even considerably lower than the mean surface of the country. It is said that in starting a new garden the practice is first to sink a well in the bottom of the basin in order to find out the depth at which water stands. The floor of the basin is then scooped out until it is so near ground water that when a hole $1\frac{1}{2}$ to 4 feet deep is made to receive the young palm its roots will have to descend only about 1 or $1\frac{1}{2}$ feet to reach standing water. It is said that to attain the desired depth it is generally necessary to remove 10 to 20 feet of sand.

The date palm is always artificially planted in the Oued Souf, never springing up spontaneously from seed, as in other oases. It is never planted elsewhere than on the floor of the basins among the dunes, or at most a very few feet above the bottom. These basins are probably in all cases natural depressions, but are artificially deepened to facilitate the roots reaching ground water. New gardens are frequently started in unoccupied basins, and old ones belonging to enterprising owners are being constantly extended by cutting down the slopes of the bordering sand hills and planting a few palms every year or so. (See Pl. III, fig. 2.) The larger and better-situated basins are now all occupied by gardens, and for the newest plantations it is often necessary to use small, shallow depressions, where there is frequently room for but half a dozen trees. Sometimes the slope is not cut down quite to the level of the older part of the garden, the new palms being set out slightly above the level, on a terrace made in the side of the sand hills. (Pl. IV, fig. 1.) When planted on the slope or near the foot of it, sections of palm log or a number of palm leaves are placed on the uphill edge of the hole to check the drifting of sand into it.

Owing to the scarcity of offshoots in the Souf region, the work of extending the gardens does not proceed as rapidly as the energetic population could wish. The French attribute the nonproduction of offshoots in the Souf to the fact that the palms are so valuable there that it does not pay to let the offshoots develop, absorbing a part of the energy that would otherwise go to fruit production. They believe that the Souafas find it actually cheaper to send to the Oued Rirh for suckers, paying 40 to 60 cents apiece for them in addition to the cost of transportation, than to let them grow on their own trees. Economic considerations aside, however, it is probable that the date palm does not sucker as freely in the Oued Souf as in other oases, because of the dry condition of the surface soil, never wet by irrigation, and because the blowing sand tends to bury the young offshoots and to lacerate their tender buds. The natives, when questioned about the comparative rarity of offshoots at the base of their palms, reply simply that it is due to the absence of irrigation, without going into details. Whatever may be the cause of the deficiency, there is a great demand for offshoots, and to supply this demand caravans are sent to procure suckers, especially of the Deglet Noor variety, to Tougourt, or even as far as Ouargla, 135 miles away. In those oases they are produced more freely, the palms being irrigated.

Offshoots for planting are generally taken from the mother palm about the end of February. The natives say that they could be planted even earlier, but in that case the parent tree is likely to suffer from the access of cold air to the wound made in cutting off the sucker. In case the offshoots are removed in midwinter, their bases are slightly charred before planting, and this is thought to protect them from the cold.

The hole made to receive the young palm is sometimes as much as 6 feet in diameter, but probably in most cases less. Its depth, as we have seen, depends largely upon the distance to ground water, being generally $1\frac{1}{2}$ to 3 feet in the bottom of the gardens near the town of El Oued. A young palm was seen near El Oued that had been set out near a well about 6 feet above the bottom of a garden, in a hole $3\frac{1}{2}$ feet deep. (See Pl. IV, fig. 1.)

The palms are not set out in straight lines. They stand much farther apart than in gardens belonging to natives in other oases, 20 feet being the average distance. This wide planting is probably necessitated by the poverty of the soil, which is practically a pure sand, while the almost entire absence of subsidiary cultures makes the shade afforded by close planting less valuable than in other oases.

It is estimated that the planting and care of a young Deglet Noor palm up to the time it begins to yield costs $25 in the Oued Souf, as against $5 to $10 in the Djérid oases of Tunis.

CARE OF PALMS.

During the first summer after it is planted the palm may receive a few irrigations by hand with water from the well that is situated on the hillside in nearly every garden, although it is said that frequently no irrigation whatever is given. While still very small, before the leaves have grown out enough to project far above the mouth of the hole in which it is planted, the tree is protected from drought and from the cold of winter by covering the hole with palm leaves, dead pumpkin vines, etc.

When the palms are manured the sand that has piled up into a low mound around the base of the tree is removed and the soil beneath is thoroughly worked. This is apparently the only cultivation the trees receive.

FIGHTING THE SAND.

While elsewhere in the Sahara irrigation entails the heaviest labor connected with palm culture, in the Oued Souf it is the struggle that must be waged with the constantly encroaching sand that demands the tireless efforts of the gardeners. Every strong wind carries great volumes of sand. The slight fences of palm leaves and the low walls of gypseous rock that are constructed along the crests of the bordering dunes are only a partial protection against this invasion. Once over these weak barriers, the sand rolls down the steep slopes almost like water. The danger is always present, but is most pressing when the dates are ripening. Then bunches of fruit that hang close to the ground can be half buried by a few hours of high wind, and only the most strenuous efforts can save them. If a second storm occurs before the bulk of the sand is removed, the crop is hopelessly lost.

The work of cleaning out the basins is very laborious, being done, like the original excavation, almost entirely by hand. Travelers in this region have compared this work to the activities of ants, rather than of men. Laborers shovel the sand into baskets and carry them in a ceaseless procession to the top of the slope, their feet sinking deep into the flowing sand at every step. After a heavy sand storm the work must be continued from dawn to dark. In summer, during the blazing midday hours, the heat is too great for such heavy labor, and the removal of the sand goes on at night and in the early morning hours. At times a large part of the population of the region is engaged in this heavy task. It is paid for at the rate of 1 cent for every 5 baskets of sand, and the laborer has, in addition, the privilege of eating as many dates as he desires in the garden in which he is working. Only rich proprietors use the sturdy little gray donkeys of the Souf for transporting the sand from their gardens.

MANURING.

The soil of the Oued Souf is practically nothing but pure sand, containing even in the older palm gardens very little organic matter. Manuring is consequently essential not only to the production of good yields but even to the well-being of the palm itself.[a]

It is not uncommon in the Souf country to see palms that have thick trunks up to a certain point, above which they contract more or less abruptly to a much smaller diameter. In many cases, at a still greater height, the trunk again becomes thicker. This state of things is explained by the natives as due to a partial starvation of the tree at

[a] For that matter, manuring is generally practiced by good farmers in the oases of the Oued Rirh and the Djérid, although there the growing of leguminous food and forage crops (broad beans and alfalfa) helps to restore to the soil the nitrogen that is taken up by the palms.

the time when the trunk began to diminish in size. If manure is subsequently supplied to it, the palm is soon able to return to its normal rate of growth and the trunk again becomes larger.

Palms are not manured until they are 10 or 12 years old. At that age each tree usually receives 10 sacks (5 camel loads) of manure, half of which is applied on one side of the trunk the first year and the other half on the other side the following year. Thereafter, in order to obtain the highest yields, the trees should be manured every twelve or fifteen years, although sometimes thirty years are allowed to elapse between two manurings. Older palms receive as much as 14 sacks of manure (7 at each application). Camels' dung (see Pl. IV, fig. 2) only is used for date palms in the Oued Souf, although in the oases of Tunis that of donkeys is preferred, the natives there considering camel manure injurious where irrigation is practiced. The cost of a sackful of camel manure in the Oued Souf was stated by one informant to be 25 to 30 cents, while another placed it at 40 to 45 cents. In either case it is evidently an expensive article.

Manure is never used until it is thoroughly rotted, and even then it is not allowed to come into direct contact with the base of the tree. It is placed in a hole that is dug to a depth of 3 to 6 feet below the general level of the floor of the basin and at a distance of 5 or 6 feet from the foot of the palm. When several neighboring palms are to be manured at the same time, the hole is dug in the center of the space among them, and is made so large that none of the palms is more than 6 feet distant from its edge.[a] The hole is then filled with a mixture of one part manure and one part of a bright yellow sand called "baker," which is somewhat more loamy and probably contains more gypsum than the surface sand of the region, and is obtained at a greater depth. Unmixed manure is never used, even though thoroughly rotted, being considered injurious to the palm roots. The soil removed in digging the hole is never put back, being "dirty," as the natives express it.

October is considered the best season for applying manure, although March is also a good time. Unskillful growers sometimes manure their palms at other seasons, but this is thought to do more harm than good. Sometimes, unless the hole is opened and the manure removed as soon as the tree shows signs of injury, it is said to die from the effects of manuring at the wrong period.

The effect of manuring upon the yield is large and almost immediate. It is said that a tree which bears 200 pounds of dates one year will often give 400 pounds the season following if meanwhile manure

[a] One such hole, freshly excavated at the time of the writer's visit, occupied much the greater part of the area among four palms, being 12 feet long and 5 feet wide. It was divided unequally by a narrow ridge of soil left in place. The object of this division could not be learned.

has been applied. No distinction between varieties is made in the Oued Souf in manuring, nor, so far as could be ascertained, in regard to other cultural practices.

HARVEST.

At the time of the writer's visit (November 22–26, 1904) the date harvest had been completed in all the gardens of the Souf country. The Deglet Noor harvest is said generally to begin about October 25. In the Tunisian oases, on the other hand, the harvest of Deglet Noor and Fteemy dates—the two most important varieties—was at its height in November, and continued throughout December and even the earlier part of January. Of course, in the latter case many of the dates were ripe long before they were gathered, and the long duration of the harvest was largely due to the relative scarcity of the expert labor required, the crop being many times as large as in the Souf. Yet it seems certain that in the Oued Souf, dates, especially the Deglet Noor variety, ripen earlier than in the Oued Rirh oases of Algeria or the Djérid oases of Tunis. This would be expected from the fact that the summer is drier and likewise hotter in the Oued Souf than in the oases of the Djérid. Furthermore, the situation of the gardens, in hollows bordered by hills of light-colored sand that are generally higher than the tallest palms, is favorable to an early ripening of the dates, as they must receive a great amount of additional heat by reflection from the soil. More perfect natural conditions for forcing fruit to early maturity could probably not be found in the world.[a]

This greater heat and dryness of the Souf climate affect the fruit in other ways than merely by hastening its ripening. The dates produced are reputed to be the best grown in the Sahara. They seem, as a matter of fact, to be sweeter and at the same time drier and more solid than in the Djérid. This is especially true of the Deglet Noor, which is of decidedly firmer texture, containing less water. The Souf dates are said to keep better and to be more adapted to export than those of the other oases, showing less tendency to blacken and become moldy.

It was a matter of regret to the writer that the harvest was not witnessed in the Souf, although it could not be learned that the methods followed there differ from those practiced in other oases. So far

[a] Rolland (Hydrologie du Sahara Algérien, Paris, 1894, p. 222) describes the basins as "a sort of fiery furnace, under the influence of solar radiation. The dates here attain perfect maturity. Here are realized, better than anywhere else in the Sahara, the conditions assigned by the Arab proverb to the prosperity of the palm and the excellence of its fruits: 'Its feet in the water and its head in the fire of heaven.'"

as is known, the pollination of the female flower clusters in the spring is also effected in the same way as in the Oued Rirh.[a]

YIELDS.

It was impossible to secure very reliable statements of yields from the natives, but from all that could be learned these must be unusually large in the Souf country. The clusters of the Deglet Noor are said frequently to weigh over 55 pounds each, and to attain sometimes 90 pounds. Single trees of this variety, which is one of the lightest bearing kinds, sometimes yield as much as 330 pounds in the Oued Souf. It was estimated in 1883 that the date crop from the 175,000 palms (of all varieties) in full bearing then existing in the Souf region was 7,000,000 pounds. This would mean an average yield of 40 pounds per tree, as against an average yield of 28 pounds estimated to have been produced in the Oued Rirh the same year.[b] A good palm in full bearing is valued at from $50 to $130, according to the variety to which it belongs.

The practice of planting the trees farther apart than in other oases is perhaps one reason for the large yields. By wide planting, not only do the roots of each palm have a larger feeding area, but the trees do not shade each other so much and more of the fruit can develop and ripen. Moreover, the climatic and topographical conditions, as we have seen, are exceptionally favorable to the ripening of dates.

VARIETIES CHIEFLY GROWN.

As has already been indicated in this paper, date palms in the Oued Souf rarely, if ever, spring up from seed, as they do in other oases where the conditions are more favorable to the spontaneous development of the palm. They are propagated only by offshoots that are taken from the parent tree and planted by the grower. Consequently we do not see a multitude of seedlings, generally of very inferior quality and of almost endless diversity of characters, filling every waste corner and roadside and even crowding out good trees in gardens that are not well cared for. Practically every palm grown in the Souf belongs to some well-known and well-liked variety.

The number of varieties found in this region is considerable. Most of the gardens contain a mixture of several kinds, although in some of the recently created ones the tendency is to plant only one

[a] Described in Bul. 53, Bureau of Plant Industry, "The Date Palm," by W. T. Swingle, 1904, pp. 26–29.

[b] These estimates are quoted from Rolland (ibid., p. 324). The overwhelming importance of the date crop in the Souf region is shown by the fact that the same author states the value of the 1883 crop of dates to have been $301,730, while that of all other crops combined was only $20,900 in that year.

sort, most often the Deglet Noor. Nearly all the popular varieties of the Souf are also common in the Oued Rirh.[a]

On the other hand, some of the most characteristic Souf types are very rare in the Djérid oases of Tunis, only 70 miles away. Such individuals as occur there are mostly grown from offshoots that have been brought directly from the Souf. The principal variety common to the two regions is the Deglet Noor, which is now abundant in Tunis, but is said to have been first introduced into that country from Algeria about two hundred and fifty years ago. The Souafas still go to the Oued Rirh oases to procure offshoots, and they very likely brought thence those with which the first gardens were started among the sand hills of the Souf.

The most important of the numerous varieties of the Souf, in point of abundance as well as of quality, are, in about the order named: Deglet Noor, Rhars, Tafazween, Massowa, Deglet Beida, and Takermest. Of these Rhars is the earliest and Deglet Noor the latest to ripen. After the Deglet Noor, Tafazween is the best sort that is widely grown. It is a large, reddish-bay-colored, translucent date, very sweet and rich in flavor.[b] A highly esteemed but very rare variety is the Fezzani, which is said to be superior even to the Deglet Noor when dried, and to keep well for two years. Rhars, a variety that is celebrated for its heavy yields, is extensively planted.

In the Oued Souf, as in other oases of Algeria and Tunis, the Deglet Noor is the only variety that has any importance as an article of export to Europe. It is consequently the most valuable, the more so because the natives themselves generally esteem it above all others. Deglet Noor dates are carried from the Souf by caravan to Biskra, whence they are shipped by railway to the seaports. Souf Deglets are said to be about the earliest to reach the Biskra market. Their good keeping and shipping qualities have already been discussed as probably due to the peculiar climatic conditions, which give them an advantage over dates from oases where the palms are lavishly irrigated and the air is moister. On the other hand, they appear to be smaller than those in the Djérid and to be inferior in color and general appearance. The latter disadvantage is very likely due in great part to the sand-laden winds to which they are exposed. The Deglet Noor palm is said to be hardier in the Souf region than elsewhere, showing greater resistance to disease and to unfavorable climatic conditions. The foliage of the date palm appears to be less subject to the attacks of scale insects than in other oases, which is perhaps attributable to the extreme dryness of the atmosphere.

[a] Exceptions are said to be the Fezzani, Massowa, Ali Rashid, and Guettara varieties.

[b] Twenty offshoots of this variety were obtained from the Oued Souf for trial in the United States through the kindness of the French commandant at El Oued, Captain Bussy.

CONCLUSION.

The type of agriculture practiced in the Oued Souf is not dry-land farming, for it depends upon the ground water, which in the gardens is everywhere near the surface of the soil. It affords us, however, an excellent object lesson of what can be done under the most adverse natural conditions in producing a valuable crop, for throughout northern Africa the Oued Souf is renowned for the large yields of its date orchards and the high quality of their fruit.

It may be that nowhere in the United States are the conditions with respect to ground water such as to allow of a close imitation of agricultural methods used in the Souf country. One lesson is, however, to be drawn from them. The sand hills concentrate and reflect so much heat that the hollows among them are veritable forcing houses, where dates ripen considerably earlier than elsewhere. Have we not here a hint of what may be done in the Salton Basin and perhaps in other hot, arid regions in the Southwest where large sand dunes exist, and where artesian or other sources of water supply for irrigation are available? It seems certain that in pockets of this character excavated among the dunes the Deglet Noor and other valuable varieties of dates could be forced to early maturity.

Dates ripened in this way a few weeks ahead of the bulk of the crop would command a fancy price, especially as the quality of the fruit produced under these conditions would in all probability be exceptionally fine. Nor are the possibilities limited to the date palm. Other fruits, such as figs, pomegranates, and grapes, could perhaps thus be put upon the market in advance of those from any other locality in the United States. The experiment is certainly worth trying. The American fruit grower, awake as he is to every new idea, may find something worthy of imitation in the example of these sturdy inhabitants of a remote corner of the Sahara.

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PLATES.

DESCRIPTION OF PLATES.

Plate I. (*Frontispiece.*) General view of the Oued Souf region from the town of El Oued, showing sand dunes and sunken gardens of date palms.

Plate II. Fig. 1.—High sand dunes east of El Oued. The group is standing on a ridge separated by a ravine from the very high dune in the background. Fig. 2.—A typical dwelling house of the Oued Souf, showing its cubical form and roof composed of flattened cupolas. Fig. 3.—General view of the Oued Souf region, showing sunken date gardens and sand dunes. Fence of dead palm leaves along crest of dune in foreground.

Plate III. Fig. 1.—Near view of sunken palm garden and surrounding dunes. Vegetable garden in left foreground, showing small size of checks. Near it a young palm, planted in a hole. Fig. 2.—Gradual extension of a palm garden by cutting down bordering sand hills. Oldest palms in background, youngest in foreground. Fig. 3.—Vegetable garden irrigated by well near bottom of basin in which date palms are grown.

Plate IV. Fig. 1.—Hole on slope of dune near bottom of basin in which a young palm is planted. Fig. 2.—Camel manure ready for application in a date garden.

Plate V. Fig. 1.—"Dokana," or mound of earth and plaster for strengthening the base of a palm. Shows also distance between trees, absence of other cultures, and play of light and shadow on floor of basin. Fig. 2.—Rhars palm, showing thickness of trunk.

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FIG. 1.—HIGH SAND DUNES EAST OF EL OUED.

FIG. 2.—A TYPICAL DWELLING HOUSE OF THE OUED SOUF, SHOWING ITS CUBICAL FORM AND ROOF COMPOSED OF FLATTENED CUPOLAS.

FIG. 3.—GENERAL VIEW OF THE OUED SOUF REGION, SHOWING SUNKEN DATE GARDENS AND SAND DUNES.

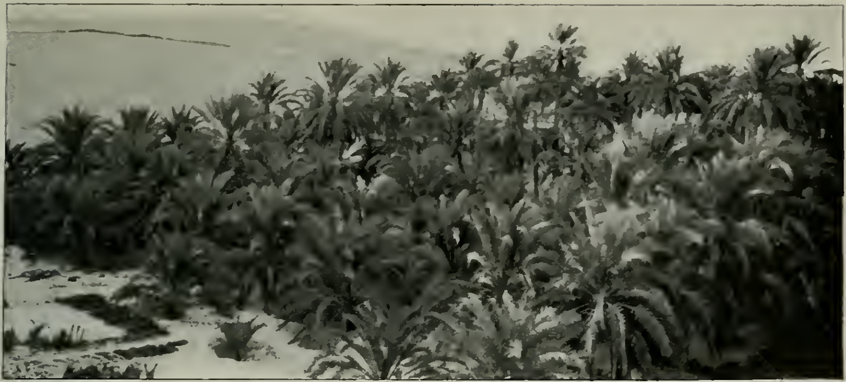

FIG. 1.—NEAR VIEW OF SUNKEN PALM GARDEN AND SURROUNDING DUNES.

FIG. 2.—GRADUAL EXTENSION OF A PALM GARDEN BY CUTTING DOWN BORDERING SAND HILLS.

FIG. 3.—VEGETABLE GARDEN IRRIGATED BY WELL NEAR BOTTOM OF BASIN IN WHICH DATE PALMS ARE GROWN.

FIG. 1.—HOLE ON SLOPE OF DUNE NEAR BOTTOM OF BASIN IN WHICH A YOUNG PALM IS PLANTED.

FIG. 2.—CAMEL MANURE READY FOR APPLICATION IN A DATE GARDEN.

FIG. 1.—"DOKANA," OR MOUND OF EARTH AND PLASTER FOR STRENGTHENING THE BASE OF A PALM.

FIG. 2.—RHARS PALM, SHOWING THICKNESS OF TRUNK.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 87.

B. T. GALLOWAY, *Chief of Bureau.*

DISEASE RESISTANCE OF POTATOES.

BY

L. R. JONES,

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VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

ISSUED DECEMBER 5, 1905.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

BUREAU OF PLANT INDUSTRY.

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Pathologist and Physiologist, and Chief of Bureau.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., October 7, 1905.

Sir: I have the honor to transmit herewith the manuscript of a technical paper entitled "Disease Resistance of Potatoes," which embodies a report upon investigations conducted in cooperation with the Vermont Agricultural Experiment Station.

This paper is a valuable contribution to our knowledge of disease resistance in European and American varieties of potatoes, and I respectfully recommend that it be issued as Bulletin No. 87 of the series of this Bureau.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The potato is one of the most important food crops of the United States. It is, moreover, one which is subject to a number of serious plant diseases. Some of these, notably the late-blight, can be controlled by spraying. Yet this remedy is not applied by all farmers, and the annual loss amounts to many millions of dollars. Other diseases, like dry-rot and the bacterial blight, are not controlled by spraying and require a different line of treatment. The subject of disease resistance in plants has received increased attention of late, and it is likely that the introduction of disease-resistant varieties of potatoes, by supplementing spraying and special cultural practices, will be of great practical value in lessening the waste caused by disease. Although but little has been done in the United States toward securing varieties resistant to disease, the attention of potato specialists in other countries has already been directed toward this aim.

As a preliminary step in our work, Dr. L. R. Jones, botanist of the Vermont Agricultural Experiment Station, was commissioned to inquire into the occurrence of potato diseases abroad and the methods employed for their control, particularly with reference to the production of disease-resistant varieties. Doctor Jones spent six months—from April to September, 1904—in this work.

In the course of Doctor Jones's European itinerary, information of more or less value was secured at the following places, successively, and this was supplemented by a considerable correspondence covering a somewhat wider area: Marseille, Naples, Florence, Munich, Halle, Berlin and vicinity, Dresden and vicinity, Bonn and vicinity, Wageningen (Holland), Amsterdam and vicinity, Groningen, Delft, Gembloux (Belgium), Paris and vicinity, London and vicinity, Reading, Cambridge, and Edinburgh and vicinity. The thanks of the Department are accorded to the various officials and other botanists in the countries visited, whose uniform courtesies made possible the success of the mission.

As shown in this report, a considerable number of varieties are reputed to be disease resistant. The best of these were selected by Doctor Jones, and limited quantities of seed tubers were imported by the Office of Seed and Plant Introduction and Distribution of the

Bureau of Plant Industry. These are now being tested in trials conducted in cooperation by the Bureau of Plant Industry and the State experiment stations in Vermont, Florida, Colorado, and Oregon, and by the Bureau at the Arlington Experimental Farm, near Washington. In order fully to acclimatize the foreign varieties, these trials will be continued for three years before a final report is made on their adaptation to American conditions. This test, together with the review of our present knowledge contained in this bulletin, will establish a proper foundation for future efforts in breeding better and more disease-resistant varieties. The field for such work is very large. Up to the present time most of the breeding has been for resistance to the late-blight (*Phytophthora infestans*), and this will continue to be the principal problem in the northern tier of States; but there is also much promise of success in securing new varieties to resist scab, dry-rot, bacterial blight, and other troubles, which in the Southern and Western States are more injurious than late-blight. It is hoped that potato specialists will give increasingly careful attention to this feature in their breeding and testing of varieties, for it is only by such a general interest and effort that the desired information can quickly be secured.

ALBERT F. WOODS,
Pathologist and Physiologist.

OFFICE OF VEGETABLE PATHOLOGICAL AND
PHYSIOLOGICAL INVESTIGATIONS,
Washington, D. C., October 5, 1905.

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CONTENTS.

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DISEASE RESISTANCE OF POTATOES.

INTRODUCTION.

Potatoes are liable to several diseases, some of greater economic importance in one part of the country, some in another.[a] The causes of most of these have been determined, and remedies of more or less practical value, chiefly spraying and seed disinfection, have been found. The success of the agents of the Department of Agriculture in securing disease-resistant varieties of various other plants has given an added interest to the question as to what may be expected in the way of securing disease-resistant varieties of potatoes. Inasmuch as this matter has engaged the attention of the potato specialists of Europe longer and more widely than has been the case in America, the attempt has been made to glean from their experience whatever may prove of assistance in furthering the work in this country.

In presenting the results it has seemed best for the sake of clearness to discuss briefly (1) certain general matters relating to potato culture in Europe; (2) the potato diseases which occur there, with comments on the resistance shown by particular varieties to each disease, and then (3) to summarize the information obtainable in America as to disease resistance of potatoes.

POTATO CULTURE IN EUROPE.

Potato culture was introduced from America into Europe more than three centuries ago. It was slower in its popularization there than in this country, but to-day the potato crop is relatively more important, both for food and for factory uses, in Europe than in America. This is partly attributable to the greater success of maize as a starch-producing plant in America and partly to the difference in economic

[a] Anyone not familiar with potato diseases should consult Farmers Bulletin No. 91, Potato Diseases and Their Treatment, by B. T. Galloway, which will be sent free of charge upon application to a Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture, Washington, D. C.

conditions—land and labor values and food habits—between the two continents. In the British Islands the annual acreage in the last decade[a] was more than one and a quarter million; in France three times and in Germany six times this amount. The crop in Great Britain is chiefly used for human food; in France about 40 per cent is used in starch and alcohol manufacture, and in Germany like conditions exist, with the use of the potato for alcohol distillation promising to increase largely.

It is the German national policy so to improve processes of culture and manufacture that potato alcohol may rival, if not displace, petroleum for lighting and fuel purposes. Various organizations are aiding in this movement, including the Deutschen-Kartoffel-Kultur-Station and the Institut für Gährungsgewerbe und Stärkefabrikation. These institutions, maintained partly by private endowment and membership and partly by government aid, have been in operation about fifteen years. Under the directorship of Profs. C. von Eckenbrecher and W. Delbrück, respectively, they give attention to all matters pertaining to potato culture, starch manufacture, and distillation, including the breeding, selecting, and trial of new varieties. They work in close cooperation with the various German experiment stations and private potato specialists. No similar institutions were met with elsewhere in Europe, although the potato growers of England have organized during the last year an association of much promise, the National Potato Society.

In any comparison of European with American varieties the difference in popular taste must be kept in mind. The English market is like the American in giving preference to varieties with white flesh, rich in starch, and in making little use of potatoes except for human food. On the continent of Europe, however, only the varieties with yellow flesh are rated as of first quality for table use. These are relatively poor in starch and richer in protein than the white-fleshed varieties, and when cooked they are not sufficiently dry and mealy to suit the American taste. On the Continent the white-fleshed, starch-rich potatoes are demanded by the starch factories and distilleries, and as a result continental potato breeders have aimed to develop white-fleshed varieties of high starch content and large productiveness, regardless of table qualities, and anyone importing their varieties for use in America must consider these facts. It is from England, therefore, that we may expect the more promising varieties.

It is worthy of note in this connection that the difference in character of the potato in popular favor in different countries is closely related to differences in methods of cooking. The varieties with yellow flesh are inclined to sogginess when baked or boiled, but are admirably suited for frying. The starch-rich white potato, which is of

[a] Sutton, A. W., Potatoes, Jour. Roy. Hort. Soc., XIX (1896), pp. 387–430.

highest quality when baked, may go to pieces if boiled and will not hold together sufficiently for frying. In the latter case steam cooking gives better results than boiling in water.[a]

The methods of culture of potatoes vary somewhat in different European countries, as they do in America. In general, closer planting is practiced than in this country, which is partly explained by the greater number of unskilled laborers in Europe. A matter of more pertinence to the present discussion is that much more attention is given, especially in England, to the source and handling of seed potatoes than is generally the case in America. The best informed English growers considered that this has much to do with the question of disease resistance, as will be explained later. Indeed, it has come to be accepted by them that, for the best results, seed potatoes should be imported from some more northern region, at least as often as every third or fourth year, and this is done by many large growers every year. English growers use Scotch seed very largely. On the grounds of Sutton & Sons, Reading, England, a comparative trial was conducted during the summer of 1904 with a number of varieties, using seed from Scotland, middle England (Lincolnshire), and southern England, respectively. When these plats were visited in August, the vigor of the plants was in all cases greatest from the Scotch-grown seed and least from that grown in the south of England. In certain varieties the development of the tops was as two to one. At the Cambridge University farms, located in the famous potato region of Lincolnshire fens, it was said that Scotch-grown seed did better than home-grown there and in the Lincolnshire district generally.

A large potato-growing company of the Canary Islands uses German in preference to English seed, because the growth from the latter is too rank and the tubers are too large. Potato growers on the island of Jersey in recent years have sent to England and Scotland for their seed. Italy and the Mediterranean islands look to France and Germany largely.

While some American potato growers recognize the importance of the source of seed and attend to this point consistently, there is generally indifference, disagreement, or lack of information on this subject, as Fraser[b] has recently shown. It is a matter deserving of further careful inquiry and experiment.

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[a] The writer is indebted to Professor Petermann for calling his attention to these matters. For a further discussion of this subject reference may be made to Petermann, A., Etudes sur la pomme de terre, Bul. de l'Inst. Chim. et Bact., No. 70, Gembloux (Belgium), 1901; and Coudon and Bussard, Annales de la science agronomique, I, Paris, 1897. To the latter, credit may be given for showing that the behavior of the potato in cooking is primarily dependent not so much on the total percentage of starch contained as on the relative percentages of starch and protein. The proper proportion of the protein is necessary to hold the starchy mass together when cooked.

[b] Fraser, S., The Potato, New York, 1905, pp. 51–52.

The relation of the maturity of seed to its value has also received considerable attention in Great Britain. Some of the best practical potato growers prefer to have potatoes intended for seed dug before they are fully mature, i. e., while the tops are still green and the outer skin of the tuber rubs up easily. These tubers are then allowed to lie on the ground a short time to "harden" in the light, i. e., to dry and be slightly sunburned, before they are put into storage.

The practice of "boxing" is common and very highly commended. This consists of setting the tubers with "seed end" up in shallow boxes or trays in a dry, light room for some weeks before planting, so as to have strong, short sprouts started upon them. In this way quicker germination, stronger young plants, and a perfect stand are secured.

The general preference in Scotland and in England is for planting small tubers, one and one-half to three ounces, planted whole. If larger tubers are used they are cut, as in this country.

OBSERVATIONS ON POTATO DISEASES AND DISEASE RESISTANCE IN EUROPE.

Insects cause the European potato grower little annoyance or loss as compared with American conditions. Nowhere in Europe, so far as learned, is any use whatever made of insecticides upon potatoes, leaf-eating insects being practically unknown. On the other hand, diseases caused by fungi or bacteria or of nonparasitic origin are even more common and destructive than in America. In the following paragraphs is a discussion of the nature and relative seriousness of such diseases as came under the writer's personal observation, coupled in each case with the evidence secured as to disease resistance. The less important and nonparasitic maladies are discussed first, reserving until later the consideration of the late-blight and rot.

CERTAIN MINOR DISEASES.

INTERNAL BROWN SPOT.

The peculiar disease of the potato called internal brown spot is as well known to plant pathologists and practical potato specialists in Europe as in America. The writer learned nothing more about it on the Continent than is set forth by Frank,[a] who reached only negative conclusions. It is considered not to be a parasitic disease, and no remedy is known and no suggestions are made except the doubtful one of avoiding the use of diseased tubers for seed. In England and Scotland several potato specialists[b] of wide experience gave evidence of like

[a] Frank, A. B., Kampfbuch gegen die Schädlinge unserer Feldfrüchte. "Buntwerden oder Eisenfleckigkeit," p. 211.

[b] Prof. J. H. Middleton, Messrs. Sutton & Sons, and Thomas A. Scarlett.

purport. The trouble is frequently observed, and is most commonly termed "sprain." It is not propagated in seed or soil and is non-parasitic. It is considered to be the direct result of malnutrition associated with unfavorable soil conditions, resulting either from too dry conditions or from the lack of potash or lime. It is frequent in light, dry soils during dry seasons, and is never seen on heavy, strong, moist soils. The remedy, in the judgment of the specialists cited, lies wholly in attention to cultural conditions and the choice of varieties.

Some varieties are more liable than others to internal brown spot and should not be used on soil that favors the disease; e. g., Mr. Scarlett stated that the British Queen variety is especially predisposed to "sprain." The primary remedy, however, lies in selection and treatment of the soil—i. e., in avoiding dry soil—and in so cultivating as to conserve moisture, while using lime and potash liberally.

FILOSITÉ, OR GROWING-OUT.

The names "filosité" and "growing-out" are applied in France[a] and England, respectively, to various forms of secondary outgrowths from tubers. Examples that were shown to the writer were in some cases merely "prongy" tubers, while in others stolons starting from the eyes produced secondary small tubers. Delacroix describes conditions where the seed tubers send out an abundance of weak shoots, both above and below ground, but these soon die without yielding any crop. The latter type is therefore allied to the curl disease of the potato.[b] The less serious forms of growing-out are attributed to climatic and soil conditions, especially to a long, wet autumn following a dry summer. The more serious types of the disease, especially as occurring in France, are attributed to varietal weakness or "running out." In both France and England the use of seed from any plants showing this tendency was condemned as tending to give a crop of generally reduced vitality.

LEAF-SPOT.

Since there has been a difference of opinion among pathologists as to the occurrence and destructiveness of the fungus *Alternaria solani* in Europe, the writer was led to keep an especially close watch for it. Prof. P. Sorauer kindly sent specimens from Europe some years ago corresponding fully with the leaf-spot disease caused by this fungus.

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[a] See Delacroix, G., Sur la filosité des pommes de terre, Jour. de l'Agriculture, December, 1903.

[b] Frisolée (French), or Kräuselkrankheit (German), is a common but not very serious potato malady of Europe, of which the cause is not clear, but apparently it is associated with varietal weakness and malnutrition. It is characterized by dwarfish plants bearing an excessive number of rather undersized leaves, which are downcurled and brittle. The tops have thus a dense or bushy appearance. They may be quite as green as normal plants.

and termed early-blight in America. It is known, therefore, that it occurs in Europe, but it can not be as common and destructive as it is here, for no trace of it could be found in any of the fields visited. Much was seen, however, of a leaf-spot disease which bears a superficial resemblance to it. This was shown us first by Dr. Otto Appel in the experimental fields of the board of health at Dahlem, near Berlin. Later it was seen elsewhere in Germany and in England. Apparently there has been a confusion of this with our American early-blight,[a] but both Doctor Appel and Professor Sorauer stated that there was no fungus present in this leaf-spot disease, and the writer's examinations confirmed this. The cause of this trouble has not as yet been clearly established, but since Appel and Sorauer both have it under observation, further advice may be expected upon it in the near future. Opportunity was presented to compare the relative development of this trouble on different varieties in the trial grounds of the University Farm, Cambridge, England, in the latter part of the summer. There was a considerable difference in the amount of spotting of the various varieties, but none was altogether free from it.

SCABBINESS OF TUBERS.

POTATO SCAB.

Scab-like diseases, i. e., those characterized by surface erosions of the tubers, are frequent in Europe and apparently more varied in nature than is recognized to be the case in America. Yet nowhere does injury to the crop from such diseases approach that which is common in this country. This is in some ways surprising and unexplained. A disease closely resembling in appearance the common American type of scab was frequently seen, but growers everywhere in Germany, France, and Great Britain testified that it is not common or destructive enough to be of much practical importance. Scientific men are not agreed either as to the cause of the disease or as to the possibility of benefit from seed disinfection. But few recommended this treatment, and no practical potato grower was met who practiced it. The most puzzling thing, in the light of American experience, is that potatoes are grown year after year continuously or in the shortest of rotations on the same soil without increase of scabbiness. In each of these countries potatoes are often grown on the same soil for ten or twenty or even forty successive years with practically no trouble

[a] See Frank, Kampfbuch, p. 220. Apparently the disease mentioned above is the same as Frank's "Pockenfleckigkeit." Frank was altogether mistaken in considering it the same as the American "early-blight," as Sorauer subsequently showed. See also Bahna, J. J., Blattbraune der Kart.; Zeitsch. f. Land. u. Fortwirtsch., 2: 113 (March, 1904). Prof. C. von Tübeuf comments upon this article and reviews the literature in the June, 1904, number of the same journal.

from scab.[a] Since this is often on rich and heavy land, such as would develop scab under like treatment in America, the European experience is difficult to understand. Does not our type of disease exist there, or is it less virulent because of some difference in the climatic and soil conditions? The writer is not prepared to answer with full confidence, but his judgment favors the second suggestion.

Europeans, both pathologists and practical men, recognize more than one form of disease under the name of scab (the German "schorf," Dutch "schurft," French "la gale"). Frank's subdivisions[b] of "schorf" into four kinds—flach, tief, buckel, and buckel-tief schorf—were familiar to the continental pathologists interviewed, but the general opinion is that these are simply forms of one common disease, the variations being attributable to the season of attack or to varietal or vegetative conditions of the potato. Frank's specimens of "tief-schorf" were seen in the museum of the board of health at Berlin and have the appearance of the common American scab.

As to the cause, opinions differ.[c] The German pathologists who have given most attention to this disease consider the commonest German form to be due to a fungus similar to Thaxter's *Oospora scabies*, but perhaps not identical with it. In Holland doubt was expressed as to the common Dutch form of potato scab being a fungous disease at all, while in Belgium and France it is considered a parasitic disease, but due to bacteria (*Micrococcus pellicidus* Roze) rather than to fungi.[d] In England *Oospora scabies* is held responsible for only the minor part of the trouble, *Sorosporium scabies* Fisch. being the commoner parasite.

VARIETAL RESISTANCE TO SCAB.

As already stated, none of these scab diseases has proved of sufficient economic importance to attract much attention from practical potato growers in Europe. Probably most of the diseases would yield to the seed-disinfection treatment practiced for potato scab in America, yet this is nowhere used by European growers, so far as learned. The only valuable data as to the relative susceptibility of varieties to scab are those furnished by the reports of Professor Eckenbrecher,[e] whose results point to certain newer varieties as being comparatively free from scab, while others are quite susceptible. Age of the variety,

[a] See Sutton, A. W., Potatoes, Jour. Roy. Soc., XIX, pp. 387–430 (1896).

[b] Kampfbuch, p. 170.

[c] These conclusions are the result of conferences with a number of men and reference to the publications of others. Among those who have given this disease careful consideration in their respective countries and whose opinions were learned are Professors F. Krüger, Berlin; Ritzema-Bos, Amsterdam; Marchal, Gembloux; Roze and Delacroix, Paris; Massee and Cooke, England.

[d] Roze, E., Histoire de la pomme de terre, Paris, 1898, p. 275.

[e] C. von Eckenbrecher, Berichte Deutsch.-Kart.-Kult.-Stat., 1903 and earlier.

however, seems to be of less consequence than it is with the blight, for while one of the least resistant is Daberschе, an old standard, one of the most resistant is Richter's Imperator, also an old variety. Other varieties reported as preeminently scab resistant are Irene and Professor Wohltmann. Boneza and Pomerania are reported resistant, but to a less degree. Seed of all these have been secured for trial in this country. Early Rose is found especially liable to scab there as it is in America. It will be better, however, to postpone the discussion of resistance to scab as shown by American varieties of potatoes until the latter part of this publication.

OTHER SCAB-LIKE DISEASES.

Rhizoctonia.—This was seen on potato tubers in Europe even more commonly than it occurs in America, but most European pathologists regard it as nonparasitic. Those who consider it as a facultative parasite attribute little injury to it generally, although some think it capable of causing rot, as described by Frank.[a]

Spongospora solani Brun.—This fungus is said[b] to cause a scab-like disease in the north of Europe. This disease occurred[c] to a considerable extent on potatoes secured by the writer's order from Groningen, Holland.

Superficial scurvy diseases attributed to other fungi occur in Europe. Frank[d] describes one such caused by *Phellomyces sclerotiophorus*, but Doctor Appel told the writer that this had not proved serious in Germany. Johnson[e] reports it as causing some trouble in Ireland. In England another scurf disease of somewhat similar appearance is attracting attention. It occurred on the Eldorado seed potatoes imported with our order from Scotland, and the cause is apparently the fungus *Spicaria nivea* Hors.[f]

Oedomyces leproides Trabut.—This is a fungus[g] which attacks the young sprouts or eyes of the tubers, stimulating them to abnormal, cauliflower-like growth, of which the dark color has given rise to the popular name black-scab. The writer did not see this disease on the

[a] Kampfbuch, p. 194.

[b] Ibid., p. 176.

[c] Found and identified by James Birch Rorer.

[d] Kampfbuch, p. 182.

[e] Johnson, T., The Diseases of the Potato and Other Plants in Ireland, Journal, Dept. Agric. Ireland, Vol. III, No. 1 (1902).

[f] So identified by Dr. Ernst A. Bessey. Dr. Thomas Milburn, of the Midland Agricultural and Dairy Institute, England, advises the writer by letter that he is engaged in a special study of this disease. He finds it to occur on most English varieties, Evergood and Sutton's Flourball being by far the worst, while East Anglian and Sutton's Discovery are the only ones he has found entirely free from it.

[g] This also occurs on beet roots. See Massee, Geo. A., Textbook of Plant Diseases, p. 225.

Continent, but while in England Dr. M. C. Cooke sent specimens, as did also Dr. John Wilson, from Scotland. It is regarded as capable of causing much harm, but fortunately has not as yet become common.

POTATO STEM DISEASES.

BLACKLEG.

"Schwarzbeinigkeit," or blackleg, is a name applied to a disease seen commonly in central Europe. It is characterized by the blackening and rotting of the main stem, accompanied by a checking of the growth, uprolling, yellowing, and ultimate death of the leaves, and more or less rotting of the tubers. It has been exhaustively studied in recent years by Appel[a] in Germany, who concludes that it is due to bacteria (*Bacillus phytophthorus*, and perhaps other allied species), which either enter from the soil or are carried in the seed tuber. These start the disease below ground, the rot proceeding, as a rule, from the seed tuber to the young plant. Appel's conclusions are generally accepted by pathologists in Germany, Holland, and Belgium, and, so far as learned, in England.

The writer had opportunity to see much of the German disease in the vicinity of Berlin, and to verify Doctor Appel's observations, in a measure, in his own laboratory. Later (August) the same malady was seen in England, where it is said to be common, though apparently less troublesome than Appel reports it from Germany. All of the personal observations of the writer therefore lead to an indorsement of Appel's conclusions both as to the bacterial nature of the disease and as to its widespread occurrence and economic importance.

In France a similar if not identical disease is attributed to bacteria. Delacroix, who has studied this, considers the organism causing the disease, which he calls *Bacillus solanicola*, to be specifically distinct from that described by Appel. He kindly showed the writer specimens of the French disease in his garden in Paris, but it was in a stage so much more advanced than that seen in Berlin that a comparison of the two does not seem justifiable.

Of course, the possible occurrence of these stem diseases in America was kept in mind. The writer has never seen much, if any, of the same trouble in potato fields in the Northeastern States and adjacent Canada which have come under his observation. Certainly it is not so common in America as it is in Europe. The symptoms correspond, however, somewhat closely to certain diseases attributed to Rhizoctonia in the South and West.[b]

[a] Appel, O., Arb. aus Biol. Abt. Gesundheitsamte, 3: 364 (1903).

[b] See especially Selby, A. D., Ohio Exp. Sta. Buls. 139 and 145, and Rolfs, F. M., Colo. Exp. Sta. Buls. 70 and 91.

The only remedies proposed or practiced for blackleg in Europe consist in selection of sound seed, careful avoidance of rotten tubers or those taken from a diseased crop, attention to rotation of crops, since the germs may persist and accumulate in the soil, and the use of disease-resisting varieties. None of these methods has been tested carefully enough to establish its merits.

The chief evidence as to varietal susceptibilities or resistance to blackleg is that of Appel.[a] He states that while no varieties have been shown to be entirely free from the disease, the evidence is that thick-skinned, starch-rich, late varieties are in general more resistant than thin-skinned, starch-poor, early varieties. The Dabersche he finds to be the most resistant of the widely used German sorts, while the Rose varieties are especially liable to blackleg. Contiguous plats of the Dabersche and White Rose in Doctor Appel's grounds showed this difference very clearly at the time of the writer's visit in July, 1904, the Rose being badly diseased, the Dabersche but slightly. At the Deutschen-Kartoffel-Kultur-Station distinct evidence of variations in disease resistance was found. It was stated at this station that in the trial grounds the red varieties were in general found to be more resistant than the white.

A considerable development of this disease was noticed at the University Farm, Cambridge, England, where extensive variety trials were being conducted. The observations of Mr. H. Henshaw, who had immediate charge of these, were in agreement with those of Doctor Appel as to the association of the disease with the rot of the seed tuber, and he regarded it as a bacterial malady. There was a difference in the amount of the disease on different varieties, but Mr. Henshaw found none wholly free from it. At the time of this visit Factor and Up-to-Date were noticeably freer from the trouble than any other varieties there under trial. They were about alike in this, as, indeed, in all other characters. Doctor Delacroix cited as especially resistant to his bacterial disease in France the variety La Czarine. He also stated that the variety Geante Bleue is resistant, but to a less degree. Laurent observed in his work on bacterial diseases that the maximum of resistance was shown by the varieties Chardon, Pousse-debout, and Chave.

OTHER STEM DISEASES.

Several other potato stem diseases have been reported in Europe, but since the writer did not study them in the field and learned nothing beyond what is recorded in literature they will be passed with brief mention. Prillieux and Delacroix have described another bacterial stem disease in France attributed to *Bacillus caulivorus*. Rhizoctonia is common on potato stems as well as tubers, but none of the patholo-

[a] Arb. aus Biol. Abt. Gesundheitsamte, 3: 408 (1903).

gists conferred with regards it as a parasite of importance on either. Professor Marchal, of Gembloux, said, however, that he sometimes found a basidiomycetous fungus, *Hypochnis solani* Prill.,[a] causing a blackleg-like stem disease in Belgium. Prof. T. Johnson, of Dublin, sent specimens of *Sclerotinia sclerotiorum*, which at times causes a destructive stem disease in Ireland, called "yellow blight." He also reports[b] the occurrence in Ireland of bacterial stem diseases, including what he believes to be the malady termed brown-rot in America and shown by Dr. Erwin F. Smith to be caused by *Bacillus solanacearum*. In none of these cases was anything learned as to relative varietal resistance to the disease in question.

LATE-BLIGHT AND ROT DUE TO PHYTOPHTHORA INFESTANS.

Late-blight and rot due to *Phytophthora infestans* occurs in Europe even more widely and destructively than in America, being recognized as the most important malady in all the countries visited by the writer—Italy, Austria, Germany, Holland, Belgium, France, and the British Islands. There was less unanimity of opinion than was anticipated as to the probable life history of the fungus, and consequently as to the remedial treatment. While all agreed that it lives over in the seed tubers, the opinion was frequently expressed, by scientific and practical men alike, that there is probably some hibernation in the soil, either in tubers left in the field or in the haulms. Possible hibernation in the tubers is to be associated with the fact that potato tubers left in the soil are not killed by frost in southern England and the south of Europe. The value of Bordeaux mixture as a remedy is recognized generally. Spraying is consistently advocated and practiced in the British Islands—especially Scotland and Ireland—the Netherlands, Italy, and portions of France. Germany has been surprisingly backward in accepting or even fairly testing this remedy. The reason seems to be that some of the experiments conducted by scientific men have shown injury to the plants, and so they have pronounced against it. No other remedial treatments are in common use. No one indorsed or practiced any method of seed disinfection. No particular culture methods were advocated or condemned other than attention to fertilization. There was a general agreement that excessive use of nitrogenous fertilizers, either chemicals or composted manures, increases the loss from this disease. Much attention is being given, however, to the relation of varieties and of source of seed to disease resistance, and the results are of sufficient importance to merit the somewhat detailed report which follows.

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[a] Probably identical with *Corticium vagum* var. *solani* Burt, which is the fruiting stage of the common Rhizoctonia of the potato.

[b] Johnson, T., Diseases of the Potato and Other Plants in Ireland, Journal, Dept. Agric. Ireland, III, No. 1 (1902)

RESISTANCE AS SHOWN TOWARD LATE-BLIGHT AND ROT.

HISTORICAL STATEMENT.

Doubtless examination of the earlier writings upon the potato disease known as late-blight and rot would show that from the beginning of its ravages differences have been observed in the resistance of varieties. Any such records of the thirty years from 1845 to 1875 would have no practical value now, since the varieties then in use have passed out of culture; nor would they have much scientific significance, owing to the lack of exact knowledge then as to the cause of disease. Going back to the origin of the varieties still in cultivation, it is found that in the early seventies an unusual amount of attention was focused upon the matter of the potato disease, as to causes and remedies. Ninety-four essays secured by the Royal Agricultural Society of England in 1872 showed agreement that an underlying cause was the degeneracy of the varieties then in culture.[a] The necessity for the production of new varieties was emphasized. The introduction of improved American varieties into England at about this period was most beneficial and stimulating to the potato specialists of that country.[b] These varieties were made the parents in further breeding. The best production of this revival was the Magnum Bonum, originated by James Clark from a cross of Early Rose with Victoria and introduced by Sutton in 1876. Experience with this variety laid the foundation for belief in possible disease resistance in potatoes both in England and on the Continent. Magnum Bonum soon became the standard main-crop variety of Great Britain and so continued until within the last fifteen years, when it yielded to Up-to-Date and others. It is still in considerable favor on the Continent.

Charles Darwin in 1877–78 became interested in the possibilities of disease-resistant breeding. Francis Darwin[c] states that Mr. James Torbitt, of Belfast, bred and selected varieties to secure disease

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[a] See Jour. Roy. Agr. Soc. Eng., XX : 291 (1884).

[b] Dean, A. Potato Improvement in the Past Twenty-five Years. Jour. Roy. Hort. Soc., XII : 41 (1890).

Mr. C. G. Pringle, who was then the foremost potato breeder in America, states that the demand from Europe for new American varieties was very active at that period, and continued until the fear of the Colorado potato beetle led to the prohibition by European governments of further importations of potato tubers from America. Thereupon Mr. Pringle supplied B. K. Bliss & Sons with specially hybridized potato seed, which was sent abroad in considerable quantity.

[c] Life and Letters of Charles Darwin, II, pp. 519–522.

The writer learns from Prof. T. Johnson, of Dublin, that Torbitt has been dead some twenty years. He was in the wine trade and raised varieties of potatoes for the berries, or seed balls, which he used as a source of material for wine. All of his varieties have disappeared except one coarse, red one, which was and is proof against disease.

resistance, his method being to cross-fertilize, rear the seedlings, and expose them ruthlessly to infection, retaining only those showing some degree of resistance. In this work he received much encouragement and some financial aid through Charles Darwin.

A committee of the English House of Commons, reporting in 1880 upon the potato disease, found all its witnesses concurring in the necessity for the production of new varieties with increased disease resistance.[a] Parliament was asked to give financial aid for experiments aiming to produce new and disease-proof varieties, but it did not do this. Earl Cathcart, in commenting on this report, states that—

> All potatoes have deteriorated in their disease-resisting powers. A variety from seed takes four to six years for its establishment, and under the most favorable circumstances a good variety might be expected to degenerate in twenty years. The production of new varieties is of national importance.

Apparently through the influence of Cathcart, Baker[b] was led to make an exhaustive comparative study of the genus Solanum in order to advise as to the relation of the cultivated varieties to the several wild species of the American continent preparatory to breeding experiments in which these might be used. As a result, two species were considered worthy of further trial in the attempt to improve disease resistance, viz, the Darwin potato, *S. maglia*, from the Chonos Archipelago, and the Uruguay potato, *S. commersonii*. Cathcart furnished Sutton with the former and he hybridized it with the common *S. tuberosum*. Sutton[c] reports that, beginning in 1886—

> Although many hundreds of flowers of *S. maglia* were artificially fertilized with pollen from cultivated varieties, only five were successful, resulting in five berries. From these but two seedlings were secured and only one of these showed any promise whatever, the second having to be grown under glass to prevent its dying. * * * This hybrid, although a vast improvement on *S. maglia*, is far behind the ordinary potato in appearance, crop, and quality. The seedling * * * grown for eight years, in 1894 was slightly diseased, although previously free from attack.

Sutton still has the *S. maglia* and this hybrid in propagation at Reading, where the writer saw them in August, 1904. Phytophthora was then more rampant on the foliage of both of these and on *S. commersonii*, which he also has, than on the average potato plants in his fields. No hybrids of *S. commersonii* had been secured by him previous to this. Mr. Lasham, potato specialist for the firm, has been giving renewed attention to the possibilities of species hybridization, and showed the writer balls which he considered to contain hybrid seeds of *S. tuberosum* × *commersonii*.

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[a] Jour. Roy. Agr. Soc. Eng., XX: 291 (1884).

[b] Baker, J. G., A Review of the Tuber-Bearing Species of Solanum. Jour. Linn. Soc., London, XX, 489–507 (1883–84).

[c] Sutton, A. W., Potatoes, Jour. Roy. Hort. Soc., XIX, 387 (1896).

Interest in the possibilities of *S. commersonii* has recently been stimulated by the experiments inspired in France by Prof. E. Heckel,[a] who believes in the economic possibilities of this species when improved by longer culture and perhaps by hybridizing, and has distributed it quite widely in France with this end in view. One French horticulturist, Labergerie,[b] claims already to have succeeded in producing a variety of edible quality, large yield, and superior disease resistance. This was seen growing in the grounds of Vilmorin-Andrieux & Co., at Paris. This firm was not yet convinced of the practical value of the plant, and since Labergerie refuses to send out any of these potatoes for trial at present, judgment must be reserved.

Returning to the consideration of the varieties of the common potato, it is found that during the last decade increasing attention has also been given to their comparative disease resistance. This has been well summarized by Prunet.[c] The main facts developed are as follows: Sorauer[d] in 1896 considered the evidence to date as showing that the highest degree of disease resistance was possessed by Magnum Bonum, the following showing some degree of resistance: Blaue Riesenkartoffel, Richter's Imperator, Athene, Reichskanzler. Rostrup,[e] writing about the same time from Denmark, places Magnum Bonum at the head as a disease-resisting variety, with Richter's Imperator and Champion as somewhat resistant.

In this connection it is noteworthy that Magnum Bonum has yielded its place in popular favor in Great Britain for main-crop purposes to Up-to-Date and other varieties, even while holding its reputation on the Continent. During the last decade these standard varieties in turn have been "running out," and the demand in England for something to take their place has stimulated potato breeders and seed specialists to direct their attention very generally to the development of a disease-resisting main-crop variety. The greatest efforts in breeding have been made during the last four years, while speculation in the most promising of the varieties produced has been at fever heat for the last two years, during which time many new varieties, more or less disease resistant, have been pushed to the front. There are now so many potato specialists in Great Britain breeding and handling varieties of reputed disease resistance that it is impracticable to mention all. Archibald Findlay,

[a] Heckel, E., Sur le *S. commersonii*, Rev. Hort. de la Soc. d'Hort. et de Bot. des Bouches-du-Rhone, No. 581, pp. 200–206 (December, 1902); also, Contrib. à l'étude botanique de quelques solanum tuberiferes, Ann. de la Faculté des Sciences de Marseille, vol. 8 (1895).

[b] Labergerie, M., Le *Solanum commersonii* et ses variations, Bul. Soc. Nat. d'Agric. de France, March, 1904.

[c] Prunet, A., Le mildieu de la pomme de terre, Rev. de Viticult., XVII, 663; XVIII, 97 et seq. (1902).

[d] Zeitsch. f. Pflanzenkr., VI, 284 (1896).

[e] Tidsskrift f. Landbrugets Planteavl, 1895, 1896, 1897.

of Mairsland, Auchtermuchty, Scotland, has originated some varieties of high repute; Sutton & Sons, of Reading, England, have also taken a prominent part in this work. Scotland-grown seed of all the leading varieties can be secured from Thomas Scarlett, of Edinburgh, and Mr. Scarlett has some promising varieties of his own introduction. Anyone desiring more specific information should secure the publications of the National Potato Society from its secretary, Walter P. Wright, Postling Vicarage, Hythe, Kent, England.

Meanwhile the German Potato Station has been making extensive tests, doing some breeding and encouraging several potato breeders.[a] These efforts have not been directed primarily to disease resistance, but the station has taken note of this feature and published the data regarding all varieties tested.

While the results of this work in Europe have been collected or correlated by no one, the writer was able to gather considerable information, in addition to that already referred to, from conversation with potato specialists, especially in Great Britain. This, together with what has been learned in America, is made the basis of the following discussion. It is to be regretted that it is impracticable to give detailed credit in some cases to those who kindly furnished the information.

THE MEANING OF DISEASE RESISTANCE.

Although potato specialists, especially in England, apply the term "disease proof" to their favorite varieties, this is not to be taken literally. No variety has as yet shown itself to be absolutely proof against disease. The writer personally collected leaves infected with the blight fungus from two varieties which were said to be "disease proof." Absolute resistance against the blight fungus has not as yet been and may never be secured. Varieties are known, however, which show a relatively high degree of disease resistance. This may be shown in the delay in date of appearance of the blight on the leaves or its slower progress after appearing, and still more clearly in the relatively small amount of loss from rot of the tubers. Most of the exact observations made in Europe have been based on this latter difference.

DISEASE RESISTANCE AND VEGETATIVE VIGOR.

Disease resistance and vegetative vigor are closely associated, although the factors involved are not necessarily identical. In any consideration of the problems of the life and death of the potato plant it must be remembered that the potato has two natural methods of

[a] The most active of these are Paulsen, Cimbal, Richter, and Dolkowski. Graf Arnim-Schlagenthin, of Nassenheide in Pommern, is an extensive breeder and dealer in new varieties, as is also F. Heine, of Hadmersleben.

reproduction, the true seed produced in the berries or "balls" following the blossoms, and the tubers produced below ground. Reproduction by seed is a sexual process, that by tubers is vegetative. Both are exhaustive of vitality. The two are in a certain sense physiologically opposed to each other and can not well be carried on at the same time by the plant. Under the natural conditions of the wild potato plant in Mexico, and doubtless elsewhere, seed production precedes tuber formation. In Europe and northern America, with a shorter season and intensive culture, the two processes overlap. As a result there is, just after the potato plant comes into blossom, a period when the natural tendencies within the plant toward seed production above and tuber formation below are such as to subject it to unusual physiological stress. This has been termed the "critical period"[a] in the development of the potato plant.

Usually the blossoms fall without the setting of the fruit, and the plant then passes into a stage where its energies are devoted to tuber formation alone. Once well started upon this vegetative period, its growth is more or less indeterminate, i. e., there is no clearly defined natural terminus to the life of the cultivated potato plant. Instead, there is the gradual decline in vegetative vigor which may prepare the way for early-blight and other diseases characteristic of weakling plants. It is noteworthy that the destructive attacks of the late-blight fungus occur, as a rule, after the blossoming period has passed. So far as the evidence goes it seems to suggest that high vegetative vigor enables the plant to ward off in some degree the fungus attack.

There is, moreover, a natural decline in vigor, or "running out," with the age of the variety. The length of life of a variety depends upon numerous conditions, and is an indefinite matter in any case. It is ordinarily placed by potato specialists at from twelve to twenty years. As a variety begins to "run out" it apparently shows, among other things, a lessened degree of general disease resistance. Thus Magnum Bonum had the highest reputation in this respect from its origin in 1876 until about 1890 in Great Britain. On the Continent it has remained longer in favor. Up-to-Date has held a like place during the last decade in Great Britain, and Richter's Imperator has a similar record in Germany. These statements are based upon the popular verdict, not upon exact experiments; but the belief that disease resistance decreases with the age of the variety is firmly established in the minds of specialists in potato culture in Great Britain, at least so far as concerns resistance to Phytophthora.

There is little definite evidence regarding the relation of vegetative vigor to resistance to other diseases, but so far as it is formulated it

[a] See Jones, L. R., Certain Potato Diseases and Their Remedies, Vermont Exp. Sta. Bul. 72: 4 (1899); also The Diseases of the Potato in Relation to Its Development, Trans. Mass. Hort. Soc. (1903), Part I: 144.

favors the general applicability of the idea. The production of berries, or seed balls, is held by some English breeders to be an indication of such vigor, and therefore presumably of disease resistance, although no one claims that the absence of these is equally strong evidence in the opposite direction. It is worthy of passing note that berries are formed much more commonly in Europe, especially in Germany and Holland, than in America, apparently because of climatic differences.

THE RELATION OF HYBRIDITY TO DISEASE RESISTANCE.

By a "new variety" of potato, as the term is commonly used, is meant one recently developed from the seed. Sports may appear and are indeed frequent in some varieties. These will, however, be mentioned later. The seed in all cases presumably represents a sexual origin, i. e., comes from a fertilized flower, but this may have been either self-fertilized or cross-fertilized. One would expect greater vigor to result from the cross-fertilization, and potato breeders are of the opinion that it is secured. On the other hand, while varieties recently originated from seed may show a high degree of disease resistance, this is not necessarily the case according to the verdict of English and German breeeders, many new varieties proving as susceptible as old ones.

Reference has already been made to the work of Cathcart and Sutton in England and of Heckel and Labergerie in France based on the hope of advantage from using one or another of the wild Solanums for such hybridizing. There are interesting possibilities along this line, since there are many wild forms of *S. tuberosum* in addition to other species of tuberiferous Solanums. Thorough trials of these are now being made by Stuart[a] at the Vermont Experiment Station which will be reviewed later in this paper. It should be emphasized at once, however, that while the use of the wild Solanums does offer interesting possibilities, there is no record of practical success from their use, if we except the doubtful one of Labergerie's variety of *S. commersonii* previously referred to. On the other hand, great practical improvements have been secured by various breeders from crossing varieties of cultivated potatoes.

IMPROVEMENT BY SELECTION.

All plants tend to vary. One of the commonest ways to improve plants is by selection from among the varying individuals. For the first two years after their origin, variants, or "rogues," are not uncommon with the seedling potato, but the variety is "fixed" by the weeding of such rogues before it is distributed for general culture, and

[a] Stuart, W., Disease-Resistant Potatoes, Vermont Exp. Sta. Bul. 115 (May, 1905).

thereafter very little variation occurs. Some modification is to be expected, nevertheless, and among other things there may be variation in disease resistance. It seems worth while, therefore, to keep a lookout for individual plants which show especial resistance to the blight when this is epidemic about them. The tubers of such individuals deserve to be carefully saved apart and planted, in order that it may be seen whether their resistance is a fixed and inheritable character or the result of some chance difference in environment. Such selection has already been undertaken by three persons to our knowledge: Appel in Germany,[a] Stuart in Vermont,[b] and Fraser in New York;[c] but no practical results have as yet been secured.

ARE EARLY OR LATE VARIETIES THE MORE RESISTANT?

The blight never becomes serious until the midseason of potato growth is passed; thus in our Northern States its worst ravages come in August and September. Therefore early varieties, as a rule, escape. But this is simply because they mature before the blight is epidemic. So far as evidence has been secured, both in America and Europe, when the early varieties are planted late enough to expose them to the disease alongside of the later ones, the early varieties as a class suffer the worst. For example, the most complete destruction by rot which the writer ever saw was with a late crop of Early Ohio potatoes attacked by the disease in September. Woods,[d] of Maine, has also found early varieties especially susceptible.

RELATION OF SOURCE OF SEED AND CULTURAL METHODS TO DISEASE RESISTANCE.

The opinions of highly intelligent potato growers in Great Britain are especially worthy of note. One of the first concerns with them is the source of their seed. Mention has already been made of the experiments at Sutton's grounds, showing the superiority of northern-grown seed. It was found to be the general verdict of practical men in Europe that northern-grown seed is more highly disease resistant, as well as more productive. If one is to aim for the best results in health of crop, therefore, attention should be directed to quality and source of seed as well as to variety.

Practical men as well as scientists generally agree that methods of culture also determine to a considerable degree liability to disease. These act not only indirectly as they affect moisture content or other physical conditions of the soil, but more directly as they affect the

[a] Appel, Otto. Die diesjährige Phytophthora-epidemie, Deutsche Landw. Presse, XXIX: 685 (1902).

[b] Vermont Exp. Sta. Bul. 115, p. 139.

[c] Reported in correspondence.

[d] Woods, C. D., Maine Exp. Sta. Rpt., XIX: 181 (1903).

vigor or inherent disease resistance of the plant itself. Seed dealers in this country, as well as in England, have also expressed a preference for seed from a crop that has not been very highly fertilized, especially with nitrogenous manures. The most detailed study along this line is that of Laurent,[a] whose results indicate that nitrogenous fertilizers predispose both the foliage and the tubers of the plants to the attacks of Phytophthora. This is in harmony with the general opinion of practical potato growers, that high manuring increases the liability to disease.

COMPOSITION AND CHARACTER OF TUBERS AS RELATED TO ROT RESISTANCE.

There is considerable evidence that the chemical composition of the tubers bears a direct relation to resistance to rot. Paulsen[b] claimed that varieties rich in nitrogen compounds are less resistant to disease than those rich in starch. He classed most of the early varieties in the first category and found the larger percentage of the second class to be of the late varieties. The table varieties of better quality were also of the first category.

Petermann[c] has recently made field and laboratory studies at the Belgium Experiment Station. These led him to practically the same conclusions, viz, (1) that varieties richer in amids are more liable to rot, although of superior table quality; and (2) that varieties relatively richer in starch, including several recently originated German factory varieties, are less liable to rot but are of inferior quality for table use.

Sorauer[d] has published similar conclusions, and he made more detailed statements as to his belief on this point in conversation last summer. In general, he believes that the varieties richer in protein are more liable to disease, while those richer in starch are more resistant. This probably explains his observation that the yellow-fleshed varieties, which are in higher repute in Germany for table use, are more liable to disease[e] than the white-fleshed varieties which are grown for factory purposes. His further observations in harmony with this idea are that the thicker and rougher skinned red varieties[f]—e. g., Daberscheн—have a higher degree of disease resistance, coupled with relatively high starch and low protein content, whereas the thin-skinned white varieties, which are more liable to the disease, have

[a] Laurent, Recherches exp. sur la mal. des plantes, Ann. Inst. Past., XIII, pp. 1–48 (1899).

[b] Biedermann's Centralbl. Agr. Chem., 1887, p. 107.

[c] Bul. Inst. Chim. et Bact. Gembloux, 70 (1901).

[d] Jahresber. d. Sondersausschen. f. Pflanzensch., XII and XIII (1902 and 1903).

[e] See evidence of this also in Jahresber. d. Sondersaussch. f. Pflanzensch., XIII, 1903.

[f] See also statement that red varieties are in general more resistant; Jahresber. d. Sondersaussch. f. Pflanzensch., XII, 1902.

proportionately less starch and more protein. As a rough empirical test he considers that if, when a fresh tuber is cut open, the flesh browns quickly on exposure to the air and the vascular bundles darken soon, it is evidence of high protein content, and therefore of liability to disease, whereas the reverse condition is evidence of probable disease resistance. Professor Sorauer also emphasized to the writer his belief in the relation of soil, manuring, or other cultural condition to disease resistance. The testimony secured elsewhere in Germany, as well as from American sources, is in harmony with these ideas so far as it goes.

While character of skin is probably a less reliable index to rot resistance than is chemical composition, yet the writer has learned of several potato experts in America, as well as others in Europe, who regard the red varieties, especially such as have a rough skin, as less liable to rot than are the white thin-skinned varieties. The Dakota Red has often been cited as an example of this class in America. Abundant evidence can be found, however, especially from English experience, of high disease resistance coupled with a thin, white skin. Breeders aiming at disease resistance need not turn from the white-skinned varieties.

CHARACTER OF STEM AND FOLIAGE AS RELATED TO DISEASE RESISTANCE.

In connection with the question of the relation of the character of the stem and foliage to disease resistance it is not safe to go far in generalizing. Mr. Lasham, potato expert and breeder with Sutton & Sons, considers that a stem that is strong, rough, and hard, almost woody at the base, is an important character if the plant is to be most highly disease resistant. The nature of the foliage is considered by others to be of greater importance, the preference being for small leaflets, rough and relatively thick rather than large and flabby. A rich dark-green is preferred to the lighter colored foliage. It seems inherently probable that the character and color of foliage should stand in close relation to the other matters which have with more certainty been shown to be related to disease resistance, viz, general vigor and capacity for starch manufacture. Those giving further attention to disease resistance may, therefore, well bear these suggestions in mind.

DISEASE-RESISTANT VARIETIES OF EUROPE.

When all the factors are considered, two important things become evident: First, that no variety will maintain its disease-resistant qualities indefinitely, losing them sooner in one locality than in another; second, that no one variety will be equally disease resistant in all countries, i. e., what is best suited to one may not be to another.

Hence we must expect much conflicting evidence regarding the same variety, especially as grown under different conditions and in different countries.

The most satisfactory way will be to summarize separately the evidence obtained in each country visited in Europe, followed by that from America.

The greatest activity in breeding for resistance occurs in Great Britain, and next to this in Germany, while France has recently shown special activity in one line. There were secured from each of these countries all the varieties of especial promise for trial in America—comprising a total of nearly one hundred. By no means all of these have an established reputation as being highly disease resistant, although all will be tested for this as well as other characters.

Experience has shown that the transference of a variety from Europe to America, or the reverse, is likely so to disturb the equilibrium of the plant that the developments of the first year are scarcely normal. At least two years are necessary for the adequate testing of imported varieties. Commercial growers should therefore make only trial plantations of any European variety until its adaptability to American conditions has been proved. Seed of the varieties secured will be under trial at several points this season and next. While it does not seem worth while to publish the full list of these in advance, the following are selected as representing the varieties or types most strongly indorsed in their respective countries for disease resistance.

GREAT BRITAIN.

More attention has been given to this question in Great Britain than anywhere else. Careful comparative observations are recorded as to the relative disease resistance of all the leading varieties. The last report of the National Potato Society specifies the following eight varieties as the best for disease resistance, named in the order of their merit. The writer appended certain facts as to the origin and characters of each. All are white skinned, white fleshed, of excellent quality, of high general vigor, and heavy yielders.

TABLE I.—*The most disease-resistant varieties of potatoes in Great Britain, as announced by the National Potato Society.*[a]

Order of merit.	Name of variety.	Originator.	When sent out.	Season.
1	Evergood	Findlay	1896	Medium late.
2	Discovery	Sutton	1903	Late.
	Royal Kidney	Findlay	1896	Second early.
3	Northern Star	do	1901	Late.
4	Sir John Llewelyn	Harris	1900	Early.
5	King Edward VII	Butler	1901	Medium.
6	Eldorado	Findlay	1903	Medium late.
7	Factor	Dobbie	1898	Late.

[a] Annual Report, National Potato Society, I: 36 (1904).

Two points brought out by the foregoing table are worthy of especial note: First, the remarkable success of one man in producing four of these eight varieties, showing that there is something more than chance in their development; second, the comparatively recent origin of all. For the latter fact there is probably a double explanation: (1) The loss of disease resistance with age of the variety; (2) the remarkable activity of British potato breeders during the last few years, with the aim above all else of securing increased disease resistance.

It should be remarked that there are a number of more recent introductions which promise to rank with the best of these varieties, but they have not as yet been so fully tested.

GERMANY AND HOLLAND.

The potato-growing industries of Germany and Holland have much in common, and similar or identical varieties are used. Data were not available for making so definite a selection as in Great Britain. The following are probably representatives of the highest grade of disease resistance achieved:

TABLE II.—*The most disease-resistant varieties of potatoes in Germany and Holland.*

Name.	Originator.	Season.	Color of skin.
Mohort	Dolkowski	Late	White.
Irene	Paulsen	Medium late	Red.
Geheimrat Thiel	Richter	do	White.
Professor Wohltmann	Cimbal	Late	Red.
Boneza	Dolkowski	Medium late	Do.
Eigenheimer	(Holland)	Medium early	White.
Paul Krüger	do	Late	Do.

The first five varieties have been imported from Germany. All of these are of the white-fleshed, starch-rich type which is being developed there primarily for factory rather than for table use. They are, however, reputed to be of fair quality except, perhaps, in the case of Irene. These, like the British varieties, are of comparatively recent introduction.

The Holland varieties are of a similar type except that Eigenheimer has a yellowish-tinted flesh.

FRANCE AND BELGIUM.

The conditions are similar in France and Belgium. Neither country has varieties of much promise for trial in our Northern States. In Belgium the varieties recommended as being most highly resistant to blight and rot were the recently originated German factory types like those already mentioned, to which might be added Topas and Professor Maercker. The verdict in France was similar, Professor Maercker again being commended, along with the English varieties

Magnum Bonum and Royal Kidney. The indorsement of these comparatively late, white-fleshed, starch-rich potatoes in France and in the other continental countries is the more significant when one remembers that the chief aim with potato specialists there is to produce the yellow-fleshed potato rich in protein.

DISEASE-RESISTANT VARIETIES OF AMERICA.

Until two or three years ago no systematic attempt was recorded, so far as the writer has learned, to determine the relative resistance to blight and rot of potato varieties in America. Of course this would not imply that individual growers have not observed these differences, but they are rarely matters of record, and as a rule are based only upon limited observations. Only two or three potato-seed dealers are advertising disease-resisting varieties with any prominence this year, and these are in all cases comparatively new and little-tried sorts.

INVESTIGATIONS AT THE EXPERIMENT STATIONS.

Promising investigations have been inaugurated at several of the State agricultural experiment stations which should soon supply data for more reliable conclusions than are now possible. Woods,[a] of the Maine station, and Green,[b] of the Minnesota station, have each reported results of variety trials as to disease resistance.

Woods found a marked difference in the ability of varieties to withstand both blight and rot. As a rule the earlier varieties were soonest attacked. The variety Rustproof showed the highest degree of foliage resistance and also the least rot, viz. only a little more than 1 per cent, whereas the average of all varieties under trial was more than 30 per cent.

Green found that the loss from rot varied widely with varieties, ranging from 1 per cent in the most resistant to 40 per cent in the least resistant types. Potatoes of the type of Sir Walter Raleigh and Rural New Yorker resisted rot better than those of any other class. Of the 49 varieties tested, only two, Clay Rose and an unnamed seedling, were practically free from rot. These trials will be continued.

Observations on disease resistance have also been made by Macoun at the Central Experimental Farm, at Ottawa, Canada. He has kindly advised the writer, in correspondence, of his conclusions. The following varieties have shown especial disease resistance as judged by appearance of blight on the foliage: Holburn Abundance and Professor Maercker are most resistant, with Swiss Snowflake, State of Maine, and Rural Blush only a little less so.

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[a] Woods, C. D., Maine Exp. Sta. Report, XIX: 181 (1903).

[b] Green, S. B., Potatoes at the University Farm, Minn. Exp. Sta. Bul. 87 (1904).

WORK AT THE VERMONT STATION.

The most extensive work on potatoes has been done by Stuart, who two years ago inaugurated at the Vermont station variety trials as to disease resistance, supplemented by breeding experiments. Professor Stuart has kindly supplied the following summary of his results to date:[a]

Eight varieties were under trial in 1903—Dakota Red, Enormous, Green Mountain, Rustproof, Squire, Sir Walter Raleigh, and two of Manum's unnamed seedlings. In 1904 the same varieties were used, with the addition of June, Mammoth Gem, Minister, New Queen, State of Maine, Sutton's Discovery, nine more of Manum's seedlings, *S. commersonii* from Doctor Heckel, of France, a Peruvian variety from the United States Department of Agriculture at Washington, and four Mexican varieties furnished by Mr. C. G. Pringle. The latter included two cultivated varieties termed Monterey and Mexican, and the two wild species, *S. polyadenium* and *S. stoloniferum*. Observations have been made as to both foliage and tuber resistance. As to foliage, none was wholly free from blight, but there was a marked difference, some being quickly and entirely destroyed, while others suffered only slightly. In 1903 Rustproof headed the list in this respect, and Dakota Red was second. In 1904 those showing greatest foliage resistance were as follows, in the order of their resistance: Monterey, *S. commersonii*, *S. polyadenium*, Rustproof, Sutton's Discovery, June, Mexican, Mammoth Gem, and Manum's No. 3. Dakota Red did not equal its 1903 record.

Judged by resistance of tubers to rot, Dakota Red made the best showing of the varieties which were tested for two seasons, but there was some rot in it both years. Of those added to the series of 1904 several varieties gave a crop of tubers entirely free from rot, namely *S. polyadenium*, *S. commersonii*, Sutton's Discovery, June, and the two Mexican varieties. It is noteworthy that these are likewise the varieties which showed the least blighting of the foliage. Possibly the absence of rot is in some degree attributable to the lessened amount of infection of tubers from vines in consequence of this, although there were adjacent plants showing badly diseased foliage.

Selection.—In 1903 a few plants in the varieties grown were observed to remain green longer than the others. The tubers from these were saved and were planted in 1904 along with others of the same variety that succumbed much earlier. So far as could be noted no increased disease-resistant qualities were transmitted to the offspring of these plants.

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[a] For further details see Stuart, W., Disease-Resistant Potatoes, Vermont Exp. Sta. Bul. 115 (May, 1905).

In view of the limited number of varieties tested and the consequent restricted scope of observation, it would hardly be justifiable as yet to give an expression of opinion as to the probable outcome of such a line of investigation. These observations are to be continued on a much larger scale the coming season.

Hybrid and other seedlings.—Seedlings were grown in 1903 from the Mexican species supplied by Mr. Pringle—*S. polyadenium*. *S. stoloniferum*, and *S. bulbocastanum*. This number has recently been augmented by *S. verrucosum* and a wild form of *S. tuberosum*. In 1904 some of these were successfully hybridized with the cultivated potato.

While it is yet too early to say very much regarding the possibilities of developing a commercially desirable disease-resistant variety of potato through the hybridization of wild species with our cultivated varieties, there seems good reason for believing that improvement may result from such crossing, especially as to disease resistance.

In addition, a large number of seedlings of the common potato were grown in 1904. Among this number several vigorous-growing plants were noted, which remained quite green up to the time of digging. Some 50 of the more promising of these were saved for trial the coming season. Selections were based on vigor of vine, size and yield of tubers, and freedom from rot.

One of the most interesting and instructive features of the seedling experiment was the object lesson it presented of the extreme vigor of some of the plants, showing quite plainly that one of the best sources for increasing the vigor lies in the production of new varieties from seed. Proper fertilization and good tillage are also important aids in increasing the vigor and disease-resisting powers of the vine.

While the data in hand do not warrant broad generalizations, the following inferences are drawn by Professor Stuart:

(1) Some varieties are less subject to vine injury than others.

(2) Some show a greater tuber resistance to rot than others.

(3) With some there seems to be a fairly close relation between resistance of vine to disease and of the tuber to rot.

(4) Selection has not given visible increase of resistance.

(5) Hybridization and the growing of seedling plants, followed by careful selection, seem to offer a more logical method of securing disease-resistant varieties than does selection.

INFORMATION SECURED BY A CIRCULAR OF INQUIRY.

In order to secure all information possible as to the relative merits of the varieties now before the public, a circular letter of inquiry was sent recently to various experiment station officers and to about two hundred potato specialists in the United States and Canada[a] asking their opinions and the basis for them. There was a surprising lack of agreement upon any one variety as being especially disease resistant. The replies indicate several things: (1) That very few American potato specialists have up to the present time given careful attention to this question; (2) that there are few varieties in common use which have preeminent worth as disease resisters; and (3) that in so large a geographical area local conditions affecting culture and disease are so widely variant as to prevent close comparisons or broad generalizations. No less than 38 varieties were commended as showing resistance to blight or rot. Of these, 26 were commended only once, while the other 12 were favorably spoken of by two or more persons. Still other varieties were mentioned, but not with sufficient positiveness to entitle them to a place in the following list. Those named more than once, with the locality in which they were indorsed, are as follows:

TABLE III.—*The best varieties of potatoes in the United States and Canada, as reported by various experiment station officers and potato specialists.*

Variety.	Number of indorsements.	Localities in which commended.
Dakota Red	10	Canada (4); Maine (3); Massachusetts; Michigan; New York.
Irish Cobbler	5	New York (2); Maine; Ohio; Rhode Island.
Green Mountain	5	Maine (2); Massachusetts (2); Vermont.
Doe's Pride	3	Maine (2); Michigan.
Norcross	3	Maine; New York; Vermont.
White Beauty	2	Maine; Minnesota.
Professor Maercker	2	Canada; Rhode Island.
Ionia Seedling	2	New York.
Quick Lunch	2	Pennsylvania; Vermont.
Rustproof	2	Vermont.
Sir Walter Raleigh	2	Minnesota; New York.
Vermont Gold Coin	2	Pennsylvania; New York.

The following varieties were mentioned once each, the commendation coming from the locality mentioned in parentheses: American Wonder (Minnesota); Babbitt (Maine); Bonanza (New York); Boss (Vermont); Buffalo (Maine); Burbank (New York); Cambridge Russet (New York); Carmen No. 3 (Ohio); Clarke's Pride (Maine); Clay Rose (Minnesota); Crines Lightning (New Jersey); Delaware (Minnesota); Enormous (New York); Gem of Aroostook (Rhode Island); Gloria (Rhode Island); Harris Snowball (New York); Holborn Abundance (Canada); Imperial Mills Prize (Maine); Keeper (New Hampshire);

[a] The writer is indebted to the following experiment station officers for helpful advice: Professors Macoun, Canada; Woods, Maine; Rane, New Hampshire; Stuart, Vermont; Brooks, Massachusetts; Wheeler and Adams, Rhode Island; Fraser and Stewart, New York; Buckhout, Pennsylvania; Halsted, New Jersey; Selby, Ohio; Taft, Michigan; and Green, Minnesota. Much information has been secured from the replies of leading potato growers and seed dealers. It is regretted that it is impracticable to give detailed credit to these correspondents.

Professor Kuehn (Rhode Island); Million Dollar (Michigan); Orange Blossom (Vermont); Rural New Yorker No. 2 (Vermont); Scabproof (Wisconsin); Squier (Vermont); Star of the East (Maine); State of Maine (Canada); Swiss Snowflake (Canada); Virgirosa (Vermont); Westfield (Vermont); White Scotch King (Minnesota). In addition three unnamed varieties received favorable mention from Vermont.

From these reports it is observed that certain varieties like Dakota Red, Rustproof, and Keeper have very well proved powers of disease resistance, but lack other desirable characters to make them popular varieties. Several of the standard main-crop varieties are in some degree disease resistant, and doubtless owe their general popularity, in a measure, to this fact, although it has not been clearly defined. To this group belong Carmen's best productions—Carmen No. 3, Sir Walter Raleigh, Rural New Yorker No. 2, and Rural Blush—Green Mountain, State of Maine, Delaware, Enormous, and White Beauty. Irish Cobbler is highly spoken of as disease resistant, but it is a question whether this may not be in part due to its early maturity, by virtue of which it escapes the worst ravages of Phytophthora.

There is also a very promising series of new seedlings which should be carefully watched as to disease-resisting characters, among which may be especially mentioned Norcross, Star of the East, and Babbitt (Johnson Seed Company); Vermont Gold Coin (Burpee); Ionia Seedling (Dibble); Harris Snowball (Harris & Co.).

It is encouraging to learn from the replies that several of the newer German and English varieties which are reputed disease resisting in their home countries have upon trial in America made a good showing. This is evidenced by the reports from the Rhode Island and Canada stations favorable to Professor Maercker, Gloria, Professor Kuehn (German), Holborn Abundance (English), and Swiss Snowflake.

RESISTANCE TO SCAB.

It is a matter of common observation that some varieties of potatoes are more liable to scab than are others. Reference has been made earlier in this publication to conclusions to this effect reached in Germany. So far as known the only American publication recording the results of comparative trials as to scab resistance is that made by the Vermont Agricultural Experiment Station in 1901–2.[a] Thirteen varieties were tested in 1901 and fourteen in 1902 in soil badly infested with scab germs. While all showed some scab, there was a considerable difference in the amount. Sir Walter Raleigh made a good showing both years, but an unnamed seedling sent by Mr. A. E. Manum, his No. 56, was more highly resistant. These trials established the writer's confidence that still more resistant strains may be secured by

[a] Jones, L. R., and W. J. Morse. Vermont Exp. Sta. Report, XV: 225 (1902).

breeding and selection. Prof. William Stuart, of the Vermont station, has undertaken this work in connection with the development of resistance to blight and rot.[a] He has made further trials during the last two years, but without conclusive results as yet.

A request for information as to relative scab resistance was inserted in the circular of inquiry, already referred to, recently sent to American potato specialists. Most of the replies to this question were negative in character, but a number gave interesting information, some of which is especially pertinent. The strongest evidence as to scab resistance comes from Mr. Hiram Presley, of Port Huron, Mich., a potato specialist, who has tested hundreds of varieties during the past thirty years. He commends the Cambridge Russet as practically exempt from scab. Mr. Frank Paddock, of Perry, N. Y., gives like evidence.

Carmen No. 3 is highly spoken of as scab resisting by several growers in Ohio, New York, and Vermont, but one Michigan correspondent condemns it.

American Giant receives strong indorsement from Freehold, N. J., and vicinity; Salzer's Scabproof from Wisconsin, and Aurora from Vermont. Favorable reports come from New York regarding Sir Walter Raleigh and Irish Cobbler, and from Canada regarding McIntyre.

The following were each commended by one correspondent from the localities mentioned in parentheses: Best (Maine); Doe's Pride (Maine); Early Freeman (Ontario); Keeper (New Hampshire); Seneca Beauty (Michigan); Squier (Vermont); White Beauty (Michigan); White Elephant (New Jersey); White Scotch King (Minnesota).

On the other hand, the Early Ohio and some of its seedlings are condemned as especially liable to scab. Early Rose, Bliss Triumph, and Beauty of Hebron are also reported to scab badly.

It is encouraging to note that in some cases the same variety is rated as in a high degree resistant to both diseases, the scab and the late-blight and rot. A similar coincidence will be found if a comparison is made of the lists of German varieties showing resistance to the several diseases discussed earlier in these pages, and the same thing was observed in some degree with the English varieties.

This indicates that the attributes which give power of resistance against one disease are not incompatible with those operative against another. Indeed, it is not unlikely that the general characteristics of disease resistance may prove to be similar or the same for these various maladies. If so, it will prove the easier to secure the model potato, which, while possessing that which is desirable in quality and productiveness, shall, in addition, show the highest degree of resistance to the various diseases. This is an ideal worth striving for.

[a] Vermont Exp. Sta. Bul. 115, p. 139.

SUMMARY.

The aim of this bulletin is to present in concise form what is known about disease resistance of potatoes. Much of this information is from European sources.

Certain minor diseases of obscure nature, but apparently nonparasitic, are first considered—the internal brown spot, filosité, and leaf-spot. Among remedial measures for each is the selection of resistant varieties.

Scab diseases of tubers are in most, and perhaps in all, cases of parasitic origin—fungous or bacterial. Apparently the variety of these is greater in Europe than in America, but the severity is less in Europe. It is undecided to what extent the American type of scab occurs in Europe, so a close comparison of conditions and remedies is not practicable. In Germany certain varieties are known to be more scab resistant than others, among them being Richter's Imperator, Professor Wohltmann, and Irene. The same is true in America, Cambridge Russet leading the list, so far as is known. Other American varieties showing a considerable degree of resistance are Carmen No. 3, American Giant, Sir Walter Raleigh, and Irish Cobbler. Scabproof and Aurora are also highly commended for scab resistance.

Various stem diseases of the potato are known. The commonest type in Europe is termed blackleg (Schwarzbeinigkeit), a bacterial disease. It is not known to occur in America, but it resembles certain maladies which do occur here and which are as yet imperfectly understood. Varietal resistance to blackleg is not fully established, but apparently Dabersche and certain similar thick-skinned, starch-rich late varieties are more resistant than thin-skinned, starch-poor early varieties of the Rose type. Factor and Up-to-Date showed a considerable degree of resistance to blackleg in England. La Czarine and other varieties are reported to show resistance to a bacterial stem disease in France.

The late-blight and rot due to the fungus *Phytophthora infestans* occurs more commonly in Europe than in America. Attention has been given for many years to relative varietal susceptibility to this disease, especially in Great Britain and in Germany. Varieties of superior disease resistance are known in both countries, and a number of the most promising from these and other European sources have been imported for trial.

The following statements are tentatively formulated as to the nature of resistance toward blight and rot and the character of the varieties exhibiting it:

(1) Disease resistance in potatoes is relative, not absolute, no variety known being wholly proof against late-blight and rot.

(2) It seems related to general vegetative vigor, and is therefore in a measure dependent upon cultural and developmental conditions and tends to decrease with the age of the variety.

(3) It can be restored by originating new varieties from seed, especially of hybrid origin. Not all seedlings show superior disease resistance.

(4) The use of other species of tuber-bearing Solanums for hybridizing offers some promise, but no practical results have yet been secured.

(5) Possibly the disease resistance in established varieties can be improved by selection, but this has not been proved.

(6) Early varieties may escape the disease by maturing before it becomes epidemic, but when similarly exposed they are as a class less resistant than late varieties.

(7) The source of seed tubers is a matter of importance, northern-grown seed giving plants of superior disease resistance in Europe. Seed from a crop that was not too highly fertilized is probably preferable. Possibly tubers are better for seed purposes if dug before they reach full maturity.

(8) High fertilization, especially with nitrogenous manures, lowers the power of the plant to resist both blight and rot.

(9) Varieties relatively rich in starch are more resistant to rot; those richer in protein are more susceptible to it.

(10) So far as skin characters are an index, the red varieties with thick and rough skin seem more resistant as a class than the thin-skinned white varieties.

(11) So far as stem and foliage characters are concerned, the evidence favors the stem that is hard, rough, and rather woody at the base, and the leaf that is small, somewhat rough, and dark colored.

The varieties rated highest as to disease resistance in England are Evergood, Discovery, Royal Kidney, Northern Star, Sir John Llewelyn, King Edward VII, Eldorado, and Factor.

In Germany and Holland the following represent the best types: Mohort, Irene, Geheimrat Thiel, Professor Wohltmann, Boneza, Eigenheimer, and Paul Krüger.

In Belgium and France no improvement as to disease resistance has been made over the best English and German types.

In America, trials as to disease resistance have been conducted at some of the experiment stations, notably in Vermont, where experiments in breeding and selection for increased resistance are under way. These results have been correlated with information recently secured by a circular of inquiry addressed to a large number of potato specialists in the Northeastern States and in Canada. From these it appears that a wide variation is shown in disease resistance among the varieties now in cultivation in America, but that no one variety is preeminent.

Among those which have been widely tested, the following deserve mention as of the resistant class: Dakota Red, Rustproof, Irish Cobbler, Sir Walter Raleigh, Doe's Pride, and White Beauty. Certain European varieties of the disease-resistant type seem to retain that character when grown in this country, e. g., Professor Maercker and Sutton's Discovery. There is much of promise in certain new varieties under trial at the Vermont station. Several new sorts of reputed disease resistance have recently been placed on the market by American seedsmen, e. g., Harris's Snowball, Dibble's Ionia Seedling, Burpee's Vermont Gold Coin, and Johnson's Norcross, Star of the East, and Babbitt. Those having opportunity should carefully observe the relative disease resistance of these and also of other new varieties.

The evidence at hand seems to justify the hope that the coordinated efforts of potato specialists working from both the practical and the scientific standpoints may soon result in the development of varieties of potatoes combining general excellence with a high degree of disease resistance. All who can do so are urged to aid toward the accomplishment of this end.

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VALLEY AT SECANQUIM, ALTA VERA PAZ, GUATEMALA, THE SCENE OF EXPERIMENTS WITH WEEVIL-RESISTING COTTON.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 88.

B. T. GALLOWAY, *Chief of Bureau.*

WEEVIL-RESISTING ADAPTATIONS OF THE COTTON PLANT.

BY

O. F. COOK,

Bionomist in Charge of Investigations in the Agricultural Economy of Tropical and Subtropical Plants.

Issued January 13, 1906.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1906.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., September 26, 1905.

Sir: I have the honor to transmit herewith a report on "Weevil-Resisting Adaptations of the Cotton Plant," and to recommend it for publication as Bulletin No. 88 of this Bureau. This report has been prepared by Mr. O. F. Cook, bionomist in charge of investigations in the agricultural economy of tropical and subtropical plants. It contains an account of his observations and experiments which show that some of the varieties of the cotton plant have definite weevil-resisting characters. The establishment of these facts opens new and unexpected lines of approach to cultural solutions of the weevil problem.

The investigation of cotton referred to in this report was begun in March, 1904, through the Laboratory of Plant Breeding, there having been set aside for it from the emergency cotton boll weevil appropriation a part of the funds which had been devoted to the breeding of weevil-resistant cotton. The existence of a field culture of cotton in the presence of the boll weevil had been ascertained by Mr. Cook during a visit to Guatemala in 1902, and it was hoped that the immunity of the cotton might prove to be due to some weevil-resistant quality.

The first result of detailed observations was the discovery of the weevil-eating kelep or so-called Guatemalan ant, which has been made the subject of previous reports through the Bureau of Entomology. It now appears that the usefulness of this insect is not limited to the boll weevils which it catches and kills. By making a regular field culture of cotton possible in the presence of the boll weevil it has contributed in an important manner to the development of the weevil-resisting characters here described. The cotton plant, it seems, has been greatly modified in protecting itself against the ravages of its insect enemy. Not only has it attracted the kelep to its service and developed other means of defense which are more direct. but even the lint, on the peculiar character of which the commercial value of the crop depends, appears to find its chief use to the plant in excluding the weevil larvæ from the seed. Our Sea Island and Upland varieties have been raised for long periods in regions where the boll weevil did not exist and, as was to have been expected, are largely lacking in protective features. The Kekchi cotton, on the other hand, which has continued its development in a weevil-infested region under the protection of the keleps, has by far the largest number of weevil-resisting characters.

The fact that weevil-resisting adaptations really exist, as shown in numerous instances in the present report, emphasizes the necessity of a thorough study of our cultivated cottons for the purpose of taking advantage of any and all protective characters.

It is possible, as Mr. Cook suggests, that the Guatemalan variety of cotton which he has discovered, and which has such a surprising number of weevil-resisting adaptations, may not prove suited to cultivation in the United States, but even in that case the value of the present paper on weevil-resisting characters would not be diminished, for it will serve as a help to all who may engage in seeking and developing such characters in the types of cotton now cultivated in our country.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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WEEVIL-RESISTING ADAPTATIONS OF THE COTTON PLANT.

INTRODUCTION.

The fact that Central American varieties of cotton have developed weevil-resisting adaptations has already received preliminary notice.[a] A third visit to Guatemala, in the spring of 1905, has given opportunity for further studies of the protective characters of the native varieties and for comparing them with the types of cotton now cultivated in the United States. For this purpose plantings of Upland and Sea Island varieties have been made in Guatemala, and as the season advanced other tests of the Guatemalan and United States varieties were arranged under very different climatic conditions in Texas and at Washington.

These opportunities of comparative observation have revealed a series of protective adaptations of such number and nicety as to furnish a unique and well-nigh incredible instance of selective development. The statement of the former paper may be repeated with emphasis, that the presence of the weevil-eating kelep has enabled the Indians of eastern Guatemala to maintain since very ancient times field culture of cotton in the presence of the weevils, with the result that there has been developed a dwarf, annual, short-season variety with numerous features which, in the absence of sufficient numbers of keleps, afford material assistance in protecting the crop against the ravages of the weevil.

Whether this Guatemalan cotton can be made of direct use in the United States or not, it demonstrates the existence in the cotton plant of weevil-resisting characters. The new variety has lint of good length and quality, so that its utilization in the United States depends upon its adaptability to our climate and methods of culture.

As already explained in publications devoted to the kelep, the weevil-eating propensities of that insect were discovered in 1904 during a visit to Guatemala which had been undertaken in the hope of finding a weevil-resisting variety of cotton. It had been observed

[a] Cotton Culture in Guatemala. Yearbook of the United States Department of Agriculture for 1904, 475–488; Science, N. S., 20: 666–670. November 18, 1904.

two years before that a field of dwarf cotton cultivated by the Indians did not suffer from the boll weevils, though these pests were abundant on a "tree cotton" a short distance away.

The kelep afforded an entirely unexpected and yet very striking explanation of the fact that cotton was being grown as a regular field crop in a region which had probably been infested with weevils for many centuries, if it were not, indeed, the original home of the species. That there was an insect in existence specially qualified by structure and habits to attack, disable, and devour the boll weevil, was welcome news in the United States, and in accordance with cabled instructions from the Secretary of Agriculture numerous colonies of the keleps were brought home and colonized in the cotton fields of Texas.

The finding of the kelep explained the failure of the weevils to prevent cotton cultivations in eastern Guatemala, and seemed at first to diminish the prospects of weevil resistance in the cotton itself. Nevertheless, the intention of studying Guatemalan varieties of cotton and the cultural methods in use in that country was not abandoned, and the results are not without bearing on the original question of the causes of the apparent immunity of the Guatemalan cottons, and also upon the more practical question of securing cotton varieties and cultural methods by which the injuries of the boll weevil in the United States may be reduced to a minimum.

The Guatemalan cotton protected by the keleps is a genuine Upland variety, very early and productive, with a fiber of good length and texture, as already stated. In addition to features which directly favor the keleps, it has many other qualities which may render it useful, even without its insect guardians. In former reports it has been compared with the very early Upland varieties, such as King and Parker; but comparative tests made in eastern Guatemala show that the native variety, which it is proposed to call *Kekchi*, represents a very distinct type of this important cultivated plant. It belongs to *Gossypium hirsutum*, the Upland species or series of varieties, in the sense that it is not a Sea Island, Egyptian, or Kidney cotton,[a] but it is distinctly more different from any of the Upland varieties now cultivated in the United States than these are from each other. It has not been ascertained that the Kekchi cotton in its

[a] The Sea Island cotton is so called because cotton of this type is cultivated on the Sea Islands of South Carolina, long famous for the excellence of their product. The Sea Island cotton came originally from Barbados, whence also its botanical name, *Gossypium barbadense*.

Upland cotton gained its name as a means of distinguishing it from the Sea Island, being cultivated in the interior, or "upland," districts of the Southern States. The Upland type of cotton was recognized as a distinct species by Linnaeus under the name *Gossypium hirsutum*, but many subsequent writers present form is suited to cultivation in the United States, but it has, without any doubt, new and significant characters which must be regarded as factors in cultural solutions of the weevil problem. (Pl. II, fig. 1.)

Although cotton was not found to be planted as a regular field culture in any localities in Guatemala where the keleps do not exist, small quantities are produced in the interior plateau region about Rabinal by what may be called dooryard cultivation, and these, too, have suggested cultural factors and expedients which may not be without practical bearing.

The present paper can claim to make only a beginning in the bionomic study of the question, but it shows at least that the weevil problem has many avenues of approach on the botanical side.

The cotton of Guatemala and neighboring countries has maintained an existence, at least, in the presence of the weevils, and has suffered an acute natural selection with reference to its ability to protect itself against the weevil or to secure the assistance of allies, such as the keleps. That no commercial cotton crop is raised or exported from such districts does not prove that they are unworthy of scientific investigation, or that they are not likely to yield materials and suggestions of practical value in meeting the invasion of weevils which is now so serious a menace to the cotton industry of the United States.

Some of these weevil-resisting adaptations have been of use in securing for the cotton the assistance of the keleps. There are others which, if properly utilized, might render these interesting insects unnecessary. Tropical America has been serving for thousands of years, evidently, as a laboratory for this class of experiments. Texas was invaded only yesterday—a decade ago. Now that we are forced to engage in the strife, the first preliminary should be, it would seem, to take stock of the weapons which nature has forged.

The present report was planned and partly written before the discovery of the true nature of the best of the weevil-resisting adaptations—the proliferation of the tissues of the buds and bolls. Some of the characters here described may have no value except as suggestions, but taken together they may be of interest as an outline of the results of the very long period of selection to which the presence of the boll weevil has subjected the Central American varieties of the cotton plant.

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have erroneously confused it with the Old World species *Gossypium herbaceum*, which is not cultivated in the United States, though often so reported.

The Egyptian and Kidney cottons belong to the Sea Island series, and are of American origin. The Kidney cottons seem not to have been cultivated on a commercial scale, but they are very widely distributed in tropical America. The name refers to the fact that the seeds of each compartment of the boll are grown together into a small compact mass, in shape suggesting a kidney.

SELECTIVE INFLUENCE OF THE BOLL WEEVIL.

The boll weevil exerts a most prejudicial effect upon the cotton crop, but, unlike most parasites, it does not cause disease or debility in its host plant. The young buds and bolls are merely pruned away, as it were, the purposes of the weevil being the better served when the plants remain vigorous and continue to produce more buds and bolls, in which more eggs can be laid and more larvæ brought to maturity. Nevertheless, if no bolls are allowed to develop no seed can be set. The fate of the cotton crop in wet seasons in Texas shows that without some form of protection the plant would have been extinct long since in all localities reached by the boll weevil.

The long contact between the boll weevil and the cotton plant in Central America has given ample opportunity for the latter to profit by the selection which the insect itself has provided. Every difference by which a cotton plant was able to resist or to avoid the weevil and thus ripen more seeds than its fellows would give it a distinct advantage, quite as if the selection were consciously carried on by the planter or the plant breeder. The case is different from that of the recent improvements of many of our cultivated plants by selection for the increase of some particular quality already existing. Such improvements can often be made appreciable, or even highly valuable, in comparatively few years, but under the desultory Indian methods of cultivation long periods of time would be required for the origination and accumulation of such characters as these protective adaptations.

Climate and other local conditions must also be taken into consideration. An adaptation which would be effective in one set of climatic conditions may be of little use, or even a positive disadvantage, in others, as, for example, the prompt shedding of the parasitized buds. In a dry region the falling of a bud to the superheated, sun-baked earth insures the death of the weevil larva, either by the heat directly or by the complete drying out of the tissues in which the larva is embedded. In the moist districts of eastern Texas, however, this expedient is quite ineffective, the larvæ often developing even better when the buds fall off and lie on moist soil than when they remain attached to the plant.

It need not surprise us to learn also that the weevil-resisting adaptations shown by the Kekchi and other cotton varieties of Central America are shared, to some extent, by those already known in the United States, since the whole Upland type of cotton appears to have been, originally, a native of the Central American region. Varieties which reached the United States from Mexico and the West Indies may, however, have had little or no contact with the weevil for many centuries, while in Central America the struggle for existence has remained severe and continuous down to the present day.

It is now known that in the plateau region of Mexico the long dry season effectually excludes the weevil, so that varieties of cotton from the Mexican highlands, instead of being weevil-proof, as sometimes represented, may have no immunity whatever when brought into the much more moist climate of the cotton belt of the United States.

The Kekchi cotton of Guatemala, on the other hand, has to a much greater degree than any of the varieties now grown in the United States the very qualities which experiment has shown to be effective for the mitigation by cultural means of the injuries inflicted by the boll weevil. That it has, in addition, other features not possessed by our United States varieties, or not hitherto interpreted as weevil-resisting adaptations, need not be looked upon as anything outside the normal order of nature, but is entirely in accord with what appears to be the biological and agricultural history of the cotton plant in Central America.

GENERAL PROTECTIVE CHARACTERS.

DWARF HABIT AND DETERMINATE GROWTH OF KEKCHI COTTON.

Although Guatemala is a tropical country and the climatic conditions are suitable for the growth of cotton throughout the year, the Kekchi cotton is cultivated only as an annual, and is smaller and more determinate in its habits of growth than the Upland varieties now known in the United States. It soon attains its full height, and after a crop of bolls has set on the lower branches there is a definite tendency to cease growing or producing new buds. The later upward growth of the plants seems to be supplementary, as it were, to the formation of the bolls; often there appear to be no more flowers formed, and many of those which come seem to be undersized, as though the plant were really mature and were approaching the natural termination of its existence. Our Upland varieties, on the contrary, continue to produce throughout the season hundreds of small squares on each plant which serve only as breeding places for the weevils.

The explanation of the high development of these short-season qualities of the Kekchi cotton is doubtless to be found in the custom of the Indians, who pull up the cotton as soon as the bulk of the crop has ripened to make room for the peppers, which are always planted with the cotton. For the Indians the peppers are an even more important crop than the cotton, so that when the time comes for clearing away the cotton they do not wait for the plants which may have delayed maturity. Late bolls, even, would never come to maturity or furnish seed for planting. The result has been a very long-sustained selection for early bearing and uniform ripening of the crop. Some of our earliest Upland sorts may begin blossoming as soon as the Kekchi, but they show far less tendency to determinate growth.

The development of earliness has been assisted, no doubt, by the climatic conditions which prevail in eastern Guatemala. The rainy season oftens begins before the cotton harvest is completed, so that the later bolls are very likely to become diseased, or, if they reach maturity and open, the lint is often beaten to the ground and made too dirty for use in spinning and weaving. In either case the seed is not harvested.

The Indians believe that even if they did not pull the cotton up it would not become a perennial, but would die out completely, even to the roots, during the rainy season. Seeds scattered accidentally in the plantation at harvest time are rotted by the rain and do not germinate, so that little or no volunteer cotton is carried over from one season to another.

If the Kekchi cotton were the only variety planted in Guatemala and the weevil had there, as in the United States, no other food plant than the cotton, the insects might all die off between April or May, when the cotton is pulled up, and October, when the next crop is planted. There is, however, enough perennial "tree" cotton in the country to keep the pest from becoming exterminated. Moreover, the question of additional food plants in Guatemala is still open.

The importance of securing short-season varieties of cotton for the United States can hardly be overestimated, since, as already intimated elsewhere,[a] there is no longer any reason to hope that the more severe winters of the northern districts of the cotton belt will give any protection against the weevils.

As long as the weevil was confined to the southern part of Texas, where the cotton could survive the winter, the destruction of the plants as soon as possible after the maturing of the crop was the only measure calculated to seriously reduce the number of weevils. It was also essential to plant cotton as early as possible in the spring to avoid the weevils bred on the volunteer, or hold-over, cotton which negligent planters had left in the ground. The extension of the pest farther north and the possibility of securing cotton varieties with determinate habits of growth introduce several new considerations. The hold-over cotton is eliminated from the problem, but in the more northern latitudes, where the cold comes earlier and the temperature remains lower throughout the winter, it may often happen that there will be no period in which the weevils can be reduced by starvation, unless time can be secured for this purpose in the spring by the planting of short-season varieties of cotton.

[a] Cook, O. F., 1905. Progress in the Study of the Kelep. Science, N. S., 21: 552.

Instead of colder winters being unfavorable to the weevils, there is every probability that cold sufficient to keep them in a torpid, inactive condition will preserve their noxious lives much better than warm and pleasant weather, which enables them to continue active and thus deplete their vital energies. The winter of 1904–5 was one of unprecedented severity in Texas, both in absolute temperature and in continued cold and wet, and yet the weevils were able, in many localities, to infest heavily the early plantings of cotton to a far greater extent than in previous years.

The farther north the locality the more will the efficiency of cultural methods of avoiding the boll weevil depend upon the planting of quick-maturing varieties of cotton. It is true that in a favorable season the cotton planted first would set its crop soonest, and thus escape a part of the damage suffered by adjoining fields of later growth, the earlier fields breeding weevils to attack in larger force the later plantings. But instead of insuring a decrease of the number of weevils in a given locality and checking the propagation of the pest, very early planting by a part of the farmers of a community might tend, after an early fall and a cold winter, to the opposite result, since it would save the lives of large numbers of weevils which would otherwise perish before the cotton, if sown a few weeks later, would be large enough to furnish the weevils with food. Dr. Herbert J. Webber states that planting could probably be deferred even to the middle of June without impairing the chances of a crop as large as that which can be obtained in the presence of the weevil.

There would seem to be little object in planting cotton where the weevils are as abundant as in some places in southern Texas in the spring of the present year, 1905. Nevertheless, the opportune occurrence of a few weeks of dry weather was able, even then, to greatly improve the prospects of a crop. No matter how bad the weevils, the planter still has hope that dry weather may come and save his crop from being a total loss. As long as indeterminate varieties are planted this possibility will always make it difficult to carry out a general policy of early destruction of the plants.

Some of our Upland varieties of cotton are early enough in the sense that they begin flowering and fruiting very promptly, but unless the season is very dry they will produce a continuous succession of buds until they are pulled up or frost cuts them off. The earliness of practical value is not to be shown merely by the date of flowering, but by the date of ripening the crop of bolls and of ceasing to form new buds in which weevils can breed. If the improvements noted in other parts of this report can be realized in practice, it would no longer be necessary to destroy the cotton plants in order to put an end to the breeding of the weevils. It would then become practicable and desirable to regulate planting so as to bring the growing period of the cotton at the most favorable season for a rapid development of the crop, and thus to give the weevils the shortest possible opportunities for breeding.[a] If the fall and winter had favored the survival of many weevils, planting could well be deferred until the weevils had disappeared, a fact which could be ascertained by starting early a few observation plants from which the weevils could be carefully picked by hand as long as they continued to appear.

The extent of the mortality of the boll weevil in the spring has been well shown in the investigations reported by Mr. W. D. Hunter on the effects of applying Paris green to the very young cotton as a means of destroying the weevils which had lived through the winter. Numerous dead weevils were found in the poisoned fields, but equal or even greater numbers were found in those to which no Paris green had been applied, and the conclusion was drawn that a large proportion of the weevils, which pass the winter in a state of hibernation or torpidity induced by the cold, perish through starvation or other causes in the spring, after the weather has become warm enough to render them active again and permit them to renew their search for cotton plants on which to feed and lay their eggs.[b]

It is easy to understand, too, that after the weevils have been reduced by the cold to a condition of inactivity involving an almost complete suspension of the vital functions, the lack of food and the lapse of time can make very little difference with them. Starvation comes much quicker during warm weather while they are going actively about, so that it is the autumn and spring which must be relied upon to reduce the numbers of the weevils rather than the cold periods of the winter months. Messrs. Hunter and Hinds have also noted as significant the fact that of weevils captured at the middle of December, 15.8 per cent passed the winter successfully, while of another lot captured a month earlier, only 1 per cent survived. Their conclusions were as follows:

> It is evident that the weevils which pass the winter and attack the crop of the following season are among those developed latest in the fall and which, in consequence of that fact, have not exhausted their vitality by oviposition or any considerable length of active life.

With these facts in mind it becomes plain that no objections need be raised on general biological principles to the introduction of new

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[a] A determinate variety of cotton would also avoid the cultural disadvantages incidental to very early planting, for if the weather happens to turn cold and wet the cotton is often either killed outright and has to be replanted or, what is still worse, it becomes permanently stunted and unproductive.

[b] Hunter, W. D., 1904. The Use of Paris Green in Controlling the Cotton Boll Weevil, Farmers' Bulletin No. 211, U. S. Department of Agriculture.

quick-maturing varieties of cotton from tropical countries on the ground that cold weather will exclude them from the United States. The early spring is the only time in which they will be likely to encounter adverse conditions in this respect, and if varieties can be secured which are able to mature a satisfactory crop in a short season, these quick-maturing qualities will far more than compensate for any lack of ability to withstand cold weather in the early spring.

The Kekchi cotton may prove, however, to be quite as tolerant of cold as the other Upland varieties now cultivated in the United States.[a] In its native country it is planted in October and grows throughout the winter months in mountain valleys where temperatures of between 40° and 60° F. are not infrequent. (Pl. I.)

VARIATIONS IN THE KEKCHI COTTON.

Very great diversity of size, habit of growth, and other features exists in the Indian cotton of the vicinity of Secanquim and Cajabon. The plants cultivated by Mr. John H. Kinsler on the United States system were also very different from any grown by the Indians, being much more robust and compact than in the more crowded native fields. The spreading lateral branches and low, compact growth of the Kekchi cotton, as shown in Plate II, figure 1, might have cultural disadvantages if these tendencies were to be maintained in regular field cultures. Such, however, is not likely to be the case. When growing closer together the plants are more upright and less leafy below.

To what extent the differences observed thus far represent varietal characters can scarcely be determined without a field test of the apparently different strains, side by side. The broken, precipitous nature of the country renders it impossible to rely upon comparisons of the conditions of the different fields.

The conservative agricultural habits of the Indians would tend to the continued planting by one man or family of the same seed for long periods of years, which might well conduce to the formation of separate strains. The low germinating power of the seed may possibly be due to such inbreeding, though it is more likely that it deteriorates because of the humidity of the climate.[b] Nevertheless, our experiments were sufficient to prove that even among plants grown from seed raised by the same Indian there were very appreciable

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[a] This was shown to be a fact before the report was printed. See p. 18.

[b] The Indians appreciate the fact that the cotton seed does not germinate well. They are accustomed to plant six seeds together, from which two or three plants usually reach maturity, often with one or two insignificant dwarfs underneath. The yield per plant in these crowded fields is naturally very small, but the larger individuals often bear from 20 to 30 bolls. At Rabinal from 6 to 10 plants in a cluster is the rule, the product of the individual being still further reduced.

differences, sufficient to have a very practical bearing upon the question of securing strains having the special characters required in the United States. Indeed, there was nearly as much diversity among the Guatemalan plants as among all the Upland varieties, though these were in some cases unusually variable, as a result apparently of the transfer to new and unwonted conditions of climate and soil.

The usual number of locks or cells in a boll of the Kekchi cotton is four, but bolls containing three or five are not uncommon; often they are on plants which have otherwise the usual number.

There is also considerable diversity on the same plant in the shape of the bolls, some, for example, remaining quite conical and pointed, while others round out to near the apex. One plant was observed in which the bolls were very nearly spherical. The involucre was also unusually large. The plant had an unusually deep red or blackish color, and was distinctly more vigorous than its neighbors, as often happens with mutations.

It is not at all probable that a close selection has ever been practiced by the Indians, so that a wide diversity of mutational characters may be expected when once the variety has been brought under careful observation.

The stems and petioles of the Kekchi cotton plant are dark red, or at least spotted with red, and the leaves turn dull red with maturity. The bracts and bolls are green when young, but with age and exposure to the sun become more or less tinged or spotted with red.[a] The outer involucral nectaries also turn deep red, especially the two upper ones, even while the buds are still very young. The great majority of the leaves are simply three-pointed, but many of them have an additional smaller lateral point on each side near the base.

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[a] One plant at Secanquim showed a very decided instance of variegation with white and red, though the latter color might have been due to an increased tendency of the white portions to take the red discoloration common on normal leaves. The lower branches of the plant show only normal green coloration, and a part of the upper branches is also normal in color and size, and with fruits rather above the average size. The variegated branches do not regularly alternate, nor do they come all from one side, but they might still have connection with the phyllotaxy. There seem to be two stages of the variegation, a white and a light greenish-yellow; the latter may belong only to young leaves. Both are distributed with the utmost irregularity, and both may affect the upper surface of the leaf while the under surface remains green, or vice versa, though the latter condition is much less common than the former. The etiolated portions of the leaves, involucres, and fruits do not attain the full size of the corresponding normal organs, so that the parts affected are more or less unsymmetrical, though where the variegation is slight this result may be apparent, or if it be complete the symmetry is not affected. Except for two premature bolls the seed was not ripe, and these were from the normal lower part of the plant.

EFFECTS OF GUATEMALAN CONDITIONS ON UNITED STATES VARIETIES.

The behavior of the United States varieties under changed climatic conditions in Guatemala is interesting in several ways. The "King," which in the United States appears to resemble the Guatemalan variety most nearly, here loses most of its distinctive characters and breaks up into a variety of types, many of which would not be recognized in the United States as at all related to King. One of these is a "limbless" or "cluster" variety, which for a time appeared to Mr. Kinsler as a very promising new sort. It was smaller and distinctly earlier than King plants of the normal type, and seemed likely to be more productive, but only a few bolls developed, and these proved to be of abnormal form, with deep grooves or notches across the tip.

One of the features in which the change of climate seems to produce remarkable effects is that of earliness. The King, which in the States is looked upon as the earliest variety, is found by Mr. Kinsler to be somewhat exceeded in this respect by "Allen," which has not been looked upon as a competitor. The Sea Island and Egyptian varieties, too, prove to be much more precocious than was expected. Some of them begin flowering almost as soon as the Upland sorts. The Rivers variety of Sea Island cotton, in particular, was very early, robust, and productive, distinctly ahead of the near-by Jannovitch, though not so tall.

ACCLIMATIZATION OF KEKCHI COTTON IN THE UNITED STATES.

It was not unexpected that the Kekchi cotton would show a change in its method of growth on being transferred to Texas. New conditions of soil and climate often cause notable disturbances of the organism. Some of the tropical cottons planted in Texas for experimental purposes have grown into large bushes without showing the slightest tendency to produce fruit or even flowers. In 1904 cotton from Peru planted at Victoria, Tex., grew most vigorously to a height of 18 feet, but remained quite sterile. It is possible, however, that even in their own country these were what are called "tree cottons," which usually grow to considerable size before beginning to flower. Letters from Mr. Kinsler, in charge of our experimental plot at Pierce, Tex., relate a similar behavior on the part of the Kekchi cotton, which at that place has grown large and rank; but toward the end of July it was beginning to fruit, so that the ripening of seeds in Texas is to be anticipated.

Two or three years will probably suffice to diminish this abnormal vegetative vigor, due to the stimulus of the new conditions, and permit a return to the normal earliness of the variety. Similar results have attended the introduction into Texas of Mexican varieties of corn. The plants grew 14 feet high the first year and bore very little seed; in the following seasons they became smaller, earlier, and more productive.

The probability that the Kekchi cotton can be grown even at the northern limits of cotton cultivation is strongly indicated by the results of an experiment at Lanham, Md. (1905). In favorable seasons cotton can be grown to maturity as far north as Washington, but the present year has been very unfavorable, the summer months being for the most part cool and rainy, and with several intervals of unusually low temperature. The cotton, which was planted intentionally in rather poor soil, to avoid too great luxuriance of growth, germinated very badly and remained small and stunted until August. The Kekchi rows have, however, produced more plants, and more of these have grown to maturity than with any of the domestic or foreign varieties included in the test. The Kekchi type has also remained more constant in Maryland than did the King variety when grown in Guatemala, though there are obvious differences between individual plants. Two plants in particular were found to have numerous buds, some ready to blossom before any of the others had begun to show signs of productive maturity.

It might be feared that a variety newly introduced from a tropical country would be likely to suffer more from low temperatures than our United States varieties, but this seems not to be the case with the Kekchi cotton, even when the cold is carried down to the freezing point. There were light frosts in Lanham about the end of September, just sufficient, as it happened, to do appreciable damage to cotton in low ground. The Kekchi plants did not suffer more than the American Upland varieties. The difference, if any, was in favor of the Kekchi cotton, perhaps on account of the closer foliage.

Many annual plants, even those of tropical origin, are most vigorous and productive at their northern limits of growth, not, as has been supposed, because this is the coldest part of their range, but because the heat and sunlight, necessary to plant growth, are greater during our summer months than can be secured in a similar time in the Tropics, owing to the much longer days of our northern latitudes.[a]

The Pachon cotton from western Guatemala, though it has grown taller at Victoria, Tex. (52–79 inches), than at Lanham, Md. (30–40 inches), has produced numerous buds in Maryland, but none in Texas. The Kekchi cotton also appears to have been more productive at Lanham than at Victoria, to judge from a recent partial report from Mr. Argyle McLachlan.

[a] Cook, O. F., 1902. Agriculture in the Tropical Islands of the United States, Yearbook of the United States Department of Agriculture for 1901, p. 367.

It is very possible, therefore, that if the Guatemalan variety is able to thrive in the United States it will ripen its crop here in even less time than it requires in Guatemala, and this is rendered the more probable from the fact that in Guatemala the cotton has to be planted in the rainy season and is obliged to exist for the first few months under conditions of excessive moisture. The dry season of this district is short and uncertain. For two years, 1903 and 1904, the Indians were unable to burn their clearings, so that the corn crop failed and the community was reduced to the verge of starvation. The cotton crop, in normal seasons, is said to be planted in the latter half of October and ripens in March.

The introduction of a dwarf, short-season cotton would require, of course, something of a change in cultural methods in the South, since the smaller size of the plants will need to be compensated by closer planting. It will be readily understood that to secure the setting of a crop in the minimum of time as many plants as possible should be set at work. The question is not that of the maximum product for each plant or for a given area. With the weevil in the field the time factor becomes of chief importance.

Little is gained in reality by the rank growth of the larger varieties; in fact there is a distinct loss in earliness, even though some bolls are set in the early part of the season. If these are overshadowed and starved by the continued upward growth, the crop is delayed and the lower part of the plant becomes, on the whole, distinctly unproductive.

EARLY BEARING FACILITATED BY LONG BASAL BRANCHES.

The earliness of the Kekchi cotton is made possible by the fact that the bolls are nearly all borne at the base of the plant, the upper branches and their foliage serving merely to assist in bringing to maturity the fruits which are set while the plant is still very young.

Like several other tropical economic species, such as coffee, cacao, and the Central American rubber tree, the cotton plant has two kinds of branches—the true or primary branch, which arises in the normal position of branches in the axil of the leaf, and the secondary or fruit branches, one of which arises at the side of each primary branch. In most varieties only a few of the true branches are developed; often none at all. They are almost always plainly indicated, however, by a small bud or a stunted leaf or two, in case the bud has not remained entirely dormant.

Cotton plants are either right-handed or left-handed in the sense that on the same plant all the secondary branches come out on the same side of the primary branches. It is possible, therefore, to determine by its position whether any particular branch is a primary or a secondary. But the function of the two sorts of branches does not always remain as distinct as in the coffee and cacao. A primary branch, like the main stem, never bears any flowers; it produces only leaves and other branches, mostly secondary.

Secondary branches, on the other hand, produce normally a flower bud at the axil of each leaf, and this rule holds very generally, except that at the lower part of the plant it sometimes happens that a branch which has the secondary position functions as a primary; that is, instead of bearing buds and flowers it produces only leaves and secondary branches. In the Kekchi cotton, as grown crowded together in the Indian fields, the primary branches seldom appear, but when more space is allowed and the soil is fertile it is usual for two branches to start from the axil of each of the lower leaves, one promptly producing flowers, the other assisting in the rapid increase of the leaf surface of the plant and of its power to elaborate food.

Under the popular idea that plants draw their food from the ground the possession of branches which bear little or no fruit might be looked upon as an undesirable character, but when we take into consideration the fact that the leaves instead of the roots are the true assimilating organs of the plant it becomes apparent that a variety of cotton which develops its lower primary branches may have an advantage in earliness over one which is obliged to depend for its foliage upon secondary or fruit-bearing branches. In the matter of determinate habits of growth these primary branches are also a feature, because they enable a plant to produce a full quota of leaves without unduly increasing the number of fruiting branches and thus continuing to add to the number of superfluous buds.

The most obvious characteristic of the Kekchi cotton as it grows in our experimental plots is the long basal branches, which often equal or exceed in length the main stem itself. The most prolific branches of the United States varieties are those which come out from the main stem at the height of about a foot, but the bulk of the crop on the Kekchi cotton is borne much closer to the ground. (Pl. II, fig. 2.) The long basal branches facilitate the early ripening of a uniform crop of cotton, but they will not be an advantage under all circumstances; as, for example, in dry regions where the weevil can be held in check by open culture. The necessary exposure of the fallen squares to the full sunlight on hot, dry soil would be interfered with by a plant of low spreading habit and dense foliage.

EARLY REJECTION OF SUPERFLUOUS SQUARES.

That the Kekchi cotton has a limited or determinate growth and does not take advantage of the perpetual summer to become a tree or even a large bush is evident from the fact that in the latter part of the season most of the flower buds and leaf buds blast and fall off while still very young, before the weevil would give attention to them. By the time the first of the cotton is beginning to ripen, most of the plants have ceased flowering and no new leaves are being put forth. Generally there are bolls only near the base of the plant.

It is a normal character of the cotton plant that the fruiting branches shall produce a bud at each node or joint; that is, at the base of each leaf. If all these buds were to be retained and treated impartially to the food materials which the plant is able to supply, the result would undoubtedly be disastrous, since the plant would be able to bring very few of its fruits to maturity, perhaps none at all, unless a part of the burden were removed by the weevils or by other outside causes.[a] It is under the necessity of throwing off a part of its load of fruit at one stage or another of its development, the younger the better.

The rejection is accomplished by the formation at the base of the peduncle, or fruit stalk, of special layers of cells of soft texture, which soon disintegrate and allow the bud or young fruit to fall off. This is one of the many instances of the prodigality of nature, which makes so many allowances in advance for the accidents which beset the existence of all living things. The waste of buds is, perhaps, not so large in proportion among the perennial "tree" cottons, which form a considerable shrub before beginning to blossom. In cultivation, however, the tendency has always been to encourage early bearing, and thus reduce the early vegetative period of the plant and bring it to a precocious maturity. The result is that fruiting branches are produced, even on young plants, and buds are formed out of all true proportion to the actual productive power.

The habit of rejecting a large part of the squares and bolls is especially obvious in the "cluster cottons," varieties in which the branches are abnormally shortened, so that the leaf surface of the plant is still further reduced. This cuts down still more the productive power of the individual plant, though there may be a gain in the number which can be grown on a given area.

But cluster cottons have not learned to moderate their promises to correspond with their powers of performance, and continue to set vast numbers of buds, flowers, and bolls, which they are unable to ripen. The same is true to a less obvious extent of all our Upland varieties, but until the advent of the boll weevil the superfluous buds were not a serious factor, and the waste under favorable conditions was often well compensated by the power to recover and set a new

[a] In Texas it is believed that rain at the time of flowering reduces the crop to half the normal quantity, or even less. The explanation given is that water settles in the flowers and prevents fertilization. This might serve as an additional indication that cotton originated in a dry climate.

crop when in unfavorable seasons the earlier buds were lost, or when, as occasionally happened in southern Texas, there was a liberal top crop, or second period of bearing, late in the autumn months.

The presence of the weevil alters all these factors. The superfluous buds become positively detrimental, for they furnish the breeding grounds for successive generations of weevils and enable the pest to attain in the latter half of the season such numbers that a top crop not only becomes utterly impossible, but a menace is prepared for the cotton of the following year. For, although only a small proportion of the weevils live through the winter, the number of survivors undoubtedly has a very practical relation to the supply maintained at the end of the previous season, and this again is merely a question of this persistent production of buds, now much worse than useless.

A short-season variety of cotton having a sufficiently determinate habit of growth would by itself constitute a solution of the weevil problem. The Department's entomological investigations in Texas indicate that it is only the weevils hatched in the last month of the growing season—in October or November—which have a prospect of surviving the winter. A cotton which ceased to produce buds after July or August would remove the chance of wintering over from all the weevils except the few that might develop in the bolls, an almost infinitesimal number compared with those that now attain maturity in the squares. Much would be gained, of course, if all planters would promptly pick their cotton and then pull up and destroy the plants, being especially careful to collect the infested bolls. But to carry out efficiently such a programme is difficult and expensive.

To what extent, if any, the Kekchi cotton will meet this need of a short-season determinate variety, it is too early to form an opinion, but the fact that it has these qualities to a higher degree than any of the varieties hitherto known in the United States must be accepted as evidence, at least, that the possibilities of this method of protection have not been realized. In the latter part of the season the Kekchi cotton ceases the upward growth of the main stem and its branches and regularly drops the greater part of its buds before they are large enough to be entered or fed upon by the weevils, and the analogies to be drawn from the habits of other plants will justify persistent efforts toward the development in this and in other stocks of the habit of rejecting the buds still earlier or of not forming them at all after the first crop of fruits has set. Many plants have, in fact, exactly this habit so desirable in cotton; they continue to flower until permitted to set seed.

SEASONAL BEARING OF PERENNIAL VARIETIES.

The continued existence of perennial cottons in weevil-infested countries, like Guatemala, proves the presence in these also of means of protection. One of the most important is, doubtless, the production of an annual crop at a definite season, leaving the weevils without opportunity to breed in the intervening months, thus greatly reducing their numbers.

The popular impression that tropical plants take advantage of the continuous summer climate and blossom continuously is correct only for a small minority. Where there are definite wet and dry seasons many tropical plants have alternating periods of growth and rest almost as pronounced as in temperate climates, and even in regions of continuous humidity there are some species which shed their leaves annually and rest for a time.

A further general reason for a simultaneous annual blossoming of all the flowers of a species is undoubtedly to be found in the greatly increased opportunities of cross-fertilization, just as many insects swarm and many birds and mammals collect in flocks before the breeding season. Simultaneous flowering is carried to a remarkable extreme among the bamboos, where whole species grow for long series of years without flowering, and then flower and die at once over long distances and in spite of local diversity of conditions which might be expected to advance or retard maturity.

Accordingly, while it would not be reasonable to insist that perennial varieties of cotton have adopted the habit of annual flowering only because of the boll weevil, the analogy of other plants may be invoked to show that such a character can be brought about by selective influence. The weevil could certainly assist in the development of such a tendency, especially if there were a season of the year in which the insects were less numerous, from climatic or other external causes as yet unknown.

The tropical varieties of cotton are, as is well known, mostly perennial, and some of them develop into trees of considerable size, the trunk attaining a diameter of 6 or 8 inches, and the main branches a length of 15 or 20 feet. The existence in Mexico of tree cotton immune to the weevils has been reported, but as yet this has not been substantiated. Possibly the weevil has not yet penetrated some of the remote and arid parts of the republic. In eastern Guatemala, at least, the tree cottons appear to enjoy no immunity from the weevil, and at the time of the visit of the writer it was often impossible to secure uninjured bolls, even as samples of the varieties. The native cottons of the island of Cuba, according to Mr. E. A. Schwarz, also have the habit of annual blossoming, in the intervals of which the number of the weevils becomes greatly reduced. The cutting back of the cotton by the Indians at Rabinal, as described in the next paragraph, is an artificial means of attaining the same end, but the native Sea Island cotton, found at San Lucas, and the Kidney cotton, at Tucuru, are the best Guatemalan examples of this protective habit.

ANNUAL CUTTING BACK OF PERENNIAL VARIETIES.

While the annual variety of cotton protected by the keleps is the basis of the only field culture found in eastern Guatemala, the Indian population of the central plateau about Salama and Rabinal raise small quantities of cotton in their dooryards by means of another cultural expedient, apparently of great antiquity, as indicated by the extent to which the plant is adapted to the cultural conditions. The variety is perennial and has very small and inactive nectaries, possibly as an adaptive result of the dryness of the climate.

Most of the perennial varieties begin bearing only after the plants have attained considerable size, but the Rabinal cotton is a notable exception to this rule and avoids injury from weevils by the very prompt flowering and fruiting of the new shoots.

The weevils are present in numbers, and are frequently seen crawling about on the plants in a leisurely manner quite different from that which they affect in regions stocked with keleps. At the time of our visit not a single boll or bud of any except the smallest size could be found which had not been attacked by them. Nevertheless, a crop of cotton is secured at another season. In the month of April the Indians cut back all the bushes to the ground, and as the cotton is always planted immediately about the doors of their houses, where the chickens and turkeys congregate, the mortality of weevils at this time is probably very great. The protection of the domestic birds doubtless continues until the new shoots have grown out of reach.

As soon as the plants are a few inches high they begin flowering, and before the weevils are sufficiently increased in numbers to become injurious a crop has been set. Flowers and fruit are commonly borne on the lower branches, only 6 or 8 inches from the ground. The Indians say that if the cotton is not cut back, but allowed to grow tall, they get no crop. The fact is that by that time the weevils are too numerous to permit normal bolls to be formed. Our search for such was quite in vain on both our visits to Rabinal. One boll which gave no certain external proof of injury was wrapped up in a paper and retained as a sample, but was overlooked in packing and not transferred to the preserving fluid. When the paper was unwrapped a few weeks later three dead boll weevils were found.

The Rabinal cotton crop is evidently not large, but the harvest is said to be regular, and the area of fertile land in this district is so small that none of it is wasted. Much foreign thread is now imported, however, for weaving in the native looms. The industry has greatly declined in the last century, perhaps because chickens have been generally substituted for turkeys, which were formerly the only domestic fowl possessed by the Indians.

All attempts at establishing field cultures of cotton in this region have failed. The local public, which does not take the weevil factor into consideration, is firmly persuaded that cotton will not bear except in the heavy, rich soil of the dooryards of the Indian villages.

HAIRY STALKS AND LEAF STEMS.

The weevil on foot is a rather slow-moving, clumsy insect, and it has been ascertained in the course of the investigations conducted by Messrs. Hunter and Hinds that its movements on the plants are to a great extent impeded by hairy stalks and leaf stems. The smooth Egyptian and Sea Island varieties were found to be more susceptible to weevil injuries than the hairy Upland sorts. The Kekchi cotton is still more hairy, however, than the United States varieties, and gains an added advantage from this fact.[a] The longer it takes the weevils to climb from one bud to another the greater are the chances of their being caught by the keleps. The latter insects, owing to their much longer legs and the claws with which their feet are armed, are not only able to travel readily over the hairs, but find them of definite assistance. On smooth surfaces they are much less adroit in catching and stinging the boll weevils. In our experiments, too, they seemed to prefer the hairy Upland cottons to the smooth Sea Island varieties.

The difference between the two insects in this respect may also be illustrated by the fact that the keleps are unable to ascend a perpendicular surface of clean glass, a feat which the weevils accomplish without difficulty.

That the Guatemalan cotton was more attractive to the keleps than the United States Upland and Sea Island varieties planted in adjacent rows seems to be indicated by a census of our plot experiment, taken April 19 by Mr. Argyle McLachlan. Kelep nests were found at the bases of 41 per cent of the plants of the other varieties.

[a] Though distinctly hairier than our ordinary Upland varieties, the Kekchi cotton is exceeded in this respect by two other Guatemalan types, as well shown in a field test at Lanham, Md. The Pachon cotton obtained by Mr. William R. Maxon in the Retalhuleu district of western Guatemala is distinctly more hairy than the Kekchi variety, though it seems to be lacking in other weevil-resisting features. The involucral bracts are not closed any more than in the Sea Island or Egyptian types. The most hairy cotton of all is the Rabinal variety, at least in the form it has taken at Lanham. The plants are very much more robust in every respect than at home in Guatemala, and the hairy covering shares in this increased vigor.

while 76 per cent of the plants of the Kekchi cotton were favored with kelep nests. This apparent preference may be somewhat exaggerated, perhaps, in view of the fact that the plants were often farther apart in the rows of the Kekchi cotton, the seed having germinated very irregularly. Moreover, the superior attraction of the Kekchi cotton for the keleps may not have consisted entirely in the greater hairiness or the more abundant nectar. The compact foliage and spreading lower branches of the Kekchi cotton give greater protection from the midday sun, which the keleps utilize by greater activity in the middle of the day.

With the Sea Island varieties it seemed obvious, however, that the smooth stems, more open habit, and smaller supply of nectar result in distinctly less attention from the keleps. From 9 or 10 o'clock on hot days they foraged very little, and seemed to have quite disappeared from these varieties, though still to be found in considerable numbers on the stems of the Upland varieties and most of all on the Kekchi cotton, which appears especially adapted for the comfort and convenience of the keleps.

It was noticed, however, that the keleps went much more often into the involucres of the Sea Island and Egyptian varieties than into those of the Kekchi cotton, for the simple reason, probably, that they can get in more easily.

In the latter part of the season, after the weevils had gained a footing in this field, Professor Pittier noticed a very decided preference on their part for the Egyptian varieties, though it seems certain that this type of cotton had never been planted in the country before. The partiality of the weevils might be explained, perhaps, on such grounds as the relative absence of the keleps, and also the ease of access to the buds of the Egyptian cotton allowed by the more open involucres. However, a slight change of food or of conditions of growth is often a distinct advantage to plants and animals, so that a direct preference for a new variety as food might reasonably be expected, and similar instances are known.

The greater hairiness of the stems and the presence of the keleps may also explain why the weevils in Guatemala were seldom seen walking about on the cotton plants as they do in Texas. On the other hand, they take to wing very readily and seem to prefer to alight in the open flowers, the only places on the cotton plants where they are safe from the keleps.

The petals are so smooth that the keleps seldom descend into the flowers, and when they do sometimes appear to be unable to climb out. The petals of the Sea Island sorts are smooth even on the margins, sometimes entirely so, while those of the Upland varieties are fringed with fine hairs well up on the sides, if not all the way round the apex.

The liability to capture by such an insect as the kelep may also afford an explanation of the peculiar sedentary habits of the male weevils, which often remain stationary in one involucre for long periods, or as long as their food supply lasts. It is necessary for the females to go about in search of fresh squares for egg laying, but similarly active habits on the part of the males would subject them to unnecessary danger.

PENDENT BOLLS.

The early bearing of the Kekchi cotton is made possible, as already noted, by the unusual development of the lower lateral branches, which often have a drooping habit, leaving the buds and bolls in pendent position, intead of upright. There are several advantages in this arrangement, one being that the instinct of the weevils leads them to the upper portion of the plant. In a very badly infested field without kelep protection, the only bolls which escaped the weevils were a few lying close to the ground on these lower pendent branches of the Kekchi cotton. Only at the time of flowering does the peduncle curve upward and give the flower its normal upright position. Thus these drooping lateral branches of the cotton, which seem to hide the buds and bolls away from the weevil, may be looked upon as a short step in the direction of such phenomena as the cleistogamous flowers of violets which remain buried in the ground, or those of the peanut which, after flowering, burrow into the soil to ripen their seeds.

The flowers of the cotton plant open in a more or less directly upright position, and this is retained by the boll in most varieties. In the so-called "stormproof" sorts, however, the bolls hang down, and this is looked upon by many planters as a distinct advantage, since when the boll is ripe and open the rain does not beat into it and wet the cotton or wash it out, but is shed by the protecting outer shell and involucre.

On pendent bolls the external nectaries are brought upward, so that there is no danger of an abundant secretion of nectar being lost by dropping off. The surface of the nectary is papillate and has a somewhat waxy appearance. The secretion often collects as a distinct drop. The nectaries are also more readily visited by the keleps, and the young bolls are likely to be better protected by them. If these remained upright, the weevils would be more likely to alight and enter the involucre at once.

The drooping habit may have a mechanical explanation as the result of the weakness of the comparatively slender lateral branches. It is also to be connected, perhaps, with the habit of early flowering and fruiting, since this would bring heavier bolls upon smaller and softer branches which would be twisted over by their weight. In the later and more upright varieties the flowers are not formed until the wood of the branches has hardened and become strong and rigid. Pendent bolls may thus be said to be incompatible with the cluster habit, which is brought about by the abnormal shortening and thickening of the lateral branches, which are able to hold their flowers and fruits rigidly upright, except as they may be turned sidewise by being crowded together. The cluster cottons, too, have the undesirable tendency to an abnormal multiplication of squares and young bolls, many more than the restricted leaf surface of the plant will enable it to ripen. This superabundance of flowers and fruits gives, however, the greater encouragement to the weevil, and uses up vegetative energy which could be better employed in the prompt ripening of the bolls already set. It is no uncommon thing, however, for even half-sized bolls of cluster cottons to die without any sign of external injury or disease, while other varieties close by remain perfectly healthy. The cause is probably to be found in inadequate nutrition, but this might also be expected to give them increased susceptibility to injury from parasitic enemies of every kind.

It is not unlikely, too, that the drooping habit may be connected with the greater size of the inside nectaries of the Guatemalan variety. These are, as far as we have seen, larger than in any other American variety yet known; but the Asiatic cottons, which have the inside nectaries still larger and more active, are also more definitely pendent. The involucre is grown together at the base, as though to more thoroughly protect the nectaries from above—from the sun, which would dry up the secretion, and from the rain, which would wash it off.

The nectar is formed in great abundance, and Mr. F. J. Tyler, of this Department, has called attention to the fact that the surface of the nectaries of the Asiatic cottons, instead of being merely papillate, as in the American Upland varieties, has a covering of close-standing fine hairs, to which its velvety appearance is due.

Finally, it may be remarked that for cotton with upright bolls the inside nectaries are often an element of danger, since when the secretion is abundant and is not removed it flows along the bases of the involucre and may serve as a medium for the germination of parasitic fungi or bacteria. Bolls are not infrequently found diseased around the base, apparently from this cause.

EXTRAFLORAL NECTARIES.

The cotton plant is not without floral nectaries similar to those of related genera, consisting of fringes of nectar-secreting hairs lining the pits inclosed between the bases of the petals. The nectar serves, doubtless, the same purpose as in other plants, the attraction of the honey-loving insects through which cross-fertilization is secured. It does not appear, however, that the floral nectaries of the cotton have any connection with the problem of weevil resistance, although the weevils seem in Guatemala to spend a considerable part of their time in the flowers, which are indeed the only safe places for them on plants protected by the keleps. It had been noticed from the first that the keleps seldom visit the cotton flowers, and Mr. Kinsler has learned a very adequate explanation of this fact, namely, that they are able to climb out of the flowers only with considerable difficulty, and sometimes remain imprisoned in spite of all their efforts to escape.

The functions of the extrafloral nectaries of plants are, as far as can be ascertained, similar to those of the floral nectaries to the extent that they attract insects, but beyond this there is a fundamental difference; the floral nectaries and highly colored floral organs serve to secure visits of flying insects and thus maintain intercommunication and cross-fertilization between the different members of the same species, in spite of the fact that the individual plants are rooted fast in the ground. The extrafloral nectaries, on the other hand, attract to the plants insects which will remain upon them as permanent residents, and this is the end secured by the extrafloral nectaries of the cotton.

It may be objected by some that no use or benefit to the plant has been ascertained in the case of many species which have extrafloral nectaries and other insect-attracting devices. Much remains to be learned concerning these marvelous biological specializations, and there are two obvious alternatives which need to be canvassed before belief in the adaptive nature of extrafloral nectaries and analogous structures can be destroyed. The character and extent of many such specializations show that they have existed for a long time. They may have served protective purposes no longer apparent. The other consideration is that some of the symbiotic specializations existing between such plants as Cecropia and Acacia and their insect inhabitants have arisen through selective encouragement, much as the special characters of our domestic plants and animals have been developed. It may be sufficient, in other words, that the nectaries or other structures be of use to the insects which have done the selecting. It may seem absurd to think of bushes or trees as having been domesticated by ants many thousands of years ago, but the wonder is no greater than that ants and termites regularly maintained subterranean fungus gardens ages before mushroom culture was undertaken by man.

NECTARIES OF THE LEAVES.

The midrib of each leaf bears on the under side an oblong pit, from which a drop of nectar may often be seen to exude. This is collected and eaten by the keleps, which are thus induced to visit all parts of the plants, especially while they are still small.

The habit of collecting the nectar was not previously known to exist among the insects of the family (Poneridæ) to which the kelep has been referred. Nevertheless, the fact is not open to question. The process is easy of observation in even greater detail than with the true ants or the bees, because the keleps do not, like these insects, have the art of regurgitating their food. They merely lap the nectar up to form a drop, which, protected by the widely opened mandibles, is carried into the nest to feed the queen and the young.

Nectaries, or at least nectary-like depressions, are to be found probably on the leaves of all varieties of cotton, though very small and apparently inactive on some of the larger tree sorts.[a] The shape of the nectaries also varies greatly in the different species and varieties, some being longitudinal, others transverse, and still others crescentic or even sagittate. Some varieties have nectaries on the three principal veins, and some even on five veins.

The leaf nectaries of the Kekchi cotton are to be found on the midrib of the leaf about 1.5 cm. from the base. They consist of a rather shallow longitudinally oval depression surrounded by a broad raised rim. The midrib often appears distinctly narrower above the depression than below it, as though there were extra tissues to supply it. The secretion is quite active, nearly all the nectaries showing a small amount of liquid, which sometimes spreads out on the adjacent surfaces.

These nectaries furnish, as might be expected, a medium favorable for the growth of molds or fungi, and there is often a considerable network of dark-colored fungus mycelium creeping in and about the moistened depressions, and with occasional erect, needlelike points, which may be fruiting bodies.

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[a] This was not true, however, of a Mexican "tree cotton" of the Upland type grown in the Department's experimental plots in Texas last year. Large nectaries were generally present on three veins of each leaf, and the midvein often had two. They were of the crescentic or sagittate type, but often extremely long and distorted. Another Mexican tree cotton, with a different type of lighter green foliage, suggesting that of Bixa, had nectaries only on the midvein and these reduced to a narrow groove. The vein was not thickened nor the margins raised. The two varieties were about as different as could well be with respect to nectaries. Neither produced either flowers or fruit, so that their true relationships were not to be ascertained.

EXTERNAL NECTARIES OF THE INVOLUCRE.

The Guatemalan cotton protected by the keleps has three broadly oval or reniform pits at the base of the involucre, one at the middle of the base of each of the involucral leaves.[a] These are larger, deeper, and more active than the nectaries of any of the Texas varieties as yet observed, though there is very great diversity of size and nectar-secreting activity. In some of the varieties these nectaries are reduced to mere rudiments or are entirely wanting. The depression may be present, but with no secreting tissue. The variety nearest approaching the Guatemalan cotton in having large and active nectaries is the Redshank, but the King and other related sorts also have fairly large nectaries.

The drooping or pendent position of the bolls in the Kekchi cotton may be correlated with the special development of these nectaries, as already noted. In the middle of the day the keleps are not very active, but the nectaries are sometimes full to overflowing. If the bolls kept the erect position usual in the varieties cultivated in the United States the nectar would frequently drop off and be lost, but when the fruits hang down the cuplike nectaries are brought uppermost and hold the liquid much longer.

The evolutionary origin of these nectaries is fairly obvious. The bracts are to be looked upon merely as modified leaves, with nectaries which have increased in size and activity as the leaves have become smaller and more specialized.

INNER NECTARIES OF THE INVOLUCRE.

As though to induce the keleps to come inside the involucre and thus more effectually protect the young buds and bolls against the weevil, the Guatemalan cotton is also provided with unusually large interior nectaries, alternating in position with those of the outer series and thus placed opposite the edges of the involucral leaves or bracts. These inside nectaries, like the outside ones, are larger and more active than those on most of the cottons cultivated in the Southern States, but the closing of the involucre and the devolopment of the inside nectaries have been carried much farther in the Old World cottons belonging to the species *Gossypium herbaceum*. Here the external nectaries are quite wanting, but the internal ones are enormously larger and heartshaped, and secrete nectar in such quantities that it often flows out in the groove between the adnate

[a] Instances are occasionally found where only two nectaries are developed, but such deficiencies are much less frequent than in other varieties of the Upland and Sea Island series. The Rabinal cotton commonly has only two external nectaries. The Old World cottons thus far observed have no nectaries in this position.

bracts to moisten the edges of the involucre. As yet, however, the purpose of these adaptations in the Asiatic cottons is entirely unknown, both the boll weevil and the kelep being absent in the Eastern Hemisphere.

The botanical homology of the inner nectaries is somewhat different from that of the outer. They correspond in all probability with the nectaries which are found on the calyx of some of the species of Hibiscus, but there the calyx is large and covers the buds and each sepal bears a nectary near its middle.

NECTARIES OF GUATEMALAN SEA ISLAND COTTON.

A variety of Kidney cotton planted in small quantities by the Indians at Trece Aguas, Guatemala, has the outer nectaries very variable in size and commonly quite wanting.[a] The inside nectaries seem always to be developed and are unusually large, being exceeded, as far as known, only by those of the Asiatic varieties. The nectar secretion is also very abundant. No weevils were found upon this cotton, nor any keleps.

On the other hand, the free-seeded Sea Island cotton found by Mr. Kinsler in the San Lucas[b] neighborhood, not far from the kelep cotton culture of Secanquim, reverses again the tendency of the Kidney cotton to the great development of the inner nectaries and the suppression of the outer. The latter are, in the San Lucas cotton, nearly always present, of rather large size, and of a red color. The inner nectaries are often rudimentary or quite absent.

CONTINUED SECRETION OF NECTAR.

Our Upland varieties commonly secrete nectar only at the time of flowering, but in the Kekchi cotton the liquid continues to exude until the boll is nearly or quite full grown, thus securing the protec-

[a] This variety not infrequently produces flowers with only two bracts, closely appressed, like a clam shell. In one such instance there were two nectaries at the base of each bract, or, to be more exact, two separate nectaries on one side and one partly divided nectary on the other, as though the nectary belonging to the deficient third bract had separated into two parts and joined the other nectaries.

[b] This San Lucas Sea Island cotton is probably the variety in which the weevils were found abundant in 1902, when the first intimation was gained that the Kekchi cotton had means of protection against the weevil. The San Lucas cotton is attacked not only by weevils, but by another long-bodied insect larva, evidently lepidopterous, that gnaws through the boll at the ends, both from above and below, and eats out the seeds. Nothing of the sort has been seen in the fields protected by the keleps. There was also noticed in this cotton an occasional abnormality closely comparable to the navel orange. Rudimentary parts like a small secondary boll were found in the middle of bolls otherwise normal. The orange tree and the cotton plant belong, it may be remembered, to related families.

tion of the keleps for a longer period. The temporary character of the secretion in our United States sorts was reported by Professor Trelease several years ago.

In Guatemala, however, the young bolls seem to be quite as efficient as the flowers. It is even possible that this generosity on the part of the plant is excessive, since if the number of keleps is small they may find all the nectar they need on the lower bolls, and hence have less inducement to inspect other parts of the plant. Under favorable conditions in Texas the cotton plant produces a much larger number of flowers than in Guatemala, so that what is lacking in quantity may be made up by numbers, in case it should become possible to utilize the keleps in Texas.

RACTLETS SUBTENDING INNER NECTARIES.

The Kekchi cotton is distinguished from all our Upland and Sea Island types by the more regular presence and much larger size of a series of bractlets, a pair of which usually subtends each of the inner nectaries. In other varieties these are either wanting entirely or are rare and rudimentary.[a] The bractlets are inserted somewhat obliquely, with their margins in contact below the nectary.

Sometimes they serve to conduct nectar to the edge of the involucral bracts, the nectar following along between the slender bractlets like ink between the nibs of a pen, as though to coax the keleps inside the involucre. This must happen rather infrequently, however, to judge from the great irregularity in the size of the bractlets. Sometimes they are half an inch or more long, and extend well into the angles of the involucre, or even project outside. (Pl. III.) Nevertheless, it

[a] Professor Trelease, who studied the American Upland varieties, appears not to have found the bractlets in pairs. He says: "These glands (the inner nectaries) belong in reality to an inner whorl of three bracts, alternating with the outer ones, but generally wanting. In stunted plants, especially as cold weather comes on, one or more of these inner bracts may be found." (See Comstock, 1875, Report upon Cotton Insects, 324.)

The shape and position of the bractlets seem to warrant the suggestion that they represent the stipules of the outer bracts instead of an independent inner whorl of bract leaves which has first become specialized and then become rudimentary. The suggestion has the further warrant in that it may help to explain the numerous involucral appendages of some of the related plants, which range about the number 9—that is, 3 leaves and 6 stipules. The normal number should be 6, if the two whorls of leaves were represented. One of the Guatemalan species of Hibiscus examined with this interpretation in mind seemed to confirm it by showing very often 3 of the appendages broader than the others, though the total number varied from 8 to 11, with an irregularity quite comparable to that of the bractlets of the cotton. Even the bracts of the cotton sometimes vary, involucres of 2 bracts being found occasionally, and in rare instances 4.

may well be questioned whether these inner bractlets have remained unusually large in the Kekchi cotton because they have a definite function or because of the greater size and activity of the adjacent nectaries.

A variety of cotton called Pachon, planted rather extensively in the Retalhuleu district of western Guatemala, and likewise protected by the keleps, is similar to the Kekchi cotton in many respects, including the possession of these large stipular bracts subtending the inner nectaries, but with the addition that the bracts are fringed with long hairs, as though to hold the nectar the better. This may also be the function of the hairs which cover the nectaries of the Old World cottons

EFFICIENCY OF THE KELEP PROTECTION.

The special development of the extrafloral nectaries in the Kekchi cotton has been noted in former reports, it being the nectaries which attract the keleps to the cotton plant. That the kelep preys upon boll weevils and protects the cotton crop was learned last year, but it was still possible to question the practical value of this form of defense. Such doubts would not have survived an inspection of our recent experiments in Guatemala. A small field of cotton just outside the kelep area was attacked by the weevils in such numbers that not a single normal boll developed on any of the United States Upland and Sea Island varieties. In the field protected by the keleps the weevils obtained no footing until the plants were well grown and an excellent crop of full-sized bolls had been developed.

To test the efficiency of the keleps as destroyers of boll weevils and as protectors of cotton would be possible in Texas only by stocking a large area with keleps—a difficult and expensive undertaking. No small tract would give a fair indication, since the weevils from the whole neighborhood would continue to come in, and, although they might soon be captured, would be able to do vastly more damage than would be possible if the whole region were stocked with keleps.

In Guatemala, however, it was quite possible to contrast a protected with an unprotected piece of cotton by the simple expedient of planting outside the area occupied by the keleps. A more striking result could hardly be imagined. For several weeks, during which the two plots were under continuous observation, the one remained almost entirely free from weevils and weevil injuries and set an excellent crop, while in the other scarcely a flower opened or a boll developed. The very few exceptions were on the concealed drooping branches of the native Kekchi cotton.

The weevils became, indeed, too numerous for their own prosperity and fed upon and destroyed the very young buds before they were old enough to breed larvæ. Twenty-five fallen squares collected and examined from under the plants of the plot without keleps yielded only 6 larvæ, or 24 per cent. They even attacked the young leaf buds, as observed last year at Rabinal.

A large proportion of the injuries were caused by feeding punctures, but this only emphasizes the fact that the number of weevils which migrated into this plot was sufficient for a complete destruction of the crop, and since the other experiment protected by the keleps was much nearer to the fields of the Indians there is every probability that the weevils would have been, if possible, even more numerous if the keleps had not been at hand to catch them.

The unprotected plot was located at about one-quarter of a mile outside of the belt of Indian cotton culture, on land not inhabited by keleps. The weevils lost no time in finding the new field. Infestation was complete, and quite as destructive as in Texas, the weevils being so numerous as to overcome whatever resistance the cotton might have been able to oppose to smaller numbers of the pests. The Sea Island, Egyptian, and United States Upland varieties were not permitted to produce flowers or even full-sized buds, and even the native Guatemalan varieties shed their squares before the persistent onslaughts of the weevils.

Cotton is regularly cultivated by the Indians in this immediate neighborhood, and Indian plantings more or less infested with weevils were to be found within short distances of the protected field. Nevertheless, the keleps proved to be sufficiently abundant on this piece of ground to completely exclude the weevils. There were enough, indeed, to protect with apparent impartiality all the kinds of cotton included in the experiment, but if the numbers had been less and the plants had been closer together, as in the Indian fields, we may be sure that those producing the most nectar would have received the most protection from the keleps.

The weevils were seldom to be found in the plot stocked with keleps as long as the Indian cotton remained in vigorous growing condition, but about the time the Indian cotton ripened, the weevils seemed to make a more determined raid on our field, and along one side nearly every plant suffered somewhat, though the weevils could rarely be found except in the open flowers, which seem to be recognized as their only safe roosting places. In a week or ten days there was a distinct falling off, so that very little damage was being done, and there was another short interval of practically complete protection. But after this a renewed onslaught began and the numbers of weevils gradually increased, the Upland and Sea Island plants continuing to produce thousands of new squares in which the weevils were able to breed, quite as in the United States.

That the keleps are definitely attracted to the cotton plants, as stated in previous reports, is fully demonstrated by the fact that many of the colonies moved their nests to new burrows excavated immediately at the bases of the cotton plants. In some parts of the field the proportion of cotton plants having kelep nests established about their roots reached nearly 75 per cent, whereas the chance that the positions of the cotton plants which stood in regular rows would coincide with those of kelep nests would not be one in hundreds.

The success of this experiment would seem to justify fully the suggestions made in connection with the first announcement of the discovery of weevil-resisting adaptations of the cotton plant, namely, that the protection which these Central American varieties had been able to secure from the kelep had afforded them an opportunity, perhaps unique, of developing other resisting adaptations. The Kekchi and other related cottons, though having no monopoly of weevil-resisting characters, furnish, however, the only instance as yet known to scientific observation in which a field culture of cotton has been maintained for long periods of time under climatic conditions favorable to the boll weevil.

In Central America, at least, the secretion of nectar by the cotton is not a useless or meaningless function, as observers of the plant in other parts of the world have sometimes supposed. The cotton is not the only plant upon which the kelep can live, nor the boll weevil the only insect upon which it preys. To secure the attention and obvious preference of the kelep the cotton has been obliged to put forth the superior attractions provided by its numerous extrafloral nectaries.

This additional proof of the value and efficiency of the kelep does not affect, of course, the possibility of acclimatizing it in the United States. A more extended search in Guatemala resulted in finding the insects under a wide range of conditions, and at altitudes of from 200 to 2,000 feet. It lives and thrives, moreover, in soils very much drier than those to which it was supposed last year to be confined. Last year's experiments in Texas indicated likewise that the kelep withstands drought much better than it does standing water in its burrows, and care is being taken this season to locate colonies with a view to adequate drainage.

OTHER NECTAR-BEARING PLANTS VISITED BY THE KELEPS.

The honey-collecting habits of the keleps are not confined to the cotton. Another favorite is a species of Bidens (*B. pilosa*) called by the Indians "tshubai," which has considerable value as a forage plant, being of quick growth and succulent texture.

The preference of the kelep for the tshubai as a second choice after cotton was noted last year, but no explanation was found, though the plant was searched foi nectaries. It was noticed by Mr. Kinsler that the keleps seemed to be giving especial attention to the midrib near its junction with the veins of the lower divisions of the leaf. Our lenses then revealed the fact that there are two minute raised wings or margins running along the upper side of the midrib and petiole, forming two narrow grooves in which the nectar is evidently secreted. The grooves are also protected by a row of fine hairs which project across them from the raised margin. The behavior of the kelep thus receives a practical explanation, and the tshubai finds a regular place next to the cotton among the plants protected by the kelep. The nectar-secreting habit of the tshubai may also explain its being eaten so readily by stock, and may help to give it standing as a forage plant, in spite of its weedy and unpopular relatives.

A second member of the composite family often visited by the keleps is the "sajal," a species of Melanthera (probably *M. deltoidea*), which also has local value as a forage plant, being eaten greedily by horses and mules, even in preference to grass. No nectaries have been found on this. A third composite, not yet identified, produces nectar in small depressions at the base of the leaf on the under side.

THE INVOLUCRE AS A PROTECTIVE STRUCTURE.

Cotton is the only plant known to be attacked by the boll weevil, and it is also unique among its relatives in the possession of a large leafy involucre. This may be a mere coincidence, or it may be that the weevil has had a considerable influence in the development of the involucre, depending upon the antiquity of the contact between the insect and its host plant. The involucre has, it is true, functions other than the exclusion of the weevils, since it takes the place of the calyx in protecting the young bud, but the reduction of the calyx probably followed the enlargement of the bracts, instead of preceding it. But however originated, the large bracts have, at the present time, a definite value in the problem of weevil resistance. There are several specialized characters which appear as though definitely calculated to increase the efficiency of the involucre in excluding the weevils from the young buds.

INVOLUCRAL BRACTS GROWN TOGETHER.

Both the Kekchi and Rabinal cottons frequently have the involucre closed at the base, the three bracts being grown together, thus making it impossible for the weevils to enter from below. In the Sea Island and Egyptian varieties, as well as in some of the Upland sorts, the bracts are not merely divided to the base, but they often have the lower corners rolled back, thus leaving an open passage for the weevils. The Rabinal cotton much excels all the other varieties thus far studied in the extent to which the bracts are grown together at the base. Sometimes they are united for a quarter or even a third of their length. (Pl. IV, fig. 1, and Pl. X, fig. 1.)

APPRESSED MARGINS OF BRACTS.

In both of these Guatemalan varieties the margins of the bracts of young involucres are firmly and closely appressed, in striking contrast with the Sea Island and Egyptian varieties, where the bud is commonly exposed even when very young. This form of protection is effective while it lasts, but in the Rabinal cotton the involucre is too small, and the growth of the young bud soon separates the bracts and permits the entrance of the weevil. The United States Upland varieties are intermediate between the Sea Island and the Kekchi cottons in the degree to which the involucres are closed and the margins fitted together. A large proportion of the Upland involucres give ready access to the weevils, while most of those of the Kekchi cotton remain effectively closed for a longer period, as will be understood after a survey of the other involucral characters which conduce to the same result.

In one respect the firmly closed involucres of the Rabinal cotton seemed almost like an advantage to the weevil rather than the contrary, for the insect is not admitted to the bud until it is about large enough to furnish a place of development for a larva. The plant having taken control, as it were, of this relation, the weevils have not needed to possess an instinct against the destruction of young buds. Those of the open involucred Sea Island varieties often were attacked while still altogether too small to bring a larva to maturity. The advantage of the closed involucres lies, no doubt, in the fact that they shorten the period of access and allow some of the buds to escape which would be punctured either for feeding or for egg laying if the weevil has a longer opportunity. (Pl. IV.)

The Rabinal cotton culture is that in which the plants are cut back yearly to the ground. During the next month, or until the buds begin to develop on the new shoots, the weevils have no breeding places and nothing to feed upon except the leaves and leaf buds. In patches where the weevils are abundant the leaf buds are eaten out so persistently as to seriously interfere with the growth of the plants, and the very young flower buds were also reached in some instances by boring through the involucres. When attacked at this stage the buds wither and drop off. They serve the weevils only for feeding purposes, and their use in this way only postpones the time when breeding can be resumed.

The cotton at Rabinal was often overrun by two species of small black ants, identified by Dr. W. H. Ashmead as belonging to the genera Solenopsis and Tapinoma.[a] There was no indication, however, that these afforded any protection against the weevils, although they might, perhaps, act as watchmen and scare weevils away when they happened to be present on buds or bolls where weevils had alighted, like other small ants which have been reported as attacking the boll weevil. The keleps belong in an entirely distinct category in being able to sting and carry off the weevils and make regular use of them as food. Instead of being of service to the cotton these small ants at Rabinal were a distinct injury; the Solenopsis was taking care of plant lice,[b] which often infested the cotton to a decidedly harmful extent. It continues and supplements the work of the boll weevils in stunting and distorting the plants. When the aphids are very numerous, the leaves are badly curled and growth is greatly impeded.

LARGE INVOLUCRES OF KEKCHI COTTON.

The Kekchi cotton has the bracts of the involucre much larger in proportion to the contained bud than the Rabinal cotton or than any of our Upland varieties. The possession of larger bracts constitutes a distinct weevil-resisting adaptation, since it permits the involucre to be more effectively closed and the protection to be continued for a longer time. Sooner or later, of course, the bracts must be separated by the growing bud. The larger the bracts the longer the bud can continue to grow before spreading the bracts apart. (Pl. IX, fig. 1.)

Prof. H. Pittier, who had charge of the Secanquim experiment in the latter part of the season, was especially impressed with the protective utility of the larger bracts of the Kekchi cotton, as shown by the following summary of his observations:

> The large size of the bracts in proportion to the floral bud is a very important protective feature. In the Kekchi cotton the amplitude of these bracts is such as to completely inclose the bud at all times before the anthesis, and even in cases when they happen to be slightly separated the occlusion is maintained by the long hairs which fringe them on all sides. The length of these hairs constitutes a serious obstacle to the progress of the weevils, whose tarsi can not obtain a firm hold on the solid surface. I have seen them drop to the ground after many awkward attempts to gain access to the squares, while on the other hand the keleps did not seem to be impeded at all by the bristles.

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[a] The material was not sufficient for a conclusive determination of the species. Doctor Ashmead says: "You have two distinct species of ants here. One, No. 1, belongs to the family Myrmicidæ and is apparently the worker of *Solenopsis picea* Emery; the other, No. 2, belongs to the family Dolichoderidæ and is apparently the worker of *Tapinoma ramulorum* Emery. I am sorry you did not have the different sexes, so that I could make positive of the species. In Solenopsis, as you probably know, there are four or five different forms, and it is not easy to identify from a single form."

[b] These have been identified by Mr. Theodore Pergande as *Aphis gossypii*, a species well known in the United States.

To show the increased size of the bracts in the Kekchi cotton, I have carefully measured over 250 squares of five of the most promising varieties of the Upland species. The dimensions taken were the length of the floral bud, and the length and breadth of the bracts. The table, in which these data are condensed in a comprehensive form, shows a decided advantage in favor of the Kekchi cotton.

TABLE I.—*Dimensions of floral buds and bracts of several varieties of cotton compared.*

Length of floral bud (millimeters).	Kekchi.			Parker.			King.			Allen.			Jewett.		
	Number of buds.	Length of bract.	Breadth of bract.	Number of buds.	Length of bract.	Breadth of bract.	Number of buds.	Length of bract.	Breadth of bract.	Number of buds.	Length of bract.	Breadth of bract.	Number of buds.	Length of bract.	Breadth of bract.
		mm.	*mm.*		*mm.*	*mm.*		*mm.*	*mm.*		*mm.*	*mm.*		*mm.*	*mm.*
5–6	1	20	11												
7–8	1	28	18	2	25	19				1	26	20			
9–10	6	39	27	13	31	20	5	33	19	18	34	21	3	38	26
11–12	5	42	30	16	36	24	7	34	23	10	34	22	2	36	21
13–14	3	42	30	18	39	25	9	40	24	18	37	23	10	39	26
15–16	4	42	30	8	38	23	6	44	25	13	39	24	7	41	28
17–18	3	47	33	6	39	26	6	40	24	5	39	25	5	39	30
19–20	2	52	30	3	43	24	4	42	26	1	49	29	1	52	38
21–22	1	37	27	3	48	26	1	43	25	1	40	26	2	47	34
23–24	3	47	36	1	36	25	2	41	26	5	40	23			
25–26	2	42	30	3	37	25				1	32	21	1	48	33
27–28				2	44	25	2	40	25	5	42	25			
29–30				2	45	24	1	49	28						
31–32				1	47	30									
33–34													1	42	32
Total	31			78			43			78			32		

The advantage is particularly notable with respect to the greater width of the bracts, which enables them to remain much more effectively closed at the angles. In the Parker, King, and Allen varieties the bracts very seldom attain a width of 30 mm., while in the Kekchi cotton the average width for all except the smallest buds is above 30 mm.

OPENING, OR FLARING, OF BRACTS AVOIDED.

The unusually large and well-closed bracts of the Kekchi cotton have another practical use in keeping the bud from drying out, as explained in the discussion of proliferation.

The external indication of this difference is that in the Kekchi cotton punctured squares commonly do not open, or flare, by the spreading apart of the involucral bracts, while among the Upland and Sea Island varieties flaring is the regular rule. Quite a percentage of the squares of Abbasi, Parker, King, and other varieties stand well open normally before any injury has occurred, but the Kekchi cotton seldom or never exposes its squares before flowering. The larger and broader involucre is also able to permit the protrusion of the flower without losing the power of closing and remaining shut for a considerable period after flowering, while the Parker and King varieties often remain quite open, so that the young boll is fully exposed to the weevils.

An example of the promptness with which weevil injuries cause the involucres of our Upland cotton to open is well shown in a note by Mr. McLachlan:

> On August 8, at 2 p. m., a small cage was placed over a small plant of Parker cotton, and 5 female and 2 male weevils were introduced. The plant possessed 36 squares, 4 flowers, and 9 bolls. The morning after the weevils were put into the cage several of the squares had flared and one had fallen. It would seem that the mechanical forces of the square are quickly affected by the work of the weevils. Here, of course, the punctures were numerous, because of the many weevils on the plant. Some of the squares were riddled with feeding and egg punctures.

The buds of Kekchi cotton often recover from three or four punctures, though they might not do so if these were all made at the same time. But it often happens that squares with numerous feeding punctures remain closed and wither up without flaring.

HAIRY MARGINS OF INVOLUCRAL BRACTS.

In addition to their larger size, the bracts of the Kekchi cotton have the marginal teeth or laciniæ more numerous and more hairy than those of our Upland varieties and able to afford more of an impediment to the entrance of the weevils. The difference was very pronounced in our experimental plot, where King, Parker, and other familiar American sorts were planted beside the Kekchi. It is as superior in this respect to the other Upland varieties as they are to the Sea Island.

The Kekchi and Rabinal varieties, though both belonging to the Upland series and having many similarities, have also very distinct differences, as, for example, in the present character. The small, firmly appressed bracts of the Rabinal cotton have the marginal laciniæ few and small; sometimes the edges are nearly entire, or merely toothed. The hairy covering is also reduced to a fine, short coat, which can afford little or no impediment to the weevils.

EXTENT OF PROTECTION BY INVOLUCRE.

That the closed involucres do indeed contribute to the protection of the young buds from the weevils became very obvious in one of our experimental plots at Secanquim, located about a quarter of a mile outside the belt of Indian cultivation of cotton. There being no keleps to afford protection, the cotton soon became thickly infested with weevils, and very few bolls were allowed to develop on any of the plants. There was a notable difference, however, in the age at which the buds were punctured. As already stated, the edges of the bracts of some of the Sea Island and Egyptian varieties separate at a much earlier period than those of the Upland varieties, and the weevils commonly attack them in their very early stages, and even while they are altogether too small to permit the development of a weevil larva. It has been pointed out already by Messrs. Hunter and Hinds that the smooth stems and petioles of the Sea Island and Egyptian cottons render them much more readily susceptible to injury by the boll weevil than are the Upland types, and if we add to this the disadvantage arising from the later development and the more open involucres the possibility of protecting the long-staple cottons against the weevils seems small indeed.

Instead of being immune to the boll weevil, as at one time hoped, the Egyptian and Sea Island varieties seem to be most lacking in weevil-resisting adaptations, as might, indeed, have been expected in view of the fact that they have been developed in regions to which the weevil has not yet penetrated. The Kidney cottons, which may be looked upon as representing the Sea Island type on the mainland of the American continents, have, as will be seen later, a peculiar feature of protective value.

ADVANTAGE OF OPEN INVOLUCRES.

It will be apparent from the facts already recited that the partly closed involucres of the Sea Island and Upland varieties now cultivated in the United States serve little or no purpose in resisting the boll weevil. On the contrary, they often appear to be an advantage to the insect, serving, as they do, to hide the parasite from its enemies and protect it against the application of insecticides or capture by insectivorous birds.[a]

The great variation in the size and shape of the involucre in the different varieties of cotton suggests the practicability of securing sorts with open involucres or with these structures reduced to small dimensions. If the weevils were to be caught by insectivorous birds, like the Cuban oriole, whose weevil-eating habits have been discovered by Mr. E. A. Schwarz, open involucres would be a distinct advantage. It might then be possible also to apply Paris green or other insecticides to young buds which are, except in the early spring, the exclusive feeding places of the weevils.

The practicability of an open involucre will need, however, to be considered from another standpoint. It must be ascertained whether the young buds will bear full exposure. Unlike most of the related plants, the cotton bud is not protected by a calyx. The involucre may be necessary as a substitute, especially in dry climates. In humid

[a] Dr. H. J. Webber states that the desirability of open involucres has been appreciated and that selections of Upland varieties with a view to the development of this character have been made.

regions, however, this requirement might be relaxed, and it is in such places that the injuries of the weevils are the greatest.[a]

BEHAVIOR OF PARASITIZED BUDS.

SHEDDING OF WEEVIL-INFESTED SQUARES.

In a dry climate, like that of the Mexican plateau region, the dropping of the squares in which the weevils have deposited eggs would constitute a very effective adaptation. The weevil larvæ do not survive a thorough drying out of the squares. It is only in the arid districts of Mexico that the cotton plant has shown its ability to escape from cultivation and maintain itself without human assistance, if indeed it be not in some places a truly indigenous wild plant, as several botanists have reported. But in a moist region like the cotton belt of eastern Texas this habit of the plant has no practical use, since as many of the weevils die when the injured squares remain attached to the plant as when they fall to the ground.

"It is generally true that squares seriously injured by the weevil sooner or later fall to the ground. Some plants, however, shed the injured squares more readily than do others. It seems to be a matter of individual variation rather than a varietal character. Thus occasional plants retain a large proportion of their infested squares, which hang by the very tip of the base of the stem. Normally the squares are shed because of the formation of an absciss layer of corky tissue across their junction with the stem. In the case of the squares which remain hanging, the formation of this layer seems to be incomplete, or else it becomes formed in an unusual plane, so that while the square is effectually cut off, it merely falls over and hangs by a bit of bark at its tip. In this position it dries thoroughly and becomes of a dark brown color. Plants showing 6 or 8 of these dried brown squares are quite common in infested fields. Although exposed to complete drying and the direct rays of the sun, the larvæ within are not all destroyed. * * *

"It seems a conservative estimate, therefore, to say that fully one-third of these exposed dried squares may be expected to produce adults. Considering the exposed condition of such squares this seems to be a very high percentage. * * * The observations made, however, certainly show that a complete

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[a] After the above had been written it was observed that the Pachon cotton from western Guatemala, grown in an experimental plot at Lanham, Md., has the peculiar feature of a large calyx, which completely covers the young bud and extends above it into long, slender, hairy tips. It may be that this is to be looked upon as still another weevil-resisting adaptation. The weevils would be able, undoubtedly, to bore through the calyx, but the hairy tips might hinder their access to the bud. The bracts are much smaller and much more open than in the Kekchi and Rabinal varieties, but the laciniæ, or teeth, along their margins are rather stiff and are clothed with numerous hairs, stronger and more bristlelike than in the Kekchi and Rabinal varieties, and able to keep the laciniæ from closing together. It may be that the greater rigidity of the laciniæ and the bristles gives better protection than the open position of the bracts would indicate. The case is in reality quite different from that of the Sea Island varieties, where the bracts are both naked and open.

drying of the square does not necessarily destroy the larva, and that a square may undergo far more exposure to direct sunshine than had been supposed possible without causing the death of the larva or pupa within."[a]

It is to be remembered, however, that such disconnected squares are thoroughly dampened every night by the dew, and that a small amount of moisture may pass out from the plant through the shred of dead tissue. In either case the hanging boll might get more moisture and less heat than if lying on the dry ground, exposed to full sunlight. Suspended bolls are exposed to air temperatures only.

If no other means of avoiding the weevil becomes practicable a great extension of the cotton production into the semiarid districts of western Texas, Oklahoma, and even Kansas is to be expected. The long days of the more northern districts will conduce to the shortening of the growing season, and if dry weather cuts down the yield the loss is likely to be neutralized by more or less complete protection against the weevils.

These contradictory effects of the same adaptation depending upon climatic condition may render necessary a complete differentiation of the cotton varieties of wet and dry regions.

It is not improbable that the Upland varieties previously known in the United States came originally from the more or less arid regions of Mexico, where absence or very small development of the basal branches keeps the ground from being constantly shaded and gives better chances for the weevils to be killed by the drying out of the fallen squares.

Our Upland cottons are undoubtedly of American origin, but the region from which they came has not been ascertained. Some of the Texas varieties are said to have been brought from Mexico. Coronado's Journal of the earliest Spanish exploration in Arizona and New Mexico contains many references to the cultivation of cotton by the Indians. There can be little doubt that the agricultural Indians of the Gulf region also cultivated cotton, though no documentary evidence of the fact seems to have come to light as yet.

It is highly probable that the original home of the cotton plant, and of the boll weevil as well, was in a somewhat arid region, since it is only under such conditions that the weevil would be effectually prevented from increasing to the fatal degree of destroying its host plant, and thus cutting off its only means of subsistence. On the other hand, it was only in a humid country like eastern Guatemala that many of these weevil-resisting adaptations would be likely to develop if, as now appears, it has required the selective influence of the boll weevil itself to bring them to their present advanced development.

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[a] Hunter, W. D., and Hinds, W. E., 1904. The Mexican Cotton Boll Weevil. Bul. 45, Division of Entomology, U. S. Department of Agriculture, pp. 73 and 74.

The adaptive character of this habit of shedding the parasitized squares seems to be confirmed by the fact that it depends upon the existence of a special layer of soft cells which readily break down when the bud is injured. Many plants have such cells as a means of shedding their fruits, but they seem not to be prevalent among the relatives of the cotton. The cotton itself does not drop the ripe bolls, and even the empty shell often remains long after the seeds are gone.

The drier the climate the more effective is the prompt shedding of injured squares. Whether there are other adaptations thus especially suited to dry climates is not yet known, our studies having been confined mostly to humid regions.

Dr. Edward Palmer, who has spent many years in botanical explorations of the dry plateau region of Mexico and who discovered that the boll weevil was a cotton pest, states that in several localities where the cotton was formerly grown without difficulty the introduction of irrigation improvements has proved disastrous. With the assistance of the moist soil the weevils are now able to reach maturity in large numbers and complete the devastation of the crop, quite as in Texas. The irrigated soil affords a situation favorable for the development of the larvæ in the fallen squares.

This is said to have been the case about Parras, and at Rio Verde, below San Luis Potosi. The culture of cotton has declined also in the "Huasteca Potosina," the tropical district between San Luis and Tampico, and on the Pacific side of Mexico, along the Santiago River above San Blas, as well as about Tepic. Doctor Palmer saw cotton growing in a wild condition in the fences at the old mission, San José de Guaymas, 6 miles from the commercial port; again at Mulege, Lower California, across the Gulf from Guaymas, the latter a much-branched, prolific tree, producing a nankeen-colored lint. About Guaymas cotton was formerly utilized by the Indians as tinder, after being dipped in a solution of saltpeter. The same facts were observed by Dr. L. O. Howard in 1899 at San José de Guaymas.

COUNTINGS OF FLARED AND FALLEN SQUARES.

An attempt was made in connection with our Guatemalan experiment to secure data on which a definite statement might be based regarding the extent to which the different varieties were protected by their involucral characters, but the problems are too complex to be reached except by more elaborate statistical studies than were practicable at that time.

Countings were made, for example, of the flared and fallen squares—that is, of those which it might be supposed that the weevils have injured—and of the number of weevil larvæ, proliferations, etc., found inside them. The results in percentages do not agree, however, with the facts obvious in the fields; indeed, they greatly misrepresent them. Thus the percentage of weevil injuries in flared and fallen squares does not appear very much higher in the Kekchi cotton than in the Sea Island and Upland varieties; yet as a matter of fact the squares of the Kekchi cotton seldom flared for any other reason than weevil injuries, and much less often for this cause than did those of other varieties. Many small squares of the Kekchi cotton fall off, however, before they are large enough or open enough to be attacked by the weevils.[a] This takes place in the other varieties to a much smaller extent, but with them the apparent percentage of weevil injuries among flared squares is much diminished, because many squares stand open and appear as though beginning to flare, even before the weevils have attacked them.

PROLIFERATION OF INTERNAL TISSUES OF BUDS.

The protection of the buds does not end with devices for the exclusion of the adult weevils, nor with the rejection of those in which they have laid their eggs. It is also possible for the plant to heal the wound, and bring the injured bud to maturity by preventing the growth of the weevil larva. Where the climate is dry the weevil larvæ in the rejected buds are killed, as already explained. The humid climate alternative of the falling of the parasitized squares is proliferation, the growth inside the bud of loose, watery tissue in which the larva does not develop. Whether the larva is killed by smothering, starving, or poisoning, or by some combination of these, is not yet known. Starvation is a sufficient explanation, since the material with which the larva becomes surrounded can be no adequate substitute for the highly nutritious pollen grains on which the infant larva would otherwise feed.

Proliferation is much more frequent in the Kekchi cotton than in any of our United States varieties, as far as known. The first and second punctures are commonly resisted successfully, but the third, fourth, or fifth attempt may succeed in the development of a larva. The proportion of weevil punctures rendered ineffective by proliferation was found to run well above 50 per cent, sometimes between 80 and 90. (Pl. V.)

The promptness and efficiency of proliferation bear an inverse proportion to the size of the buds. As the latter grow larger the mass of anthers inside becomes less compact, and the other tissues become too

[a] Professor Pittier found in the latter part of the season that the buds of the Kekchi cotton were sometimes cut away at the base and left hanging in a wilted condition. These were at first taken for flared squares as the result of weevil injuries, but it was later ascertained that this was not the case, though the true cause was not learned. The damage was done in the night.

nearly mature to put forth new growth. If the presence of the larva at this stage is sufficient to cause the bud to fall off, the development of the parasite to maturity is well assured, the large bud affording good protection and adequate food.

In the Kekchi cotton, however, such late attacks very seldom cause the bud to fall off. Larvæ developed in the larger buds are turned out of doors, as it were, by the opening of the flower. The tendency of injured buds to persist is notably greater than in the United States, either because of some physiological difference between the varieties, or because of the larger and more firmly closed involucres of the Kekchi cotton, which keep the buds surrounded with a moist atmosphere and protect it against drying out while the new tissues are forming to heal the wound and encyst the egg.

In the closely planted Indian fields the squares seldom flare as in the Texas varieties. They generally remain in place and continue to grow until the bracts have reached nearly their full normal size. In fields partially protected by the keleps the weevil larvæ do not seem to develop in buds as small as in Texas. Proliferation may partly explain this delay and also the more firmly closed involucres, but in our unprotected plot the weevils were able by repeated punctures to infest smaller squares and reach maturity in them, after they had fallen to the ground.

The behavior of weevil larvæ inside the squares in Guatemala seems also to differ appreciably from that observed in Texas where younger squares are usually much more accessible to the weevils, and are commonly punctured. In Texas the larvæ regularly grow to maturity, depending for food upon the pollen, which is completely eaten out. In Guatemala this very seldom occurs. Small squares with well-developed weevil larvæ are rarely found under normal conditions, nor do the larvæ depend upon the pollen as their principal article of diet, as in Texas.

Several reasons for this difference may be considered. The first is that the larger and more firmly closed involucre of the Kekchi cotton gives the buds several days of protection, so that the average size would naturally be larger. The examination of large numbers of squares picked at random from the Indian cotton fields by Messrs. Kinsler and McLachlan show also that a very large proportion of the punctures are followed by proliferation, and that this means of protection is much more efficient in the younger squares. Another reason must be sought, however, for the failure of the larvæ to eat the pollen of the large buds where proliferation is less prompt and less frequent. The impression might be gained that the pollen of the Kekchi cotton is in some way not acceptable to the weevils, since even when there is an abundance of pollen at hand they prefer to eat out the style and central column of the flower, and thence down into the ovary or young boll. After this has been consumed the larvæ return to the upper part of the bud to finish the remainder of the pollen.

Nevertheless, this suggestion of a protecting quality in the pollen itself can not be accepted with much confidence because the weevils showed in numerous instances that they could live and thrive upon the pollen of the young squares, quite as in the United States. This occurred in the experimental plot where there were no keleps, and the weevils were very numerous and persistent in their attacks. After two or three punctures the squares flared and fell to the ground in the usual manner, and in these the weevil larvæ were able to reach maturity.

A more probable reason for the usual failure of the larvæ to eat the pollen as freely as in the United States is furnished by the opinion of Mr. W. D. Hunter, that the original habit of the weevil was to attack the bolls, like related species of Anthonomus, which live upon various kinds of fruits.[a] If this be true with reference to the boll weevil we may think of the Guatemalan members of the species as having retained somewhat more of the ancestral habits which with them are definitely useful, because the cotton variety with which they have to deal has perfected, to a larger extent than the Texas varieties, the art of proliferation.

As a further indication of the greater strength among the Guatemalan weevils of the instinct of attacking the ovary of the bud may be mentioned the fact that a very large proportion of the punctures occur low down—that is, on or below the level of the apex of the young boll. The larva commonly eats directly to the center of the bud and hollows out the apex of the young boll. This habit gives rather less opportunity for successful proliferation than in Texas, because the cavity hollowed out by the larva lies below the level of the staminal tube, the tissues of which are the most active in proliferation. The Kekchi cotton shows occasionally another form of proliferation not recorded from Texas, namely, that of the base of the corolla. Sometimes this enlargement takes place in an outward direction, forming a wart or protuberance on one side of the bud, as shown in Plate VI. In other instances the direction is reversed and the ingrowing edges of the wound made by the weevil fill the internal cavity and prevent the development of the larva. The proliferation of the corolla, besides being less

[a] A new species of Anthonomus with habits closely identical with those of the boll weevil, but parasitic on the pepper plant (Capsicum), has been discovered recently in Texas by Mr. E. A. Schwarz. This gains an added interest from the fact already noted that it is the regular custom of the Indians of Alta Vera Paz to plant peppers among the cotton.

frequent than that of the staminal tube, is probably also less effective, since the weevil larvæ could escape before it into the center of the flower while the proliferation from the staminal tube grows outward, as though to meet the intruder and keep him separated from the more special organs.

The habit of the larvæ to seek the center of the bud and gnaw off the style is responsible for the loss of large numbers of younger bolls which have suffered no direct injury from the weevil. Even though the larva be subsequently killed by proliferation or though the flower drops off and carries the larva with it, the lack of pollination must prevent the development of the young boll unless parthenogenesis takes place, which seems improbable.

Larvæ were found in several instances in nearly full-sized buds about to open, and in another case a more than half-grown larva was found inside the central column of an open flower. More or less distorted flowers with unmistakable signs of previous proliferation in the bud stages are commonly found in the Kekchi cotton fields.

Summarizing the results of the study of proliferation in the Kekchi cotton, it may be said that although the frequency of proliferation in the young squares is very great, its efficiency in preventing the breeding of the weevils is somewhat less than might be expected in Texas, owing to the difference of food habits among the weevils. If the Texas weevils are as consistent in their habits as now supposed, the introduction of the Kekchi cotton or of a similar proliferating variety might be of great benefit as a preventive measure. The extent, however, to which it could be made to compass the complete destruction of the weevil would depend somewhat upon the degree, if any, to which they might return to the habit shown in Guatemala of feeding upon the ovaries or boll rudiments rather than upon the pollen of the young buds, an important and hitherto unsuspected difference in habits between the weevils of Texas and those of Guatemala.

CAUSES AND CONDITIONS OF BUD PROLIFERATION.

That the proliferation is occasioned by the injuries of the weevil is too obvious to admit of doubt, but it may be of much practical importance to learn the exact way in which the new growth of tissue is brought about. The disturbing factor might be either mechanical or chemical. The new growth may be a direct response to injury of the weevils in feeding or laying eggs, or it might be stimulated indirectly by the secretions of the young larva, or by chemical changes or decay of the damaged tissue. A second mechanical possibility is that of pressure developed in the young and rapidly growing bud.

The burrowing of the weevil relieves this pressure at one point, and may thus furnish the exciting cause of the rapid growth in this direction of the tissue of the staminal tube.

It seems not improbable that a relation will be found between the method of culture and the extent and frequency of proliferation. Open-field conditions, with much bare ground about the plants, would increase the daily exposure of heat and dry air, and this would conduce to the wilting of the punctured squares, which might then be expected to flare and fall off instead of remaining to proliferate. The result of weevil work in our open-culture plots was obviously different from that in the more crowded cotton fields of the Indians. On the widely separated plants the squares often fell off and permitted the larvæ to develop, as in Texas, except that there was still a distinct tendency on the part of the larvæ to attack the pistil and ovary first, before eating out the pollen.

PROLIFERATION IN OTHER VARIETIES.

Proliferation is by no means confined to the Kekchi cotton, but probably occurs, occasionally at least, in all the Upland and Sea Island varieties. A noteworthy Guatemalan Sea Island cotton was found by Mr. Kinsler in the aldea of San Lucas, a few miles from Secanquim.[a] Both the buds and the bolls afforded fine examples of effective proliferation. Even the Egyptian varieties showed a distinct ability in this direction. In one instance no less than 17 of 23 punctured squares of Jannovitch had proliferated, and 15 cases seemed to have been effective.

Proliferation ceases to occur when the bud has become too large. The anthers are no longer so closely packed together and the tissues of the staminal tube are too nearly mature. By that time, however, the style may be sufficiently developed to furnish adequate food. It is well known, however, that the period of development of the weevil larvæ may be greatly prolonged, and this would seem likely in the present instance, since the tissues of the styles must be less nutritious than the pollen. The delay also would be advantageous, since it would permit the young boll to become larger.

[a] This variety is peculiar in having about half of each seed covered only with a very fine, short, bright bluish-green lint. The upper half bears the long white fiber, and is smooth and black when this has been removed. Some of the plants had excellent crops of bolls, unusually uniform in size and apparent age, as though the habit of seasonal flowering were well accentuated. The variety is evidently perennial and grows to a height of from 6 to 8 feet, but on the other plants the leaves, flowers, and bolls were much reduced in size. The plants were all occupied by small black ants. On some of them no weevils nor any indications of weevil injury were found, but others only a few rods away were badly infested.

But as the power of effective proliferation declines in the larger buds another factor of protection comes into play. The later the attack of the weevil the greater is the chance that the bud will mature and the flower will open and turn the weevil larva out of its quarters to die. And since buds commonly mature which have been attacked while still young enough to proliferate, it is easy to understand why attacks made in the later stages seem to be effective only in exceptional instances.

An element of uncertainty often attaches to the enumeration of weevil injuries because of the difficulty of finding the egg or very young larvæ of the weevil in the squares which have been only recently attacked. This is especially true in small squares where the anthers are still white and of about the same color, size, and general appearance as the eggs. The possible error does not, however, materially affect the result, since it is to be expected that the same proportion of bolls will proliferate and the same percentage of weevil larvæ develop as in the squares which are far enough advanced to show definite results.

PROTECTION OF THE BOLLS.

If it be true, as already intimated, that the original habit of the weevil was to attack the boll instead of the bud, the opportunity for the selective development of protective characters of the boll has been greater. This suggestion seems to accord with the results, since the boll of the Kekchi cotton has a series of protective characters even more striking and effective than those of the involucre and the bud.

PERSISTENCE OF FLOWERS.

As long as the flower remains in place the young boll is thoroughly protected, the weevils having no means of access except by boring through the withering tissues, which seems not to be attempted. In the Kekchi cotton the flower falls only when detached by the swelling of the young boll. This may also be true of other varieties. (See Pl. IX.)

The frequent sequel of proliferation in the bud, as noted above, is the loss of the young boll through lack of pollination. This is especially true in Guatemala, owing to the tendency of the weevil larvæ to eat away the style. On one occasion Mr. Kinsler collected from a field of Indian cotton 28 young bolls showing signs of debility. These measured from 13 to 20 mm. in length, most of them about 15 mm. None of the smaller bolls showed signs of weevil injury, but in many of them the ovules were already shriveling up. A few punctures were found in some of the larger bolls, and in some of these proliferation had occurred. The development of the weevil larvæ to maturity seemed unlikely in any case, because the unfertilized ovules were already withering.

Presumably there are various stages and degrees of fertilization. Some of the stigmas of proliferated buds seem to have adequate pollen, so that the bolls can develop normally, while others obtain none at all or only a little. The persistence of injured flowers is much greater. They may not fall off at all, and often remain attached by the withered style to the boll when nearly full size.

It thus happens that injured flowers protect their young bolls longer than the others, but in most instances such bolls remain small or unsymmetrical, presumably as a result of inadequate fertilization. It is quite possible, however, for normal bolls to develop occasionally from weevil-infested buds which never open, for the style often pushes through and becomes fully exposed, so that fertilization by pollen from another flower might readily take place.

IMMUNITY OF VERY YOUNG BOLLS.

For reasons not yet ascertained, the weevils in Guatemala seldom or never attacked the very young bolls. This may be due to a conservative instinct on the part of the weevil, like that which forbids the laying of any additional eggs in a bud already parasitized.[a] It is not impossible, however, that the oil glands with which the surface of the young boll is very thickly beset may have a protective function. As the boll grows larger the glands do not appear to increase in numbers, but become separated much more widely. On bolls of the Kekchi cotton the oil glands are usually absent from a distinct longitudinal band running down the middle of each carpel. (Pl. VII.) A large proportion of the weevil egg punctures are made along this naked band, although very few of them take effect. The wall is thicker here, and the weevil in boring meets the tough lining of the boll chamber at an angle, and is seldom able to penetrate. If this interpretation of the facts be correct, the naked band constitutes a veritable weevil trap, a device for inducing the weevil to make its punctures and lay its eggs in the part of the boll where they can do no harm.[b]

To ascribe a protective value to the oil glands is not unreasonable in view of the fact reported by Messrs. Quaintance and Brues.

[a] Hunter, W. D., and Hinds, W. E., 1905. The Mexican Cotton Boll Weevil. Bul. 51, Bureau of Entomology, U. S. Department of Agriculture, p. 78.

[b] This peculiarity of a glandless longitudinal band in the middle of each carpel was also noticed in a variety of cotton cultivated by the Moqui Indians of Arizona, grown in 1904, in the Department's plant-breeding experimental field at Terrell, Tex. The Moqui cotton is interesting also by reason of its short, squarish, distinctly apiculate bolls, more like some of the Old World cottons than are those of other members of the Upland series.

that the Egyptian cotton, the bolls of which are excessively oily, is on this account immune from the bollworm.[a] The oil contained in the glands has a deep-brown color, a sticky, molasses-like consistence, a disagreeable, pungent odor, and a sharp, resinous taste, suggesting turpentine or Canada balsam.

The development of the oil glands seems to be especially great in the Egyptian variety known as Mit Afifi, and the glands are more superficial. By slight pressure, or by drawing the nail across the surface, the oily liquid is freely obtained. Most of the Upland varieties have the oil glands much more scattering and deep set than the Egyptian sorts, and it is not possible to squeeze the resin out of them in any such manner.

On Redshank and other Upland types the resin glands are marked by slight superficial depressions, but a cross section shows them to be well below the surface, with several layers of chlorophyll-bearing cells between. On the Egyptian sorts the glands are also set in depressions, but the gland itself is very close to the surface, and makes the bottom of the depression again convex, the superficial layer of cells being very thin. It seems to break spontaneously in some instances; at least there are frequently small spots of hardened resin, and very slight pressure brings out the dark, gummy fluid. The fingers receive a permanent brownish stain, which with the acrid, biting sensation experienced when the liquid is applied to the tongue, increases the probability that substances of a definitely protective character are present. It is well known that many of the aromatic oils are for some reason highly distasteful or even fatal to many insects.

The Sea Island and Kidney cottons have the oil glands conspicuously developed, like the Egyptian varieties, but the Old World cotton (*Gossypium herbaceum*) is in this, as well as in other respects, more nearly related to the American Upland cotton (*Gossypium hirsutum*). The Aidin (Asia Minor) variety of *Gossypium herbaceum* has the oil glands rather small and deep set, with the superficial pits rather shallow, more so than the Ceylon or Korean types.

Even the petals of the Guatemalan Kidney cotton found at Trece Aguas[b] contained oil glands. The color of the petals was a uniform pale yellow, without purple spots on the inside, but in the upper

[a] Quaintance, A. L., and Brues, C. T., 1905. The Cotton Bollworm, Bul. 50, Bureau of Entomology, U. S. Department of Agriculture, p. 71.

[b] The Kidney cotton at Trece Aguas is called *paiyi*, and seems to have little or no relation in the minds of the Indians with the dwarf Upland cotton, which is called *nok*. In the Secanquim district, only a few miles away, this name *paiyi* (pronounced like the English words *pie ye*) is not recognized. Kidney cotton, though apparently not now planted by the Indians, is not entirely unknown to them. They call it simply *che nok*, or tree cotton.

half specked with minute brown glandular dots.[a] The oil glands of the bolls of this Kidney cotton are apparently quite as strongly developed as in the Egyptian varieties, or even more so. They are distributed very irregularly over the surface, and are not lacking above the dissepiments, along the middle of the carpels. The position and structure of the glands seem also to be the same as in the Egyptian cottons. They are close to the surface and show as distinct black spots, there being no green tissues over them as in the Upland and *herbaceum* types.

I am indebted to Mr. Guy N. Collins for the suggestion that the present inefficiency of the oil glands as a means of protecting the cotton from the boll weevil furnishes no argument against the adaptation of the glands nor their development through the selective agencies of the boll weevil itself. This fact is sufficiently obvious when once stated, but it is not commonly taken into account in considering questions of this kind. We may be sure that the gradual development of a protective character like the oil gland would carry with it a corresponding increase in the power of the weevil to avoid or to endure the injury. The ultimate value of the device would depend on whether the glands were able to keep ahead of the weevils in quantity and distastefulness. The readiness with which the boll weevils attack the Egyptian cotton renders it obvious that oil is now no adequate protection, but the preference of the weevils for the unprotected strips of the bolls of the Kekchi cotton indicates that the weevils still dislike the oil, though they may have foiled the attempt of the plant to protect itself in this way.

There are two attendant facts which under certain circumstances might readily obscure the immunity of the young bolls. Many such small bolls fall off, a particularly large number it seemed from our row of Parker cotton, but an examination of these failed to show anything in the way of weevil injuries, except such as had been inflicted while the bud or flower was still in place, the style and a small apical cavity having been eaten away in numerous instances. Many small bolls were to all appearances quite uninjured. They may have been rejected by the plant as supernumerary, the plant being unable to furnish the food material needed to bring them to maturity, or they may have failed of fertilization as a result of weevil injuries to the bud or from other causes, such as the absence of bees, which were extremely scarce in the Guatemalan cotton fields. The frequency with which the boll weevils were found inside the

[a] The flowers of the Kekchi cotton are pure creamy white when young and as long as they remain open. When old and rolled together they become a pinkish red. They are not yellow or bluish at any stage. The stamens and pistils are also nearly white, the latter with rows of oil glands showing as small grayish dots.

cotton flowers and well dusted over with pollen suggests the possibility that in this district at least they were a not unimportant agency of cross-fertilization. The performance of such a service by the boll weevil would be comparable to the famous case of the yucca and its moth, the plant being dependent for cross-fertilization upon its insect parasite. The weevils eat the pollen from the bud; that they visit the flowers for the same purpose seems highly probable. The investigations of Messrs. Hunter and Hinds have shown, indeed, that a pollen diet is a necessity for the complete sexual maturity and reproduction of the weevils; if without buds to feed upon they seldom copulated and never laid eggs.[a]

RAPID GROWTH OF YOUNG BOLLS.

Mr. John H. Kinsler, who gave careful attention to the earlier stages of the Guatemalan experiment, gained an impression that the young bolls of the Kekchi cotton increased in size with a rapidity distinctly greater than that of the United States Upland varieties planted alongside. It was not practicable to establish the fact by carrying out a series of daily measurements, though it was possible to ascertain from dated tags used in connection with the hybridization experiments that the Kekchi cotton can grow bolls to full size in less than a month from the time the flower opens. Plate IX, figure 2, shows on the right two bolls of Kekchi cotton less than a month from flowering. On the left are the two largest bolls from an adjoining plant of King, the seed of both varieties having been sown the same day.

Such an acceleration of the growth would be of very obvious utility in lessening the period in which the danger of infestation is greatest. A large proportion of the weevils found in adult bolls of Kekchi cotton were in "locks" or compartments of diminutive size, showing that the infestation had taken place while the boll was less than half grown. Indeed, the weevils seldom seem to be able to affect lodgment in bolls more than half grown, although numerous attempts are made in fields where the weevils are numerous. The following field note describes such an instance:

> A boll showing many external marks of weevil punctures was found on being cut up with care to have been attacked at least fourteen times. In five cases the outer wall seemed not to have been penetrated, but in nine others there had been complete perforations. All of these had been closed, however, by proliferation from the inner surface, and no living larvæ were found.

Such persistent attacks, however, may finally induce a diseased condition which interferes with the normal growth of the boll, even

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[a] Hunter, W. D., and Hinds, W. E., 1905. The Mexican Cotton Boll Weevil, Bul. 51, Bureau of Entomology, U. S. Department of Agriculture, p. 113.

though the weevils be successfully resisted. Such injured bolls often show a brownish discoloration of the interior tissues near the base and connecting with the nectaries, which may indicate a bacterial disease, to be discussed later. Sometimes this affects the walls only, sometimes one or more seeds and the surrounding lint.

THICK-WALLED BOLLS.

In the Kekchi cotton there are considerable variations in the thickness of the outer wall of the boll. Not infrequently the wall equals or exceeds the length of a weevil's snout, so that only the largest or longest snouted weevils would be able to make an opening into the interior cavity. It was noted, also, that on the inside such bolls are often quite free from these injuries or small larvæ, though numerous attempts may have been made. Large larvæ or pupæ may be found, but these have come, obviously, from eggs laid while the boll was still young. On some plants the development of large thick walls takes place very promptly, so that a protective character of considerable value might be obtained if this feature could be increased and rendered constant. Early development of the thick walls was indicated by the fact that the young seeds and lint did not fill the cavity, and the seeds were still far from mature. Instances might be drawn from other plants where the growth of the pod or seed vessels far outruns the seeds at first, so that the development of such a character in cotton might reasonably be expected.

Even when a wall thicker than usual has been bored through, the egg must be laid on the outside of the mass of lint which still intervenes between it and the young seed, so that the larva's chances of development are greatly lessened. As will be shown later in the discussion of proliferation in the bolls, the instances are very numerous in which, although the wall is penetrated, no further damage results; either the egg is not laid or the development of the larva is prevented by proliferation. In any event the boll escapes further injury, and it is a very significant fact that in the dissection of a large number of such bolls of Kekchi cotton scarcely any young larvæ were found, in spite of the fact that most of them had been punctured not once only, but many times.

TOUGH LININGS OF CHAMBERS OF BOLLS.

The three, four, or five chambers which contain the locks of cotton in the unopened boll have each a complete membranous lining. In the Kekchi cotton, at least, this is extremely tough and parchment-like, even in bolls not yet full grown and in which the seeds are not yet fully formed. This membrane is readily separable from the more fleshy external layers of the boll, and though flexible, it is very firm and incompressible, and resists tearing unless considerable strength be exerted.

A large percentage of attempted punctures of the larger bolls failed because the weevils are unable to penetrate this protective lining. This fact is readily determined by the study of radial sections of the outer wall through the warts which mark the weevils' points of attack. The different texture of the new tissue which has closed the wound shows, usually, that the cavity eaten out by the weevil extended down to the tough basal lining, even when no evidence of the injury has become apparent on the inside. In other instances, also very frequent, the new tissue, developed as a result of the irritation of the attempted puncture, exceeds the cavity and causes an inward swelling or prominence of the inner lining analogous to the projecting warts which are the usual external indication of weevil punctures.

It occasionally happens, too, that the projection of the new tissue occurs almost entirely in the inside, the external wart being very slightly developed or not at all, though the new tissue and the inner swelling show that a puncture had been attempted.

The utility of this lining as a means of excluding the boll weevil seems not to have been considered heretofore, and there has been no opportunity as yet to compare the Kekchi cotton with other varieties with regard to this feature.[a] Certain it is, however, that in the Kekchi cotton the parchment lining is almost as firm and tough as that which surrounds an adult coffee seed. And it is certain, also, that a very large proportion of the attempted punctures of the bolls failed to bore through this inner wall of defense.

The examination of a large number of bolls, which were full size or nearly so, though still far from maturity, in most cases failed to find more than a very few instances, if any, of very recent perforation, though there were large numbers of instances where the weevils had gnawed their way down through the parchment and deposited an egg. In many such cases the proliferation or new growth induced by the injury causes the parchment to be raised up from the wall on the inside to form a blister-like, rounded protuberance. (Pl. VIII.) Eggs laid outside the parchment are firmly embedded in the new

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[a] Since this was written Mr. McLachlan has reported the existence of the same form of protection in Upland varieties in Texas. The following note describes the results of injuries inflicted upon the bolls of a plant of Parker cotton in four days from August 8 to August 12, 1905:

"The 9 larger bolls, when opened, were found to have 28 weevil eggs deposited in them; 6 had struck the dissepiment; 12 were not entirely through the shuck of the boll (either not more than half way there or else stuck in the tough inner tissue of the shuck); the others were embedded in the lint. In only two instances was there any proliferation apparent. The outer shuck had proliferated at the wound and in one case had encysted the egg. The other had merely forced the egg to one side, having begun the development too late."

growth and do not appear to hatch, or if they do the larvæ are not able to do any damage, since they can not penetrate into the interior of the boll. It quite frequently happens that eggs are laid in the sinus or groove between the linings of two locks, but without penetrating the parchment of either. The tissue is here somewhat looser than in other parts of the wall. In a few instances it was observed that the larvæ had hatched, but no case was found which indicated that larvæ hatched outside the parchment lining had been able to penetrate to the interior cavity.

PROLIFERATION FROM THE WALL OF THE BOLL.

The wall of the boll offers an active form of weevil resistance by proliferation, in a manner somewhat analogous to that of the proliferation of the square. The channel excavated by the weevil is closed by the new growth, which continues to push out on the inner surface of the wall in the form of a rounded, blister-like protuberance of loose tissue. This surrounds and encysts the weevil egg, and prevents its development. A section through the mass of new tissue shows the egg embedded in it or pressed against the lint. Proliferation often takes place even when the tough lining of the chamber has not been penetrated, and then appears as a prominence underneath the membrane.

It has been seen from the preceding paragraph describing the thick walls and tough lining that in the Kekchi cotton, at least, the weevil is practically excluded from the boll after the boll has reached about three-quarters of its full size; but even in its younger stages also there is a measure of defense through the formation of new tissue as a result of the irritation set up by the weevil's injuries in a manner analogous to that which induces the formation of galls and other vegetable excrescences.

The first result of the proliferation is to fill up and heal the wound bored out by the weevil. The cavity is not only completely filled, but in most cases a wartlike prominence is formed on the outside, and if the parchment lining or the inner wall has been penetrated the new proliferating tissue also grows through on the inside and often spreads out as a biscuit or button shaped protuberance of soft white or transparent tissue several millimeters in diameter and readily visible to the naked eye. (Pl. VIII.)

There are two alternatives in the fate of an egg destroyed by proliferation. Either it is completely surrounded in the proliferating tissue outside or inside of the parchment wall or it is carried on the apex of the proliferation down against the lint and flattened between the growing surfaces. After the egg has disintegrated and disappeared its position is frequently shown by a minute brown stain. Such a discoloration often spreads back into the loose tissue and then gradually extends over the whole lock of cotton of that particular chamber. The seeds fail to develop and finally shrivel up.

If the proliferation results, as usual, in the death of the weevil egg or young larva, the process of abnormal growth ceases with the formation of a knob or button of the new tissue on the inside of the wall of the boll. When, however, the young weevil escapes destruction and continues to eat and grow, the proliferating tissue also continues to increase, until in some instances the whole compartment is filled with a silvery-white cheesy material which seems to arise not only from about the original perforation of the outer wall, but also from other parts which have been injured and irritated by the presence of the weevil larva. This, with other facts already stated, seems to show that in some varieties of cotton, at least, the tendency to proliferation is very general, or, in other words, constitutional, which warrants a larger hope of increasing this character and making it uniform by selection.

When proliferation, which results from the presence of the weevil larva, has become very extensive and fills the entire compartment, the weevil larva is sometimes found to have eaten through the dissepiment into the next chamber, perhaps to escape starvation. Such extensive proliferation, accompanied by the failure of the seeds to develop, means, of course, that the weevils gained entrance while the boll was still very young. Moreover, if the boll had been older there would have been plenty of food for the larva without the necessity of entering a second compartment. Finally, the dissepiment would have been too tough for the larva to penetrate easily.

Further proof of the fact that the weevil larvæ are seldom or never able to gain a footing in the larger bolls is to be found in the fact, already stated, that the weevil larvæ found in them are nearly always in undersized compartments, much smaller than those which have remained uninjured, and have thus been able to continue their normal development.

It is to be supposed, perhaps, that if the weevils could gain access to large bolls and feed upon the nearly adult seed they would be able to develop in less time than they usually spend in reaching maturity on the rather poor provender they secure among the abnormal tissues which arise after they have entered the young bolls.

The exclusion of the weevil from the large bolls has been evidently not only an important measure of protection for the cotton, but it has probably compelled the weevil to accustom itself to a gradually longer and less prosperous development in the boll. The development of the weevil-resisting adaptations on the part of the cotton plant has left the insect with two opposite alternatives. It must enter the boll early and submit to a very long period of development or enter the square late and develop very promptly. The insect has been able, as we know, to avail itself with a large measure of success of both these alternatives, but it is not without encouragement for future progress in weevil resistance to know that the plant has so successfully guarded itself in two parts of its life history.

If additional evidence be needed to show that the food supply obtained by the weevil larvæ in the bolls is very different from that in the squares, it is to be found in the large, firm-walled cells of compacted excrement with which they surround themselves in the bolls before reaching maturity. The food being of a much coarser nature and the period of development about three times as long, the amount of waste material is naturally very much greater. If feeding upon the boll is, as now appears probable, the ancestral habit of the weevil, it need not surprise us that the protective adaptations of the boll are more numerous and effective than those of the bud, which may have been attacked by the weevil in comparatively recent times.

TIME REQUIRED FOR PROLIFERATION.

In connection with the experiments in Texas, Mr. McLachlan attempted to ascertain the time required for proliferation to take place after the injury had been inflicted. The amount of proliferation and the time required for it to develop may be expected to depend much on external conditions. Squares of Parker cotton showed no development in six hours, but observation on bolls showed that proliferation was complete in twenty-four hours. Two of Mr. McLachlan's observations are described in the following notes:

On August 14, at 9.15 a. m., a wire cage was placed over a plant of King cotton, and four weevils, of which at least two were females, were put inside. Later, three more were introduced. At the time there were 11 bolls, 39 squares, and 1 flower on the plant.

On August 17, at 1 p. m., 11 bolls and 18 squares were picked, a little more than three days being allowed for the weevils to work. There was no rain, and of the 18 squares examined only one revealed proliferated tissue, though the weevils had scarred the buds in more than 33 separate places and had deposited 15 eggs. But the bolls showed better results. They had been scarred at 32 different points, and 23 eggs were discovered when the bolls were cut open. In 12 cases inward proliferation of the "shuck" had destroyed the eggs. Several of the incited growths had caught the egg, encysted it, and carried it along, inclosed at the apex, as they pushed their way into the lint. As in the Parker cotton examined a short time ago, weevils seem to have some difficulty in getting the egg through the shuck of the boll. In dry weather it appears that the King cotton is as backward as the Parker in proliferation in the squares, but in bolls proliferation goes forward as well in dry as in wet weather.

On the 30th of August, at 10.15 a. m., a boll (half grown and tender) was bagged with a weevil. At 6 p. m. of the same day an egg puncture was found on the fruit, but at 8 a. m. of the 31st no further injury had been inflicted. At 12 m., September 1, four more egg punctures were discovered, and the boll was pulled and examined. The first puncture was then forty-two hours old and the other four some twenty-four hours old. The examination revealed marked proliferation in every case, with no greater growth in that of forty-two hours' duration than there was in that of twenty-four. Eggs had been laid inside the wall of the boll, since it was easy, in the case of young, tender fruit, for the weevil to cut an opening to the lint. But every one of the five eggs had been encysted by the proliferated tissue. It is quite possible that one or two of the punctures reckoned as twenty-four hours old were still more recent.

EFFICIENCY OF ADAPTIVE CHARACTERS OF BOLLS.

The amount of protection afforded in Guatemala by the weevil-resisting characters of the bolls might be greatly underestimated if it were to be supposed that the weevils make numerous attacks upon the bolls for the purpose of feeding upon them.

In their accounts of the habits of the boll weevil in Texas, Messrs. Hunter and Hinds have devoted a chapter to "effects of feeding upon squares and bolls,"[a] but in Guatemala no indications were found that weevils punctured the larger bolls for any other purpose than egg laying. It is true that the outer surfaces of bolls are frequently marked with scars of weevil punctures from which no larvæ have developed and no internal injuries have resulted, but these failures can be explained in other ways than by the supposition that the weevils feed upon the tough and innutritious outer walls of the bolls. In Guatemala, at least, it appears that the weevil scars on large bolls mark attempts at egg laying, though for a variety of reasons already recited most of them are not effective. The only instance where weevils were found feeding in bolls in Guatemala was at Rabinal. Two weevils were together attacking a small boll, and had eaten out large superficial pits, quite unlike the punctures in which eggs are laid.

Feeding punctures in bolls are referred to by Mr. McLachlan in a note dated at Victoria, Tex., August 31, 1905. Such injuries were not found, however, to lead to the formation of external warts which could be mistaken for egg punctures, doubtless for the reason which Mr. McLachlan gives:

> It has been noticed that in bolls no proliferation occurs following the injury from a feeding puncture, however serious that may be. Furthermore, from the above and other observations it is apparent that proliferation is not excited by the egg puncture or the egg, unless the puncture extends through the inside tissue and the egg is fixed in the tissue or has been pushed through it to the lint. In that case a dense knob of proliferation occurs on the inner side of the shuck, in the center of which the egg is often encysted. There must be a constant irritant like the egg, with an opening to give it access to the lint, in order to occasion the specialized growth. As a suggestion it might be noted that all the egg punctures are sealed by the adult weevil at the time of egg laying, while the feeding punctures are left open.

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[a] Hunter, W. D., and Hinds, W. E., 1905. The Mexican Cotton Boll Weevil, Bul. 51, Bureau of Entomology, U. S. Department of Agriculture, p. 59, Pl. VIII.

The feeding experiment reported by Messrs. Hunter and Hinds[a] shows that weevils fed exclusively upon bolls lived less than twenty days, while those fed upon the squares lived nearly seventy days. The bolls proved to be much less suitable for food than the leaves, on which the weevils were able to prolong life for thirty days and upward, though no eggs were laid on a leaf diet. It may be that in Texas, where the army worms sometimes destroy all the leaves, the weevils might be driven to gnawing the bolls for food, but in Guatemala the plants remain in full leaf throughout the growing season.

BACTERIAL DISEASES FOLLOWING WEEVIL INJURIES.

In the study of the bolls of the Kekchi cotton three diseased conditions were observed, some or all of which may be of bacterial origin, the bacteria having been introduced, perhaps, by the weevils at the time of egg laying. None of these diseased conditions is frequent, and as they do not permit the fruit to reach normal maturity it seems very unlikely that they can be introduced into the United States with the seeds. It may be stated in addition that the seed obtained by Mr. Kinsler in the season of 1905 has been carefully selected in the field and comes from the earliest and most vigorous bolls.

The first of the diseased conditions consists in a white deliquescence of the immature seeds and lint as though the lock had been dipped in milk. There is also a distinct odor of fermentation. Another disease turns the seed and lint brown. Though observed only in bolls which have been punctured by the weevil, there was often an apparent connection between the disease inside and the large extrafloral nectaries. A column of transparent or somewhat discolored tissue extends from each nectary obliquely upward to the cavity of the boll. This may be a symptom of the disease or it may indicate that bacteria find their way into the bolls by way of the nectaries.

The third abnormal condition was also indicated by a brown discoloration of the wall and contents of the affected compartment of the boll. The seeds and lint soon die and shrivel. No special indication of bacterial activity was noted, and it may be that the death of the weevil egg or larva has some prejudicial effect upon the surrounding cells, as suggested by the brown discoloration already noted in describing the effects of proliferation. Such a disturbance might continue to spread and thus cause the death of the young seeds.

BREEDING IN BUDS A DERIVED HABIT.

The fact that the weevil larvæ are found in the young buds of the cotton plant and also in the full-grown bolls has been taken to mean that it affects all the intervening stages as well. This would imply

[a] Hunter, W. D., and Hinds, W. E., l. c., pp. 34–35.

also that if the weevil fed originally upon the bolls it has followed back to earlier and earlier stages and finally to the bud. The facts already detailed seem to prove, however, that this is not the case. The weevil does not attack the very young bolls, nor does it operate while the flower is open or while it remains in place, though in a withered condition. The hatching of the weevil larva in the large buds is likewise ineffective because the larva is deprived of shelter when the flower opens. It seems necessary to believe, therefore, that the parasitism of the weevils upon the buds of the cotton is a habit quite distinct from that of its relations to the boll. The habit of breeding in the bud marked a new departure in the biological history of the insect and not a gradual change from the previous habit of infesting the bolls only. Nevertheless, the change of habits need not be thought of as anything very remarkable from the standpoint of the insect. A cotton bud is very much larger than a small boll. The peculiarity lies in the plant rather than in the insect, since very few plants afford a continuous and abundant succession of large, pollen-filled buds. It is this quality of the cotton plant which has enabled the weevil to develop its peculiar and highly destructive secondary habits of feeding upon the buds and using them as breeding places. If the boll weevil were restricted, like related beetles, to parasitism upon the fruit of the cotton, it would have remained a comparatively harmless and agriculturally insignificant enemy. These considerations may assist in a better appreciation of the extent to which the weevil's power of injury would be diminished if we could obtain a variety of cotton with a fully determinate habit of growth, one which would cease producing buds as soon as a crop of cotton had been set.

The much more rapid development of weevil larvæ in the bud is to be connected, doubtless, with the much richer food offered by the mass of pollen, but it may represent also a somewhat more definitely adaptive specialization of the life history of the weevil, for it is generally a question of eating the pollen promptly or not at all. If the bud falls off on moist ground the pollen would be completely decomposed long before the larva could develop, at the rate at which it grows in the boll, and if the bud did not drop off, but continued to grow, the flower would open and turn the larva out. It is obliged, therefore, to do damage fast enough to keep the flower from opening, and must then eat the remaining pollen before it spoils and leaves the larva too hungry and stunted to pass through the final metamorphosis into the adult stage. In a cotton which has a highly developed habit of shedding the injured buds it would not be so necessary for the larva to attack the pistil. It may be that this policy on the part of the weevils in Guatemala has a use to the weevil as being necessary to prevent the opening of the flower and cause the falling of the bud.

The diversity in size of the boll weevils, while not unprecedented among insects, is unusual, and not without biological significance in the present connection. An explanation of the variation in size is to be found, no doubt, in the varying amounts of food which the weevil larvæ can obtain, but there is needed, none the less, a special adaptability on the part of the weevil to permit it to reach a normal reproductive maturity in spite of very unfavorable conditions. The smaller weevils probably have less than a quarter of the weight of the large ones, which means that they are able to develop with a correspondingly small proportion of the food required to raise a full-sized weevil. The weevils developed in the bolls have a much greater uniformity of size. The small weevils are at once a means and a result of the acquisition of the habit of living in the buds, and especially in the small ones, where the supply of food is often very small.

RELATION BETWEEN PROLIFERATION IN BUDS AND IN BOLLS.

The analogy of the mucilaginous tissue found in the young fruits of okra and other relatives of the cotton would lead us to expect that proliferation could occur more readily in the boll than in the bud, which may mean that all the varieties which proliferate in the bud will do so in the bolls as well.

It was at first supposed that if the buds proliferated but not the bolls the result would be merely a postponement of the breeding season of the weevil for two or three weeks, or until the bolls had time to develop. Such a delay would be of great practical importance in retarding for that length of time the effective breeding period of the weevils. Moreover, most of the eggs of the weevils which had passed through hibernation would be lost by being laid in the buds, which would further keep down numbers in the early part of the season. There is, however, the further and still more important consideration, that the period of development of the weevil in the boll is very much longer than required for it to mature and emerge from the square.[a]

[a] Determinations of the length of the life cycle in bolls have been made only in a few instances. In 7 cases between August 15 and November 11, 1903, the average time required from the deposition of the egg to the escape of the adult from the opening boll was sixty-one days. The average effective temperature for the period was 31.7° F., and the average total effective temperature required for development in bolls was therefore 1,933.7° F., or nearly two and one-half times as much as in squares. Several larvæ often develop within a single boll. They appear to remain in the larval stage until the boll becomes sufficiently mature or so severely injured as to begin to dry and crack open. When this condition of the boll is reached, pupation takes place, and by the time the spreading of the carpels is sufficient to permit the escape of the weevils they have become adult.—Hunter, W. D., and Hinds, W. E., The Mexican Cotton Boll Weevil, Bul. 45, Division of Entomology, U. S. Dept. of Agriculture, 1904, p. 75.

Moreover, it seems that the adult weevil does not come out through the wall of the boll, but waits to be liberated when the boll opens to maturity. This would mean that if proliferation can exclude the weevil from breeding in the squares it would afford a practical solution of the problem, since instead of merely delaying the emergence of the first brood of weevils for two or three weeks, none of them would be able to set about the work of destruction until the crop had begun to ripen, and all danger of appreciable damage would have passed. It seems, therefore, that the proliferation in the squares is the much more valuable characteristic to be considered in seeking for a weevil-resistant cotton. Proliferation in the bolls is very desirable, but the absence of it should not be allowed to figure very largely against a variety which might have a pronounced tendency toward proliferation in the bud. Nevertheless, other factors must enter the calculation, for thin-walled bolls might allow the weevils to escape earlier. In moist weather the bolls might not crack open, but give the weevils comfortable shelter all winter, as would seem to have been the case in the spring of 1905, when various observers noted that some of the weevils seemed to have the appearance of having emerged only recently from the pupal condition, their very light color showing that their outer covering of scales was still in place.

The probability is, however, that the proliferation in both places will be found to depend upon the same internal factor or quality, so that it will be safe to assume that a high degree of proliferation in the bud could be taken as an index of what might be expected from the bolls. This would simplify the problem of selection by permitting us to confine our attention to the buds.

PROTECTION OF SEEDS BY LINT.

Like the large leafy involucre, the lint is also a peculiar feature of the cotton plant which may prove to have a practical connection with the weevil. Cotton is the only food plant of the boll weevil, and only the cotton, of all the related plants, has an abundant provision of lint. Some of the species of Hibiscus have the seeds slightly silky, but the cotton stands quite alone in the length and abundance of the hairy covering which grows out from the seeds at the time the bolls are most subject to weevil injuries.

From the standpoint of those who believe that all characters are useful to the organisms which possess them, the interpretation of the lint as a weevil-resisting adaptation will not appear unreasonable, since it can scarcely be claimed that there is any other use of the lint so important to the plant as protection of the seeds from the weevils. In other respects the lint seems rather a disadvantage than otherwise. In a humid tropical country the seeds, if left to themselves, remain inclosed in the tangled mass of lint and usually rot. Birds might carry the lint away to build nests, and in so doing might assist in scattering the seeds, but in most of the varieties the seeds are to be detached only with difficulty.

Composed as it is of nearly pure cellulose, the lint can afford very little nourishment, even in the younger stages. Between the lint and the watery proliferating tissue the weevil larva must find the inside of a cotton boll a very inhospitable place unless it can penetrate to the seeds. Dead and moribund larvæ are occasionally found in these unfavorable situations. And even the seeds themselves do not provide so favorable a food as the pollen, as shown by the much longer time required by the larvæ to develop in the boll than in the square.

PROTECTIVE SEED ARRANGEMENT IN KIDNEY COTTON.

Further intimation of the protective value of the lint is to be found in the very peculiar Kidney cottons, so called because the seeds are crowded together in the central angle of the chamber and adhere firmly to each other, thus forming a small, kidney-like mass. This unique arrangement brings all the lint to the outside of the seed, and may be the explanation of the fact that the Kidney cottons are the only representatives of the Sea Island type which have gained a wide distribution on the mainland. The separate-seeded Sea Island cottons came from Barbados, where the boll weevil did not exist and has not yet been introduced. (See Pl. X, fig. 2.)

The outer wall of the boll of the Kidney cotton is notably thinner than that of Kekchi cotton, so that the beaks of the weevils could reach through without difficulty. But with the layer of lint to supplement it the wall becomes, for practical purposes, much thicker than in the free-seeded varieties. The inner parchment lining is rather tough, though apparently less so than in the Kekchi cotton.

The Indians about Trece Aguas, Guatemala, are said to recognize the weevils as enemies of the dwarf cotton, but it is the local opinion that the Kidney cotton is proof against them.

No weevils were found on the two bushes of Kidney cotton examined in that locality, but these were single plants growing near Indian houses several miles away from the nearest field culture. In a forest-covered country like this part of Guatemala the luxuriant and tangled vegetation may well impede the flight of such an insect as the weevil. And if it lives, as supposed, only on cotton, its chance of reaching a single bush of tree cotton would be very small. That the buds and young bolls of the Kidney cotton are able to offer any absolute resistance to the weevil seems very improbable, and the abundance of weevils found on the large tree of Kidney cotton at Tucuru last year proved that the immunity, if any, is not general.

The Kidney cotton, though commonly treated as a distinct species under the name *Gossypium peruvianum*, agrees with the Sea Island type in all its characters except the peculiar arrangement of the seeds. If this should prove to be an adaptive feature the idea of specific distinctness would have little left to support it.

CULTURAL VALUE OF KIDNEY COTTON.

The possession by the Kidney cotton of a definite weevil-resisting adaptation would naturally raise a question regarding its cultural value. It belongs to the Sea Island series, and has the long, fine fiber and smooth seeds. The growing of the seeds together in masses would still further facilitate picking and ginning operations. The bolls, too, of this Guatemalan Kidney cotton, at least, are larger than those of any of the Sea Island varieties.

It is not likely, however, that any of the varieties of Kidney cotton thus far known will be found of use in the United States, for all are perennial "tree cottons," which have refused thus far to flower or fruit in the period of growth allowed by the shorter summers of our Temperate Zone. In tropical regions this objection would not hold, and there appears to be no reason why the Kidney cottons should be disregarded in the search for varieties suited to the various soils and climates. The Trece Aguas Kidney cotton, for example, seems to thrive well in a humid mountain climate considered by the natives to be unfavorable for the annual Kekchi cotton, which is planted several hundred feet lower down.

THE NATURE AND CAUSES OF ADAPTATIONS.

To explain how such characters as the weevil-resisting adaptations arise involves an interpretation of general evolutionary questions upon which the scientific world is still by no means agreed. Nevertheless, it is evident that students of such subjects should conduct and describe their investigations in accordance with some consistent plan or policy, if their writings are to be understood or their facts intelligibly recorded. Moreover, it would be scarcely reasonable to maintain that such characters can be further increased by selective influence unless it could be believed that they had been assisted in the past by the same agency.

It seems necessary to state that in the present report it is not assumed that the weevil-resisting characters have arisen as direct protective responses to the injuries, or that they are the results merely of stimulation or irritation caused by the weevils, as other writers on evolutionary subjects might hold. Nor have they been thought of as caused by selection in any strict sense of the word. Though constituting a most striking instance of the results of selective influence, it is believed that the cotton plant must first have originated in some measure the protective characters before the external conditions (in this instance, the weevils) could make them of advantage to the plants and thus encourage their further development.

The older theory that environment and natural selection are the efficient or actuating causes of evolutionary change has lost many adherents in the last decade, especially among those who found themselves unable to credit any longer the idea that all the characters and differences of plants and animals are, or have been, of use to them. It has been shown, too, by Professor Weissman and his followers, that direct adaptations or responses of individual organisms to the environment are seldom or never inherited by their offspring. To take the place of the doctrine of direct environmental influence in evolution it has been suggested that there may be an internal "hereditary mechanism," as it has been called, which determines adult characters in advance, in the reproductive cells, so that modifications of the specific or varietal type can arise suddenly. Selection would determine, of course, which of such new "mutations" should survive, but it would be a mere accidental coincidence if the new character happened to fit the conditions better than the old.

It is possible, however, to explain evolutionary progress and selective adaptations without ascribing them either to external causes or to theoretical internal mechanisms. The diversity which plants or animals of the same parentage often show under the same conditions makes it evident that there is no precise mechanism which determines their form in advance, and all attempts at securing any absolute uniformity or "fixity" of form and color have failed. The fact is that organisms, even of the same species or variety, are normally diverse, and must have ancestry mixed by interbreeding if bodily vigor is to be maintained for any great number of generations.

The generalized "specific type," which is a product, as it were, of this diversity and interbreeding, is constantly and gradually changing, and in many ways at once, though in some characters more rapidly than in others. Selection, while in no strict sense a cause of this vital motion of the species or variety, may profoundly influence the direction and rate of change. Selection, in other words, explains adaptation, but does not explain evolution.[a]

The word adaptation is used in more than one sense by writers on biological subjects. Some treat as adaptations the changes of form or structure by which many plants and animals are able to conform to the needs of different conditions. There are several plants, for example, which have normal broad leaves when they grow on land, and very narrow and much-divided leaves when they grow submerged

[a] Natural Selection in Kinetic Evolution, Science, N. S., 19: 549, 1904.

in water. Some plants are hairy in dry localities, but are nearly naked in humid districts. Others treat these direct responses to external conditions under the heading of accommodation, and reserve the word adaptation for characters which appear regularly in a species or variety, but which fit it for some special condition, such as that presented to the cotton plant by the boll weevil. It has seemed proper, therefore, to discuss as protective adaptations any characters which seem to give the Central American varieties an advantage in withstanding the attacks of the weevil, particularly if it can be shown also that the presence of the weevil would tend to the preservation and extension of the given character.

In the strict sense of the words, the weevil-resisting adaptations of the cotton plant would include only those characters which have been increased by the selective influence of the boll weevil, but in the broader practical sense we may treat as a weevil-resisting adaptation any feature which tends to limit the destructiveness of the insect.

The adaptive nature of some of the characters of the Central American varieties discussed in the present paper is reasonably obvious, but in other instances extended studies in developmental biology and primitive agriculture might be necessary to determine the origin and development of a varietal characteristic which may have significance in the weevil problem.

It is easy to understand that so injurious an insect as the boll weevil has exerted a definite selective influence ever since its remote ancestors turned their attention to the cotton. Perhaps its earlier food plants were completely exterminated. The nearest living relatives of the cotton are the species of Hibiscus, Paritium, and Thespesia, none of which is known to have any attractions for the weevil. It is evident, too, that in the presence of the weevil the cotton plant would have met long ago a like fate if it had not been able to take on its various adaptive characters. That so many of the features by which it differs from its nearest relatives have such obvious connection with the weevil would certainly justify the belief that strong adaptive influence had been at work, even if the other circumstances were unknown.

In thinking of the relation between two organisms like the weevil and the cotton we often fall into the error of too great humanizing, so to speak; that is, we ascribe too great intelligence or too complete a reaction to cause or conditions. Thus the weevil, although highly specialized in some of its instincts, has, of course, no equivalent for the human judgment. It will puncture, as already seen, buds much too small to raise a larva, and will lay its eggs in the rind of the boll, where the larvæ can never develop. If the conditions are too favorable to the weevil, as in humid regions, it would undoubtedly exterminate its own host plant by permitting the cotton to produce no seed. Paradoxical as it may at first seem, we may, nevertheless, believe that the best conditions for the perpetuation of the weevil are those which are not altogether favorable to its unlimited multiplication.

CONSCIOUS AND UNCONSCIOUS SELECTION.

There are two principal ways in which improved varieties of cotton and other cultivated plants come into existence. The first is by sudden or abrupt changes, or sports; also called mutations, saltations, and discontinuous variations. These are represented in cotton by the occasional appearance of a plant with brown lint,[a] deeply divided leaves[b] (okra cotton) or very short branches (cluster cotton). The Guatemalan varieties represent a second type of evolutionary history, in which improvement is accomplished by more gradual progressive change, fostered and accelerated by selection.

Two forms of selection are commonly recognized, natural and artificial, the latter effected by man, the former by circumstances of the environment. This distinction is of doubtful value in any case, and quite obscures the important point in the evolutionary history of cotton and other plants domesticated by primitive man. It would be much better to think of selection as either conscious or unconscious, and between these two a very practicable difference exists. Conscious selection implies the preservation of individuals having a desired quality in the highest degree, while unconscious selection, whether by man, animals, or inanimate conditions, means merely the rejection of the most unfit, so that the improvement of the species or variety is gradual. Conscious selection acts, of course, much more

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[a] In Guatemala several tribes of Indians prefer brown cotton, and for certain garments use brown cotton only. Separate plantings of brown cotton are not made in the neighborhood of Secanquim, where our experiment was located, but there were said to be such at Cajabon and Lanquin, only a few leagues away. The Cajabon people have a dark-brown cotton called "caneh nok," and a lighter brown called "canni nok."

On the Pacific slope Mr. William R. Maxon found considerable culture of a brown cotton called "ixcaco." At Antigua a similar brown variety is said to have been grown formerly in considerable quantities, the common name of which is "cuyuscate." It was not learned that any special religious use or significance is attached to brown cotton in Guatemala, as is said to be the case in Peru and in India.

[b] Some may be inclined to interpret these as reversions and to argue that the deeply divided involucral leaves may be a reminiscence of an ancestral character of the cotton. Or it may be that the divisions attained by the involucral leaves represent a tendency of specialization which the remainder of the leaves sometimes share by mutation, in accordance with the principle of translocation of characters recently formulated by Dr. R. G. Leavitt (Contrib. Ames Bot. Lab. No. 3).

speedily than unconscious, but is subject to the serious danger of weakening its protégés by inbreeding, if the selection be too rigid and persistent.

The unconscious selection by which the development of the protective characters of the Guatemalan types of cotton has been encouraged differs in no respect from the progress by which adaptive evolution takes place in nature. The Indians have planted and harvested the crop, it is true, instead of the birds or other natural agents, but they have been entirely unconscious of the struggle for existence to which the cotton plant was being subjected by the presence of the boll weevil. The Indians were only another factor, along with the dry and moist climates, the keleps, and the turkeys. The problem has been solved in a genuinely natural fashion, and affords an excellent illustration of the nature of selective influence in evolution.

Instead of representing the final possibilities of improvement in characters which give protection against the boll weevil, the Indian varieties of cotton may be looked upon rather as affording materials which conscious selection can render still more valuable. The proliferation character, for example, might never be brought to uniform expression by unconscious selection, because the possession of it would give the individual plant no advantage over its neighbors in the production of seed. The proliferating plant might produce no weevils itself, but the free movement of the insects would keep the general average the same. Indeed, a plant might easily sacrifice all its buds, set no fruit at all, and thus fail to perpetuate itself. Proliferation can become a direct advantage to the individual plant only under conscious selection. The full value of the newly ascertained protective adaptations will not be known until they have had the direct selective encouragement now commonly accorded to desirable characters of other cultivated plants.

It may appear remarkable that such definite and potentially valuable characters as the weevil-resisting adaptations of the Kekchi cotton should have remained so completely unrecognized hitherto. The explanation of this doubtless lies in the fact that cotton culture is practiced in Central America largely by the Indians and very little by the foreigners or the more intelligent part of the native community, so that it had not received scientific study. Even the existence and utility of the keleps, though apparently known to the Indians from ancient times, had entirely escaped the attention of the European residents of the country. That the Indians should have come to recognize the keleps as beneficial and necessary to a full crop of cotton, although not knowing that the weevils injure the cotton or that the keleps eat the weevils, only shows in higher relief the completely unconscious character of the selection conducted in this system of primitive agriculture. The Indians of Alta Vera Paz are extremely stolid, uncommunicative people, from whom little information is likely to be obtained except as replies to direct questions. Familiar from their earliest childhood with the agricultural lore of their own tribe, it does not occur to them that these everyday incidents can be of interest to the white stranger, or if they perceive his interest they learned long since to fear it as a danger of further intrusion. Even our own cotton experiments were misunderstood as a menace of additional demands for lands from the white men who now own so large a part of the country.

SUMMARY OF ADAPTATIONS.

If the facts stated in the present report have been correctly observed and interpreted, we must admit that the cotton plant is in a high state of adaptive specialization in its relations with its now famous insect enemy, the boll weevil. Indeed, it may be that the most distinctive and important characters of the plant, from both the botanical and the agricultural standpoints—such as the involucre, the nectaries, the oil glands, the large bolls, and the very lint itself—are adaptive features which the selective influence of the weevil has brought to their present degree of development.

CLASSIFICATION OF ADAPTATIONS.

The adaptations of the cotton plant might be summarized from three different standpoints. A historical treatment would proceed from the adaptations of the bolls to those of the buds. Breeding in the buds, for instance, was evidently a later adaptation on the part of the weevils which has called for a second set of the protective characters on the part of the plant.

It may be better, however, to classify the adaptations as such, without special regard to their historical sequence of derivation. The more practical purposes are served by dividing the adaptations into four groups: (1) Those calculated to avoid the weevils by general habits of growth; (2) those which exclude the weevils, or at least hinder their operations in the buds and bolls; (3) those which attract insect enemies such as the weevil-eating kelep; (4) those which prevent the development of the weevil larvæ, even after the eggs have been laid.

ADAPTATIONS TO AVOID WEEVILS.

1. Determinate growth.
2. Early bearing.
3. Long basal branches.
4. Early rejection of superfluous squares.
5. Seasonal bearing of perennial varieties.
6. Prompt bearing after cutting back.
7. Hairy stalks and leaf stems.
8. Pendent bolls.
9. Rapid growth of young bolls.

ADAPTATIONS TO EXCLUDE WEEVILS.

1. Involucral bracts grown together at base.
2. Closely appressed margins of involucral bracts.
3. Margins of involucral bracts strongly laciniate and hairy.
4. Unusual size and width of involucral bracts.
5. Calyx produced into slender hairy laciniæ.
6. Persistent flowers.
7. Oil glands (?) of very young bolls.
8. Thick-walled bolls.
9. Tough linings of boll chambers.

ADAPTATIONS ATTRACTIVE TO THE KELEP.

1. Nectaries of leaves.
2. Large outer nectaries of involucre.
3. Large inner nectaries of involucre.
4. Bractlets subtending inner nectaries.
5. Continued secretion of nectar.
6. Hairy stalks and leaf stems.
7. Dwarf, compact habits of growth.

ADAPTATIONS TO PREVENT DEVELOPMENT OF WEEVIL LARVÆ.

1. Shedding of weevil-infested buds.
2. Proliferation of internal tissues of buds.
3. Proliferation from the walls of the bolls.
4. Absence of oil glands over dissepiments.
5. Growth of lint on seed.
6. Compacted seeds (Kidney cotton).
7. Lint confined to outer end of seed (San Lucas Sea Island cotton).

ADAPTIVE CHARACTERS OF DIFFERENT TYPES OF COTTON.

The third standpoint for viewing the adaptive characters is that of the different types of cotton. All varieties share, to some extent, the older adaptive features, but the special characters are accentuated in different degrees in the various types. Our study has been directed toward the Kekchi variety, both on account of its relation to the keleps and because it has seemed to possess by far the largest series of adaptive features. But now that the existence of adaptations of practical value has been ascertained it will be necessary to canvass the field thoroughly.

ADAPTATIONS OF KEKCHI COTTON.

An enumeration of the adaptations of the Kekchi cotton is scarcely necessary, because that variety has nearly the whole series and most of them in a more accentuated form than the other types thus far studied. The few exceptions are noted below.

ADAPTATIONS OF RABINAL COTTON.

1. Prompt bearing after cutting back.
2. Very hairy stalks, leaf stems, and involucral bracts.
3. Closely appressed margins of involucral bracts.
4. Involucral bracts grown together at base.

ADAPTATIONS OF PACHON COTTON.

1. Involucral bracts margined with stiff laciniæ and bristles.
2. Calyx large, the divisions slender and hairy.

ADAPTATIONS OF SAN LUCAS SEA ISLAND COTTON.

1. Definite seasonal bearing.
2. Lint confined to outer half of seed.
3. Proliferation in buds.
4. Proliferation in bolls.

ADAPTATIONS OF KIDNEY COTTON.

1. Definite seasonal bearing.
2. Seeds compacted at center, covered with thick layer of lint.

ADAPTATIONS OF UPLAND COTTON.

1. Shedding of weevil-infested buds.

This is the only weevil-resisting character in which the Upland varieties excel the Kekchi cotton, but, as already explained, the habit is of practical use only in dry climates. The Upland cottons share, however, a large number of the adaptations, though in a less degree than in the Kekchi. Thus there is proliferation both in buds and in bolls, the stems and petioles are somewhat hairy, the habit of growth is somewhat reduced from the tree-cotton stage, the nectaries are often large and active, the involucral bracts are sometimes well folded together, etc.

And now that the possibility of weevil resistance has been shown, variations may be found in all probability among our United States varieties which will enable weevil-resisting strains of the Upland sorts to be developed. At this stage of the inquiry it is too much to hope that the Kekchi type will prove to be adapted to the wide diversity of conditions to be found in the cotton belt. Either the Kekchi or the native cottons, or both, are likely to require extensive modification before the full value of the weevil-resisting adaptations can be realized.

CONCLUDING REMARKS.

The protection afforded by the weevil-resisting adaptations is most effective at the two ends of the period of development, but continues in varying degrees from the young bud to the ripe boll. Under favorable conditions an extremely small proportion of the weevil eggs develop to maturity. Instead of a single attack being fatal to a bud or boll, the same fruit at its different stages may resist numerous punctures and egg-layings. The young bud is protected for a time by the closed involucre. After the weevils have gained entrance the first egg, and often the second or third, may be rendered harmless through the proliferation of the bud in its younger stages. Proliferation becomes less certain as the bud increases in size, but if egg laying be delayed a few days too long the development of the larvæ is rendered impossible by the opening of the flower. Then ensues another period of immunity while the withered flower remains in place and while the bolls are still too small to be attacked. Between about the quarter and the three-quarter size the bolls can still be parasitized, though proliferation reduces the successful attempts to a very small percentage. But after the lint has grown out, the lining has hardened, and the walls have become thick, the boll is well-nigh impregnable, though the surface may be roughened by a dozen or a score of warts, which mark the location of as many persistent but ineffectual attempts to gain entrance.

As an instance of adaptive specialization the cotton plant seems destined to a very high rank. The development of such a series of protective characters can scarcely be explained except upon the supposition that the culture of cotton in Guatemala is extremely ancient, and of this there are many other indications.

The practical utilization of these protective characters in the cotton industry of the United States may require the solution of many preliminary problems of acclimatization and adaptation, as well as of physiology and cultural methods. The proliferation characters, for example, appear to be much more pronounced in some varieties than in others, but they are also affected, probably to a very considerable extent, by conditions of climate or soil which check the growth of the plant or cut down its water supply and thus reduce the normal turgidity of the tissues.[a]

The weevil-resisting characters are much more highly developed in the variety of cotton cultivated by the Kekchi Indians of eastern Guatemala than in any other type yet known, and it produces also large bolls and lint of good length and quality, so that it may be of value in the United States. But even though the Kekchi cotton in its present form should prove, for any reason, not to be adapted to cultural conditions in the United States, it demonstrates, at least, the fact that the Upland type of cotton is capable of assuming other characters which will render it far better adapted to cultivation in the presence of the boll weevil than the varieties hitherto grown in the United States.

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[a] That the transfer to Texas will not destroy the proliferating habit of the Kekchi cotton is shown by the following report from Mr. McLachlan:

"On the 23d of August Mr. Kinsler and I made a comparative examination of four varieties of cotton at Mackay, Tex., to determine the nature of their proliferation. Rows of Kekchi cotton from Secanquim and Lanquin, and two of native Upland varieties (Parker and King) were compared. The results, in brief, are that in squares the Kekchi cotton proliferated much more readily than did the native varieties. In the bolls all four varieties were about equally active in this protective adaptation. The extent of proliferation in the Guatemalan bolls was, if different in any way, somewhat greater than in the native varieties."

No end is in sight of the new problems and adjustments of cotton culture occasioned by the invasion of the weevils, and no assurances can be given in advance regarding the utility of the weevil-resisting adaptations, any more than with the kelep, or so-called "Guatemalan ant." Both have a present value, however, in proving that the weevil is no invulnerable dragon which it is hopeless to resist. Instead of having no enemies, as long supposed, the weevil is regularly preyed upon by the active and efficient kelep. And instead of there being no remedies which can be used against the weevil, it is now found that the cotton plant itself has a whole series of weevil-resisting characters—a whole boll weevil armory, as it were, from which we may select and sharpen the weapons which prove best suited to our purposes.

The weevil period of each year, that in which the damage is done, extends from the time when the squares are large enough for egg laying to the period when a full crop would normally be set. If the value of the cotton crop be divided by the number of days of this period, the result will show the value of each day of protection. It has been estimated by Mr. W. D. Hunter that the boll weevil damaged the cotton crop in 1904 to the extent of $20,000,000. It is therefore a very conservative estimate that when the pest shall have spread over the other cotton-growing States the damage will be well beyond a million dollars a day for the growing season—in unfavorable years probably two million dollars or more a day. Each day of protection which can be secured by the utilization of weevil-resisting adaptations will have, therefore, very definite and considerable value, so that the study and perfection of this group of characters are sure to be the objects not only of formal scientific study on the part of specialists but of general interest and consideration on the part of the practical cotton-growing public.

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PLATES.

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DESCRIPTION OF PLATES.

PLATE I. (*Frontispiece.*) Valley at Secanquim, Alta Vera Paz, Guatemala, the scene of experiments with weevil-resisting cotton.

PLATE II. Fig. 1.—Mature plant of Kekchi cotton, to show small size and determinate habits of growth, compact foliage, and long basal branches. Fig. 2.—Plant shown in figure 1, opened to show numerous large bolls and habit of fruiting on basal branches.

PLATE III. Involucres of Kekchi cotton, opened to show external and internal nectaries, bracts, and bractlets. (Natural size.)

PLATE IV. Fig. 1.—Involucres of Rabinal cotton, showing connate and closely appressed involucral bracts. (Natural size.) Fig. 2.—Open involucres of Egyptian cotton. (Natural size.)

PLATE V. Fig. 1.—Young buds of Kekchi cotton, showing numerous weevil punctures. The buds were split in half so that the full number of punctures could be seen. (Natural size.) Fig. 2.—Buds of Kekchi cotton (same as fig. 1), showing successful proliferations. (Natural size.)

PLATE VI. Large buds of Kekchi cotton, the distortion indicating proliferation. (Natural size.)

PLATE VII. Weevil-infested bolls of Kekchi cotton, showing larger number of punctures along the middle line of the carpel, where the oil glands are absent. (Natural size.)

PLATE VIII. Carpels of Kekchi cotton, showing method of proliferation. (Natural size.)

PLATE IX. Fig. 1.—Kekchi cotton, successive stages of the boll. Fig. 2.—Kekchi bolls (right): King bolls (left), to show comparative size. (Reduced to about one-half natural size.)

PLATE X. Fig. 1.—Rabinal cotton, showing foliage, connate bracts, and weevil-infested bolls. (Reduced.) Fig. 2.—Bolls and seeds of Kidney cotton, showing oil glands and protective arrangement of lint and seeds. (Reduced.)

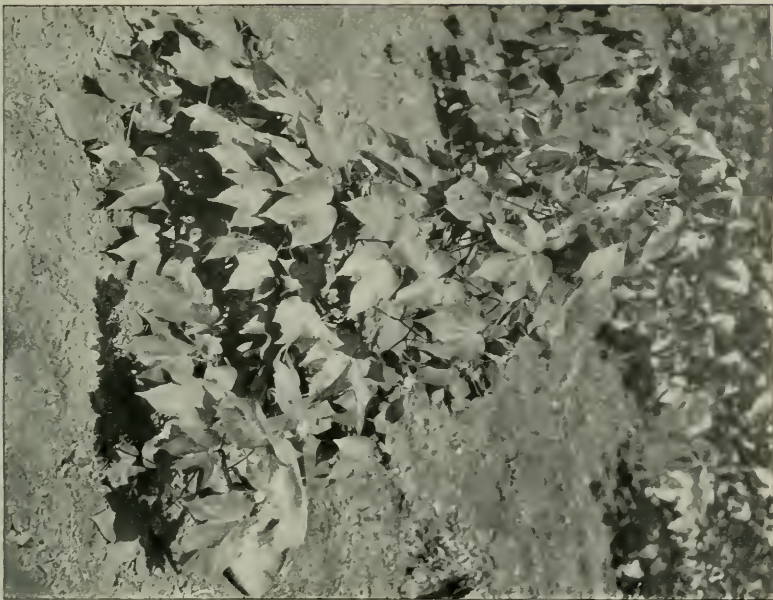


FIG. 1.—MATURE PLANT OF KEKCHI COTTON.

FIG. 2.—KEKCHI COTTON PLANT WITH BOLLS.

INVOLUCRES OF KEKCHI COTTON, SHOWING NECTARIES AND BRACTLETS.

(Natural size.)

FIG. 1.—INVOLUCRES OF RABINAL COTTON, SHOWING CONNATE AND APPRESSED MARGINS.

(Natural size.)

FIG. 2.—OPEN INVOLUCRES OF EGYPTIAN COTTON.

(Natural size.)

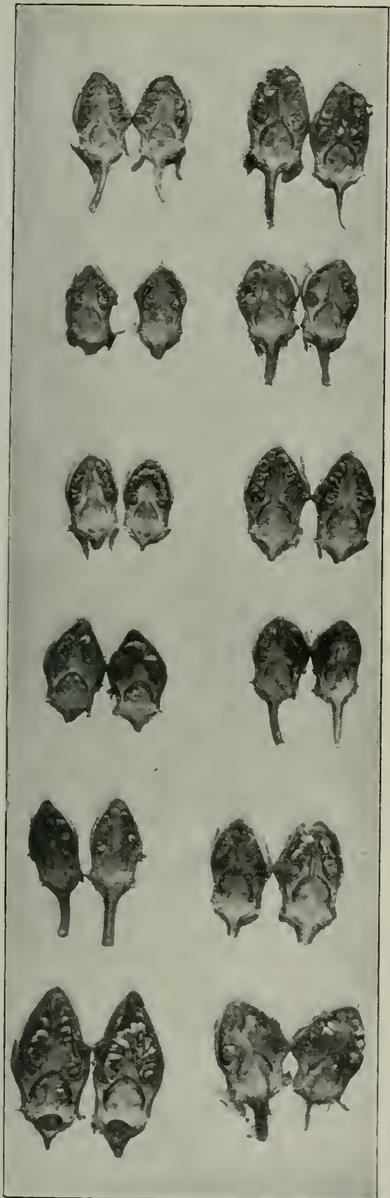


FIG. 1.—YOUNG BUDS OF KEKCHI COTTON WITH WEEVIL PUNCTURES.

(Natural size.)

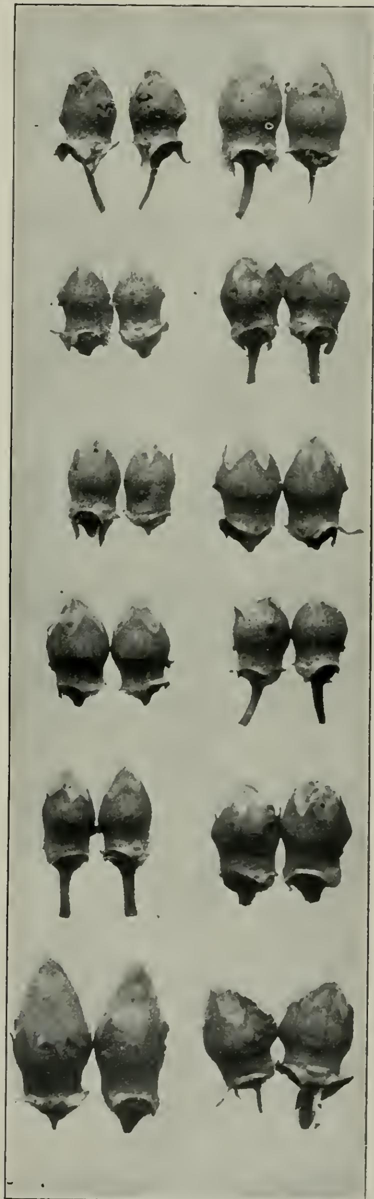
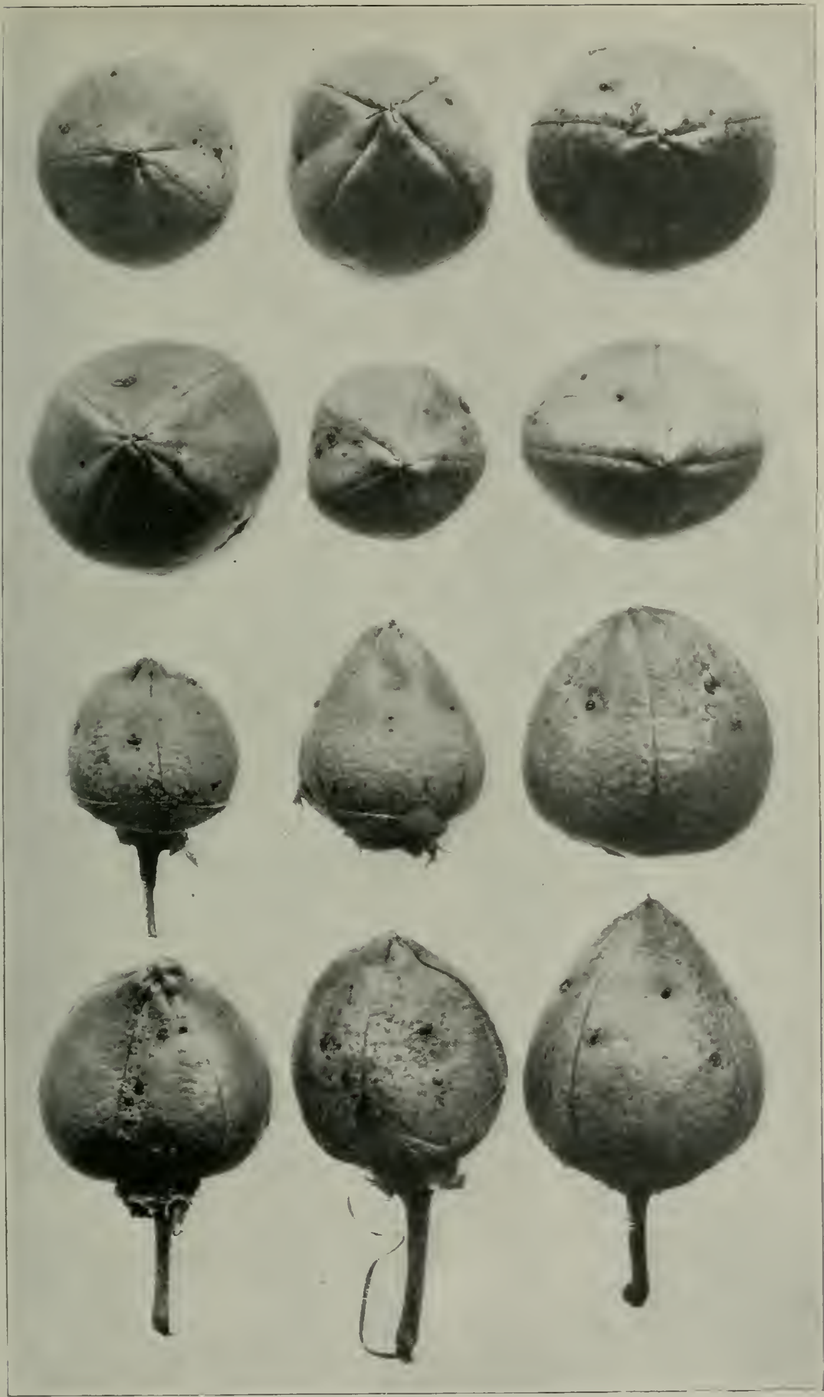


FIG. 2.—BUDS OF KEKCHI COTTON WITH PROLIFERATION.

(Natural size.)

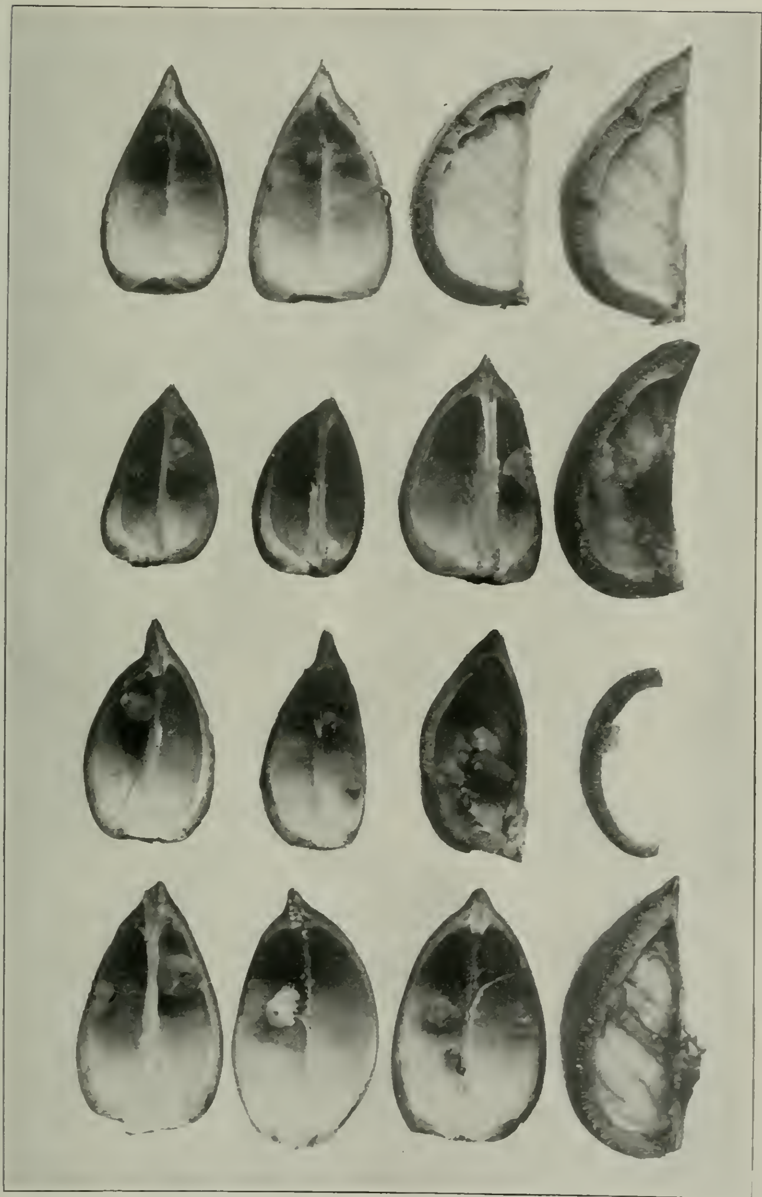
LARGE BUDS OF KEKCHI COTTON WITH PROLIFERATION.

(Natural size.)



WEEVIL-INFESTED BOLLS OF KEKCHI COTTON.

(Natural size)



CARPELS OF KEKCHI COTTON, SHOWING PROLIFERATION.

(Natural size.)

FIG. 1.—KEKCHI COTTON, SUCCESSIVE STAGES OF THE BOLL.
(Reduced.)

FIG. 2.—KEKCHI COTTON BOLLS (RIGHT) COMPARED WITH KING BOLLS (LEFT).
(Reduced.)

FIG. 1.—RABINAL COTTON WITH BOLLS.
(Reduced.)

FIG 2.—BOLLS AND SEEDS OF KIDNEY COTTON.
(Reduced.)

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 89.

B. T. GALLOWAY, *Chief of Bureau.*

WILD MEDICINAL PLANTS OF THE UNITED STATES.

BY

ALICE HENKEL,

ASSISTANT, DRUG-PLANT INVESTIGATIONS.

ISSUED JANUARY 16, 1906.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1906.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., October 30, 1905.

SIR: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 89 of the series of this Bureau the accompanying manuscript entitled "Wild Medicinal Plants of the United States." This paper was prepared by Miss Alice Henkel, Assistant in Drug-Plant Investigations, and has been submitted by the Physiologist in Charge with a view to its publication.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

PREFACE.

In connection with the work of Drug-Plant Investigations many inquiries are received from various parts of the country asking for a list of the drug-producing plants of the regions concerned and for information as to the parts of the plants used in medicine, etc. It being impossible to comply with requests of this nature in any satisfactory way, Miss Henkel was asked to compile a list of the drug plants of this country, using as a basis the catalogues of dealers in crude drugs and the standard works on systematic botany. It has seemed from an inspection of these lists and of much current pharmaceutical literature that the recent changes in botanical nomenclature have succeeded one another too rapidly to permit the drug dealer and the pharmacist to keep pace with them. This has resulted in considerable confusion in regard to botanical names, and in some cases in the matter of the common names of drug-producing plants. In such a list as that herewith presented the opportunity for helping to clear up this situation has seemed worth improving. The recent appearance of the new Pharmacopœia, in which the botanical nomenclature has been revised, has seemed to emphasize the desirability of making this attempt, since the names in the case of official plants will be fairly definitely fixed among pharmacists for the next ten years. In the accompanying list the pharmacopœial names are given and a revision of the nomenclature of the unofficial drugs is also presented. Mr. Frederick V. Coville, Botanist, has kindly revised the botanical names used in this publication.

It is hoped that this compilation will tend to unify usage among those who have to do with crude drugs and drug plants.

RODNEY H. TRUE,
Physiologist in Charge

OFFICE OF DRUG-PLANT INVESTIGATIONS,
Washington, D. C., October 12, 1905.

B. P. I.—187.

WILD MEDICINAL PLANTS OF THE UNITED STATES.

In the preparation of this bulletin only such wild medicinal plants as have a commercial value were considered; that is, such as were usually mentioned in the trade lists of drug dealers throughout the country. Plants that were found listed by only one or two firms have been omitted.

Both official and nonofficial drugs are included in this list. A number of drug plants that were official in the United States Pharmacopœia for 1890 have been dropped from the Eighth Decennial Revision (1900), which became official on September 1, 1905, and a few new ones have been added. In this bulletin the drugs that were official in the Pharmacopœia for 1890 are so indicated, while those of the new edition are marked simply "official."

In the following list the information on each species is given under the accepted botanical name. This name and that of the family to which the plant belongs occupy the first line of the description. Botanical synonyms, if any, are mentioned, and these are followed in the next line by the most common names. A few words of information indicating the most important features of habit and stature, as well as the sort of situation in which found, together with the geographical distribution in the United States, are then given in each case. This information is too meager for the identification of the plants concerned in all cases, but it was impossible within the space limits of a publication such as this to include more descriptive matter. The parts of the plants used and the official status of the product close the description. Unless otherwise indicated, the products mentioned are used in the dried state.

Abies balsamea (L.) Mill. **Pine family** (**Pinaceae**).

Balsam-fir; Canada balsam tree.

Slender, evergreen, native tree, 50 to 60 feet high, occurring in damp woods from Newfoundland to the high mountains of southwestern Virginia, west to Minnesota, and northward.

Parts used.—Balsam, known as Canada turpentine, Canada balsam, or balsam of fir (official); also bark (nonofficial).

Abies canadensis Michx. Same as *Tsuga canadensis.*

Abies nigra Desf. Same as *Picea mariana.*

Abscess-root. See *Polemonium reptans.*

Absinth. See *Artemisia absinthium.*

Absinthium. See *Artemisia absinthium.*

Acacia, false. See *Robinia pseudacacia.*

Acer rubrum L. **Maple family (Aceraceae).**

Red maple; swamp-maple.

Large, native tree, often 120 feet in height, growing in swamps and low grounds from Canada to Florida and Texas.

Part used.—Bark (nonofficial.)

Achillea millefolium L. **Aster family (Asteraceae).**

Yarrow; milfoil; thousandleaf.

Perennial weed, 10 to 20 inches high, common in fields and waste places nearly throughout the United States, especially eastward; naturalized from Europe and Asia.

Part used.—Herb (nonofficial).

Acorus calamus L. **Arum family (Araceae).**

Calamus; sweet-flag.

Native, herbaceous perennial, about 2 feet high, found in wet and muddy places and along streams from Nova Scotia to Minnesota, southward to Florida and Texas.

Part used.—Unpeeled, dried rhizome (official).

Actaea alba (L.) Mill. **Crowfoot family (Ranunculaceae).**

White cohosh; white baneberry; necklace-weed; rattlesnake-herb.

Native, perennial herb, 1 to 2 feet high, found in rich woods from Nova Scotia to Georgia and Missouri, and northward; most common from Indiana and Kentucky to Pennsylvania and New York.

Parts used.—Rhizome and rootlets (nonofficial).

Actaea racemosa L. Same as *Cimicifuga racemosa.*

Actaea rubra (Ait.) Willd. **Crowfoot family (Ranunculaceae).**

Synonym.—*Actaea spicata* var. *rubra* Ait.

Red cohosh; red baneberry; rattlesnake-herb.

Native, perennial herb, 1 to 2 feet high, found in woods from Nova Scotia to the Middle States, west to the Rocky Mountains; most abundant from New England to Ontario.

Parts used.—Rhizome and rootlets (nonofficial).

Actaea spicata var. *rubra* Ait. Same as *Actaea rubra.*

Adam-and-Eve. See *Aplectrum spicatum.*

Adder's-tongue, yellow. See *Erythronium americanum.*

Adiantum pedatum L. **Fern family (Polypodiaceae).**

Maidenhair-fern.

Native fern, 9 to 15 inches high, growing in rich moist soil in woods in Canada and almost all parts of the United States.

Part used.—Herb (nonofficial).

Aesculus glabra Willd. **Buckeye family (Aesculaceae).**

Ohio buckeye; fetid buckeye; smooth buckeye.

Small, native tree, 20 to 40 feet in height, found in woods and on river banks from Pennsylvania south to Alabama, westward to Michigan and the Indian Territory.

Parts used.—Bark and fruit (nonofficial).

Aesculus hippocastanum L. **Buckeye family (Aesculaceae).**

Horse-chestnut.

Large tree, 60 feet or more in height. Escaped from cultivation, southeastern New York and New Jersey. Native of Asia.

Parts used.—Bark and fruit (nonofficial).

Afterbirth-weed. See *Stylosanthes biflora.*

Agrimonia eupatoria (of American authors, not L.). Same as *Agrimonia hirsuta.*

Agrimonia hirsuta (Muhl.) Bicknell. **Rose family (Rosaceae).**

Synonym.—*Agrimonia eupatoria* of most American authors, not L.[a]

Agrimony; tall hairy agrimony.

Perennial herb, 3 to 4 feet high, found in woods and thickets from New Brunswick to Minnesota and Nebraska, south to North Carolina; also in California. Native.

Part used.—Herb (nonofficial).

Agrimony. See *Agrimonia hirsuta.*

Agrimony, tall hairy. See *Agrimonia hirsuta.*

Agropyron repens (L.) Beauv. **Grass family (Poaceae).**

Synonym.—*Triticum repens* Beauv.

Triticum; couch-grass; dog-grass; quack-grass.

A troublesome grass in cultivated land from Maine to Maryland, west to Minnesota and Missouri; sparingly distributed in the South. Introduced from Europe.

Part used.—Rhizome, gathered in spring (official).

Ague-tree. See *Sassafras variifolium.*

Agueweed. See *Eupatorium perfoliatum* and *Gentiana quinquefolia.*

Alder, black. See *Ilex verticillata.*

Alder, common. See *Alnus rugosa.*

Alder, red. See *Alnus rugosa.*

Alder, smooth. See *Alnus rugosa.*

Alder, tag-. See *Alnus rugosa.*

Aletris farinosa L. **Lily family (Liliaceae).**

Star-grass; false (not true) unicorn-root;[b] colic-root.

Native, perennial herb, 2 to 3 feet high; in dry, sandy soil from Maine to Minnesota, south to Florida and Tennessee.

Part used.—Rhizome (nonofficial), gathered after the plant has flowered.

Allspice, Carolina. See *Butneria florida.*

Allspice, Florida. See *Butneria florida.*

Allspice, wild. See *Benzoin benzoin.*

Alnus rugosa (Du Roi) K. Koch. **Birch family (Betulaceae).**

Synonym.—*Alnus serrulata* Willd.

Tag-alder; common alder; red alder; smooth alder.

Native shrub, or sometimes a small tree, occurring in swamps and marshy borders of streams from the New England States west to Minnesota and southward to Florida and Texas.

Part used.—Bark (nonofficial).

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[a] According to Bicknell (Bul. Torr. Bot. Club, 23: 508–525, 1896), the name *Agrimonia eupatoria* L., long used in local floras and text-books for the agrimony of the Eastern States, has been doing duty for a group of related species, of which at least five are now clearly recognized. Furthermore, Doctor Britton (Bul. Torr. Bot. Club, 18: 366, 1891) states that the true *Agrimonia eupatoria* is not known at all as an American plant. The native plant to which the name *Agrimonia eupatoria* has been most frequently applied by American authors is *Agrimonia hirsuta* (Muhl.) Bicknell.

[b] The name "true unicorn-root" has long been applied to *Aletris farinosa*, but as "unicorn-root" was the common name first given to *Chamaelirium luteum* (*Helonias dioica*), this should more properly be called the true unicorn-root and *Aletris farinosa* the false unicorn-root.

Alnus serrulata Willd. Same as *Alnus rugosa.*

Alsine media L. **Pink family (Silenaceae).**

Synonym.—Stellaria media Cyr.

Common chickweed.

Small, annual herb, probably introduced from Europe, and now common in fields and around dwellings throughout the United States.

Part used.—Herb (nonofficial).

Althaea. See *Althaea officinalis.*

Althaea officinalis L. **Mallow family (Malvaceae).**

Althaea; marshmallow; sweatweed; mortification-root.

Perennial herb, 2 to 4 feet high, naturalized from Europe; occurs in salt marshes, coast of Massachusetts and New York, and in Pennsylvania.

Parts used.—Root from plants of second year's growth, deprived of the periderm (official); leaves and flowers (nonofficial) are also used.

Alum-root. See *Geranium maculatum* and *Heuchera americana.*

Ambrosia artemisiaefolia L. **Ragweed family (Ambrosiaceae).**

Roman wormwood; ragweed; hogweed; stammerwort.

Coarse, native weed, annual, 1 to 3 feet high; in waste places, eastern United States, west to British Columbia and Mexico.

Part used.—Herb (nonofficial).

Ampelopsis quinquefolia Michx. Same as *Parthenocissus quinquefolia.*

Amy-root. See *Apocynum cannabinum.*

Anagallis arvensis L. **Primrose family (Primulaceae).**

Red chickweed; red pimpernel; scarlet pimpernel; shepherd's-weatherglass.

Low, spreading, annual herb, naturalized from Europe, and growing along roadsides and in fields almost throughout the United States.

Part used.—Herb (nonofficial).

Anaphalis margaritacea (L.) Benth. & Hook. **Aster family (Asteraceae).**

Synonyms.—Gnaphalium margaritaceum L.; *Antennaria margaritacea* Hook.

Everlasting; pearly everlasting; large-flowered everlasting; cottonweed.

White-hairy or woolly perennial herb, native in dry soil from Newfoundland to Alaska, south to North Carolina and California.

Part used.—Leaves (nonofficial).

Andromeda arborea L. Same as *Oxydendrum arboreum.*

Anemone patens var. *nuttalliana* A. Gray. Same as *Pulsatilla hirsutissima.*

Angelica, American. See *Angelica atropurpurea.*

Angelica atropurpurea L. **Parsley family (Apiaceae).**

Synonym.—Archangelica atropurpurea Hoffm.

Purple-stemmed angelica; American angelica; masterwort.

Tall, stout, perennial herb, 4 to 6 feet high; native in swamps and damp places from Labrador to Delaware and west to Minnesota.

Parts used.—Root and seeds (nonofficial).

Angelica, purple-stemmed. See *Angelica atropurpurea.*

Anise-root. See *Washingtonia longistylis.*

Antennaria margaritacea Hook. Same as *Anaphalis margaritacea.*

Anthemis cotula L. **Aster family (Asteraceae).**

Synonym.—Maruta cotula DC.

Mayweed; dog-fennel; fetid camomile (or chamomile).

Strong-scented, annual herb, naturalized from Europe; occurs in dry soil, fields, waste places, and along roadsides almost throughout North America, with the exception of the extreme North.

Part used.—Herb (nonofficial).

Aplectrum hyemale Nutt. Same as *Aplectrum spicatum.*

Aplectrum spicatum (Walt.) B. S. P. **Orchid family (Orchidaceae).**

Synonym.—Aplectrum hyemale Nutt.

Adam-and-Eve; putty-root.

Native herb, perennial, 1 to 2 feet high; in rich woods and swamps from Canada to Georgia and California.

Part used.—Root (nonofficial).

Apocynum. See *Apocynum cannabinum.*

Apocynum androsaemifolium L. **Dogbane family (Apocynaceae).**

Bitterroot; spreading dogbane; honeybloom.

Perennial herb, 1 to 4 feet high, native in fields and thickets from Canada south to Georgia and Arizona. The most common species in Canada and the Northeastern States.

Part used.—Root (nonofficial).

Apocynum cannabinum L. **Dogbane family (Apocynaceae).**

Apocynum; Canadian hemp; black Indian hemp; amy-root.

Perennial herb, 2 to 3 feet high, native in moist ground and borders of fields throughout the United States.

Part used.—Rhizome of this or of closely allied species of Apocynum (official).

Apple, custard-. See *Asimina triloba.*

Apple, May-. See *Podophyllum peltatum.*

Apple, thorn-. See *Datura stramonium.*

Apple-of-Peru. See *Datura stramonium.*

Aquilegia canadensis L. See under *Aquilegia vulgaris.*

Aquilegia vulgaris L. **Crowfoot family (Ranunculaceae).**

European columbine; garden-columbine.

Perennial herb, with showy flowers. Naturalized from Europe, and well known in cultivation; escaped from gardens into woods and fields; frequent in the Eastern and Middle States. The wild columbine (*Aquilegia canadensis* L.), occurring in rocky woods throughout Canada and the eastern United States, is said to possess properties similar to those of the European columbine.

Part used.—Herb (nonofficial).

Aralia hispida Vent. **Ginseng family (Araliaceae).**

Dwarf elder; wild elder; bristly sarsaparilla.

Erect, leafy perennial, 1 to 3 feet high, native in sandy woods and fields from Labrador south to North Carolina, west to Minnesota and Indiana.

Part used.—Root (nonofficial).

Aralia nudicaulis L. **Ginseng family (Araliaceae).**

American sarsaparilla; wild sarsaparilla; false sarsaparilla; Virginian sarsaparilla; small spikenard.

Herbaceous perennial, native, growing in moist woods from Newfoundland west to Manitoba and south to North Carolina and Missouri.

Part used.—Root (nonofficial).

Aralia racemosa L. **Ginseng family (Araliaceae).**

Indian-root; spikenard; American spikenard; spignet.

Herbaceous perennial, native, 3 to 6 feet high, growing in rich woods and rocky places from Canada to Georgia, west to Minnesota and Missouri.

Part used.—Root (nonofficial).

Arbor-vitae. See *Thuja occidentalis.*

Arbutus, trailing. See *Epigaea repens.*

Archangelica atropurpurea Hoffm. Same as *Angelica atropurpurea.*

Arctium lappa L. **Aster family (Asteraceae).**

Synonym.—Lappa major Gaertn.

Lappa; burdock; cockle-button; beggars'-buttons; bardane.

Coarse, biennial weed, 4 to 9 feet high, introduced from the Old World, and occurring along roadsides and in fields and waste places in the Eastern and Central States.

Parts used.—Root of this or of other species of Arctium collected from plants of first year's growth (official). The fresh leaves and the seeds are also used (nonofficial).

Arctostaphylos glauca Lindl. **Heath family (Ericaceae).**

Manzanita.

A shrub-like tree, 9 to 25 feet high, growing in California, in dry, rocky districts on the western slopes of the Sierras.

Part used.—Leaves (nonofficial).

Arctostaphylos uva-ursi (L.) Spreng. **Heath family (Ericaceae).**

Uva-ursi; bearberry; upland-cranberry.

Low, evergreen perennial, with trailing stems, native in rocky or dry, sandy soils from the Middle Atlantic States north to Labrador, westward to California and Alaska.

Part used.—Leaves (official).

Arisaema triphyllum (L.) Torr. **Arum family (Araceae).**

Synonym.—Arum triphyllum L.

Indian turnip; wild turnip; wake-robin; Jack-in-the-pulpit.

Native, perennial herb, 10 inches to 3 feet high, found in moist woods from Canada to Florida, west to Kansas and Minnesota.

Part used.—Partially dried corm (nonofficial).

Aristolochia reticulata Nutt. **Birthwort family (Aristolochiaceae).**

Serpentaria; Texas serpentaria; Texas snakeroot; Red River snakeroot.

Perennial herb, about 1½ feet in height, native in the Southwestern States, occurring on river banks from Arkansas to Louisiana.

Parts used.—Rhizome and roots (official).

Aristolochia serpentaria L. **Birthwort family (Aristolochiaceae).**

Serpentaria; Virginia serpentaria; Virginia snakeroot.

Native, perennial herb, 10 inches to 3 feet high, found in rich woods from Connecticut to Michigan and southward.

Parts used.—Rhizome and roots (official).

Arrowwood. See *Viburnum dentatum*.

Arrowwood, Indian. See *Euonymus atropurpureus*.

Artemisia abrotanum L. **Aster family (Asteraceae).**

Southernwood.

Shrubby, perennial herb, about 2 to 4 feet in height, occurring in waste places from Massachusetts to Nebraska. Adventive from Europe.

Part used.—Herb (nonofficial).

Artemisia absinthium L. **Aster family (Asteraceae).**

Absinthium; wormwood; absinth.

Shrubby, perennial herb, 2 to 3 feet high, naturalized from Europe, and occurring in waste places and along roadsides from Newfoundland to New York and westward.

Parts used.—Leaves and tops (official in U. S. P. 1890).

Artemisia vulgaris L. **Aster family (Asteraceae).**

Common mugwort.

Perennial herb, 1 to 3½ feet high, naturalized from Europe; found in waste places, Nova Scotia to the Middle States and westward to Michigan.

Part used.—Herb (nonofficial).

Arum triphyllum L. Same as *Arisaema triphyllum*.

Asarum canadense L. **Birthwort family (Aristolochiaceae).**

Canada snakeroot; wild ginger; Indian ginger.

Perennial herb, about 1 foot in height, native in rich woods from Canada to North Carolina and Kansas.

Parts used.—Rhizome and rootlets (nonofficial).

Asclepias. See *Asclepias tuberosa*.

Asclepias cornuti Dec. Same as *Asclepias syriaca*.

Asclepias incarnata L. **Milkweed family (Asclepiadaceae).**

White Indian hemp; swamp-milkweed; swamp-silkweed; rose-colored silkweed.

Perennial herb, 2 to 4 feet high, native in swamps from Canada to Tennessee and Kansas.

Part used.—Root (nonofficial).

Asclepias syriaca L. **Milkweed family (Asclepiadaceae).**

Synonym.—*Asclepias cornuti* Dec.

Common milkweed; silkweed.

Perennial herb, 3 to 5 feet high, native in fields and waste places from Canada to North Carolina and Kansas.

Part used.—Root (nonofficial).

Asclepias tuberosa L. **Milkweed family (Asclepiadaceae).**

Asclepias; pleurisy-root; butterfly-weed; Canada-root; whiteroot.

Native, perennial herb, 1 to 2 feet high, growing in dry fields from Canada to Florida and Arizona; most abundant southward.

Part used.—Root (official in U. S. P. 1890).

Ash, American mountain-. See *Sorbus americana*.

Ash, black. See *Fraxinus nigra*.

Ash, cane-. See *Fraxinus americana*.

Ash, hoop-. See *Fraxinus nigra*.

Ash, prickly. See *Fagara clava-herculis* and *Xanthoxylum americanum*.

Ash, wafer-. See *Ptelea trifoliata*.

Ash, white. See *Fraxinus americana*.

Asimina triloba (L.) Dunal. **Custard-apple family (Anonaceae).**

North American pawpaw; custard-apple.

Small, native tree, growing in rich soil along the banks of streams from New York to Michigan and southward. Most common in the Ohio Valley.

Part used.—Seed (nonofficial).

Aspen, American. See *Populus tremuloides*.

Aspen, quaking. See *Populus tremuloides*.

Aspidium. See *Dryopteris filix-mas* and *D. marginalis*.

Aspidium filix-mas Sw. Same as *Dryopteris filix-mas*.

Aspidium marginale Sw. Same as *Dryopteris marginalis*.

Asplenium filix-foemina (L.) Bernh. Same as *Athyrium filix-foemina*.

Aster puniceus L. **Aster family (Asteraceae).**

Red-stalked aster; cocash; meadow-scabish.

Perennial herb, with stout, reddish stem, 3 to 8 feet high, native; in swamps and on banks of streams, Nova Scotia to Minnesota, south to North Carolina, Ohio, and Michigan.

Part used.—Root (nonofficial).

Aster, red-stalked. See *Aster puniceus*.

Asthma-weed, Queensland. See *Euphorbia pilulifera*.

Athyrium filix-foemina (L.) Roth. **Fern family** (**Polypodiaceae**).

Synonym.—Asplenium filix-foemina (L.) Bernh.

Backache-brake; female-fern; lady-fern.

Native fern, with leaves 1 to 3 feet long; in woods and thickets, Canada to Alaska, southward to Florida and Arizona.

Part used.—Rhizome (nonofficial).

Avens, purple. See *Geum rivale.*

Avens, water-. See *Geum rivale.*

Backache-brake. See *Athyrium filix-foemina.*

Backache-root. See *Lacinaria spicata.*

Balm. See *Melissa officinalis.*

Balm, bee-. See *Monarda didyma.*

Balm, field-. See *Glecoma hederacea.*

Balm, garden-. See *Melissa officinalis.*

Balm, horse-. See *Collinsonia canadensis.*

Balm, lemon-. See *Melissa officinalis.*

Balm, mountain-. See *Eriodictyon californicum.*

Balm, scarlet. See *Monarda didyma.*

Balm, sweet. See *Melissa officinalis.*

Balm-of-Gilead. See *Populus candicans.*

Balmony. See *Chelone glabra.*

Balsam, sweet. See *Gnaphalium obtusifolium.*

Balsam tree, Canada. See *Abies balsamea.*

Balsam, white. See *Gnaphalium obtusifolium.*

Balsam-fir. See *Abies balsamea.*

Bamboo-brier. See *Smilax pseudo-china.*

Baneberry, red. See *Actaea rubra.*

Baneberry, white. See *Actaea alba.*

Baptisia tinctoria (L.) R. Br. **Pea family** (**Fabaceae**).

Wild indigo; yellow indigo; American indigo; indigo-weed; horsefly-weed.

Native, perennial herb, 2 to 3 feet high, growing in dry, poor soil from Maine to Minnesota, south to Florida and Louisiana.

Parts used.—Root and leaves (nonofficial).

Barberry, holly-leaved. See *Berberis aquifolium.*

Bardane. See *Arctium lappa.*

Basswood. See *Tilia americana.*

Bay, rose-. See *Rhododendron maximum.*

Bay, sweet. See *Magnolia virginiana.*

Bay, white. See *Magnolia virginiana.*

Bayberry. See *Myrica cerifera.*

Bean, bog-. See *Menyanthes trifoliata.*

Bean, buck-. See *Menyanthes trifoliata.*

Bean, hog's-. See *Hyoscyamus niger.*

Bearberry. See *Arctostaphylos uva-ursi.*

Bearberry-tree. See *Rhamnus purshiana.*

Bear's-foot, yellow. See *Polymnia uvedalia.*

Bear's-weed. See *Eriodictyon californicum.*

Beaver-poison. See *Cicuta maculata.*

Beaverroot. See *Nymphaea advena.*

Beaver-tree. See *Magnolia virginiana.*

Bedstraw. See *Galium aparine.*

Bee-balm. See *Monarda didyma.*

Beech, American. See *Fagus americana.*

Beechdrops. See *Leptamnium virginianum.*

Beechnut-tree. See *Fagus americana.*

Bee-plant. See *Scrophularia marilandica.*

Beggars'-buttons. See *Arctium lappa.*

Bellwort, perfoliate. See *Uvularia perfoliata.*

Benjamin-bush. See *Benzoin benzoin.*

Bennet. See *Pimpinella saxifraga.*

Benzoin benzoin (L.) Coulter. **Laurel family** (**Lauraceae**).

Synonyms.—Laurus benzoin L.; *Lindera benzoin* Meissn.; *Benzoin odoriferum* Nees.

Spicebush; feverbush; Benjamin-bush; wild allspice; spicewood.

Indigenous shrub, 5 to 12 feet high; in damp, shady woods, and along streams, Massachusetts to Michigan, south to North Carolina and Kansas.

Parts used.—Bark and berries (nonofficial).

Benzoin odoriferum Nees. Same as *Benzoin benzoin.*

Berberis. See *Berberis aquifolium.*

Berberis aquifolium Pursh. **Barberry family** (**Berberidaceae**).

Berberis; Oregon grape; holly-leaved barberry; Rocky Mountain grape.

A shrub, native in woods from Colorado to the Pacific Ocean; especially abundant in Oregon and northern California.

Parts used.—Rhizome and roots of this and of other species of Berberis (official).

Bergamot, wild. See *Monarda fistulosa.*

Bethroot, ill-scented. See *Trillium erectum.*

Betony, Paul's-. See *Veronica officinalis.*

Betula lenta L. **Birch family** (**Betulaceae**).

Sweet birch; black birch; cherry birch.

Large, indigenous forest tree; Newfoundland to Ontario, south to Florida and Tennessee.

Part used.—Bark (nonofficial). Oil of betula, obtained by maceration and distillation from the bark, is official.

Bikukulla canadensis (Goldie) Millsp. **Poppy family** (**Papaveraceae**).

Synonyms.—Corydalis formosa Pursh; *Corydalis canadensis* Goldie; *Dicentra canadensis* Walp.

Turkey-corn; squirrel-corn; turkey-pea; staggerweed.

Native, perennial plant, 6 to 12 inches high; in rich woods from Nova Scotia south along the mountains to Kentucky, and westward to Missouri and Minnesota.

Part used.—Tubers (nonofficial).

Birch, black. See *Betula lenta.*

Birch, cherry. See *Betula lenta.*

Birch, sweet. See *Betula lenta.*

Bird's-foot violet. See *Viola pedata.*

Birthroot. See *Trillium erectum.*

Bitterbloom. See *Sabbatia angularis.*

Bitter-buttons. See *Tanacetum vulgare.*

Bitterroot. See *Apocynum androsaemifolium.*

Bittersweet. See *Solanum dulcamara.*

Bittersweet, false. See *Celastrus scandens.*

Bitterweed. See *Erigeron canadensis.*

Blackberry, high-bush. See *Rubus nigrobaccus.*

Blackberry, knee-high. See *Rubus cuneifolius.*

Blackberry, low running. See *Rubus procumbens.*

Blackberry, low-bush. See *Rubus trivialis.*

Blackberry, sand-. See *Rubus cuneifolius.*

Blackcap. See *Rubus occidentalis.*

Blackroot. See *Veronica virginica.*

Blackroot, Indian. See *Pterocaulon undulatum.*

Blackwort. See *Symphytum officinale.*

Bladderpod. See *Lobelia inflata.*

Blazingstar. See *Chamaelirium luteum.*

Blazingstar, blue. See *Lacinaria scariosa.*

Blazingstar, scaly. See *Lacinaria squarrosa.*

Bloodroot. See *Sanguinaria canadensis.*

Bloodwort. See *Hieracium venosum.*

Bloodwort, striped. See *Hieracium venosum.*

Blowball. See *Taraxacum officinale.*

Blue-curls. See *Prunella vulgaris.*

Bog-bean. See *Menyanthes trifoliata.*

Bog-myrtle. See *Myrica gale.*

Boneset. See *Eupatorium perfoliatum.*

Boneset, deerwort-. See *Eupatorium ageratoides.*

Boneset, purple. See *Eupatorium purpureum.*

Bouncing-Bet. See *Saponaria officinalis.*

Bowman's-root. See *Porteranthus trifoliatus* and *Veronica virginica.*

Boxwood. See *Cornus florida.*

Brake, backache-. See *Athyrium filix-foemina.*

Brake, buckhorn-. See *Osmunda regalis.*

Brake, rock-. See *Polypodium vulgare.*

Brassica nigra (L.) Koch. **Mustard family (Brassicaceae).**

Synonym.—Sinapis nigra L.

Sinapis nigra; black mustard; brown mustard; red mustard.

Annual herb, introduced from Europe; found in fields and waste places almost throughout the United States.

Part used.—Seed (official); the volatile oil obtained from black mustard seed is also official.

Brauneria angustifolia (DC.) Heller. **Aster family (Asteraceae).**

Synonym.—Echinacea angustifolia DC.

Echinacea; pale-purple coneflower; Sampson-root; niggerhead (in Kansas).

Native, perennial, herbaceous plant, 2 to 3 feet high, occurring in rich prairie soil or sandy soil from Alabama to Texas and northwestward; most abundant in Kansas and Nebraska.

Part used.—Root (nonofficial).

Broom. See *Cytisus scoparius.*

Broom, green. See *Cytisus scoparius.*

Broom, Scotch. See *Cytisus scoparius.*

Brownwort. See *Prunella vulgaris.*

Bruisewort. See *Symphytum officinale.*

Buck-bean. See *Menyanthes trifoliata.*

Buckeye, fetid. See *Aesculus glabra.*

Buckeye, Ohio. See *Aesculus glabra.*

Buckeye, smooth. See *Aesculus glabra.*

Buckhorn-brake. See *Osmunda regalis.*

Buckthorn. See *Rhamnus cathartica.*

Bugle, sweet. See *Lycopus virginicus.*

Bugle, water-. See *Lycopus virginicus.*

Bugleweed. See *Lycopus virginicus.*

Bullbrier. See *Smilax pseudo-china.*

Bull-nettle. See *Solanum carolinense.*

Bulrush. See *Typha latifolia.*

Burdock. See *Arctium lappa.*

Burnet-saxifrage. See *Pimpinella saxifraga.*

Burningbush. See *Euonymus atropurpurea.*

Bursa bursa-pastoris (L.) Britton. **Mustard family (Brassicaceae).**

Synonym.—Capsella bursa-pastoris Medic.

Shepherd's-purse; cocowort; toywort.

Annual plant, about 1 foot in height, found in fields and waste places; widely distributed. Introduced from Europe.

Part used.—Herb (nonofficial).

Burseed, spiny. See *Xanthium spinosum.*

Burweed, thorny. See *Xanthium spinosum.*

Butneria florida (L.) Kearney. **Strawberry-shrub family (Calycanthaceae).**

Synonym.—Calycanthus floridus L.

Hairy strawberry-shrub; sweet-scented shrub; Carolina allspice; Florida allspice.

Native shrub, 4 to 8 feet high; in rich soil, Virginia to Mississippi.

Part used.—Bark (nonofficial).

Butterfly-weed. See *Asclepias tuberosa.*

Butternut. See *Juglans cinerea.*

Buttonbush. See *Cephalanthus occidentalis.*

Button-snakeroot. See *Eryngium yuccifolium.*

Button-snakeroot, dense. See *Lacinaria spicata.*

Button-snakeroot, large. See *Lacinaria scariosa.*

Button-tree. See *Cephalanthus occidentalis.*

Buttonwood-shrub. See *Cephalanthus occidentalis.*

Cabbage, skunk-. See *Spathyema foetida.*

Cabbage, swamp-. See *Spathyema foetida.*

Calamus. See *Acorus calamus.*

Calfkill. See *Kalmia angustifolia.*

Calico-bush. See *Kalmia latifolia.*

Calycanthus floridus L. Same as *Butneria florida*.

Camomile, fetid. See *Anthemis cotula*.

Canada balsam tree. See *Abies balsamea*.

Canada-root. See *Asclepias tuberosa*.

Cancerroot. See *Leptamnium virginianum*.

Candleberry. See *Myrica cerifera*.

Cane-ash. See *Fraxinus americana*.

Cankerroot. See *Coptis trifolia* and *Limonium carolinianum*.

Canker-weed. See *Nabalus serpentarius*.

Canker-weed, white. See *Nabalus albus*.

Cankerwort. See *Taraxacum officinale*.

Canoewood. See *Liriodendron tulipifera*.

Capsella bursa-pastoris Medic. Same as *Bursa bursa-pastoris*.

Cardinal, red. See *Lobelia cardinalis*.

Cardinal-flower. See *Lobelia cardinalis*.

Cardinal-flower, blue. See *Lobelia siphilitica*.

Carduus arvensis (L.) Robs. **Aster family (Asteraceae).**

Synonym.—Cirsium arvense Scop.

Canada thistle; creeping thistle; cursed thistle.

Perennial herb, 1 to 3 feet high; growing in cultivated fields, pastures, and waste places from Newfoundland to Virginia, west to Minnesota and Nebraska. A bad weed, introduced from Europe.

Part used.—Root (nonofficial).

Carduus benedictus Auct. Same as *Cnicus benedictus*.

Carpenter's-square. See *Scrophularia marilandica*.

Carrion-flower. See *Smilax herbacea*.

Carrot, wild. See *Daucus carota*.

Carya alba Nutt. Same as *Hicoria ovata*.

Cascara sagrada. See *Rhamnus purshiana*.

Cassia marilandica L. **Senna family (Caesalpiniaceae).**

American senna; wild senna; locust-plant.

Native, perennial herb; in swamps and wet soil, New England to Florida, west to Louisiana and Nebraska.

Part used.—Leaves (nonofficial).

Castalia odorata (Dryand.) Woodv. & Wood. **Water-lily family (Nymphaeaceae).**

Synonym.—Nymphaea odorata Dryand.

White pond-lily; water-lily; sweet-scented water-lily.

Indigenous, aquatic herb; perennial; in ponds, marshes, and sluggish streams, from Canada to Florida and Louisiana.

Part used.—Rhizome (nonofficial).

Castanea. See *Castanea dentata*.

Castanea dentata (Marsh.) Borkh. **Beech family (Fagaceae).**

Castanea; chestnut; American chestnut.

A large, spreading tree, occurring in rich woods from Maine to Michigan, south to Tennessee. Especially abundant in the Allegheny region. Native.

Part used.—Leaves (official in U. S. P. 1890).

Catchweed. See *Galium aparine*.

Catfoot. See *Glecoma hederacea*.

Catgut. See *Cracca virginiana.*

Catmint. See *Nepeta cataria.*

Catnip. See *Nepeta cataria.*

Cattail, broad-leaved. See *Typha latifolia.*

Cattail-flag. See *Typha latifolia.*

Caulophyllum. See *Caulophyllum thalictroides.*

Caulophyllum thalictroides (L.) Michx. **Barberry family (Berberidaceae).**

Caulophyllum; blue cohosh; squawroot; papoose-root.

Native, perennial herb, 1 to 3 feet high; found in rich, shady woods from New Brunswick to South Carolina, westward to Nebraska; abundant throughout the Allegheny Mountain region.

Parts used.—Rhizome and roots (official in U. S. P. 1890).

Ceanothus americanus L. **Buckthorn family (Rhamnaceae).**

Jersey tea; New Jersey tea; redroot.

A native shrub, growing in dry, open woods from Canada to Florida and Texas.

Parts used.—Root, root-bark, and leaves (nonofficial).

Cedar, red. See *Juniperus virginiana.*

Cedar, shrubby red. See *Juniperus sabina.*

Cedar, white. See *Thuja occidentalis.*

Cedar, yellow. See *Thuja occidentalis.*

Celandine. See *Chelidonium majus.*

Celandine, garden-. See *Chelidonium majus.*

Celandine, great. See *Chelidonium majus.*

Celandine, wild. See *Impatiens aurea.*

Celastrus scandens L. **Staff-tree family (Celastraceae).**

False bittersweet; staff-tree; waxwork; fevertwig.

An indigenous, twining, woody vine; in rich, damp soil, woods, and thickets, Ontario to Manitoba, south to North Carolina and New Mexico.

Part used.—Bark of plant and of root (nonofficial).

Centaurea benedicta L. Same as *Cnicus benedictus.*

Centaury, American. See *Sabbatia angularis.*

Centaury, ground-. See *Polygala nuttallii.*

Cephalanthus occidentalis L. **Madder family (Rubiaceae).**

Buttonbush; button-tree; buttonwood-shrub; globeflower.

Indigenous shrub, 6 to 12 feet high; in swamps and damp places, Canada to Florida and California.

Part used.—Bark (nonofficial).

Cercis canadensis L. **Senna family (Caesalpiniaceae).**

Judas-tree; redbud.

Small, native tree, growing in rich soil from New Jersey to Minnesota, south to Florida and Texas.

Part used.—Bark of root (nonofficial).

Chamaelirium luteum (L.) A. Gray. **Bunchflower family (Melanthiaceae).**

Synonym.—Helonias dioica Pursh.

True (not false) unicorn-root;[a] blazingstar; starwort; drooping starwort.

Slender, perennial herb, about 2 feet high; native in moist meadows and thickets from Massachusetts to Michigan, south to Florida and Arkansas.

Part used.—Rhizome (nonofficial).

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[a] The name "unicorn-root" was first applied to *Chamaelirium luteum*, and the designation "true unicorn-root" would seem to belong more properly to that species than to *Aletris farinosa*, to which the name unicorn-root was given later, and which may thus be called "false unicorn-root."

Chamaenerion angustifolium (L.) Scop. **Evening-primrose family (Onagraceae).**

Synonym.—Epilobium angustifolium L.

Great willow-herb; wickup.

Native, perennial herb, 2 to 8 feet high, found in dry soil from Canada to Alaska, south to North Carolina, Arizona, and California. Very common from Pennsylvania northward.

Parts used.—Leaves and root (nonofficial).

Chamomile, fetid. See *Anthemis cotula.*

Champion-oak. See *Quercus rubra.*

Checkerberry. See *Gaultheria procumbens* and *Mitchella repens.*

Cheeseflower. See *Malva sylvestris.*

Cheeses. See *Malva rotundifolia.*

Chelidonium. See *Chelidonium majus.*

Chelidonium majus L. **Poppy family (Papaveraceae).**

Chelidonium; celandine; garden-celandine; great celandine; tetterwort.

Perennial herb, 1 to 2 feet high, growing along fences, roadsides, and in waste places; common in the East. Naturalized from Europe.

Part used.—Entire plant (official in U. S. P. 1890).

Chelone glabra L. **Figwort family (Scrophulariaceae).**

Balmony; turtle-head; shellflower; snakehead; salt-rheum weed.

Native, perennial, herbaceous plant, 2 to 3 feet high; in swamps and along streams, Newfoundland to Manitoba, south to Florida and Kansas.

Part used.—Herb, and especially the leaves (nonofficial).

Chenopodium. See *Chenopodium ambrosioides* and *C. anthelminticum.*

Chenopodium ambrosioides L. **Goosefoot family (Chenopodiaceae).**

Chenopodium; Mexican tea; American wormseed; Jerusalem tea; Spanish tea.

Strong-scented herb, 2 to 3 feet high, annual; naturalized from tropical America, and occurring in waste places, meadows, and pastures from New England to Florida, west to California.

Part used.—Fruit (official in U. S. P. 1890).

Chenopodium anthelminticum L. **Goosefoot family (Chenopodiaceae).**

Chenopodium; wormseed; Jerusalem oak.

Annual, sometimes perennial, herb, usually taller than *C. ambrosioides*, naturalized from Europe, and found in waste places from southern New York to Wisconsin, south to Florida and Mexico.

Parts used.—Fruit (official in U. S. P. 1890). The oil of chenopodium, distilled from this plant, is official.

Chenopodium botrys L. **Goosefoot family (Chenopodiaceae).**

Jerusalem oak.

Annual herb, about 2 feet high, introduced from Europe; found in waste places from Nova Scotia to New York and Kentucky, westward to Oregon.

Parts used.—Herb and seeds (nonofficial).

Cherry birch. See *Betula lenta.*

Cherry, rum-. See *Prunus serotina.*

Cherry, wild. See *Prunus serotina.*

Chervil, sweet. See *Washingtonia longistylis.*

Chestnut. See *Castanea dentata.*

Chestnut, American. See *Castanea dentata.*

Chestnut, horse-. See *Aesculus hippocastanum.*

Chickentoe. See *Corallorhiza odontorhiza.*

Chickweed, common. See *Alsine media.*

Chickweed, red. See *Anagallis arvensis.*

Chicory. See *Cichorium intybus.*

Chimaphila. See *Chimaphila umbellata.*

Chimaphila umbellata (L.) Nutt. **Wintergreen family (Pyrolaceae).**

Chimaphila; pipsissewa; prince's-pine; bitter wintergreen; rheumatism-weed.

Small, perennial herb, native in dry, shady woods, especially in pine forests, from Nova Scotia to Georgia, west to California.

Part used.—Leaves (official).

China-root, American. See *Smilax pseudo-china.*

China-root, false. See *Smilax pseudo-china.*

Chionanthus virginica L. **Olive family (Oleaceae).**

Fringe-tree; old-man's-beard.

A shrub or small tree, native in moist thickets from Delaware to Florida and Texas.

Part used.—Bark of root (nonofficial).

Chittem-bark. See *Rhamnus purshiana.*

Chrysanthemum leucanthemum L. **Aster family (Asteraceae).**

Synonym.—Leucanthemum vulgare Lam.

Oxeye daisy; white daisy.

Perennial herb, 1 to 3 feet high, naturalized from Europe; occurring in pastures, meadows, and waste places in nearly every section of the country, but less abundantly in the South and rarely in the West.

Part used.—Herb (nonofficial).

Chrysanthemum parthenium (L.) Pers. **Aster family (Asteraceae).**

Synonym.—Pyrethrum parthenium Smith.

Common feverfew; featherfew; febrifuge-plant.

Perennial herb, naturalized from Europe. Mostly escaped from cultivation; in waste places, New Brunswick to New Jersey, and locally in the interior.

Part used.—Herb (nonofficial).

Cichorium intybus L. **Chicory family (Cichoriaceae).**

Chicory; succory.

Perennial herb, 1 to 3 feet high, growing in fields, waste places, and along roadsides from Nova Scotia to North Carolina, west to Nebraska. Abundant eastward. Naturalized from Europe.

Part used.—Root (nonofficial).

Cicuta maculata L. **Parsley family (Apiaceae).**

Water-hemlock; musquash-root; beaver-poison.

Native perennial, 3 to 6 feet high, stout, erect; poisonous. Found in swamps and low grounds from Canada south to Florida and New Mexico.

Part used.—Leaves (nonofficial).

Cimicifuga. See *Cimicifuga racemosa.*

Cimicifuga racemosa (L.) Nutt. **Crowfoot family (Ranunculaceae).**

Synonym.—Actaea racemosa L.

Cimicifuga; black snakeroot; black cohosh; squawroot; rattle-root.

Native, perennial herb, 3 to 8 feet high; in rich soil in shady woods, Maine to Georgia, west to Wisconsin and Missouri. Most abundant in the Ohio Valley.

Parts used.—Rhizome and roots (official).

Cinquefoil. See *Potentilla canadensis.*

Cirsium arvense Scop. Same as *Carduus arvensis.*

Cleavers. See *Galium aparine.*

Cleaverwort. See *Galium aparine.*

Clematis. See *Clematis virginiana.*

Clematis virginiana L. **Crowfoot family (Ranunculaceae).**

Virgin's-bower; clematis.

Shrubby, perennial vine; native; found along river banks in hedges and thickets from Canada to Georgia and Kansas.

Parts used.—Leaves and flowers (nonofficial).

Clotbur, spiny. See *Xanthium spinosum.*

Clotweed, thorny. See *Xanthium spinosum.*

Clover, bitter. See *Sabbatia angularis.*

Clover, meadow-. See *Trifolium pratense.*

Clover, purple. See *Trifolium pratense.*

Clover, red. See *Trifolium pratense.*

Clover, yellow sweet. See *Melilotus officinalis.*

Club-moss. See *Lycopodium clavatum.*

Cnicus benedictus L. **Aster family (Asteraceae).**

Synonyms.—Carduus benedictus Auct.; *Centaurea benedicta* L.

Blessed thistle; holy thistle; bitter thistle; spotted thistle; St. Benedict's-thistle.

Annual plant, 1 to 2 feet high; in waste places, Southern States, and in California and Utah; introduced from Europe.

Part used.—Herb (nonofficial).

Cocash. See *Aster puniceus.*

Cocash-weed. See *Senecio aureus.*

Cockle-button. See *Arctium lappa.*

Cocowort. See *Bursa bursa-pastoris.*

Cohosh, black. See *Cimicifuga racemosa.*

Cohosh, blue. See *Caulophyllum thalictroides.*

Cohosh, red. See *Actaea rubra.*

Cohosh, white. See *Actaea alba.*

Colic-root. See *Aletris farinosa*, *Dioscorea villosa*, *Lacinaria spicata*, and *L. squarrosa.*

Collinsonia canadensis L. **Mint family (Menthaceae).**

Stoneroot; richweed; knobroot; horse-balm.

Native, perennial herb, about 2 feet high, occurring in rich, moist woods from Maine to Wisconsin, south to Florida and Kansas.

Parts used.—Root and leaves (nonofficial).

Colt's-foot. See *Tussilago farfara.*

Colt's-tail. See *Erigeron canadensis.*

Columbine, European. See *Aquilegia vulgaris.*

Columbine, garden-. See *Aquilegia vulgaris.*

Columbine, wild. See under *Aquilegia vulgaris.*

Columbo, American. See *Frasera carolinensis.*

Comfrey. See *Symphytum officinale.*

Compass-plant. See *Silphium laciniatum.*

Comptonia asplenifolia Gaertn. Same as *Comptonia peregrina.*

Comptonia peregrina (L.) Coulter. **Bayberry family (Myricaceae).**

Synonyms.—Comptonia asplenifolia Gaertn.; *Myrica asplenifolia* L.

Sweet fern; spleenwortbush; meadow-fern.

Shrubby plant, about 2½ feet high, native; in thin sandy or stony woods and on hillsides, Canada to North Carolina, Indiana, and Michigan.

Parts used.—Leaves and tops (nonofficial).

Coneflower, pale-purple. See *Brauneria angustifolia.*

Coneflower, tall. See *Rudbeckia laciniata.*

Congo-root. See *Psoralea pedunculata.*

Conium. See *Conium maculatum.*

Conium maculatum L. **Parsley family (Apiaceae).**

Conium; poison-hemlock; spotted parsley; spotted cowbane.

Biennial herb, 2 to 6 feet high, naturalized from Europe; common in waste places, especially in the Eastern and Middle States. Poisonous.

Parts used.—Full-grown, but unripe, fruit, carefully dried and preserved (official); leaves (nonofficial).

Consumptive's-weed. See *Eriodictyon californicum.*

Convallaria. See *Convallaria majalis.*

Convallaria biflora Walt. Same as *Polygonatum biflorum.*

Convallaria majalis L. **Lily-of-the-valley family (Convallariaceae).**

Convallaria; lily-of-the-valley.

A low, perennial herb; indigenous; on the higher mountains from Virginia to the Carolinas.

Parts used.—Rhizome and roots (official); herb and flowers (nonofficial).

Convallaria racemosa L. Same as *Vagnera racemosa.*

Convolvulus panduratus L. Same as *Ipomoea pandurata.*

Coolwort. See *Tiarella cordifolia.*

Coptis trifolia (L.) Salisb. **Crowfoot family (Ranunculaceae).**

Goldthread; cankerroot; mouthroot; yellowroot.

Low, native, perennial herb, growing in damp mossy woods and bogs from Canada and Alaska south to Maryland and Minnesota; most common in the New England States, northern New York and Michigan, and in Canada.

Parts used.—Rhizome and rootlets (nonofficial).

Corallorhiza odontorhiza (Willd.) Nutt. **Orchid family (Orchidaceae).**

Crawley-root; coralroot; dragon's-claw; chickentoe.

Leafless plant, 6 to 15 inches high, found in rich woods from Maine to Florida, west to Michigan and Missouri. Native.

Part used.—Rhizome (nonofficial).

Coralroot. See *Corallorhiza odontorhiza.*

Corn, squirrel-. See *Bikukulla canadensis.*

Corn, turkey-. See *Bikukulla canadensis.*

Cornel, silky. See *Cornus amomum.*

Corn-snakeroot. See *Eryngium yuccifolium* and *Lacinaria spicata.*

Cornus amomum Mill. **Dogwood family (Cornaceae).**

Synonym.—*Cornus sericea* L.

Red osier; swamp-dogwood; silky cornel; rose-willow.

Native shrub, 3 to 10 feet high; in low woods and along streams, Canada to Florida, west to Texas and the Dakotas.

Part used.—Bark (nonofficial).

Cornus circinata L'Her. **Dogwood family (Cornaceae).**

Green osier; round-leaved dogwood.

Native shrub, 3 to 10 feet high; in shady places, Canada and the northeastern United States.

Part used.—Bark (nonofficial).

Cornus florida L. **Dogwood family (Cornaceae).**

Flowering dogwood; boxwood.

Small, native tree or large shrub, growing in woods from Canada to Florida, Texas and Missouri. Most abundant in the Middle States.

Parts used.—Bark of tree and of root, the latter preferred (nonofficial).

Cornus sericea L. Same as *Cornus amomum*.

Corydalis canadensis Goldie. Same as *Bikukulla canadensis*.

Corydalis formosa Pursh. Same as *Bikukulla canadensis*.

Cotton-gum. See *Nyssa aquatica*.

Cottonweed. See *Anaphalis margaritacea*.

Couch-grass. See *Agropyron repens*.

Coughweed. See *Senecio aureus*.

Coughwort. See *Tussilago farfara*.

Cowbane, spotted. See *Conium maculatum*.

Cow-lily. See *Nymphaea advena*.

Cow-parsnip. See *Heracleum lanatum*.

Cracca virginiana L. **Pea family (Fabaceae).**

Synonym.—Tephrosia virginiana Pers.

Devil's-shoestring; hoary pea; goat's-rue; catgut.

Hoary, perennial herb, 1 to 2 feet high, native; occurring in dry, sandy soil from New England to Florida, west to Texas and Minnesota.

Part used.—Root (nonofficial).

Cramp-bark. See *Viburnum opulus*.

Cranberry, high-bush. See *Viburnum opulus*.

Cranberry, upland-. See *Arctostaphylos uva-ursi*.

Crane's-bill, spotted. See *Geranium maculatum*.

Crane's-bill, wild. See *Geranium maculatum*.

Crataegus oxyacantha L. **Apple family (Malaceae).**

Hawthorn; hedgethorn; whitethorn; maythorn.

Shrub or tree, introduced from Europe, and sparingly escaped from cultivation.

Part used.—Berries (nonofficial).

Crawley-root. See *Corallorhiza odontorhiza*.

Crosswort. See *Eupatorium perfoliatum*.

Cucumber-tree. See *Magnolia acuminata* and *M. tripetala*.

Cudweed, low. See *Gnaphalium uliginosum*.

Cudweed, marsh-. See *Gnaphalium uliginosum*.

Culver's-physic. See *Veronica virginica*.

Culver's-root. See *Veronica virginica*.

Cunila mariana L. Same as *Cunila origanoides*.

Cunila origanoides (L.) Britton. **Mint family (Menthaceae).**

Synonym.—Cunila mariana L.

American dittany; stonemint.

Indigenous, perennial plant, found on dry hills and in dry woods from New York to Florida, west to Ohio.

Part used.—Herb (nonofficial).

Cup-plant. See *Silphium perfoliatum*.

Custard-apple. See *Asimina triloba*.

Cynoglossum officinale L. **Borage family (Boraginaceae).**

Hound's-tongue; gypsy-flower.

Biennial herb, about 3 feet high, naturalized from Europe, and occurring in waste places from Canada to North Carolina, west to Kansas and Minnesota.

Parts used.—Leaves and root (nonofficial).

Cypripedium. See *Cypripedium hirsutum* and *C. parviflorum*.

Cypripedium hirsutum Mill. **Orchid family (Orchidaceae).**

Synonym.—Cypripedium pubescens Willd.

Cypripedium; large yellow ladies-slipper; yellow moccasin-flower; American valerian.

Herb, 1 to 2 feet high, native in woods and thickets from Nova Scotia south to Alabama and west to Nebraska and Missouri.

Parts used.—Rhizome and roots (official).

Cypripedium parviflorum Salisb. **Orchid family (Orchidaceae).**

Cypripedium; small yellow ladies-slipper.

Herb, 1 to 2 feet high; native in woods and thickets from British America to Georgia, Missouri, and Oregon.

Parts used.—Rhizome and roots (official).

Cypripedium pubescens Willd. Same as *Cypripedium hirsutum.*

Cytisus scoparius (L.) Link. **Pea family (Fabaceae).**

Synonym.—Sarothamnus scoparius Wimm.

Scoparius; broom; green broom; Scotch broom.

Stiff, wiry plant, 3 to 5 feet high; naturalized from Europe; growing in dry, sandy soil from Massachusetts to Virginia and becoming common in many places in the northwestern United States.

Part used.—Tops (official).

Daisy, oxeye. See *Chrysanthemum leucanthemum.*

Daisy, white. See *Chrysanthemum leucanthemum.*

Daisy-fleabane. See *Erigeron philadelphicus.*

Damiana. See *Turnera microphylla.*

Dandelion. See *Taraxacum officinale.*

Daphne mezereum L. **Mezereon family (Daphnaceae).**

Synonym.—Mezereum officinarum C. A. Mey.

Mezereum; mezereon; spurge-laurel; paradise-plant; spurge-olive.

A very hardy shrub, introduced from Europe and escaped from cultivation in Canada and New England.

Part used.—Bark of this and of other European species of Daphne (official).

Datura stramonium L. **Potato family (Solanaceae).**

Stramonium; jimson-weed; Jamestown-weed; thorn-apple; apple-of-Peru.

Poisonous weed; annual, 2 to 5 feet high; introduced from the Tropics, and occurring in fields and waste places throughout the United States, with the exception of the North and West.

Parts used.—Leaves (official); seeds (official in U. S. P. 1890).

Daucus carota L. **Parsley family (Apiaceae).**

Wild carrot; Queen-Anne's-lace.

Biennial herb, 2 to 3 feet high; naturalized from Europe; common almost throughout the United States, growing in old fields and along roadsides.

Parts used.—Root, fruit, and leaves (nonofficial).

Deerberry. See *Gaultheria procumbens* and *Mitchella repens.*

Deer-laurel. See *Rhododendron maximum.*

Deer's-tongue. See *Trilisa odoratissima.*

Deerwood. See *Ostrya virginiana.*

Deerwort-boneset. See *Eupatorium ageratoides.*

Delphinium consolida L. **Crowfoot family (Ranunculaceae).**

Field-larkspur; knight's-spur; lark-heel.

An annual herb, about 2 feet high; naturalized from Europe, and found in waste places from southern New Jersey and Pennsylvania southward. The indig-

Delphinium consolida—Continued.

enous tall larkspur, *Delphinium urceolatum* Jacq. (*D. exaltatum* Ait.), is used for similar purposes. This is found in woods from Pennsylvania to Minnesota, south to Alabama and Nebraska.

Parts used.—Herb and seeds (nonofficial).

Delphinium exaltatum Ait. See under *Delphinium consolida.*

Delphinium urceolatum Jacq. See under *Delphinium consolida.*

Devil's-bit. See *Lacinaria scariosa.*

Devil's-shoestring. See *Cracca virginiana.*

Dewberry. See *Rubus procumbens.*

Dewberry, one-flowered. See *Rubus villosus.*

Dewberry, southern. See *Rubus trivialis.*

Dicentra canadensis Walp. Same as *Bikukulla canadensis.*

Digitalis. See *Digitalis purpurea.*

Digitalis purpurea L. **Figwort family (Scrophulariaceae).**

Digitalis; foxglove; fairy-fingers; thimbles; lady's-glove.

Very handsome biennial plant, 3 to 4 feet high; introduced from Europe as a garden plant, and now escaped from cultivation in parts of Oregon, Washington, and West Virginia.

Parts used.—Leaves from plants of second year's growth, gathered at commencement of flowering (official).

Dioscorea villosa L. **Yam family (Dioscoreaceae).**

Wild yam; colic-root; rheumatism-root.

Slender, herbaceous, native vine, growing in moist thickets from Rhode Island to Minnesota, south to Florida and Texas; more common in central and southern parts of the United States.

Part used.—Rhizome (nonofficial).

Diospyros virginiana L. **Ebony family (Diospyraceae).**

Persimmon.

Indigenous tree, 15 to 50 feet in height; in fields and woods, Rhode Island to Kansas, Florida, and Texas.

Parts used.—Bark and unripe fruit (nonofficial).

Dirca palustris L. **Mezereon family (Daphnaceae).**

Leatherwood; moosewood; American mezereon; wickopy; rope-bark.

A native shrub, occurring in woods and thickets, New Brunswick to Florida, west to Missouri and Minnesota; most common in the Northern and Eastern States.

Part used.—Bark (nonofficial).

Ditch-stonecrop. See *Penthorum sedoides.*

Dittany, American. See *Cunila origanoides.*

Dock, bitter. See *Rumex obtusifolius.*

Dock, blunt-leaved. See *Rumex obtusifolius.*

Dock, broad-leaved. See *Rumex obtusifolius.*

Dock, curled. See *Rumex crispus.*

Dock, narrow. See *Rumex crispus.*

Dock, sour. See *Rumex crispus.*

Dock, spatter-. See *Nymphaea advena.*

Dock, velvet. See *Verbascum thapsus.*

Dock, yellow. See *Rumex crispus.*

Dogbane, spreading. See *Apocynum androsaemifolium.*

Dogberry. See *Sorbus americana.*

Dog-fennel. See *Anthemis cotula.*

Dog-grass. See *Agropyron repens.*

Dog's-tooth violet. See *Erythronium americanum.*

Dogwood, flowering. See *Cornus florida.*

Dogwood, round-leaved. See *Cornus circinata.*

Dogwood, swamp-. See *Cornus amomum.*

Dooryard-plantain. See *Plantago major.*

Dracontium foetidum L. Same as *Spathyema foetida.*

Dragon's-claw. See *Corallorhiza odontorhiza.*

Dropwort, western. See *Porteranthus trifoliatus.*

Drosera rotundifolia L. **Sundew family** (**Droseraceae**).

Round-leaved sundew; youthwort.

Low, perennial herb, growing in bogs and muddy shores of rivers from Canada to Florida and California.

Part used.—Herb (nonofficial).

Dryopteris filix-mas (L.) Schott. **Fern family** (**Polypodiaceae**).

Synonyms.—Aspidium filix-mas Sw.; *Polypodium filix-mas* L.

Aspidium; male-fern.

Fern, with leaves 1 to 3 feet long; in rocky woods from Canada to northern Michigan, and in the Rocky Mountains to Arizona.

Part used.—Rhizome (official).

Dryopteris marginalis (L.) A. Gray. **Fern family** (**Polypodiaceae**).

Synonyms.—Aspidium marginale Sw.; *Polypodium marginale* L.

Aspidium; evergreen wood-fern; marginal-fruited shield-fern.

Fern, with leaves 6 inches to 2½ feet long; in rocky woods from Canada south to Alabama and Arkansas.

Part used.—Rhizome (official).

Dulcamara. See *Solanum dulcamara.*

Dysentery-weed. See *Gnaphalium uliginosum.*

Earth-smoke. See *Fumaria officinalis.*

Echinacea. See *Brauneria angustifolia.*

Echinacea angustifolia DC. Same as *Brauneria angustifolia.*

Elder. See *Sambucus canadensis.*

Elder, American. See *Sambucus canadensis.*

Elder, dwarf. See *Aralia hispida.*

Elder, sweet. See *Sambucus canadensis.*

Elder, wild. See *Aralia hispida.*

Elecampane. See *Inula helenium.*

Elk-tree. See *Oxydendrum arboreum.*

Elkwood. See *Magnolia tripetala.*

Elliott's-sabbatia. See *Sabbatia elliottii.*

Elm. See *Ulmus fulva.*

Elm, Indian. See *Ulmus fulva.*

Elm, moose-. See *Ulmus fulva.*

Elm, red. See *Ulmus fulva.*

Elm, slippery. See *Ulmus fulva.*

Emetic-root. See *Euphorbia corollata.*

Epigaea repens L. **Heath family (Ericaceae).**

Gravel-plant; trailing arbutus; mayflower.

Small, shrubby, native plant, spreading on the ground in sandy soil, especially under evergreen trees, from Florida to Michigan and northward.

Part used.—Leaves (nonofficial).

Epilobium angustifolium L. Same as *Chamaenerion angustifolium*.

Epilobium palustre L. **Evening-primrose family (Onagraceae).**

Swamp willow-herb; wickup.

Slender, erect, native herb, 6 to 18 inches high, found in swamps and marshes from Canada and the New England States west to Colorado and Washington.

Parts used.—Leaves and root (nonofficial).

Epiphegus virginiana Bart. Same as *Leptamnium virginianum*.

Equisetum hyemale L. **Horsetail family (Equisetaceae).**

Common scouring-rush; horsetail; shave-grass.

Rush-like perennial plant, growing in wet places along river banks and borders of woods throughout nearly the whole of North America.

Part used.—Plant (nonofficial).

Erechtites hieracifolia (L.) Raf. **Aster family (Asteraceae).**

Fireweed; pilewort.

Native, annual herb, 1 to 8 feet high, in woods, fields, and waste places, Canada to Florida, Louisiana, and Nebraska.

Part used.—Herb (nonofficial).

Erigeron canadensis L. **Aster family (Asteraceae).**

Synonym.—*Leptilon canadense* (L.) Britton.[a]

Canada fleabane; horseweed; colt's-tail; prideweed; bitterweed.

Native, annual weed, 3 inches to 10 feet in height; in fields and meadows, along roadsides, and in waste places, almost throughout North America.

Part used.—Herb (nonofficial); the oil of erigeron, distilled from the fresh, flowering herb, is official.

Erigeron philadelphicus L. **Aster family (Asteraceae).**

Philadelphia fleabane; sweet scabious; daisy-fleabane.

Native, perennial herb, 1 to 3 feet high, in fields and woods throughout North America, except extreme North.

Part used.—Herb (nonofficial).

Eriodictyon. See *Eriodictyon californicum*.

Eriodictyon californicum (H. & A.) Greene. **Waterleaf family (Hydrophyllaceae).**

Synonym.—*Eriodictyon glutinosum* Benth.

Eriodictyon; yerba santa; mountain-balm; consumptive's-weed; bear's-weed.

Shrubby plant, 2 to 4 feet high, native; grows in clumps in dry situations and among rocks throughout California and northern Mexico.

Part used.—Leaves (official).

Eriodictyon glutinosum Benth. Same as *Eriodictyon californicum*.

Eryngium yuccaefolium Michx. Same as *Eryngium yuccifolium*.

Eryngium yuccifolium Michx. **Parsley family (Apiaceae).**

Synonym.—*Eryngium yuccaefolium* Michx.

Water-eryngo; button-snakeroot; rattlesnake-weed; rattlesnake-master; corn-snakeroot.

Native, perennial herb, 1 to 5 feet high, growing in swamps and low wet ground from the pine barrens of New Jersey west to Minnesota, and south to Texas and Florida.

Part used.—Rhizome (nonofficial).

[a] Some authors hold that this plant belongs to the genus *Leptilon* and that its name should be *Leptilon canadense* (L.) Britton. The Pharmacopœia is here followed.

Eryngo, water-. See *Eryngium yuccifolium*.

Erythronium americanum Ker. **Lily family (Liliaceae).**

Yellow adder's-tongue; dog's-tooth violet; yellow snowdrop; rattlesnake-violet; yellow snakeleaf.

Native, perennial herb, occurring in moist woods and thickets, Nova Scotia to Minnesota, south to Arkansas and Florida.

Parts used.—Leaves and root (nonofficial).

Euonymus. See *Euonymus atropurpureus*.

Euonymus atropurpureus Jacq. **Staff-tree family (Celastraceae).**

Euonymus; wahoo; burningbush; spindle-tree; Indian arrowwood.

Native shrub or small tree, growing in woods and thickets from Ontario and eastern United States west to Montana.

Part used.—Bark of root (official).

Eupatorium. See *Eupatorium perfoliatum*.

Eupatorium ageratoides L. f. **Aster family (Asteraceae).**

White snakeroot; white sanicle; Indian sanicle; deerwort-boneset; poolwort; poolroot; richweed; squaw-weed.

Erect, perennial herb, 1 to 4 feet high, native; in rich woods from Canada to Georgia, west to Nebraska and Louisiana.

Part used.—Root (nonofficial).

Eupatorium aromaticum L. **Aster family (Asteraceae).**

Smaller white snakeroot; poolwort; poolroot; wild hoarhound.

Native, perennial herb, 1 to 2 feet high; in dry soil from Massachusetts to Florida, especially throughout the Middle States.

Part used.—Root (nonofficial).

Eupatorium perfoliatum L. **Aster family (Asteraceae).**

Eupatorium; boneset; thoroughwort; Indian sage; agueweed; crosswort.

Native, perennial herb, 1 to 5 feet high; in low, wet places from Canada to Florida, west to Texas and Nebraska.

Parts used.—Leaves and flowering tops (official).

Eupatorium purpureum L. **Aster family (Asteraceae).**

Queen-of-the-meadow; gravelroot; Joe-Pye-weed; purple boneset; kidneyroot.

Native, perennial herb, 3 to 10 feet high; in low grounds from Canada to Florida and Texas.

Parts used.—Root and herb (nonofficial).

Euphorbia corollata L. **Spurge family (Euphorbiaceae).**

Flowering spurge; emetic-root; milk-ipecac; snakemilk; purging-root.

Native, perennial herb, about 3 feet in height, growing in dry fields and woods from Ontario to Florida and Minnesota to Texas.

Part used.—Root (nonofficial).

Euphorbia hypericifolia A. Gray. Same as *Euphorbia nutans*.

Euphorbia ipecacuanhae L. **Spurge family (Euphorbiaceae).**

Wild ipecac; ipecac-spurge; American ipecac; Carolina ipecac.

Native, perennial herb, 4 to 10 inches high; in dry, sandy soil, mostly near the coast, from Connecticut to Florida.

Part used.—Root (nonofficial).

Euphorbia nutans Lag. **Spurge family (Euphorbiaceae).**

Synonym.—*Euphorbia hypericifolia* A. Gray.

Large spotted spurge; black purslane; fluxweed; milk-purslane.

Native, annual plant, from ½ to 2 feet in height; in rich soils, fields, and thickets throughout eastern North America, except extreme north, and extending west to the Rocky Mountains.

Part used.—Herb (nonofficial).

Euphorbia pilulifera L. **Spurge family (Euphorbiaceae).**

Pill-bearing spurge; snakeweed; Queensland asthma-weed.

Herbaceous annual, 10 to 15 inches high, occurring from the Gulf States through Texas to New Mexico.

Part used.—Herb (nonofficial).

Evening-primrose. See *Oenothera biennis.*

Everlasting. See *Anaphalis margaritacea.*

Everlasting, large-flowered. See *Anaphalis margaritacea.*

Everlasting, pearly. See *Anaphalis margaritacea.*

Eve's-cup. See *Sarracenia flava.*

Fagara clava-herculis (L.) Small. **Rue family (Rutaceae).**

Synonym.—*Xanthoxylum clava-herculis* L.

Xanthoxylum; southern prickly ash; toothache-tree; yellowthorn; yellow-wood; Hercules-club.

Small, indigenous, very prickly tree, sometimes 45 feet in height, occurring along streams from southern Virginia to Florida, west to Texas and Arkansas.

Parts used.—Bark official under the name "Xanthoxylum"; berries (nonofficial).

Fagus americana Sweet. **Beech family (Fagaceae).**

Synonym.—*Fagus ferruginea* Ait.

American beech; beechnut-tree.

Large, native forest tree, growing in rich soil from Nova Scotia to Florida, west to Wisconsin and Texas.

Parts used.—Bark and leaves (nonofficial).

Fagus ferruginea Ait. Same as *Fagus americana.*

Fairy-fingers. See *Digitalis purpurea.*

Featherfew. See *Chrysanthemum parthenium.*

Febrifuge-plant. See *Chrysanthemum parthenium.*

Female-fern. See *Athyrium filix-foemina* and *Polypodium vulgare.*

Fennel, dog-. See *Anthemis cotula.*

Fern, evergreen wood-. See *Dryopteris marginalis.*

Fern, female-. See *Athyrium filix-foemina* and *Polypodium vulgare.*

Fern, lady-. See *Athyrium filix-foemina.*

Fern, maidenhair-. See *Adiantum pedatum.*

Fern, male-. See *Dryopteris filix-mas.*

Fern, marginal-fruited shield-. See *Dryopteris marginalis.*

Fern, meadow-. See *Comptonia peregrina.*

Fern, parsley-. See *Tanacetum vulgare.*

Fern, royal. See *Osmunda regalis.*

Fern, sweet. See *Comptonia peregrina.*

Fernroot. See *Polypodium vulgare.*

Feverbush. See *Benzoin benzoin* and *Ilex verticillata.*

Feverfew, common. See *Chrysanthemum parthenium.*

Feverroot. See *Triosteum perfoliatum.*

Fevertwig. See *Celastrus scandens.*

Field-balm. See *Glecoma hederacea.*

Field-larkspur. See *Delphinium consolida.*

Field-sorrel. See *Rumex acetosella.*

Figwort, Maryland. See *Scrophularia marilandica.*

Fir, balsam-. See *Abies balsamea.*

Fireweed. See *Erechtites hieracifolia.*

Fit-plant. See *Monotropa uniflora.*

Fitroot. See *Monotropa uniflora.*

Fivefinger. See *Potentilla canadensis.*

Flag, blue. See *Iris versicolor.*

Flag, cattail-. See *Typha latifolia.*

Flag, sweet-. See *Acorus calamus.*

Flag, water-. See *Iris versicolor.*

Flag-lily. See *Iris versicolor.*

Flannel-leaf. See *Verbascum thapsus.*

Fleabane, Canada. See *Erigeron canadensis.*

Fleabane, daisy-. See *Erigeron philadelphicus.*

Fleabane, Philadelphia. See *Erigeron philadelphicus.*

Fluxweed. See *Euphorbia nutans.*

Flytrap. See *Sarracenia purpurea.*

Foamflower. See *Tiarella cordifolia.*

Foxglove. See *Digitalis purpurea.*

Fragaria virginiana Duchesne. **Rose family (Rosaceae).**

Virginia strawberry; scarlet strawberry.

Native, perennial herb, occurring in dry soil from Canada to Georgia, west to Indian Territory and Minnesota.

Part used.—Leaves (nonofficial).

Frankenia grandifolia Cham. & Schlecht. **Frankenia family (Frankeniaceae).**

Yerba reuma.

Native, perennial herb, 8 to 13 inches high, common in salt marshes and sandy localities near the coast in California.

Part used.—Herb (nonofficial).

Frasera carolinensis Walt. **Gentian family (Gentianaceae).**

Synonym.—Frasera walteri Michx.

American columbo; Indian lettuce; meadowpride; pyramid-flower.

Smooth, perennial herb, 3 to 8 feet high, found in dry soil from New York to Wisconsin, south to Georgia and Kentucky.

Part used.—Root (nonofficial).

Frasera walteri Michx. Same as *Frasera carolinensis.*

Fraxinus acuminata Lam. Same as *Fraxinus americana.*

Fraxinus alba Marsh. Same as *Fraxinus americana.*

Fraxinus americana L. **Olive family (Oleaceae).**

Synonyms.—Fraxinus alba Marsh; *Fraxinus acuminata* Lam.

White ash; cane-ash.

Large, native forest tree, in rich woods from Nova Scotia to Minnesota, south to Florida and Texas. Occurs chiefly in the Northern States and Canada.

Part used.—Bark (nonofficial).

Fraxinus nigra Marsh. **Olive family (Oleaceae).**

Synonym.—Fraxinus sambucifolia Lam.

Black ash; hoop-ash.

Native tree, 40 to 70 feet in height, occurring in swamps and wet woods from Canada to Virginia and Arkansas.

Part used.—Bark (nonofficial).

Fraxinus sambucifolia Lam. Same as *Fraxinus nigra*.

Fringe-tree. See *Chionanthus virginica*.

Frost-plant. See *Helianthemum canadense*.

Frostweed. See *Helianthemum canadense*.

Frostwort. See *Helianthemum canadense*.

Fuller's-herb. See *Saponaria officinalis*.

Fumaria officinalis L. **Poppy family (Papaveraceae).**

Fumitory; hedge-fumitory; earth-smoke.

Annual plant, 10 to 15 inches high, adventive from Europe and found in waste places about dwellings, in cultivated land, and on ballast, Nova Scotia to the Gulf States.

Part used.—Herb (nonofficial).

Fumitory. See *Fumaria officinalis*.

Fumitory, hedge-. See *Fumaria officinalis*.

Gagroot. See *Lobelia inflata*.

Gale, sweet. See *Myrica gale*.

Galium aparine L. **Madder family (Rubiaceae).**

Cleavers; goose-grass; cleaverwort; bedstraw; catchweed.

Annual plant, with weak, procumbent stem, 2 to 6 feet long, growing in shady thickets and margins of woods, New Brunswick south to Florida and Texas. Naturalized from Europe.

Part used.—Herb of this and of other species of Galium (nonofficial).

Gallweed. See *Gentiana quinquefolia*.

Garden-balm. See *Melissa officinalis*.

Garden-celandine. See *Chelidonium majus*.

Garden-columbine. See *Aquilegia vulgaris*.

Garden-valerian. See *Valeriana officinalis*.

Garget. See *Phytolacca decandra*.

Gaultheria procumbens L. **Heath family (Ericaceae).**

Wintergreen; checkerberry; mountain-tea; teaberry; deerberry.

Small, native perennial, with evergreen leaves, found in sandy soils in cool, damp woods, especially under evergreen trees, in Canada and the northeastern United States.

Part used.—Leaves (nonofficial); the oil of gaultheria, distilled from the leaves, is official.

Gay-feather. See *Lacinaria scariosa* and *L. spicata*.

Gelsemium. See *Gelsemium sempervirens*.

Gelsemium sempervirens (L.) Ait. f. **Logania family (Loganiaceae).**

Gelsemium; yellow jasmine; Carolina jasmine; wild woodbine.

Twining, shrubby perennial, native, growing on low ground in woods and thickets from eastern Virginia to Florida and Texas, mostly near the coast.

Parts used.—Rhizome and roots (official).

Gemfruit. See *Tiarella cordifolia*.

Gentian, American. See *Gentiana saponaria*.

Gentian, blue. See *Gentiana saponaria*.

Gentian, five-flowered. See *Gentiana quinquefolia*.

Gentian, horse-. See *Triosteum perfoliatum*.

Gentian, marsh-. See *Gentiana villosa*.

Gentian, snake-. See *Nabalus serpentarius*.

Gentian, soapwort-. See *Gentiana saponaria.*

Gentian, stiff. See *Gentiana quinquefolia.*

Gentian, straw-colored. See *Gentiana villosa.*

Gentian, striped. See *Gentiana villosa.*

Gentian, white. See *Triosteum perfoliatum.*

Gentiana catesbaei Walt. Same as *Gentiana saponaria.*

Gentiana ochroleuca Froel. Same as *Gentiana villosa.*

Gentiana quinqueflora Lam. Same as *Gentiana quinquefolia.*

Gentiana quinquefolia L. **Gentian family (Gentianaceae).**

Synonym.—Gentiana quinqueflora Lam.

Stiff gentian; five-flowered gentian; agueweed; gallweed.

Native, annual plant, 1 to 2 feet in height, growing in pastures and other open situations from Maine to Michigan, south to Florida and Missouri.

Parts used.—Root and herb (nonofficial).

Gentiana saponaria L. **Gentian family (Gentianaceae).**

Synonym.—Gentiana catesbaei Walt.

American gentian; blue gentian; soapwort-gentian.

Native, perennial herb, 1 to 2½ feet high; in wet soil, Ontario to Minnesota, south to Louisiana and Florida.

Part used.—Root (nonofficial).

Gentiana villosa L. **Gentian family (Gentianaceae).**

Synonym.—Gentiana ochroleuca Froel.

Striped gentian; straw-colored gentian; marsh-gentian; Sampson's-snakeroot.

Native, perennial herb, 6 to 18 inches high; in shaded places, Middle and Southern States.

Part used.—Root (nonofficial).

Geranium. See *Geranium maculatum.*

Geranium maculatum L. **Geranium family (Geraniaceae).**

Geranium; wild crane's-bill; spotted crane's-bill; wild geranium; spotted geranium; alum-root.

Native, perennial herb, 1 to 1½ feet high; found in low grounds and open woods from Canada south to Georgia and Missouri.

Part used.—Rhizome (official).

Geranium, spotted. See *Geranium maculatum.*

Geranium, wild. See *Geranium maculatum.*

Geum rivale L. **Rose family (Rosaceae).**

Water-avens; purple avens.

Native, perennial herb, 1 to 2 feet high, occurring in swamps and wet meadows from Canada to Pennsylvania and Colorado, especially in the Northern and Middle States.

Parts used.—Rhizome and rootlets (nonofficial).

Ghostflower. See *Monotropa uniflora.*

Gillenia trifoliata Moench. Same as *Porteranthus trifoliatus.*

Gill-over-the-ground. See *Glecoma hederacea.*

Ginger, Indian. See *Asarum canadense.*

Ginger, wild. See *Asarum canadense.*

Gingerroot. See *Tussilago farfara.*

Ginseng. See *Panax quinquefolium.*

Glecoma hederacea L. **Mint family (Menthaceae).**

Synonym.—Nepeta glechoma Benth.

Ground-ivy; gill-over-the-ground; catfoot; field-balm.

Low, perennial herb, with creeping stem. Naturalized from Europe and found in waste places, woods, and thickets from Newfoundland to Minnesota, south to Georgia and Kansas.

Part used.—Herb (nonofficial).

Globeflower. See *Cephalanthus occidentalis.*

Gnaphalium margaritaceum L. Same as *Anaphalis margaritacea.*

Gnaphalium obtusifolium L. **Aster family (Asteraceae).**

Synonym.—Gnaphalium polycephalum Michx.

Sweet balsam; life-everlasting; sweet life-everlasting; white balsam.

Native, herbaceous annual, 1 to 2 feet high; in dry, open places and old fields from Nova Scotia and Manitoba south to Florida and Texas.

Part used.—Herb (nonofficial).

Gnaphalium polycephalum Michx. Same as *Gnaphalium obtusifolium.*

Gnaphalium uliginosum L. **Aster family (Asteraceae).**

Mouse-ear; low cudweed; marsh-cudweed; wartwort; dysentery-weed.

Annual herb, 2 to 8 inches high, occurring in damp soil from Newfoundland to Minnesota, south to Indiana and Virginia; apparently naturalized from Europe.

Part used.—Herb (nonofficial).

Gnaphalium undulatum Walt. Same as *Pterocaulon undulatum.*

Goat's-rue. See *Cracca virginiana.*

Goldenrod, anise-scented. See *Solidago odora.*

Goldenrod, fragrant-leaved. See *Solidago odora.*

Goldenrod, sweet. See *Solidago odora.*

Goldenseal. See *Hydrastis canadensis.*

Goldthread. See *Coptis trifolia.*

Goodyera pubescens R. Br. Same as *Peramium pubescens.*

Goodyera repens R. Br. Same as *Peramium repens.*

Goose-grass. See *Galium aparine.*

Grape, Oregon. See *Berberis aquifolium.*

Grape, Rocky Mountain. See *Berberis aquifolium.*

Gravel-plant. See *Epigaea repens.*

Gravelroot. See *Eupatorium purpureum.*

Gravel-weed. See *Onosmodium virginianum.*

Greenbrier, long-stalked. See *Smilax pseudo-china.*

Grindelia. See *Grindelia robusta* and *G. squarrosa.*

Grindelia robusta Nutt. **Aster family (Asteraceae).**

Grindelia; gum-plant.

Perennial herb, about 1½ feet high, native in the States west of the Rocky Mountains.

Parts used.—Leaves and flowering tops (official).

Grindelia, scaly. See *Grindelia squarrosa.*

Grindelia squarrosa (Pursh) Dunal. **Aster family (Asteraceae).**

Grindelia; scaly grindelia; broad-leaved gum-plant.

Perennial herb, 1 to 2 feet high, native; occurring on the plains and prairies from the Saskatchewan to Minnesota, Texas, and California.

Parts used.—Leaves and flowering tops (official).

Gromwell, Virginia false. See *Onosmodium virginianum*

Ground-centaury. See *Polygala nuttallii.*

Ground-ivy. See *Glecoma hederacea.*

Ground-raspberry. See *Hydrastis canadensis.*

Ground-squirrel pea. See *Jeffersonia diphylla.*

Gum, cotton-. See *Nyssa aquatica.*

Gum, red. See *Liquidambar styraciflua.*

Gum, star-leaved. See *Liquidambar styraciflua.*

Gum, sweet-. See *Liquidambar styraciflua.*

Gum, tupelo. See *Nyssa aquatica.*

Gum-plant. See *Grindelia robusta.*

Gum-plant, broad-leaved. See *Grindelia squarrosa.*

Gypsy-flower. See *Cynoglossum officinale.*

Gypsy-weed. See *Lycopus virginicus.*

Hackmatack. See *Larix laricina.*

Haircap-moss. See *Polytrichum juniperinum.*

Hamamelis. See *Hamamelis virginiana.*

Hamamelis virginiana L. **Witch-hazel family** (**Hamamelidaceae**).

Hamamelis; witch-hazel; winterbloom; snapping hazel.

Indigenous shrub, found in low, damp woods from New Brunswick to Minnesota, south to Florida and Texas.

Parts used.—Leaves (collected in autumn), bark, and twigs (official).

Hardhack. See *Spiraea tomentosa.*

Hart's-thorn. See *Rhamnus cathartica.*

Haw, black. See *Viburnum prunifolium.*

Hawkweed, early. See *Hieracium venosum.*

Hawthorn. See *Crataegus oxyacantha.*

Hazel, snapping. See *Hamamelis virginiana.*

Heal-all. See *Prunella vulgaris* and *Scrophularia marilandica.*

Healing-herb. See *Symphytum officinale.*

Heart-liverleaf. See *Hepatica acuta.*

Heartsease. See *Viola tricolor.*

Hedeoma. See *Hedeoma pulegioides.*

Hedeoma pulegioides (L.) Pers. **Mint family** (**Menthaceae**).

Hedeoma; American pennyroyal; tickweed; squawmint.

Low, native, annual plant, 6 to 12 inches high, growing in barren woods and dry fields, Nova Scotia to Minnesota, south to Nebraska and Florida.

Parts used.—Leaves and flowering tops, and the volatile oil distilled from these, are official.

Hedge-fumitory. See *Fumaria officinalis.*

Hedgethorn. See *Crataegus oxyacantha.*

Helenium autumnale L. **Aster family** (**Asteraceae**).

Sneezeweed; sneezewort; swamp-sunflower.

Native perennial, 2 to 3 feet high, growing in swamps, wet fields, and meadows, Canada to Florida and Arizona.

Part used.—Herb (nonofficial).

Helianthemum canadense (L.) Michx. **Rock-rose family (Cistaceae).**

Frostweed; frostwort; frost-plant; Canadian rock-rose.

Native, perennial herb, about one foot in height; in dry, sandy soil, Maine to Wisconsin, south to North Carolina and Kentucky.

Part used.—Herb (nonofficial).

Hellebore, American. See *Veratrum viride.*

Hellebore, green. See *Veratrum viride.*

Hellebore, swamp-. See *Veratrum viride.*

Helmetpod. See *Jeffersonia diphylla.*

Helonias dioica Pursh. Same as *Chamaelirium luteum.*

Hemlock. See *Tsuga canadensis.*

Hemlock, poison-. See *Conium maculatum.*

Hemlock, water-. See *Cicuta maculata.*

Hemlock-spruce. See *Tsuga canadensis.*

Hemp, black Indian. See *Apocynum cannabinum.*

Hemp, Canadian. See *Apocynum cannabinum.*

Hemp, white Indian. See *Asclepias incarnata.*

Henbane. See *Hyoscyamus niger.*

Hepatica acuta (Pursh) Britton. **Crowfoot family (Ranunculaceae).**

Synonym.—*Hepatica acutiloba* DC.

Heart-liverleaf; sharp-lobed liverleaf; liverwort.

Perennial herb, 4 to 9 inches high, found in woods from Quebec and Ontario, south to Georgia (but rare near the coast), west to Iowa and Minnesota.

Part used.—Leaves (nonofficial).

Hepatica acutiloba DC. Same as *Hepatica acuta.*

Hepatica hepatica (L.) Karst. **Crowfoot family (Ranunculaceae).**

Synonym.—*Hepatica triloba* Chaix.

Round-lobed liverleaf; kidney-liverleaf; liverwort.

Perennial herb, 4 to 6 inches high; in woods from Nova Scotia to northern Florida, west to Iowa and Missouri; less common than the heart-liverleaf.

Part used.—Leaves (nonofficial).

Hepatica triloba Chaix. Same as *Hepatica hepatica.*

Heracleum lanatum Michx. **Parsley family (Apiaceae).**

Masterwort; cow-parsnip; youthwort.

Native, perennial herb, 3 to 5 feet high, growing in moist meadows and cultivated ground from Canada south to North Carolina, Utah, and California.

Parts used.—Root, leaves, and seeds (nonofficial).

Hercules-club. See *Fagara clava-herculis.*

Heuchera americana L. **Saxifrage family (Saxifragaceae).**

Alum-root; American sanicle.

Native, perennial herb, 2 to 4 feet in height; in shady, rocky woodlands from Connecticut to Minnesota, south to Alabama and Louisiana.

Part used.—Root (nonofficial).

Hickory, shellbark-. See *Hicoria ovata.*

Hicoria ovata (Mill.) Britton. **Walnut family (Juglandaceae).**

Synonym.—*Carya alba* Nutt.

Shagbark, shellbark-hickory.

Large, native tree, sometimes 120 feet in height; in rich soil from Quebec to southern Ontario and Minnesota, south to Florida and Texas.

Parts used.—Bark and leaves (nonofficial).

Hieracium venosum L. **Chicory family** (**Cichoriaceae**).

Early hawkweed; rattlesnake-weed; bloodwort; striped bloodwort.

Perennial herb, 1 to 2 feet high, native; occurring in dry woods and thickets from Maine to Georgia, west to Nebraska; more common in the northern and eastern United States.

Parts used.—Leaves and root (nonofficial).

Highbelia. See *Lobelia siphilitica.*

Hive-vine. See *Mitchella repens.*

Hoarhound. See *Marrubium vulgare.*

Hoarhound, water-. See *Lycopus virginicus.*

Hoarhound, wild. See *Eupatorium aromaticum.*

Hog-potato. See *Ipomoea pandurata.*

Hog's-bean. See *Hyoscyamus niger.*

Hogweed. See *Ambrosia artemisiaefolia.*

Holly, American. See *Ilex opaca.*

Holly, white. See *Ilex opaca.*

Honeybloom. See *Apocynum androsaemifolium.*

Hoodwort. See *Scutellaria lateriflora.*

Hoop-ash. See *Fraxinus nigra.*

Hop-hornbeam. See *Ostrya virginiana.*

Hop-tree. See *Ptelea trifoliata.*

Hornbeam, hop-. See *Ostrya virginiana.*

Horse-balm. See *Collinsonia canadensis.*

Horse-chestnut. See *Aesculus hippocastanum.*

Horsefly-weed. See *Baptisia tinctoria.*

Horsefoot. See *Tussilago farfara.*

Horse-gentian. See *Triosteum perfoliatum.*

Horseheal. See *Inula helenium.*

Horsemint. See *Monarda fistulosa* and *M. punctata.*

Horse-nettle. See *Solanum carolinense.*

Horsetail. See *Equisetum hyemale.*

Horseweed. See *Erigeron canadensis.*

Hound's-tongue. See *Cynoglossum officinale.*

Hydrangea. See *Hydrangea arborescens.*

Hydrangea arborescens L. **Hydrangea family** (**Hydrangeaceae**).

Hydrangea; wild hydrangea; seven-barks.

Indigenous shrub, 5 or 6 feet in height; on rocky river banks from southern New York to Florida, west to Iowa and Missouri; very abundant in the valley of the Delaware.

Part used.—Root (nonofficial).

Hydrangea, wild. See *Hydrangea arborescens.*

Hydrastis. See *Hydrastis canadensis.*

Hydrastis canadensis L. **Crowfoot family** (**Ranunculaceae**).

Hydrastis; goldenseal; yellowroot; ground-raspberry; orangeroot; yellow puccoon.

Perennial herb, about 1 foot in height, native in rich soil in shady woods, southern New York to Minnesota, south to Georgia and Missouri, but principally in Ohio, Indiana, Kentucky, and West Virginia.

Parts used.—Rhizome and roots (official).

Hyoscyamus. See *Hyoscyamus niger.*

Hyoscyamus niger L. **Potato family (Solanaceae).**

Hyoscyamus; henbane; hog's-bean; insane-root.

Biennial herb, 6 inches to 2 feet high, sparingly naturalized from Europe, in waste places from Nova Scotia to Ontario, New York, and Michigan.

Parts used.—Leaves and flowering tops from plants of second year's growth (official); seeds are also used (nonofficial).

Hypericum perforatum L. **St. John's-wort family (Hypericaceae).**

John's-wort; common St. John's-wort.

Herbaceous perennial, 1 to 2 feet high, naturalized from Europe; common in fields and waste places throughout almost the entire United States, except the Southern States.

Part used.—Herb (nonofficial).

Hyssop. See *Hyssopus officinalis.*

Hyssop, wild. See *Verbena hastata.*

Hyssop-skullcap. See *Scutellaria integrifolia.*

Hyssopus officinalis L. **Mint family (Menthaceae).**

Hyssop.

Perennial herb, 1 to 3 feet high, naturalized from Europe, and found along roadsides and in waste places from Ontario and Maine to North Carolina, and on the Pacific coast.

Part used.—Herb (nonofficial).

Ilex opaca Ait. **Holly family (Aquifoliaceae).**

American holly; white holly.

Native tree, 20 to 40 feet in height, with evergreen leaves; in moist woodlands, Maine to Florida, and west to Missouri and Texas; most abundant in the Atlantic States.

Parts used.—Leaves and bark (nonofficial).

Ilex verticillata (L.) A. Gray. **Holly family (Aquifoliaceae).**

Synonym.—*Prinos verticillata* L.

Black alder; feverbush; Virginia winterberry.

A native shrub, growing in moist woods and along banks of streams from Nova Scotia to Florida, west to Wisconsin and Missouri.

Parts used.—Bark and berries (nonofficial).

Impatiens aurea Muhl. **Jewelweed family (Impatientaceae).**

Synonym.—*Impatiens pallida* Nutt.

Jewelweed; pale touch-me-not; snapweed; wild celandine.

Native, annual plant, 2 to 4 feet high, found in rich soil in moist, shady places from Quebec to Oregon, south to Georgia and Kansas.

Part used.—Herb (nonofficial).

Impatiens biflora Walt. **Jewelweed family (Impatientaceae).**

Synonym.—*Impatiens fulva* Nutt.

Jewelweed; spotted touch-me-not; snapweed; silverleaf.

Native, annual plant, 2 to 5 feet high, growing in rich soil in moist, shady places from Canada to Alaska and Oregon, south to Florida and Missouri; more common than the pale touch-me-not.

Part used.—Herb (nonofficial).

Impatiens fulva Nutt. Same as *Impatiens biflora.*

Impatiens pallida Nutt. Same as *Impatiens aurea.*

Indian-cup. See *Silphium perfoliatum.*

Indian-paint. See *Sanguinaria canadensis.*

Indian-physic. See *Porteranthus trifoliatus.*

Indian-pipe. See *Monotropa uniflora.*

Indian-root. See *Aralia racemosa.*

Indigo, American. See *Baptisia tinctoria.*

Indigo, wild. See *Baptisia tinctoria.*

Indigo, yellow. See *Baptisia tinctoria.*

Indigo-weed. See *Baptisia tinctoria.*

Inkberry. See *Phytolacca decandra.*

Inkroot. See *Limonium carolinianum.*

Insane-root. See *Hyoscyamus niger.*

Inula. See *Inula helenium.*

Inula helenium L. **Aster family** (**Asteraceae**).

Inula; elecampane; horseheal; scabwort.

Rough, perennial herb, 3 to 6 feet high, naturalized from Europe, and found along roadsides and in fields and pastures from Nova Scotia to North Carolina, westward to Missouri and Minnesota.

Part used.—Root (official in U. S. P. 1890).

Ipecac, American. See *Euphorbia ipecacuanhae.*

Ipecac, Carolina. See *Euphorbia ipecacuanhae.*

Ipecac, false. See *Porteranthus trifoliatus.*

Ipecac, milk-. See *Euphorbia corollata.*

Ipecac, wild. See *Euphorbia ipecacuanhae* and *Triosteum perfoliatum.*

Ipecac-spurge. See *Euphorbia ipecacuanhae.*

Ipomoea pandurata (L.) Meyer. **Morning-glory family** (**Convolvulaceae**).

Synonym.—Convolvulus panduratus L.

Manroot; man-of-the-earth; wild potato; hog-potato; wild jalap.

Native perennial, with trailing stems 2 to 12 feet long; in dry fields or on hills from Connecticut to Michigan, south to Florida and Texas.

Part used.—Root (nonofficial).

Iris. See *Iris versicolor.*

Iris versicolor L. **Iris family** (**Iridaceae**).

Iris; blue flag; flag-lily; liver-lily; water-flag; snake-lily.

Native, perennial plant, 2 to 3 feet high, found in wet, marshy localities from Newfoundland to Manitoba, south to Florida and Arkansas.

Parts used.—Rhizome and roots (official in U. S. P. 1890).

Ironwood. See *Ostrya virginiana.*

Ivy, American. See *Parthenocissus quinquefolia.*

Ivy, ground-. See *Glecoma hederacea.*

Ivy, poison-. See *Rhus radicans* and *R. toxicodendron.*

Jack-in-the-pulpit. See *Arisaema triphyllum.*

Jacob's-ladder. See *Polemonium reptans.*

Jacob's-ladder, American. See *Smilax herbacea.*

Jalap, wild. See *Ipomoea pandurata.*

James-tea. See *Ledum groenlandicum.*

Jamestown-weed. See *Datura stramonium.*

Jasmine, Carolina. See *Gelsemium sempervirens.*

Jasmine, yellow. See *Gelsemium sempervirens.*

Jeffersonia diphylla (L.) Pers. **Barberry family (Berberidaceae).**

Twinleaf; rheumatism-root; helmetpod; yellowroot; ground-squirrel pea.

Native, perennial plant, 8 to 14 inches in height, growing in woods and near streams from New York to Virginia, westward to Wisconsin.

Part used.—Rhizome (nonofficial).

Jewelweed. See *Impatiens aurea* and *I. biflora.*

Jimson-weed. See *Datura stramonium.*

Job's-tears, wild. See *Onosmodium virginianum.*

Joe-Pye-weed. See *Eupatorium purpureum.*

John's-wort. See *Hypericum perforatum.*

Judas-tree. See *Cercis canadensis.*

Juglans. See *Juglans cinerea.*

Juglans cinerea L. **Walnut family (Juglandaceae).**

Juglans; butternut; white walnut.

Indigenous tree, 20 to 50 feet in height, common in rich woods from New Brunswick to North Dakota, south to Georgia, Mississippi, and Arkansas.

Part used.—Bark of root, collected in autumn (official in U. S. P. 1890).

Juniper. See *Juniperus communis.*

Juniperus communis L. **Pine family (Pinaceae).**

Juniper.

Evergreen shrub or low tree, common on dry, sterile hills from Canada south to New Jersey, west to Nebraska, and in the Rocky Mountains to New Mexico.

Part used.—Fruit (nonofficial). The oil of juniper, distilled from the fruit, is official.

Juniperus sabina L. **Pine family (Pinaceae).**

Sabina; savin; shrubby red cedar.

A shrub, usually procumbent, seldom more than 4 feet in height, occurring in rocky places in the northern United States.

Part used.—Tops, and the oil of savin, distilled from the fresh tops, are official.

Juniperus virginiana L. **Pine family (Pinaceae).**

Red cedar; red savin.

A tree, sometimes 100 feet in height, common in dry soil from Canada to Florida and Arizona.

Parts used.—Leaves and "cedar apples" (nonofficial).

Kalmia angustifolia L. **Heath family (Ericaceae).**

Sheep-laurel; lambkill; calfkill; narrow-leaved laurel.

Native, evergreen shrub, about 3 feet high, growing in moist soil from Canada south to Georgia.

Part used.—Leaves (nonofficial).

Kalmia latifolia L. **Heath family (Ericaceae).**

Mountain-laurel; calico-bush; broad-leaved laurel; sheep-laurel.

Native, evergreen shrub, 10 to 20 feet high, growing in sandy or rocky soil from New Brunswick to Ohio, Florida, and Louisiana.

Part used.—Leaves (nonofficial).

Kidney-liverleaf. See *Hepatica hepatica.*

Kidneyroot. See *Eupatorium purpureum.*

Knight's-spur. See *Delphinium consolida.*

Knobroot. See *Collinsonia canadensis.*

Knotweed, biting. See *Polygonum hydropiper.*

Koellia montana (Michx.) Kuntze. **Mint family (Menthaceae).**

Synonym.—Pycnanthemum montanum Michx.

Thin-leaved mountain-mint.

Native perennial, 2 to 3 feet high, found in woods from southern Virginia to Georgia and Alabama.

Part used.—Herb (nonofficial).

Koellia pilosa (Nutt.) Britton. **Mint family (Menthaceae).**

Synonym.—Pycnanthemum pilosum Nutt.

Hairy mountain-mint.

Native perennial, 1 to 2½ feet high, occurring in prairies and dry woods from Ohio to Georgia, west to Missouri and Arkansas.

Part used.—Herb (nonofficial).

Lacinaria scariosa (L.) Hill. **Aster family (Asteraceae).**

Synonym.—Liatris scariosa Willd.

Blue blazingstar; large button-snakeroot; rattlesnake-master; gay-feather; devil's-bit.

Native, perennial herb, 4 to 5 feet high, found in dry woods and sandy fields from Maine to Florida, west to Texas and Nebraska.

Part used.—Root (nonofficial).

Lacinaria spicata (L.) Kuntze. **Aster family (Asteraceae).**

Synonym.—Liatris spicata Willd.

Dense button-snakeroot; colic-root; prairie-pine; gay-feather; rattlesnake-master; corn-snakeroot; backache-root.

Native, perennial herb, 2 to 5 feet high, in moist places from Massachusetts to Florida, west to Wisconsin and Arkansas.

Part used.—Root (nonofficial).

Lacinaria squarrosa (L.) Hill. **Aster family (Asteraceae).**

Synonym.—Liatris squarrosa Willd.

Scaly blazingstar; colic-root; rattlesnake-master (in the South).

Native, perennial herb, 2 to 3 feet high, in dry soil, Ontario to Florida, west to Nebraska and Texas.

Part used.—Root (nonofficial).

Lactuca canadensis L. **Chicory family (Cichoriaceae).**

Synonym.—Lactuca elongata Muhl.

Wild lettuce; tall lettuce; wild opium; trumpet-milkweed.

Annual or biennial plant, 3 to 10 feet in height, native in moist, open places, British America south to Georgia and Louisiana.

Part used.—Herb (nonofficial).

Lactuca elongata Muhl. Same as *Lactuca canadensis.*

Ladies-slipper, large yellow. See *Cypripedium hirsutum.*

Ladies-slipper, small yellow. See *Cypripedium parviflorum.*

Lady-fern. See *Athyrium filix-foemina.*

Lady's-glove. See *Digitalis purpurea.*

Lambkill. See *Kalmia angustifolia.*

Lappa. See *Arctium lappa.*

Lappa major Gaertn. Same as *Arctium lappa.*

Larch, American. See *Larix laricina.*

Larch, black. See *Larix laricina.*

Larix americana Michx. Same as *Larix laricina.*

Larix laricina (Du Roi) Koch. **Pine family (Pinaceae).**

Synonym.—Larix americana Michx.

Tamarack; American larch; hackmatack; black larch.

A tall, slender tree, native in swampy woods and moist places from Canada south to New Jersey, Indiana, and Minnesota.

Part used.—Bark (nonofficial).

Lark-heel. See *Delphinium consolida.*

Larkspur, field-. See *Delphinium consolida.*

Larkspur, tall. See under *Delphinium consolida.*

Laurel, broad-leaved. See *Kalmia latifolia.*

Laurel, deer-. See *Rhododendron maximum.*

Laurel, great. See *Rhododendron maximum.*

Laurel, mountain-. See *Kalmia latifolia.*

Laurel, narrow-leaved. See *Kalmia angustifolia.*

Laurel, rose-. See *Rhododendron maximum.*

Laurel, sheep-. See *Kalmia angustifolia* and *K. latifolia.*

Laurel, spurge-. See *Daphne mezereum.*

Laurel, swamp-. See *Magnolia virginiana.*

Laurus benzoin L. Same as *Benzoin benzoin.*

Lavender, sea-. See *Limonium carolinianum.*

Leafcup, yellow. See *Polymnia uvedalia.*

Leatherwood. See *Dirca palustris.*

Ledum groenlandicum Oeder. **Heath family (Ericaceae).**

Synonym.—Ledum latifolium Ait.

Labrador tea; continental tea; James-tea.

Evergreen shrub, 1 to 4 feet high, native in cold bogs and damp mountain woods, northern part of the United States and in Canada.

Part used.—Leaves (nonofficial).

Ledum latifolium Ait. Same as *Ledum groenlandicum.*

Lemon, wild. See *Podophyllum peltatum.*

Lemon-balm. See *Melissa officinalis.*

Leonurus cardiaca L. **Mint family (Menthaceae).**

Motherwort; lion's-tail; throwwort.

Perennial plant, 2 to 5 feet high, naturalized from Europe, and occurring in fields and waste places from Nova Scotia to North Carolina westward to Nebraska.

Part used.—Herb (nonofficial).

Leptamnium virginianum (L.) Raf. **Broomrape family (Orobanchaceae).**

Synonyms.—Epiphegus virginiana Bart.; *Orobanche virginiana* L.

Beechdrops; cancerroot.

Plant 6 inches to 2 feet in height, parasitic upon the roots of beech trees from New Brunswick to Florida, west to Michigan and Louisiana.

Part used.—Whole plant (nonofficial).

Leptandra. See *Veronica virginica.*

Leptandra virginica (L.) Nutt. Same as *Veronica virginica.*

Leptilon canadense (L.) Britton. Same as *Erigeron canadensis.*

Lettuce, Indian. See *Frasera carolinensis.*

Lettuce, tall. See *Lactuca canadensis.*

Lettuce, white. See *Nabalus albus* and *N. serpentarius.*

Lettuce, wild. See *Lactuca canadensis.*

Leucanthemum vulgare Lam. Same as *Chrysanthemum leucanthemum.*

Leverwood. See *Ostrya virginiana.*

Liatris odoratissima Michx. Same as *Trilisa odoratissima.*

Liatris scariosa Willd. Same as *Lacinaria scariosa.*

Liatris spicata Willd. Same as *Lacinaria spicata.*

Liatris squarrosa Willd. Same as *Lacinaria squarrosa.*

Life-everlasting. See *Anaphalis margaritacea* and *Gnaphalium obtusifolium.*

Life-everlasting, sweet. See *Gnaphalium obtusifolium.*

Liferoot. See *Senecio aureus.*

Ligustrum vulgare L. **Olive family (Oleaceae).**

Privet; primwort; prim.

A shrub, 5 or 6 feet high, introduced from Europe; escaped from cultivation and grows wild in woods and along roadsides from Ontario to Pennsylvania and North Carolina.

Part used.—Leaves (nonofficial).

Lily, cow-. See *Nymphaea adrena.*

Lily, flag-. See *Iris versicolor.*

Lily, large yellow pond-. See *Nymphaea advena.*

Lily, liver-. See *Iris versicolor.*

Lily, snake-. See *Iris versicolor.*

Lily, sweet-scented water-. See *Castalia odorata.*

Lily, water-. See *Castalia odorata.*

Lily, white pond-. See *Castalia odorata.*

Lily-of-the-valley. See *Convallaria majalis.*

Lime, Ogeechee. See *Nyssa ogeche.*

Limonium carolinianum (Walt.) Britton.
Plumbago family (Plumbaginaceae).

Synonym.—*Statice caroliniana* Walt.

Marsh-rosemary; inkroot; sea-lavender; cankerroot.

Native, perennial herb, 1 to 2 feet high, in salt meadows on the Atlantic and Gulf coasts.

Part used.—Root (nonofficial).

Linden, American. See *Tilia americana.*

Lindera benzoin Meissn. Same as *Benzoin benzoin.*

Lion's-foot. See *Nabalus albus* and *N. serpentarius.*

Lion's-tail. See *Leonurus cardiaca.*

Liquidambar styraciflua L. **Witch-hazel family (Hamamelidaceae).**

Sweet-gum; star-leaved gum; red gum.

Large, native tree, 80 to 140 feet high, in moist woods from Connecticut to Florida, Illinois, and Missouri. Most common near the coast in the Middle and Southern States.

Parts used.—Bark and resin (nonofficial).

Liriodendron tulipifera L. **Magnolia family (Magnoliaceae).**

Tulip-tree; yellow poplar; whitewood; tulip-poplar; canoewood.

An indigenous tree, 60 to 190 feet in height, growing in rich woods from New England to Florida, west to Michigan and Arkansas; reaches greatest size in the Middle and Southern States.

Part used.—Bark of trunk and of root (nonofficial).

Lithospermum virginianum L. Same as *Onosmodium virginianum.*

Liverleaf, heart-. See *Hepatica acuta.*

Liverleaf, kidney-. See *Hepatica hepatica.*

Liverleaf, round-lobed. See *Hepatica hepatica.*

Liverleaf, sharp-lobed. See *Hepatica acuta.*

Liver-lily. See *Iris versicolor.*

Liverwort. See *Hepatica acuta* and *H. hepatica.*

Lobelia. See *Lobelia inflata.*

Lobelia, blue. See *Lobelia siphilitica.*

Lobelia cardinalis L. Bellflower family (Campanulaceae).

Cardinal-flower; red cardinal; red lobelia.

Native, perennial herb, 2 to 4 feet high, with showy scarlet flowers; in moist soil from British America south to Florida and Texas.

Part used.—Herb (nonofficial).

Lobelia, great. See *Lobelia siphilitica.*

Lobelia inflata L. Bellflower family (Campanulaceae).

Lobelia; Indian tobacco; gagroot; vomitwort; bladderpod.

Native, annual, herbaceous plant, 1 to 3 feet high, poisonous; in dry soil, fields, old pastures, and along roadsides from Canada to Georgia, Nebraska, and Arkansas.

Parts used.—Leaves and tops, collected after a portion of the capsules have become inflated (official). The seeds are also used (nonofficial).

Lobelia, red. See *Lobelia cardinalis.*

Lobelia siphilitica L. Bellflower family (Campanulaceae).

Blue cardinal-flower; great lobelia; blue lobelia; highbelia.

Native, perennial herb, about 1 to 3 feet high, growing in moist soil from Ontario to Georgia, west to Louisiana and the Dakotas.

Part used.—Herb (nonofficial).

Locust, black. See *Robinia pseudacacia.*

Locust, yellow. See *Robinia pseudacacia.*

Locust-plant. See *Cassia marilandica.*

Locust-tree. See *Robinia pseudacacia.*

Lycopodium. See *Lycopodium clavatum.*

Lycopodium clavatum L. Club-moss family (Lycopodiaceae).

Lycopodium; club-moss; stag's-horn.

Native perennial, with trailing stem, growing in dry situations in woods from Canada to North Carolina, Michigan, and Washington.

Part used.—Spores of this or of other species of Lycopodium (official).

Lycopus virginicus L. Mint family (Menthaceae).

Bugleweed; sweet bugle; water-bugle; gypsy-weed; water-hoarhound.

Indigenous, perennial herb, 10 to 20 inches in height; in wet, shady places from Canada to Florida, Missouri, and Nebraska.

Part used.—Herb (nonofficial).

Madweed. See *Scutellaria lateriflora.*

Magnolia acuminata L. Magnolia family (Magnoliaceae).

Cucumber-tree; mountain-magnolia; blue magnolia.

Native tree, 60 to 80 feet in height, occurring in the mountainous regions from New York to Georgia. More abundant in the Southern States.

Part used.—Bark (nonofficial).

Magnolia, blue. See *Magnolia acuminata.*

Magnolia glauca L. Same as *Magnolia virginiana.*

Magnolia, mountain-. See *Magnolia acuminata.*

Magnolia, sweet. See *Magnolia virginiana.*

Magnolia tripetala L. **Magnolia family (Magnoliaceae).**

Synonym.—Magnolia umbrella Lam.

Cucumber-tree; umbrella-tree; elkwood.

A small native tree, not more than 40 feet high, growing in rather moist, rich soil; widely distributed in the Appalachian Mountain region, but nowhere very common.

Part used.—Bark (nonofficial).

Magnolia umbrella Lam. Same as *Magnolia tripetala.*

Magnolia virginiana L. **Magnolia family (Magnoliaceae).**

Synonym.—Magnolia glauca L.

White bay; sweet bay; sweet magnolia; beaver-tree; swamp-sassafras; swamp-laurel.

A native tree, averaging about 25 feet in height, growing in swamps and morasses, Massachusetts to the Gulf of Mexico.

Part used.—Bark (nonofficial).

Maidenhair-fern. See *Adiantum pedatum.*

Male-fern. See *Dryopteris filix-mas.*

Mallow, common. See *Malva sylvestris.*

Mallow, dwarf. See *Malva rotundifolia.*

Mallow, high. See *Malva sylvestris.*

Mallow, low. See *Malva rotundifolia.*

Mallow, running. See *Malva rotundifolia.*

Malva rotundifolia L. **Mallow family (Malvaceae).**

Low mallow; running mallow; cheeses; dwarf mallow.

Annual or biennial procumbent plant, naturalized from Europe, and widely distributed as a weed in waste places.

Parts used.—Leaves and flowers (nonofficial).

Malva sylvestris L. **Mallow family (Malvaceae).**

High mallow; common mallow; cheeseflower.

Biennial herb, adventive from Europe; sparingly distributed in the United States and Canada, growing in waste places and along roadsides.

Part used.—Flowers (nonofficial).

Mandrake, American. See *Podophyllum peltatum.*

Mandrake, wild. See *Podophyllum peltatum.*

Man-of-the-earth. See *Ipomoea pandurata.*

Manroot. See *Ipomoea pandurata.*

Manzanita. See *Arctostaphylos glauca.*

Maple, red. See *Acer rubrum.*

Maple, swamp-. See *Acer rubrum.*

Maple, vine-. See *Menispermum canadense.*

Marrubium. See *Marrubium vulgare.*

Marrubium vulgare L. **Mint family (Menthaceae).**

Marrubium; hoarhound.

Bushy, perennial herb, 1 to 3 feet high, naturalized from Europe, and growing in dry, sandy soil, in fields and waste places, from Maine southward to Texas and westward to California and Oregon.

Parts used.—Leaves and flowering tops (official).

Marsh-cudweed. See *Gnaphalium uliginosum.*

Marsh-gentian. See *Gentiana villosa.*

Marshmallow. See *Althaea officinalis.*

Marsh-rosemary. See *Limonium carolinianum.*

Marsh-trefoil. See *Menyanthes trifoliata.*

Maruta cotula DC. Same as *Anthemis cotula.*

Masterwort. See *Angelica atropurpurea* and *Heracleum lanatum.*

May-apple. See *Podophyllum peltatum.*

Mayflower. See *Epigaea repens.*

May-pops. See *Passiflora incarnata.*

Maythorn. See *Crataegus oxyacantha.*

Mayweed. See *Anthemis cotula.*

Meadow-clover. See *Trifolium pratense.*

Meadow-fern. See *Comptonia peregrina.*

Meadowpride. See *Frasera carolinensis.*

Meadow-scabish. See *Aster puniceus.*

Meadowsweet, pink. See *Spiraea tomentosa.*

Mealy-tree. See *Viburnum dentatum.*

Melilot, yellow. See *Melilotus officinalis.*

Melilotus officinalis (L.) Lam. **Pea family (Fabaceae).**

Yellow melilot; yellow sweet clover.

Annual or biennial herb, 1 to 3 feet high, introduced from Europe, and occurring in waste places throughout the eastern United States.

Parts used.—Leaves and flowering tops (nonofficial).

Melissa. See *Melissa officinalis.*

Melissa officinalis L. **Mint family (Menthaceae).**

Melissa; balm; lemon-balm; garden-balm; sweet balm.

Perennial herb, 10 to 20 inches high, naturalized from Europe, and growing in waste places, fields, and woods from Maine to Georgia.

Parts used.—Leaves and tops (official in U. S. P. 1890).

Menispermum. See *Menispermum canadense.*

Menispermum canadense L. **Moonseed family (Menispermaceae).**

Menispermum; yellow parilla; Canada moonseed; Texas sarsaparilla; vine-maple.

Native, perennial, woody climber, found in woods along streams from Canada to Georgia and Arkansas.

Parts used.—Rhizome and roots (official in U. S. P. 1890).

Mentha piperita. See *Mentha piperita* L.

Mentha piperita L. **Mint family (Menthaceae).**

Mentha piperita; peppermint.

Aromatic, perennial herb, 1 to 2 feet high, naturalized from Europe, and occurring in damp places from Nova Scotia to Minnesota, south to Florida and Tennessee. Cultivated principally in Michigan and New York.

Parts used.—Leaves and flowering tops, and the oil of peppermint distilled from these, are official.

Mentha spicata L. **Mint family (Menthaceae).**

Synonym.—*Mentha viridis* L.

Mentha viridis; spearmint.

Aromatic, perennial herb, 1 to 2 feet high, naturalized from Europe, and growing in moist fields and waste places from Nova Scotia to Utah, south to Florida and Kansas. Also cultivated.

Parts used.—Leaves and flowering tops, and the oil of spearmint distilled from these, are official.

Mentha viridis. See *Mentha spicata.*

Mentha viridis L. Same as *Mentha spicata.*

Menyanthes trifoliata L. **Buck-bean family** (**Menyanthaceae**).

Buck-bean; bog-bean; marsh-trefoil; water-shamrock.

Indigenous, perennial plant, about 1 foot in height, found in spongy, boggy soils and swamps from Canada and Alaska south to Pennsylvania, Minnesota, and California.

Parts used.—Rhizome and leaves (nonofficial).

Mezereon. See *Daphne mezereum.*

Mezereon, American. See *Dirca palustris.*

Mezereum. See *Daphne mezereum.*

Mezereum officinarum C. A. Mey. Same as *Daphne mezereum.*

Micromeria chamissonis (Benth.) Greene. **Mint family** (**Menthaceae**).

Synonym.—*Micromeria douglasii* Benth.

Yerba buena.

A trailing, perennial herb, common in woods along the Pacific coast of the United States.

Part used.—Plant (nonofficial).

Micromeria douglasii Benth. Same as *Micromeria chamissonis.*

Milfoil. See *Achillea millefolium.*

Milk-ipecac. See *Euphorbia corollata.*

Milk-purslane. See *Euphorbia nutans.*

Milkweed, common. See *Asclepias syriaca.*

Milkweed, swamp-. See *Asclepias incarnata.*

Milkweed, trumpet-. See *Lactuca canadensis.*

Milkwort, Nuttall's-. See *Polygala nuttallii.*

Mint, hairy mountain-. See *Koellia pilosa.*

Mint, mountain-. See *Monarda didyma.*

Mint, thin-leaved mountain-. See *Koellia montana.*

Mistletoe. See *Phoradendron flavescens.*

Mistletoe, American. See *Phoradendron flavescens.*

Mitchella repens L. **Madder family** (**Rubiaceae**).

Squaw-vine; checkerberry; partridgeberry; deerberry; hive-vine; squawberry.

Small, creeping, evergreen herb, common in moist woods from Nova Scotia to Minnesota, south to Florida and Arkansas.

Part used.—Plant (nonofficial).

Miterwort, false. See *Tiarella cordifolia.*

Moccasin-flower, yellow. See *Cypripedium hirsutum.*

Mohawk-weed. See *Uvularia perfoliata.*

Monarda didyma L. **Mint family** (**Menthaceae**).

Bee-balm; Oswego tea; mountain-mint; scarlet balm.

Native perennial, 2 to 3 feet high, growing in moist soil, especially along streams, from New Brunswick to Michigan and south to Georgia.

Part used.—Herb (nonofficial).

Monarda fistulosa L. **Mint family** (**Menthaceae**).

Wild bergamot; horsemint.

Native perennial, 2 to 3 feet high, found on dry hills and in thickets from Ontario south to Florida and Louisiana.

Part used.—Herb (nonofficial).

Monarda punctata L. **Mint family (Menthaceae).**

Horsemint.

Native, perennial herb, 2 to 3 feet high, found in dry, sandy fields from New York to Florida, west to Wisconsin and Texas.

Part used.—Herb (nonofficial).

Monotropa uniflora L. **Indian-pipe family (Monotropaceae).**

Indian-pipe; fit-plant; fitroot; ghostflower; pipe-plant.

A curious plant, white in all its parts, growing in rich, moist woods from Canada to Florida, westward to Washington and California.

Part used.—Root (nonofficial).

Moonseed, Canada. See *Menispermum canadense.*

Moose-elm. See *Ulmus fulva.*

Moosewood. See *Dirca palustris.*

Mortification-root. See *Althaea officinalis.*

Moss, club-. See *Lycopodium clavatum.*

Moss, haircap-. See *Polytrichum juniperinum.*

Motherwort. See *Leonurus cardiaca.*

Mountain-ash, American. See *Sorbus americana.*

Mountain-balm. See *Eriodictyon californicum.*

Mountain-laurel. See *Kalmia latifolia.*

Mountain-magnolia. See *Magnolia acuminata.*

Mountain-mint. See *Monarda didyma.*

Mountain-mint, hairy. See *Koellia pilosa.*

Mountain-mint, thin-leaved. See *Koellia montana.*

Mountain-sumac. See *Sorbus americana.*

Mountain-tea. See *Gaultheria procumbens.*

Mouse-ear. See *Gnaphalium uliginosum.*

Mouthroot. See *Coptis trifolia.*

Mugwort, common. See *Artemisia vulgaris.*

Mullein. See *Verbascum thapsus.*

Musquash-root. See *Cicuta maculata.*

Mustard, black. See *Brassica nigra.*

Mustard, brown. See *Brassica nigra.*

Mustard, red. See *Brassica nigra.*

Mustard, white. See *Sinapis alba.*

Mustard, yellow. See *Sinapis alba.*

Myrica asplenifolia L. Same as *Comptonia peregrina.*

Myrica cerifera L. **Bayberry family (Myricaceae).**

Bayberry; wax-myrtle; candleberry; waxberry.

Grows in sandy swamps or wet woods from Florida and Texas northward to Maryland. In the South it is a small evergreen tree, becoming in its northward range a tall, semi-deciduous shrub, or a dwarfed and deciduous shrub.

Parts used.—Bark of root, leaves, and berries (nonofficial).

Myrica gale L. **Bayberry family (Myricaceae).**

Sweet gale; Dutch myrtle; bog-myrtle; golden osier.

Indigenous shrub, growing in swamps and along streams from Canada and Alaska to Virginia and Washington.

Parts used.—Leaves and buds (nonofficial).

Myrtle, bog-. See *Myrica gale.*

Myrtle, Dutch. See *Myrica gale.*

Myrtle, wax-. See *Myrica cerifera.*

Nabalus albus (L.) Hook. **Chicory family (Cichoriaceae).**

Synonym.—Prenanthes alba L.

Lion's-foot; rattlesnake-root; white lettuce; white canker-weed.

Native, perennial herb, 2 to 4 feet high, common in rich, moist woods from Canada to Georgia and Kentucky.

Part used.—Plant (nonofficial).

Nabalus serpentarius (Pursh) Hook. **Chicory family (Cichoriaceae).**

Synonym.—Prenanthes serpentaria Pursh.

Lion's-foot; canker-weed; white lettuce; rattlesnake-root; snake-gentian.

Native, perennial herb, about 2 feet high, growing in dry, sandy soil in fields and thickets from Ontario to Florida and Alabama.

Part used.—Plant (nonofficial).

Nannybush. See *Viburnum lentago.*

Necklace-weed. See *Actaea alba* and *Onosmodium virginianum.*

Nepeta cataria L. **Mint family (Menthaceae).**

Catnip; catmint.

Common, perennial weed, 2 to 3 feet high, naturalized from Europe; found in waste places and cultivated land from Canada to Minnesota, south to Virginia and Arkansas.

Part used.—Herb (nonofficial).

Nepeta glechoma Benth. Same as *Glecoma hederacea.*

Netleaf-plantain. See *Peramium pubescens.*

Netleaf-plantain, smaller. See *Peramium repens.*

Nettle, bull-. See *Solanum carolinense.*

Nettle, great. See *Urtica dioica.*

Nettle, horse-. See *Solanum carolinense.*

Nettle, stinging. See *Urtica dioica.*

Niggerhead. See *Brauneria angustifolia.*

Nightshade, woody. See *Solanum dulcamara.*

Nuphar adrena R. Br. Same as *Nymphaea adrena.*

Nuttall's-milkwort. See *Polygala nuttallii.*

Nymphaea advena Soland. **Water-lily family (Nymphaeaceae).**

Synonym.—Nuphar advena R. Br.

Large yellow pond-lily; cow-lily; spatter-dock; beaverroot.

An aquatic plant, found in ponds and slow streams from Canada to Florida, and westward to the Rocky Mountains.

Part used.—Rhizome (nonofficial).

Nymphaea odorata Dryand. Same as *Castalia odorata.*

Nyssa aquatica L. **Dogwood family (Cornaceae).**

Synonym.—Nyssa uniflora Wang.

Large tupelo; cotton-gum; tupelo gum.

A large, native tree, occurring in swamps from southern Virginia to Florida, west to Texas and Missouri.

Part used.—Root wood (nonofficial).

Nyssa capitata Walt. Same as *Nyssa ogeche.*

Nyssa ogeche Marsh. **Dogwood family (Cornaceae).**

Synonym.—Nyssa capitata Walt.

Sour tupelo; Ogeechee lime.

A small tree, growing in swamps near the seacoast from southern South Carolina to Florida.

Part used.—Root wood (nonofficial).

Nyssa uniflora Wang. Same as *Nyssa aquatica.*

Oak, champion-. See *Quercus rubra.*

Oak, Jerusalem. See *Chenopodium anthelminticum* and *C. botrys.*

Oak, poison-. See *Rhus radicans* and *R. toxicodendron.*

Oak, red. See *Quercus rubra.*

Oak, Spanish. See *Quercus rubra.*

Oak, stone-. See *Quercus alba.*

Oak, white. See *Quercus alba.*

Oenothera biennis L. **Evening-primrose family (Onagraceae).**

Synonym.—Onagra biennis (L.) Scop.

Evening-primrose; tree-primrose; night willow-herb.

Annual or biennial plant, 2 to 5 feet high, common in fields and waste places from Labrador to Florida, west to the Rocky Mountains. Native.

Part used.—Plant (nonofficial).

Old-man's-beard. See *Chionanthus virginica.*

Olive, spurge-. See *Daphne mezereum.*

Onagra biennis (L.) Scop. Same as *Oenothera biennis.*

Onosmodium virginianum (L.) DC. **Borage family (Boraginaceae).**

Synonym.—Lithospermum virginianum L.

Virginia false gromwell; gravel-weed; necklace-weed; pearl-plant; wild Job's-tears.

Rough-hairy, native, perennial herb, 1 to 2 feet high; in dry, hilly grounds from the New England States to Florida, Kansas, and Texas.

Parts used.—Root and seeds (nonofficial).

Opium, wild. See *Lactuca canadensis.*

Orangeroot. See *Hydrastis canadensis.*

Orobanche virginiana L. Same as *Leptamnium virginianum.*

Osier, golden. See *Myrica gale.*

Osier, green. See *Cornus circinata.*

Osier, red. See *Cornus amomum.*

Osmorrhiza longistylis DC. Same as *Washingtonia longistylis.*

Osmunda regalis L. **Royal fern family (Osmundaceae).**

Royal fern; buckhorn-brake.

A tall, native fern, with fronds 3 to 4 feet high, occurring in swamps and marshes from Canada to Florida and Mississippi.

Part used.—Rhizome (nonofficial).

Ostrya virginiana (Mill.) Willd. **Birch family (Betulaceae).**

Hop-hornbeam; ironwood; deerwood; leverwood.

Native tree, 25 to 30 feet in height, growing in rich woods, Canada and eastern United States.

Part used.—Bark (nonofficial).

Oxalis acetosella L. **Wood-sorrel family (Oxalidaceae).**

White wood-sorrel; shamrock; sour trefoil.

Small, native, perennial herb, found in cold, damp woods, Canada south to Michigan and North Carolina.

Part used.—Herb (nonofficial).

Oxeye daisy. See *Chrysanthemum leucanthemum.*

Oxydendrum arboreum (L.) DC. **Heath family (Ericaceae).**

Synonym.—Andromeda arborea L.

Sourwood; sorrel-tree; elk-tree.

Native tree, sometimes 40 to 50 feet in height, growing in rich woods from Ohio to Maryland, south to Alabama and Florida.

Parts used.—Leaves and bark (nonofficial)

Palmetto, saw-. See *Serenoa serrulata.*

Panax quinquefolium L. **Ginseng family (Araliaceae).**

Ginseng.

Native, perennial herb, about 1 foot in height, found in rich, shady woods from the Middle and Northern States south to Alabama and Georgia.

Part used.—Root (nonofficial).

Pansy. See *Viola tricolor.*

Papoose-root. See *Caulophyllum thalictroides.*

Paradise-plant. See *Daphne mezereum.*

Parilla, yellow. See *Menispermum canadense.*

Parsley, spotted. See *Conium maculatum.*

Parsley-fern. See *Tanacetum vulgare.*

Parsnip, cow-. See *Heracleum lanatum.*

Parthenocissus quinquefolia (L.) Planch. **Grape family (Vitaceae).**

Synonym.—Ampelopsis quinquefolia Michx.

American ivy; Virginia creeper.

A common, woody vine, native in woods and thickets from Canada to Florida and Texas.

Parts used.—Bark and young twigs (nonofficial).

Partridgeberry. See *Mitchella repens.*

Pasqueflower, American. See *Pulsatilla hirsutissima.*

Passiflora incarnata L. **Passion-flower family (Passifloraceae).**

Passion-flower; passion-vine; may-pops.

Climbing, perennial plant, native in dry soil from Virginia to Florida, westward to Missouri and Arkansas.

Parts used.—Root and stem base (nonofficial).

Passion-flower. See *Passiflora incarnata.*

Passion-vine. See *Passiflora incarnata.*

Paul's-betony. See *Veronica officinalis.*

Pawpaw, North American. See *Asimina triloba.*

Pea, ground-squirrel. See *Jeffersonia diphylla.*

Pea, hoary. See *Cracca virginiana.*

Pea, turkey-. See *Bikukulla canadensis.*

Pearl-plant. See *Onosmodium virginianum.*

Pencil-flower. See *Stylosanthes biflora.*

Pennyroyal, American. See *Hedeoma pulegioides.*

Penthorum sedoides L. **Virginia stonecrop family (Penthoraceae).**

Virginia stonecrop; ditch-stonecrop.

Native, perennial herb, about 1 foot in height, growing in ditches and swamps from New Brunswick to Minnesota, south to Florida and Texas.

Part used.—Herb (nonofficial.)

Pepper, water-. See *Polygonum hydropiper.*

Peppermint. See *Mentha piperita.*

Pepper-plant. See *Polygonum hydropiper.*

Peramium pubescens (Willd.) MacM. **Orchid family (Orchidaceae).**

Synonym.—*Goodyera pubescens* R. Br.

Downy rattlesnake-plantain; rattlesnake-weed; netleaf-plantain; scrofula-weed.

Native, perennial herb, 8 to 12 inches in height, occurring in rich woods from Newfoundland to Minnesota, south to Florida and Tennessee. Most common southward.

Part used.—Plant (nonofficial).

Peramium repens (L.) Salisb. **Orchid family (Orchidaceae).**

Synonym.—*Goodyera repens* R. Br.

White plantain; lesser rattlesnake-plantain; smaller netleaf-plantain; squirrel-ear.

A smaller plant than *P. pubescens*, but very similar to it and more common northward.

Part used.—Plant (nonofficial).

Persimmon. See *Diospyros virginiana.*

Phoradendron flavescens (Pursh) Nutt. **Mistletoe family (Loranthaceae).**

Synonym.—*Viscum flavescens* Pursh.

Mistletoe; American mistletoe.

Parasitic shrub, found on deciduous-leaved trees from New Jersey to Missouri, south to Florida and Texas.

Parts used.—Leaves and branches (nonofficial).

Phytolacca. See *Phytolacca decandra.*

Phytolacca americana L. Same as *Phytolacca decandra.*

Phytolacca decandra L.[a] **Pokeweed family (Phytolaccaceae).**

Synonym.—*Phytolacca americana* L.[a]

Phytolacca; poke; pokeweed; garget; scoke; inkberry.

Native, perennial herb, with large and branching stem, 6 to 10 feet high; in rich, moist soil, Maine to Minnesota, south to Florida and Texas.

Parts used.—Root collected in autumn (official); fruit (official in U. S. P. 1890); leaves (nonofficial).

Picea mariana (Mill.) B. S. P. **Pine family (Pinaceae).**

Synonym.—*Abies nigra* Desf.

Black spruce; spruce-gum tree.

Indigenous, evergreen tree, 40 to 80 feet in height, growing on elevated situations and in cold bogs from Canada south along the mountains to North Carolina, and to Minnesota.

Parts used.—Branches, and the essence obtained from the same (nonofficial).

Pilewort. See *Erechtites hieracifolia* and *Scrophularia marilandica.*

Pilotweed. See *Silphium laciniatum.*

Pimpernel. See *Pimpinella saxifraga.*

Pimpernel, red. See *Anagallis arvensis.*

Pimpernel, scarlet. See *Anagallis arvensis.*

[a] *Phytolacca americana* L. by right of priority should be accepted, but *P. decandra* L. is used in conformity with the Pharmacopœia.

Pimpinella saxifraga L. **Parsley family (Apiaceae).**

Burnet-saxifrage; bennet; pimpernel.

Erect, perennial herb, 1 to 2 feet high, adventive from Europe, and found in waste places in eastern Pennsylvania, at several localities in the valley of the Delaware, and in Ohio.

Part used.—Root (nonofficial).

Pine, northern. See *Pinus strobus.*

Pine, prairie-. See *Lacinaria spicata.*

Pine, prince's-. See *Chimaphila umbellata*

Pine, Weymouth. See *Pinus strobus.*

Pine, white. See *Pinus strobus.*

Pink, rose-. See *Sabbatia angularis.*

Pinkroot. See *Spigelia marilandica.*

Pinkroot, Indian. See *Spigelia marilandica.*

Pinkroot, Maryland. See *Spigelia marilandica.*

Pinus strobus L. **Pine family (Pinaceae).**

White pine; northern pine; Weymouth pine.

Large, indigenous forest tree, sometimes 175 feet in height, growing in woods from Canada south to Georgia and Iowa.

Part used.—Bark (nonofficial).

Pipe-plant. See *Monotropa uniflora.*

Pipsissewa. See *Chimaphila umbellata.*

Pitcher-plant. See *Sarracenia purpurea.*

Plantago major L. **Plantain family (Plantaginaceae).**

Common plantain; dooryard-plantain; greater plantain.

Perennial herb, 1 to 3 feet high, naturalized from Europe; common in fields and waste places and along roadsides nearly throughout North America.

Parts used.—Root and leaves (nonofficial).

Plantain, common. See *Plantago major.*

Plantain, dooryard-. See *Plantago major.*

Plantain, downy rattlesnake-. See *Peramium pubescens.*

Plantain, greater. See *Plantago major.*

Plantain, lesser rattlesnake-. See *Peramium repens.*

Plantain, netleaf-. See *Peramium pubescens.*

Plantain, smaller netleaf-. See *Peramium repens.*

Plantain, white. See *Peramium repens.*

Pleurisy-root. See *Asclepias tuberosa.*

Podophyllum. See *Podophyllum peltatum.*

Podophyllum peltatum L. **Barberry family (Berberidaceae).**

Podophyllum; May-apple; wild mandrake; American mandrake; wild lemon.

Native, perennial herb, 1 to $1\frac{1}{2}$ feet high, found in low, rich woods from Canada to Minnesota, south to Florida and Texas.

Part used.—Rhizome (official).

Poison-hemlock. See *Conium maculatum.*

Poison-ivy. See *Rhus radicans* and *R. toxicodendron.*

Poison-oak. See *Rhus radicans* and *R. toxicodendron.*

Poison-vine. See *Rhus radicans.*

Poke. See *Phytolacca decandra.*

Pokeweed. See *Phytolacca decandra.*

Polar-plant. See *Silphium laciniatum.*

Polecat-weed. See *Spathyema foetida.*

Polemonium reptans L. **Phlox family** (**Polemoniaceae**).

American Greek valerian; abscess-root; sweetroot; Jacob's-ladder.

Native, perennial herb, 12 to 20 inches high, growing in woods and damp ground from New York to Minnesota, south to Georgia and Missouri.

Part used.—Root (nonofficial).

Polygala nuttallii T. & G. **Milkwort family** (**Polygalaceae**).

Nuttall's-milkwort; ground-centaury.

Slender, erect, annual herb, 6 to 12 inches high, native in dry, sandy soil from Massachusetts to North Carolina, west to Alabama and Missouri.

Part used.—Herb (nonofficial).

Polygala senega L. **Milkwort family** (**Polygalaceae**).

Senega; Seneca snakeroot.

Native, perennial herb, 8 to 12 inches high, found in rocky woods and on hillsides from New Brunswick and western New England to Minnesota, south to North Carolina and Missouri.

Part used.—Root (official).

Polygonatum biflorum (Walt.) Ell. **Lily-of-the-valley family** (**Convallariaceae**).

Synonyms.—*Convallaria biflora* Walt.; *Salomonia biflora* (Walt.) Britton.

Hairy Solomon's-seal; smaller Solomon's-seal.

Native, perennial herb, 8 inches to 3 feet high, found in woods and thickets from Canada south to Florida and Michigan.

Part used.—Rhizome (nonofficial).

Polygonatum commutatum (Roem. & Schult.) Dietr. **Lily-of-the-valley family** (**Convallariaceae**).

Synonyms.—*Polygonatum giganteum* Dietr.; *Salomonia commutata* (Roem. & Schult.) Britton.

Giant Solomon's-seal; great Solomon's-seal; smooth Solomon's-seal.

Native, perennial herb, 1 to 8 feet high, occurring in moist woods and along streams from Canada to Georgia, west to Louisiana and Utah.

Part used.—Rhizome (nonofficial).

Polygonatum giganteum Dietr. Same as *Polygonatum commutatum*.

Polygonum hydropiper L. **Buckwheat family** (**Polygonaceae**).

Smartweed; water-pepper; biting knotweed; pepper-plant.

Smooth, annual plant, 8 inches to 2 feet high, naturalized from Europe; common in moist waste places almost throughout North America.

Part used.—Herb (nonofficial).

Polygonum punctatum Ell. **Buckwheat family** (**Polygonaceae**).

Dotted smartweed; water-smartweed.

Native, annual or perennial herb, found in swamps and other wet places throughout most of North America.

Part used.—Herb (nonofficial).

Polymnia uvedalia L. **Aster family** (**Asteraceae**).

Yellow bear's-foot; yellow leafcup; uvedalia.

Large, native, perennial plant, 3 to 6 feet high; in ravines and edges of woods from New York to Michigan, south to Florida and Texas.

Part used.—Root (nonofficial).

Polypodium filix-mas L. Same as *Dryopteris filix-mas.*

Polypodium marginale L. Same as *Dryopteris marginalis.*

Polypodium vulgare L. **Fern family (Polypodiaceae).**

Common polypody; fernroot; rock-brake; female-fern.

Native fern, 3 to 10 inches in height, with a perennial, creeping rhizome; on shady, rocky banks, in woods and mountains almost throughout North America.

Parts used.—Rhizome and tops (nonofficial).

Polypody, common. See *Polypodium vulgare.*

Polytrichum juniperinum Hedw. **Haircap-moss family (Polytrichaceae).**

Haircap-moss; robin's-rye.

Native moss, 4 to 7 inches in height, growing along margins of dry woods and exposed places, mostly on poor, sandy soil.

Part used.—Whole plant (nonofficial).

Pond-lily, large yellow. See *Nymphaea advena.*

Pond-lily, white. See *Castalia odorata.*

Poolroot. See *Eupatorium ageratoides, E. aromaticum,* and *Sanicula marilandica.*

Poolwort. See *Eupatorium ageratoides* and *E. aromaticum.*

Poplar, silver. See *Populus alba.*

Poplar, silverleaf-. See *Populus alba.*

Poplar, trembling. See *Populus tremuloides.*

Poplar, tulip-. See *Liriodendron tulipifera.*

Poplar, white. See *Populus alba* and *P. tremuloides.*

Poplar, yellow. See *Liriodendron tulipifera.*

Populus alba L. **Willow family (Salicaceae).**

White poplar; silverleaf-poplar; silver poplar; white-bark.

A large tree, sometimes 120 feet in height, naturalized in the United States; occurs along roadsides from New Brunswick to Virginia.

Part used.—Bark, collected in spring (nonofficial).

Populus balsamifera candicans A. Gray. Same as *Populus candicans.*

Populus candicans Ait. **Willow family (Salicaceae).**

Synonym.—*Populus balsamifera candicans* A. Gray.

Balm-of-Gilead.

A large tree, about 80 feet in height, mostly escaped from cultivation, New Brunswick to New Jersey, west to Minnesota.

Parts used.—Leafbuds and bark (nonofficial).

Populus tremuloides Michx. **Willow family (Salicaceae).**

Quaking aspen; American aspen; white poplar; trembling poplar; quiverleaf.

A slender, indigenous tree, growing in dry or moist soil from lower Canada south to Kentucky and in the Rocky Mountains to Lower California.

Part used.—Bark, collected in spring (nonofficial).

Porteranthus trifoliatus (L.) Britton. **Rose family (Rosaceae).**

Synonym.—*Gillenia trifoliata* Moench.

Indian-physic; Bowman's-root; false ipecac; western dropwort.

Native, perennial herb, 2 to 3 feet high, found in moist, shady places in rich woods from New York to Michigan, south to Georgia and Missouri; more common in the Atlantic States than in the Western States.

Part used.—Root (nonofficial).

Potato, hog-. See *Ipomoea pandurata.*

Potato, wild. See *Ipomoea pandurata.*

Potentilla canadensis L. **Rose family (Rosaceae).**

Fivefinger; cinquefoil.

A small, annual or biennial plant, with creeping stems, growing in dry soil from Quebec to Georgia, west to Minnesota and the Indian Territory.

Part used.—Plant (nonofficial).

Prairie-pine. See *Lacinaria spicata.*

Prenanthes alba L. Same as *Nabalus albus.*

Prenanthes serpentaria Pursh. Same as *Nabalus serpentarius.*

Prickly ash, northern. See *Xanthoxylum americanum.*

Prickly ash, southern. See *Fagara clava-herculis.*

Prideweed. See *Erigeron canadensis.*

Prim. See *Ligustrum vulgare.*

Primrose, evening-. See *Oenothera biennis.*

Primrose, tree-. See *Oenothera biennis.*

Primwort. See *Ligustrum vulgare.*

Prince's-pine. See *Chimaphila umbellata.*

Prinos verticillatus L. Same as *Ilex verticillata.*

Privet. See *Ligustrum vulgare.*

Prunella vulgaris L. **Mint family (Menthaceae).**

Self-heal; heal-all; brownwort; sicklewort; blue-curls.

Perennial plant, 2 inches to 2 feet high, naturalized from Europe, and found in fields, woods, and waste places throughout nearly the whole of North America.

Part used.—Herb (nonofficial).

Prunus serotina Ehrh. **Plum family (Amygdalaceae).**

Synonym.—Prunus virginiana Mill., not of Linnaeus.

Prunus virginiana; wild cherry; rum-cherry.

A large, indigenous tree, 50 to 80 feet high, growing in woods or open places from Ontario to Florida, west to Texas and Dakota. Most abundant in the Southwestern States.

Part used.—Bark, which should be collected in autumn and carefully dried and preserved (official).

Prunus virginiana. See *Prunus serotina.*

Prunus virginiana Mill., not L. Same as *Prunus serotina.*

Psoralea. See *Psoralea pedunculata.*

Psoralea melilotoides Michx. Same as *Psoralea pedunculata.*

Psoralea pedunculata (Mill.) Vail. **Pea family (Fabaceae).**

Synonym.—Psoralea melilotoides Michx.

Psoralea; Samson's-snakeroot; Congo-root.

Slender, herbaceous perennial, 1 to 2½ feet high, native in dry soil in open woods from Ohio and Kentucky southward.

Parts used.—Root and leaves (nonofficial).

Ptelea trifoliata L. **Rue family (Rutaceae).**

Wafer-ash; wingseed; hop-tree; shrubby trefoil.

Native shrub, 6 to 8 feet high; in shady woods from New York to Florida, west to Minnesota and Texas; grows more abundantly west of the Alleghenies.

Parts used.—Bark of root, fruit, and leaves (nonofficial).

Pterocaulon undulatum (Walt.) Mohr. **Aster family (Asteraceae).**

Synonym.—Gnaphalium undulatum Walt.

Indian blackroot.

Native, perennial herb, growing in sandy pine lands from North Carolina to Florida and Mississippi.

Part used.—Root (nonofficial).

Puccoon, red. See *Sanguinaria canadensis.*

Puccoon, yellow. See *Hydrastis canadensis.*

Pulsatilla, American. See *Pulsatilla hirsutissima.*

Pulsatilla hirsutissima (Pursh) Britton. **Crowfoot family** (**Ranunculaceae**).

Synonym.—*Anemone patens* var. *nuttalliana* A. Gray.

American pasqueflower; American pulsatilla.

Native, perennial herb, 6 to 16 inches high, found in the prairie regions of Illinois, west to the Rocky Mountains and the Northwest.

Part used.—Flowering herb (nonofficial).

Purging-root. See *Euphorbia corollata.*

Purslane, black. See *Euphorbia nutans.*

Purslane, milk-. See *Euphorbia nutans.*

Pussy-willow. See *Salix nigra.*

Putty-root. See *Aplectrum spicatum.*

Pycnanthemum montanum Michx. Same as *Koellia montana.*

Pycnanthemum pilosum Nutt. Same as *Koellia pilosa.*

Pyramid-flower. See *Frasera carolinensis.*

Pyrethrum parthenium Smith. Same as *Chrysanthemum parthenium.*

Pyrus americana DC. Same as *Sorbus americana.*

Quack-grass. See *Agropyron repens.*

Queen-Anne's-lace. See *Daucus carota.*

Queen-of-the-meadow. See *Eupatorium purpureum.*

Queen's-delight. See *Stillingia sylvatica.*

Queensland asthma-weed. See *Euphorbia pilulifera.*

Queen's-root. See *Stillingia sylvatica.*

Quercus. See *Quercus alba.*

Quercus alba L. **Beech family** (**Fagaceae**).

Quercus; white oak; stone-oak.

Large, indigenous forest tree, 50 to 100 feet in height, in woods from Maine to Minnesota, south to Florida and Texas. More abundant in the Middle States.

Part used.—Bark, "collected from trunks or branches 10 to 25 years of age, and deprived of the periderm" (official).

Quercus rubra L. **Beech family** (**Fagaceae**).

Red oak; champion-oak; Spanish oak.

Large, wide-spreading, indigenous forest tree, about 70 feet in height, from Nova Scotia to Minnesota, south to Florida and Texas. More common in the Northern States and in Canada.

Part used.—Bark (nonofficial).

Quinine-flower. See *Sabbatia elliottii.*

Quinine-herb. See *Sabbatia elliottii.*

Quinine-plant. See *Sabbatia elliottii.*

Quiverleaf. See *Populus tremuloides.*

Ragged-cup. See *Silphium perfoliatum.*

Ragweed. See *Ambrosia artemisiaefolia.*

Ragwort, golden. See *Senecio aureus.*

Raspberry, black. See *Rubus occidentalis.*

Raspberry, ground-. See *Hydrastis canadensis.*

Raspberry, wild red. See *Rubus strigosus.*

Rattle-root. See *Cimicifuga racemosa.*

Rattlesnake-herb. See *Actaea alba* and *A. rubra.*

Rattlesnake-master. See *Eryngium yuccifolium*, *Lacinaria scariosa*, *L. spicata*, and *L. squarrosa*.

Rattlesnake-plantain, downy. See *Peramium pubescens*.

Rattlesnake-plantain, lesser. See *Peramium repens*.

Rattlesnake-root. See *Nabalus albus* and *N. serpentarius*.

Rattlesnake-violet. See *Erythronium americanum*.

Rattlesnake-weed. See *Eryngium yuccifolium*, *Hieracium venosum*, and *Peramium pubescens*.

Redbud. See *Cercis canadensis*.

Redroot. See *Ceanothus americanus*.

Rhamnus cathartica L. **Buckthorn family (Rhamnaceae).**

Buckthorn; hart's-thorn; waythorn.

A shrub 6 to 15 feet high, introduced from Europe; escaped from hedges and growing in dry soil in the New England and Middle States.

Part used.—Berries (nonofficial).

Rhamnus purshiana. See *Rhamnus purshiana* DC.

Rhamnus purshiana DC. **Buckthorn family (Rhamnaceae).**

Rhamnus purshiana; cascara sagrada; chittem-bark; sacred-bark; bearberry-tree.

Small, indigenous tree, 15 to 20 feet in height, found on the sides and bottoms of canyons, Rocky Mountains west to the Pacific Ocean, and extending north into British America.

Part used.—Bark, collected at least one year before being used (official).

Rheumatism-root. See *Dioscorea villosa* and *Jeffersonia diphylla*.

Rheumatism-weed. See *Chimaphila umbellata*.

Rhododendron maximum L. **Heath family (Ericaceae).**

Great laurel; rose-bay; deer-laurel; rose-laurel.

Tall, native, evergreen shrub or small tree, found in low woods and along streams from Canada to Georgia.

Part used.—Leaves (nonofficial).

Rhus aromatica Ait. **Sumac family (Anacardiaceae).**

Fragrant sumac; sweet-scented sumac.

Indigenous shrub, 2 to 6 feet high, growing in woods and rocky situations, Canada to Florida, especially along the mountains, west to Minnesota and Arkansas.

Part used.—Bark of root (nonofficial).

Rhus glabra. See *Rhus glabra* L.

Rhus glabra L. **Sumac family (Anacardiaceae).**

Rhus glabra; smooth sumac; scarlet sumac.

Indigenous, branching shrub, from 4 to 12 feet high; in dry soil, thickets, and waste grounds nearly throughout the United States and Canada.

Parts used.—Fruit (official); bark and leaves (nonofficial).

Rhus radicans L.[a] **Sumac family (Anacardiaceae).**

Rhus toxicodendron (pharmacopœial name, 1890); poison-ivy; poison-oak; poison-vine.

Native, woody vine, clinging to trees and fence rows; Canada to Florida, west to Nebraska and Arkansas. Very poisonous to the touch.

Part used.—Fresh leaves (official in U. S. P. 1890).

Rhus toxicodendron. See *Rhus radicans*.

[a] *Rhus radicans* L. was formerly believed to be a variety of *Rhus toxicodendron* L., but the two are now regarded as distinct species, and the leaves from both have been used under the pharmacopœial name (U. S. P. 1890) Rhus toxicodendron.

Rhus toxicodendron L. **Sumac family (Anacardiaceae).**

Poison-ivy; poison-oak.

Low, erect, and finely pubescent plant, more shrubby than *Rhus radicans*, and found in dry soil in more southern localities from Virginia to Georgia. Very poisonous to the touch.

Part used.—Fresh leaves, collected with those of *Rhus radicans*.

Richweed. See *Collinsonia canadensis* and *Eupatorium ageratoides*.

Robinia pseudacacia L. **Pea family (Fabaceae).**

Locust-tree; black locust; yellow locust; false acacia.

A large, indigenous tree, sometimes 80 feet in height, growing in woods from Pennsylvania south along the western slope of the Allegheny Mountains to Georgia, west to the Indian Territory. Most abundant in the Middle and Eastern States.

Part used.—Bark of root (nonofficial).

Robin's-rye. See *Polytrichum juniperinum*.

Rock-brake. See *Polypodium vulgare*.

Rock-rose, Canadian. See *Helianthemum canadense*.

Rope-bark. See *Dirca palustris*.

Rose, Canadian rock-. See *Helianthemum canadense*.

Rose-bay. See *Rhododendron maximum*.

Rose-laurel. See *Rhododendron maximum*.

Rosemary, marsh-. See *Limonium carolinianum*.

Rose-pink. See *Sabbatia angularis*.

Rose-willow. See *Cornus amomum*.

Rosinweed. See *Silphium laciniatum*.

Roundwood. See *Sorbus americana*.

Rubus. See *Rubus cuneifolius*, *R. nigrobaccus*, *R. procumbens*, *R. trivialis*, and *R. villosus*.

Rubus canadensis T. & G., not L. Same as *Rubus procumbens*.

Rubus cuneifolius Pursh. **Rose family (Rosaceae).**

Rubus; sand-blackberry; knee-high blackberry.

Shrubby plant, 1 to 3 feet high; in sandy soil from Connecticut to Florida, west to Missouri and Louisiana.

Part used.—Bark of rhizome (official).

Rubus idaeus var. *americanus* Torr. Same as *Rubus occidentalis*.

Rubus nigrobaccus Bailey. **Rose family (Rosaceae).**

Synonym.—*Rubus villosus* A. Gray, not Ait.

Rubus; high-bush blackberry.

Slender shrub, 3 to 7 feet high, growing in dry fields and along roadsides, New England States to Florida, and west to Arkansas.

Part used.—Bark of rhizome (official).

Rubus occidentalis L. **Rose family (Rosaceae).**

Synonym.—*Rubus idaeus* var. *americanus* Torr.

Black raspberry; thimbleberry; blackcap.

A straggling shrub, growing along the borders of woods and in rocky thickets from Canada south to Georgia and Missouri.

Parts used.—Fruit and leaves (nonofficial).

Rubus procumbens Muhl. **Rose family (Rosaceae).**

Synonym.—Rubus canadensis T. & G., not L.

Rubus; low running blackberry; dewberry.

Shrubby, trailing plant, found in dry soil from Newfoundland to Lake Superior, south to Virginia and the Indian Territory.

Part used.—Bark of root (official in U. S. P. 1890).

Rubus strigosus Michx. **Rose family (Rosaceae).**

Wild red raspberry.

Shrubby plant, found in dry or rocky situations from Canada to North Carolina and New Mexico.

Parts used.—Fruit and leaves (nonofficial).

Rubus trivialis Michx. **Rose family (Rosaceae).**

Rubus; southern dewberry; low-bush blackberry.

Shrubby, procumbent plant, found in sandy soils, Virginia to Florida, west to Missouri and Texas.

Part used.—Bark of root (official in U. S. P. 1890).

Rubus villosus A. Gray, not Ait. Same as *Rubus nigrobaccus.*

Rubus villosus Ait. **Rose family (Rosaceae).**

Rubus; one-flowered dewberry.

Trailing plant, with slender branches, growing in sandy or dry soil near the coast from Maine to South Carolina.

Part used.—Bark of rhizome (official)

Rudbeckia laciniata L. **Aster family (Asteraceae).**

Thimbleweed; tall coneflower.

Much-branched, native perennial, 3 to 12 feet high; in moist thickets, Canada and Montana, south to Florida and New Mexico.

Part used.—Herb (nonofficial).

Rum-cherry. See *Prunus serotina.*

Rumex. See *Rumex crispus.*

Rumex acetosella L. **Buckwheat family (Polygonaceae).**

Sheep-sorrel; field-sorrel; sour-grass; common sorrel.

Annual or perennial herb, abundant in dry fields, pastures, and waste ground throughout the United States.

Part used.—Leaves (nonofficial).

Rumex crispus L. **Buckwheat family (Polygonaceae).**

Rumex; yellow dock; curled dock; narrow dock; sour dock.

A weed introduced from Europe, and common in cultivated and waste ground throughout the United States. Perennial plant, 2 to 4 feet high.

Part used.—Root of this and some other species of Rumex (official in U. S. P. 1890).

Rumex obtusifolius L. **Buckwheat family (Polygonaceae).**

Bitter dock; blunt-leaved dock; broad-leaved dock.

A perennial weed, 2 to 4 feet high, naturalized from Europe, and found in waste places from New England to Florida, west to Texas and Oregon.

Part used.—Root, collected with that of *Rumex crispus.*

Sabal. See *Serenoa serrulata.*

Sabbatia angularis (L.) Pursh. **Gentian family (Gentianaceae).**

American centaury; rose-pink; bitterbloom; bitter clover.

Native, biennial plant, 1 to 2 feet high, growing in damp, rich soil, in meadows and among high grass, from New York to Michigan, south to Florida and the Indian Territory.

Part used.—Herb (nonofficial).

Sabbatia elliottii Steud. **Gentian family (Gentianaceae).**

Synonym.—Sabbatia paniculata Ell.

Quinine-flower; quinine-plant; quinine-herb; Elliott's-sabbatia.

An erect, native herb, about one foot in height, growing in pine barrens from North Carolina to Florida.

Part used.—Herb (nonofficial).

Sabbatia, Elliott's-. See *Sabbatia elliottii.*

Sabbatia paniculata Ell. Same as *Sabbatia elliottii.*

Sabina. See *Juniperus sabina.*

Sacred-bark. See *Rhamnus purshiana.*

Sage, Indian. See *Eupatorium perfoliatum.*

Saint-Benedict's thistle. See *Cnicus benedictus.*

Saint-John's wort, common. See *Hypericum perforatum.*

Salix alba L. **Willow family (Salicaceae).**

White willow; European willow.

A large tree, sometimes 90 feet in height, introduced from Europe; occurs in moist soil along streams from Pennsylvania northward to New Brunswick and Ontario, sparingly escaped from cultivation.

Part used.—Bark (nonofficial).

Salix nigra Marsh. **Willow family (Salicaceae).**

Black willow; pussy-willow; swamp-willow.

Tall, indigenous tree, growing on banks of rivers from Canada to Florida and California.

Parts used.—Bark, and fresh aments gathered early in May (nonofficial).

Salomonia biflora (Walt.) Britton. Same as *Polygonatum biflorum.*

Salomonia commutata (Roem. & Schult.) Dietr. Same as *Polygonatum commutatum.*

Salt-rheum weed. See *Chelone glabra.*

Sambucus. See *Sambucus canadensis.*

Sambucus canadensis L. **Honeysuckle family (Caprifoliaceae).**

Sambucus; elder; American elder; sweet elder.

Indigenous shrub, 6 to 10 feet high, growing in low, damp ground from Canada to Florida and Arizona.

Parts used.—Flowers (official in U. S. P. 1890); bark and berries (nonofficial).

Sampson-root. See *Brauneria angustifolia.*

Sampson's-snakeroot. See *Gentiana villosa.*

Samson's-snakeroot. See *Psoralea pedunculata.*

Sand-blackberry. See *Rubus cuneifolius.*

Sandbrier. See *Solanum carolinense.*

Sanguinaria. See *Sanguinaria canadensis.*

Sanguinaria canadensis L. **Poppy family (Papaveraceae).**

Sanguinaria; bloodroot; red puccoon; Indian-paint; tetterwort.

Native, perennial herb, about 6 inches high, found in rich, open woods from Nova Scotia to Nebraska, south to Florida and Arkansas.

Part used.—Rhizome, "collected after the death of the foliage" (official).

Sanicle, American. See *Heuchera americana* and *Sanicula marilandica.*

Sanicle, black. See *Sanicula marilandica.*

Sanicle, Indian. See *Eupatorium ageratoides.*

Sanicle, white. See *Eupatorium ageratoides.*

Sanicula marilandica L. **Parsley family (Apiaceae).**

Black sanicle; black snakeroot; American sanicle; poolroot.

Native, perennial herb, 1 to 3 feet high; in rich woods, Canada to Georgia.

Part used.—Root (nonofficial).

Saponaria officinalis L. **Pink family (Silenaceae).**

Soapwort; soaproot; bouncing-Bet; fuller's-herb.

Stout, perennial herb, 1 to 2 feet high, naturalized from Europe and found along roadsides and waste places; common almost everywhere.

Parts used.—Root and herb (nonofficial).

Sarothamnus scoparius Wimm. Same as *Cytisus scoparius.*

Sarracenia flava L. **Pitcher-plant family (Sarraceniaceae).**

Trumpetleaf; trumpets; Eve's-cup; watercup; yellow-flowered watercup.

Curious, indigenous perennial, about 1 to 3 feet high, found in low, wet pine barrens in the southeastern United States.

Parts used.—Root and sometimes the leaves (nonofficial).

Sarracenia purpurea L. **Pitcher-plant family (Sarraceniaceae).**

Pitcher-plant; flytrap; sidesaddle-flower; watercup; smallpox-plant.

Indigenous perennial, 1 to 2 feet high, growing in wet, boggy places and marshes, from Canada to Minnesota and Florida.

Parts used.—Root and sometimes the leaves (nonofficial).

Sarsaparilla, American. See *Aralia nudicaulis.*

Sarsaparilla, bristly. See *Aralia hispida.*

Sarsaparilla, false. See *Aralia nudicaulis.*

Sarsaparilla, Texas. See *Menispermum canadense.*

Sarsaparilla, Virginian. See *Aralia nudicaulis.*

Sarsaparilla, wild. See *Aralia nudicaulis.*

Sassafras. See *Sassafras variifolium.*

Sassafras officinale Nees & Eberm. Same as *Sassafras variifolium.*

Sassafras sassafras (L.) Karst. Same as *Sassafras variifolium.*

Sassafras, swamp-. See *Magnolia virginiana.*

Sassafras variifolium (Salisb.) O. Kuntze.[a] **Laurel family (Lauraceae).**

Synonyms.—*Sassafras officinale* Nees & Eberm.; *Sassafras sassafras* (L.) Karst.[a]

Sassafras; ague-tree.

Native tree, sometimes reaching a height of 125 feet; in rich woods, Massachusetts to Ontario and Michigan, south to Florida and Texas.

Parts used.—Bark of root, collected in early spring or autumn and deprived of the periderm (official); pith (official); and the oil of sassafras distilled from the root, especially the root bark (official).

Satureia hortensis L. **Mint family (Menthaceae).**

Summer-savory.

Hairy, aromatic, annual herb, adventive from Europe and occurring in waste places from Canada to Pennsylvania and Nevada.

Part used.—Herb (nonofficial).

Savin. See *Juniperus sabina.*

Savin, red. See *Juniperus virginiana.*

Savory, summer-. See *Satureia hortensis.*

Saw-palmetto. See *Serenoa serrulata.*

Saxifrage, burnet-. See *Pimpinella saxifraga.*

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[a] Although the combination *Sassafras sassafras* (L.) Karst. should be accepted by strict right of priority, the usage of the Pharmacopœia is followed.

Scabious, sweet. See *Erigeron philadelphicus.*

Scabish, meadow-. See *Aster puniceus.*

Scabwort. See *Inula helenium.*

Scarletberry. See *Solanum dulcamara.*

Scoke. See *Phytolacca decandra.*

Scoparius. See *Cytisus scoparius.*

Scouring-rush, common. See *Equisetum hyemale.*

Scrofula-plant. See *Scrophularia marilandica.*

Scrofula-weed. See *Peramium pubescens.*

Scrophularia marilandica L. **Figwort family (Scrophulariaceae).**

Synonym.—Scrophularia nodosa var. *marilandica* A. Gray.

Maryland figwort; scrofula-plant; carpenter's-square; heal-all; bee-plant; pile-wort.

Smooth, native perennial, 3 to 5 feet high; moist, shady ground in woods and thickets, New York to North Carolina and Kansas.

Parts used.—Herb and root (nonofficial).

Scrophularia nodosa var. *marilandica* A. Gray. Same as *Scrophularia marilandica.*

Scutellaria. See *Scutellaria lateriflora.*

Scutellaria hyssopifolia L. Same as *Scutellaria integrifolia.*

Scutellaria integrifolia L. **Mint family (Menthaceae).**

Synonym.—Scutellaria hyssopifolia L.

Larger skullcap; hyssop-skullcap.

Native, perennial herb, 6 inches to 2 feet high, found in fields and woods from Connecticut south to Florida and Texas.

Part used.—Herb (nonofficial).

Scutellaria lateriflora L. **Mint family (Menthaceae).**

Scutellaria; skullcap; madweed; hoodwort.

Smooth, branching perennial, 1 to 2 feet high, native in damp places along banks of streams from Canada south to Florida, New Mexico, and Washington.

Part used.—Plant (official).

Sea-lavender. See *Limonium carolinianum.*

Self-heal. See *Prunella vulgaris.*

Senecio aureus L. **Aster family (Asteraceae).**

Liferoot; swamp squaw-weed; golden ragwort; cocash-weed; coughweed.

Indigenous, perennial herb, 1 to 2½ feet high, growing in swamps and wet meadows, Newfoundland to Ontario, south to Florida, Missouri, and Texas.

Parts used.—Root and herb (nonofficial).

Senega. See *Polygala senega.*

Senna, American. See *Cassia marilandica.*

Senna, wild. See *Cassia marilandica.*

Serenoa serrulata (Roem. & Schult.) Hook. f. **Palm family (Phoenicaceae).**

Sabal; saw-palmetto.

A palm, 3 to 7 feet in height, found in sandy soil from North Carolina and Arkansas to Florida and Texas.

Part used.—Partially dried ripe fruit (official).

Serpentaria. See *Aristolochia reticulata* and *A. serpentaria*

Serpentaria, Texas. See *Aristolochia reticulata.*

Serpentaria, Virginia. See *Aristolochia serpentaria.*

Service-tree, American. See *Sorbus americana.*

Seven-barks. See *Hydrangea arborescens.*

Shagbark. See *Hicoria ovata.*

Shamrock. See *Oxalis acetosella.*

Shamrock, water-. See *Menyanthes trifoliata.*

Shave-grass. See *Equisetum hyemale.*

Sheepberry. See *Viburnum lentago.*

Sheep-laurel. See *Kalmia angustifolia* and *K. latifolia.*

Sheep-sorrel. See *Rumex acetosella.*

Shellbark-hickory. See *Hicoria ovata.*

Shellflower. See *Chelone glabra.*

Shepherd's-purse. See *Bursa bursa-pastoris.*

Shepherd's-weatherglass. See *Anagallis arvensis.*

Shield-fern, marginal-fruited. See *Dryopteris marginalis.*

Shrub, sweet-scented. See *Butneria florida.*

Shrub yellowroot. See *Xanthorrhiza apiifolia.*

Sicklewort. See *Prunella vulgaris.*

Sidesaddle-flower. See *Sarracenia purpurea.*

Silkweed. See *Asclepias syriaca.*

Silkweed, rose-colored. See *Asclepias incarnata.*

Silkweed, swamp-. See *Asclepias incarnata.*

Silphium laciniatum L. **Aster family (Asteraceae).**

Rosinweed; compass-plant; pilotweed; polar-plant.

Coarse, native perennial, 3 to 12 feet high, growing on prairies from Ohio to Alabama, west to Texas and South Dakota.

Part used.—Herb (nonofficial).

Silphium perfoliatum L. **Aster family (Asteraceae).**

Cup-plant; Indian-cup; ragged-cup.

Stout, perennial herb, 4 to 8 feet high, native in moist soil and low ground from Ontario and the eastern United States west to Louisiana and Nebraska.

Part used.—Root (nonofficial).

Silverleaf. See *Impatiens biflora, Spiraea tomentosa,* and *Stillingia sylvatica.*

Silverleaf-poplar. See *Populus alba.*

Simpler's-joy. See *Verbena hastata.*

Sinapis alba. See *Sinapis alba* L.

Sinapis alba L. **Mustard family (Brassicaceae).**

Sinapis alba; white mustard; yellow mustard.

Annual herb, about 2 feet in height, naturalized from Europe, and found in fields and waste places, but not so widely distributed as the black mustard.

Part used.—Seed (official).

Sinapis nigra. See *Brassica nigra.*

Sinapis nigra L. Same as *Brassica nigra.*

Skullcap. See *Scutellaria lateriflora.*

Skullcap, hyssop-. See *Scutellaria integrifolia.*

Skullcap, larger. See *Scutellaria integrifolia.*

Skunk-cabbage. See *Spathyema foetida.*

Skunkweed. See *Spathyema foetida.*

Sloe. See *Viburnum prunifolium.*

Smallpox-plant. See *Sarracenia purpurea.*

Smartweed. See *Polygonum hydropiper.*

Smartweed, dotted. See *Polygonum punctatum.*

Smartweed, water-. See *Polygonum punctatum.*

Smilacina racemosa Desf. Same as *Vagnera racemosa.*

Smilax herbacea L. **Smilax family (Smilacaceae).**

Carrion-flower; American Jacob's-ladder.

Native, herbaceous perennial, occurring in woods and thickets in Canada and the eastern United States.

Part used.—Herb (nonofficial).

Smilax pseudo-china L. **Smilax family (Smilacaceae).**

Bamboo-brier; long-stalked greenbrier; American China-root; false China-root; bullbrier.

Perennial vine, native, growing in dry or sandy thickets, Maryland to Florida, west to Texas and Nebraska.

Part used.—Rhizome (nonofficial).

Snake-gentian. See *Nabalus serpentarius.*

Snakehead. See *Chelone glabra.*

Snakeleaf, yellow. See *Erythronium americanum.*

Snake-lily. See *Iris versicolor.*

Snakemilk. See *Euphorbia corollata.*

Snakeroot, black. See *Cimicifuga racemosa* and *Sanicula marilandica.*

Snakeroot, button-. See *Eryngium yuccifolium.*

Snakeroot, Canada. See *Asarum canadense.*

Snakeroot, corn-. See *Eryngium yuccifolium* and *Lacinaria spicata.*

Snakeroot, dense button-. See *Lacinaria spicata.*

Snakeroot, large button-. See *Lacinaria scariosa.*

Snakeroot, Red River. See *Aristolochia reticulata.*

Snakeroot, Sampson's- See *Gentiana villosa.*

Snakeroot, Samson's-. See *Psoralea pedunculata.*

Snakeroot, Seneca. See *Polygala senega.*

Snakeroot, smaller white. See *Eupatorium aromaticum.*

Snakeroot, Texas. See *Aristolochia reticulata.*

Snakeroot, Virginia. See *Aristolochia serpentaria.*

Snakeroot, white. See *Eupatorium ageratoides.*

Snake-violet. See *Viola pedata.*

Snakeweed. See *Euphorbia pilulifera.*

Snapweed. See *Impatiens aurea* and *I. biflora.*

Sneezeweed. See *Helenium autumnale.*

Sneezewort. See *Helenium autumnale.*

Snowdrop, yellow. See *Erythronium americanum.*

Soaproot. See *Saponaria officinalis.*

Soapwort. See *Saponaria officinalis.*

Soapwort-gentian. See *Gentiana saponaria.*

Solanum carolinense L. **Potato family (Solanaceae).**

Horse-nettle; bull-nettle; sandbrier.

Rough-hairy, native, perennial herb, common in dry fields and on sandy or gravelly banks from the eastern United States west to Texas and Nebraska.

Parts used.—Root, leaves, and berries (nonofficial).

Solanum dulcamara L. **Potato family (Solanaceae).**

Dulcamara; bittersweet; woody nightshade; violet-bloom; scarletberry.

Climbing, shrubby perennial, naturalized from Europe; found in low, damp grounds and moist banks, New Brunswick to Minnesota, south to New Jersey and Kansas.

Part used.—Young branches (official in U. S. P. 1890).

Solidago odora Ait. **Aster family (Asteraceae).**

Sweet goldenrod; fragrant-leaved goldenrod; anise-scented goldenrod.

Slender, perennial herb, 2 to 3 feet high, native; in dry soil from Maine to Texas.

Parts used.—Leaves and tops (nonofficial).

Solomon's-seal, false. See *Vagnera racemosa.*

Solomon's-seal, giant. See *Polygonatum commutatum.*

Solomon's-seal, great. See *Polygonatum commutatum.*

Solomon's-seal, hairy. See *Polygonatum biflorum.*

Solomon's-seal, small. See *Vagnera racemosa.*

Solomon's-seal, smaller. See *Polygonatum biflorum.*

Solomon's-seal, smooth. See *Polygonatum commutatum.*

Sorbus americana Marsh. **Apple family (Malaceae).**

Synonym.—Pyrus americana DC.

American mountain-ash; roundwood; dogberry; mountain-sumac; American service-tree.

Indigenous tree or tall shrub, growing in low woods or moist ground from Newfoundland south along the mountains to North Carolina, and to Michigan.

Parts used.—Bark and berries (nonofficial).

Sorrel, common. See *Rumex acetosella.*

Sorrel, field-. See *Rumex acetosella.*

Sorrel, sheep-. See *Rumex acetosella.*

Sorrel, white wood-. See *Oxalis acetosella.*

Sorrel-tree. See *Oxydendrum arboreum.*

Sour-grass. See *Rumex acetosella.*

Sourwood. See *Oxydendrum arboreum.*

Southernwood. See *Artemisia abrotanum.*

Spathyema foetida (L.) Raf. **Arum family (Araceae).**

Synonyms.—Dracontium foetidum L.; *Symplocarpus foetidus* Nutt.

Skunk-cabbage; skunkweed; polecat-weed; swamp-cabbage.

Indigenous, perennial herb, about 1 to 2 feet high, found in swamps and wet soil from Canada south to Florida, Iowa, and Minnesota. Appears very early in spring.

Parts used.—Rhizome and roots (nonofficial).

Spatter-dock. See *Nymphaea advena.*

Spearmint. See *Mentha spicata.*

Speedwell, common. See *Veronica officinalis.*

Speedwell, tall. See *Veronica virginica.*

Spicebush. See *Benzoin benzoin.*

Spicewood. See *Benzoin benzoin.*

Spigelia. See *Spigelia marilandica.*

Spigelia marilandica L. **Logania family** (**Loganiaceae**).

Spigelia; pinkroot; Maryland pinkroot; Indian pinkroot; worm-grass.

Erect, native, perennial herb, 6 inches to $1\frac{1}{2}$ feet high, found in rich woods, New Jersey to Florida, west to Texas and Wisconsin. Occurs principally in the Southern States.

Parts used.—Rhizome and roots (official).

Spignet. See *Aralia racemosa.*

Spikenard. See *Aralia racemosa.*

Spikenard, American. See *Aralia racemosa.*

Spikenard, false. See *Vagnera racemosa.*

Spikenard, small. See *Aralia nudicaulis.*

Spikenard, wild. See *Vagnera racemosa.*

Spindle-tree. See *Euonymus atropurpureus.*

Spiraea. See *Spiraea tomentosa.*

Spiraea tomentosa L. **Rose family** (**Rosaceae**).

Spiraea; hardhack; steeplebush; pink meadowsweet; silverleaf.

Native shrub, occurring in low grounds and moist meadows from Nova Scotia south to Georgia, west to Kansas and Manitoba.

Parts used.—Leaves and root (nonofficial).

Spleenwortbush. See *Comptonia peregrina.*

Spruce, black. See *Picea mariana.*

Spruce, hemlock-. See *Tsuga canadensis.*

Spruce, weeping. See *Tsuga canadensis.*

Spruce-gum tree. See *Picea mariana.*

Spurge, flowering. See *Euphorbia corollata.*

Spurge, ipecac-. See *Euphorbia ipecacuanhae.*

Spurge, large spotted. See *Euphorbia nutans.*

Spurge, pill-bearing. See *Euphorbia pilulifera.*

Spurge-laurel. See *Daphne mezereum.*

Spurge-olive. See *Daphne mezereum.*

Squawberry. See *Mitchella repens.*

Squawbush. See *Viburnum opulus.*

Squawflower. See *Trillium erectum.*

Squawmint. See *Hedeoma pulegioides.*

Squawroot. See *Caulophyllum thalictroides* and *Cimicifuga racemosa.*

Squaw-vine. See *Mitchella repens.*

Squaw-weed. See *Eupatorium ageratoides.*

Squaw-weed, swamp. See *Senecio aureus.*

Squirrel-corn. See *Bikukulla canadensis.*

Squirrel-ear. See *Peramium repens.*

Staff-tree. See *Celastrus scandens.*

Stagbush. See *Viburnum prunifolium.*

Staggerweed. See *Bikukulla canadensis.*

Stag's-horn. See *Lycopodium clavatum.*

Stammerwort. See *Ambrosia artemisiaefolia.*

Star-grass. See *Aletris farinosa.*

Starwort. See *Chamaelirium luteum.*

Starwort, drooping. See *Chamaelirium luteum.*

Statice caroliniana Walt. Same as *Limonium carolinianum.*

Steeplebush. See *Spiraea tomentosa.*

Stellaria media Cyr. Same as *Alsine media.*

Stillingia. See *Stillingia sylvatica.*

Stillingia sylvatica L. **Spurge family (Euphorbiaceae).**

Stillingia; queen's-root; queen's-delight; silverleaf.

Native, herbaceous perennial, 1 to 3 feet in height, occurring in dry, sandy soil, and pine barrens from Maryland to Florida, west to Kansas and Texas.

Part used.—Root (official).

Stonecrop, ditch-. See *Penthorum sedoides.*

Stonecrop, Virginia. See *Penthorum sedoides.*

Stonemint. See *Cunila origanoides.*

Stone-oak. See *Quercus alba.*

Stoneroot. See *Collinsonia canadensis.*

Stramonium. See *Datura stramonium.*

Strawberry, scarlet. See *Fragaria virginiana.*

Strawberry, Virginia. See *Fragaria virginiana.*

Strawberry-shrub, hairy. See *Butneria florida.*

Stylosanthes biflora (L.) B. S. P. **Pea family (Fabaceae).**

Synonym.—*Stylosanthes elatior* Sw.

Pencil-flower; afterbirth-weed.

Wiry, perennial herb, 6 inches to 2 feet in height, native; occurring in dry soil from New York to Florida, west to the Indian Territory.

Part used.—Herb (nonofficial).

Stylosanthes elatior Sw. Same as *Stylosanthes biflora.*

Succory. See *Cichorium intybus.*

Sumac, fragrant. See *Rhus aromatica.*

Sumac, mountain-. See *Sorbus americana.*

Sumac, scarlet. See *Rhus glabra.*

Sumac, smooth. See *Rhus glabra.*

Sumac, sweet-scented. See *Rhus aromatica.*

Summer-savory. See *Satureia hortensis.*

Sundew, round-leaved. See *Drosera rotundifolia.*

Sunflower, swamp-. See *Helenium autumnale.*

Swamp squaw-weed. See *Senecio aureus.*

Swamp willow-herb. See *Epilobium palustre.*

Swamp-cabbage. See *Spathyema foetida.*

Swamp-dogwood. See *Cornus amomum.*

Swamp-hellebore. See *Veratrum viride.*

Swamp-laurel. See *Magnolia virginiana.*

Swamp-maple. See *Acer rubrum.*

Swamp-milkweed. See *Asclepias incarnata.*

Swamp-sassafras. See *Magnolia virginiana.*

Swamp-silkweed. See *Asclepias incarnata.*

Swamp-sunflower. See *Helenium autumnale.*

Swamp-willow. See *Salix nigra.*

Sweatweed. See *Althaea officinalis.*

Sweet-cicely. See *Washingtonia longistylis.*

Sweet-flag. See *Acorus calamus.*

Sweet-gum. See *Liquidambar styraciflua.*

Sweetroot. See *Polemonium reptans.*

Symphytum officinale L. **Borage family (Boraginaceae).**

Comfrey; healing-herb; blackwort; bruisewort.

Erect, perennial herb, 2 to 3 feet high, naturalized from Europe; found in waste places, Newfoundland to Minnesota, south to Maryland.

Part used.—Root (nonofficial).

Symplocarpus foetidus Nutt. Same as *Spathyema foetida.*

Tag-alder. See *Alnus rugosa.*

Tamarack. See *Larix laricina.*

Tanacetum. See *Tanacetum vulgare.*

Tanacetum vulgare L. **Aster family (Asteraceae).**

Tanacetum; tansy; double tansy; bitter-buttons; parsley-fern.

Strong-scented, perennial herb, $1\frac{1}{2}$ to 3 feet high, introduced from Europe; escaped from cultivation and found along roadsides from Nova Scotia to Minnesota, south to North Carolina and Missouri.

Parts used.—Leaves and flowering tops (official in U. S. P. 1890).

Tanbark-tree. See *Tsuga canadensis.*

Tansy. See *Tanacetum vulgare.*

Tansy, double. See *Tanacetum vulgare.*

Taraxacum. See *Taraxacum officinale.*

Taraxacum officinale Weber.[a] **Chicory family (Cichoriaceae).**

Synonym.—*Taraxacum taraxacum* (L.) Karst.[a]

Taraxacum; dandelion; blowball; cankerwort.

Low, perennial weed, 5 to 10 inches high, naturalized from Europe; very abundant in lawns, meadows, and waste places throughout the United States, with the exception of the South.

Part used.—Root, collected in autumn (official).

Taraxacum taraxacum (L.) Karst. Same as *Taraxacum officinale.*

Tea, continental. See *Ledum groenlandicum.*

Tea, James-. See *Ledum groenlandicum.*

Tea, Jersey. See *Ceanothus americanus.*

Tea, Jerusalem. See *Chenopodium ambrosioides.*

Tea, Labrador. See *Ledum groenlandicum.*

Tea, Mexican. See *Chenopodium ambrosioides.*

Tea, mountain-. See *Gaultheria procumbens.*

Tea, New Jersey. See *Ceanothus americanus.*

Tea, Oswego. See *Monarda didyma.*

Tea, Spanish. See *Chenopodium ambrosioides.*

Teaberry. See *Gaultheria procumbens.*

Tephrosia virginiana Pers. Same as *Cracca virginiana.*

Tetterwort. See *Chelidonium majus* and *Sanguinaria canadensis.*

Thimbleberry. See *Rubus occidentalis.*

[a] Although the combination *Taraxacum taraxacum* (L.) Karst. should be accepted by right of priority, the usage of the Pharmacopœia is followed.

Thimbles. See *Digitalis purpurea*.

Thimbleweed. See *Rudbeckia laciniata*.

Thistle, bitter. See *Cnicus benedictus*.

Thistle, blessed. See *Cnicus benedictus*.

Thistle, Canada. See *Carduus arvensis*.

Thistle, creeping. See *Carduus arvensis*.

Thistle, cursed. See *Carduus arvensis*.

Thistle, holy. See *Cnicus benedictus*.

Thistle, St. Benedict's-. See *Cnicus benedictus*.

Thistle, spotted. See *Cnicus benedictus*.

Thorn-apple. See *Datura stramonium*.

Thoroughwort. See *Eupatorium perfoliatum*.

Thousandleaf. See *Achillea millefolium*.

Throwwort. See *Leonurus cardiaca*.

Thuja occidentalis L. **Pine family** (**Pinaceae**).

Arbor-vitae; white cedar; yellow cedar.

Indigenous, evergreen tree, 20 to 50 feet in height; in wet soil and along banks of streams, Canada to North Carolina, Illinois, and Minnesota. Especially abundant in Canada and the Northern States.

Parts used.—Branchlets and leaves (nonofficial).

Tiarella cordifolia L. **Saxifrage family** (**Saxifragaceae**).

Coolwort; false miterwort; foamflower; gemfruit.

Slender, indigenous perennial, 6 to 12 inches high, found in rich, moist woods, Nova Scotia to Minnesota, south, especially along the mountains, to Georgia and Indiana.

Part used.—Herb (nonofficial).

Tickweed. See *Hedeoma pulegioides*.

Tilia americana L. **Linden family** (**Tiliaceae**).

Synonym.—*Tilia glabra* Vent.

Basswood; American linden; whitewood.

Large, indigenous forest tree, 60 to 125 feet in height; in rich woods, especially along the mountains, from Canada to Georgia, west to Texas and Nebraska.

Part used.—Inflorescence of this and of other species of Tilia (nonofficial).

Tilia glabra Vent. Same as *Tilia americana*.

Tinker's-weed. See *Triosteum perfoliatum*.

Tobacco, Indian. See *Lobelia inflata*.

Toothache-tree. See *Fagara clava-herculis* and *Xanthoxylum americanum*.

Touch-me-not, pale. See *Impatiens aurea*.

Touch-me-not, spotted. See *Impatiens biflora*.

Toywort. See *Bursa bursa-pastoris*.

Tree-primrose. See *Oenothera biennis*.

Trefoil, marsh-. See *Menyanthes trifoliata*.

Trefoil, shrubby. See *Ptelea trifoliata*.

Trefoil, sour. See *Oxalis acetosella*.

Trifolium pratense L. **Pea family** (**Fabaceae**).

Red clover; meadow-clover; purple clover.

Perennial herb, 6 inches to 2 feet high; common in fields and meadows throughout the eastern United States; naturalized from Europe, and widely cultivated.

Part used.—Blossoms (nonofficial).

Trilisa odoratissima (Walt.) Cass. **Aster family (Asteraceae).**

Synonym.—Liatris odoratissima Michx.

Vanilla-plant; deer's-tongue; vanilla-leaf; Carolina vanilla.

Rather stout, native, perennial herb, 2 to 3 feet high, with fragrant leaves; in pine barrens from Virginia south to Florida and Louisiana.

Part used.—Leaves (nonofficial).

Trillium erectum L. **Lily-of-the-valley family (Convallariaceae).**

Wake-robin; ill-scented bethroot; birthroot; squawflower.

Stout, native perennial, 8 to 16 inches high, growing in rich soil in damp, shady woods from Canada south to Tennessee and Missouri.

Part used.—Rhizome of this and of several other species of Trillium (nonofficial).

Triosteum perfoliatum L. **Honeysuckle family (Caprifoliaceae).**

Feverroot; horse-gentian; tinker's-weed; white gentian; wild ipecac.

Indigenous, perennial herb, 2 to 4 feet high; in rich soil in shady locations, Quebec to Minnesota, south to Alabama and Kansas.

Part used.—Root (nonofficial).

Triticum. See *Agropyron repens.*

Triticum repens Beauv. Same as *Agropyron repens.*

Trumpetleaf. See *Sarracenia flava.*

Trumpet-milkweed. See *Lactuca canadensis.*

Trumpets. See *Sarracenia flava.*

Tsuga canadensis (L.) Carr. **Pine family (Pinaceae).**

Synonym.—Abies canadensis Michx.

Hemlock; hemlock-spruce; weeping spruce; tanbark-tree.

Indigenous tree, about 75 feet in height, in forests from Canada south to Alabama and Wisconsin.

Parts used.—Bark and prepared resinous exudate (nonofficial).

Tulip-poplar. See *Liriodendron tulipifera.*

Tulip-tree. See *Liriodendron tulipifera.*

Tupelo gum. See *Nyssa aquatica.*

Tupelo, large. See *Nyssa aquatica.*

Tupelo, sour. See *Nyssa ogeche.*

Turkey-corn. See *Bikukulla canadensis.*

Turkey-pea. See *Bikukulla canadensis.*

Turnera aphrodisiaca Ward. Same as *Turnera microphylla.*

Turnera microphylla Desv. **Turnera family (Turneraceae).**

Synonym.—Turnera aphrodisiaca Ward.

Damiana.

A small, shrubby plant, native of Lower California, Texas, and northern Mexico, growing in dry soil.

Part used.—Leaves (nonofficial).

Turnip, Indian. See *Arisaema triphyllum.*

Turnip, wild. See *Arisaema triphyllum.*

Turtle-head. See *Chelone glabra.*

Tussilago farfara L. **Aster family (Asteraceae).**

Colt's-foot; coughwort; horsefoot; gingerroot.

Perennial herb, 3 to 18 inches high, naturalized from Europe; in moist places along roadsides and brooks, northeastern United States and Minnesota to Canada.

Parts used.—Leaves and root (nonofficial).

Twinleaf. See *Jeffersonia diphylla.*

Typha latifolia L. **Cattail family (Typhaceae).**

Broad-leaved cattail; cattail-flag; bulrush.

Native marsh plant, perennial, 4 to 8 feet high; found in marshes, ditches, muddy pools, and other wet places throughout North America, except extreme northern part.

Part used.—Root (nonofficial).

Ulmus. See *Ulmus fulva.*

Ulmus fulva Michx. **Elm family (Ulmaceae).**

Synonym.—Ulmus pubescens Walt.

Ulmus; elm; slippery elm; red elm; moose-elm; Indian elm.

Indigenous tree, 50 to 60 feet high, growing on hills, along streams and in woods from Quebec to North Dakota, south to Florida and Texas. More common in the western part of its range.

Part used.—Bark deprived of its periderm (official).

Ulmus pubescens Walt. Same as *Ulmus fulva.*

Umbrella-tree. See *Magnolia tripetala.*

Unicorn-root, false. See *Aletris farinosa.*

Unicorn-root, true. See *Chamaelirium luteum.*

Upland-cranberry. See *Arctostaphylos uva-ursi.*

Urtica dioica L. **Nettle family (Urticaceae).**

Stinging nettle; great nettle.

Herbaceous, perennial plant, 2 to 4 feet high, with stinging hairs; naturalized from Europe and found in waste places from Canada and Minnesota south to South Carolina and Missouri.

Parts used.—Flowers, leaves, and root (nonofficial).

Uva-ursi. See *Arctostaphylos uva-ursi.*

Uvedalia. See *Polymnia uvedalia.*

Uvularia perfoliata L. **Bunchflower family (Melanthiaceae).**

Perfoliate bellwort; Mohawk-weed.

Native, perennial herb, 6 to 20 inches high; in moist woods and thickets, Quebec to Florida and Mississippi.

Part used.—Root (nonofficial).

Vagnera racemosa (L.) Morong. **Lily-of-the-valley family (Convallariaceae).**

Synonyms.—Convallaria racemosa L.; *Smilacina racemosa* Desf.

False Solomon's-seal; small Solomon's-seal; wild spikenard; false spikenard.

Indigenous, perennial herb, 1 to 3 feet high, found in moist woods and thickets from Canada south to Georgia and Arizona.

Part used.—Root (nonofficial).

Valerian. See *Valeriana officinalis.*

Valerian, American. See *Cypripedium hirsutum.*

Valerian, American Greek. See *Polemonium reptans.*

Valerian, garden-. See *Valeriana officinalis.*

Valeriana. See *Valeriana officinalis.*

Valeriana officinalis L. **Valerian family (Valerianaceae).**

Valeriana; valerian; garden-valerian; vandal-root.

Perennial herb, 2 to 5 feet high, native of Europe; escaped from gardens to roadsides in New York and New Jersey.

Parts used.—Rhizome and roots (official).

Vandal-root. See *Valeriana officinalis.*

Vanilla, Carolina. See *Trilisa odoratissima.*

Vanilla-leaf. See *Trilisa odoratissima.*

Vanilla-plant. See *Trilisa odoratissima.*

Velvet-plant. See *Verbascum thapsus.*

Veratrum. See *Veratrum viride.*

Veratrum viride Ait. **Bunchflower family (Melanthiaceae).**

Veratrum; American hellebore; swamp-hellebore; green hellebore.

Native, perennial herb, 2 to 7 feet high, growing in swamps, wet woods, and meadows, Canada and Alaska, Minnesota south to Georgia.

Parts used.—Rhizome and roots of this or *V. album* (official).

Verbascum thapsus L. **Figwort family (Scrophulariaceae).**

Mullein; velvet dock; velvet-plant; flannel-leaf.

Tall, erect, biennial weed, sometimes 7 feet in height; naturalized from Europe and growing in fields, pastures, and waste places, Nova Scotia to Minnesota, southward to Florida.

Parts used.—Leaves and flowers (nonofficial).

Verbena hastata L. **Vervain family (Verbenaceae).**

Vervain; simpler's-joy; wild hyssop.

Erect, indigenous perennial, 3 to 4 feet high, found in fields, meadows, and waste places, Canada to Nebraska, New Mexico, and Florida.

Parts used.—Root and herb (nonofficial).

Veronica officinalis L. **Figwort family (Scrophulariaceae).**

Common speedwell; Paul's-betony.

Perennial herb, 3 to 10 inches high; in dry fields and woods, Nova Scotia to Michigan, south to North Carolina and Tennessee.

Part used.—Herb (nonofficial).

Veronica, tall. See *Veronica virginica.*

Veronica virginica L.[a] **Figwort family (Scrophulariaceae).**

Synonym.—*Leptandra virginica* (L.) Nutt.[a]

Leptandra; Culver's-root; Culver's-physic; blackroot; Bowman's-root; tall speedwell; tall veronica.

Indigenous, perennial plant, 2 to 5 feet high, in moist, rich ground in woods, meadows, and thickets from Canada to Alabama and Nebraska.

Parts used.—Rhizome and roots (official).

Vervain. See *Verbena hastata.*

Viburnum dentatum L. **Honeysuckle family (Caprifoliaceae).**

Arrowwood; mealy-tree.

Smooth, indigenous shrub, about 15 feet in height, growing on low ground and in damp woods and thickets from New Brunswick and Ontario south along the mountains to Georgia, and westward to Minnesota.

Part used. —Bark (nonofficial).

Viburnum lentago L. **Honeysuckle family (Caprifoliaceae).**

Nannybush; sheepberry; sweet viburnum.

An indigenous shrub, sometimes a small tree; in rich soil from Canada to Georgia and Missouri.

Part used.—Bark of the root of this species or of *V. prunifolium* official under the name "Viburnum prunifolium."

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[a] Some authors hold that this plant belongs to the genus Leptandra and that its name should be *Leptandra virginica* (L.) Nutt. The Pharmacopœia is here followed.

Viburnum opulus. See *Viburnum opulus* L.

Viburnum opulus L. **Honeysuckle family (Caprifoliaceae).**

Viburnum opulus; cramp-bark; high-bush cranberry; squawbush.

Indigenous shrub, 4 to 10 feet in height, found in low, rich woods and borders of fields from New Jersey, Michigan, and Oregon, northward.

Part used.—Bark (official).

Viburnum prunifolium. See *Viburnum lentago* and *V. prunifolium* L.

Viburnum prunifolium L. **Honeysuckle family (Caprifoliaceae).**

Black haw; sloe; stagbush.

Indigenous shrub or small tree, growing in dry woods and thickets and on rocky hillsides, Connecticut to Florida, west to Michigan and Texas. Most abundant in the South.

Part used.—Bark of the root of this species or of *V. lentago* official under the name "Viburnum prunifolium."

Viburnum, sweet. See *Viburnum lentago.*

Vine-maple. See *Menispermum canadense.*

Viola odorata L. **Violet family (Violaceae).**

English violet; sweet violet; March violet.

Low herb, native of Europe; escaped from gardens, Nova Scotia to New York and New Jersey, and on the Pacific coast.

Part used.—Flowers (nonofficial).

Viola pedata L. **Violet family (Violaceae).**

Bird's-foot violet; wood-violet; snake-violet.

Native plant, perennial, 3 to 10 inches high, occurring in dry fields and on hillsides from Maine to Minnesota, south to Florida and Missouri.

Parts used.—Herb and root (nonofficial).

Viola tricolor L. **Violet family (Violaceae).**

Pansy; heartsease.

Small herb, 4 to 12 inches high, introduced from Europe; found in waste places, sparingly escaped from gardens.

Part used.—Flowering herb (nonofficial).

Violet, bird's-foot. See *Viola pedata.*

Violet, dog's-tooth. See *Erythronium americanum.*

Violet, English. See *Viola odorata.*

Violet, March. See *Viola odorata.*

Violet, rattlesnake-. See *Erythronium americanum.*

Violet, snake-. See *Viola pedata.*

Violet, sweet. See *Viola odorata.*

Violet, wood-. See *Viola pedata.*

Violet-bloom. See *Solanum dulcamara.*

Virginia creeper. See *Parthenocissus quinquefolia.*

Virgin's-bower. See *Clematis virginiana.*

Viscum flavescens Pursh. Same as *Phoradendron flavescens.*

Vomitwort. See *Lobelia inflata.*

Wafer-ash. See *Ptelea trifoliata.*

Wahoo. See *Euonymus atropurpureus.*

Wake-robin. See *Arisaema triphyllum* and *Trillium erectum.*

Walnut, white. See *Juglans cinerea.*

Wartwort. See *Gnaphalium uliginosum.*

Washingtonia longistylis (Torr.) Britton. **Parsley family** (**Apiaceae**).

Synonym.—*Osmorrhiza longistylis* DC.

Sweet-cicely; anise-root; sweet chervil.

Erect, rather stout, perennial herb, 2 to 3 feet high, native: in rich, moist woods and banks of streams from Canada to Alabama and Texas.

Part used.—Root (nonofficial).

Water-avens. See *Geum rivale.*

Water-bugle. See *Lycopus virginicus.*

Watercup. See *Sarracenia flava* and *S. purpurea.*

Watercup, yellow-flowered. See *Sarracenia flava.*

Water-eryngo. See *Eryngium yuccifolium.*

Water-flag. See *Iris versicolor.*

Water-hemlock. See *Cicuta maculata.*

Water-hoarhound. See *Lycopus virginicus.*

Water-lily. See *Castalia odorata.*

Water-lily, sweet-scented. See *Castalia odorata.*

Water-pepper. See *Polygonum hydropiper.*

Water-shamrock. See *Menyanthes trifoliata.*

Water-smartweed. See *Polygonum punctatum.*

Waxberry. See *Myrica cerifera.*

Wax-myrtle. See *Myrica cerifera.*

Waxwork. See *Celastrus scandens.*

Waythorn. See *Rhamnus cathartica.*

White-bark. See *Populus alba.*

Whiteroot. See *Asclepias tuberosa.*

Whitethorn. See *Crataegus oxyacantha.*

Whitewood. See *Liriodendron tulipifera* and *Tilia americana.*

Wickopy. See *Dirca palustris.*

Wickup. See *Chamaenerion angustifolium* and *Epilobium palustre.*

Willow, black. See *Salix nigra.*

Willow, European. See *Salix alba.*

Willow, pussy-. See *Salix nigra.*

Willow, rose-. See *Cornus amomum.*

Willow, swamp-. See *Salix nigra.*

Willow, white. See *Salix alba.*

Willow-herb, great. See *Chamaenerion angustifolium.*

Willow-herb, night. See *Oenothera biennis.*

Willow-herb, swamp. See *Epilobium palustre.*

Wingseed. See *Ptelea trifoliata.*

Winterberry, Virginia. See *Ilex verticillata.*

Winterbloom. See *Hamamelis virginiana.*

Wintergreen. See *Gaultheria procumbens.*

Wintergreen, bitter. See *Chimaphila umbellata.*

Witch-hazel. See *Hamamelis virginiana.*

Woodbine, wild. See *Gelsemium sempervirens.*

Wood-fern, evergreen. See *Dryopteris marginalis.*

Wood-sorrel, white. See *Oxalis acetosella.*

Wood-violet. See *Viola pedata.*

Worm-grass. See *Spigelia marilandica.*

Wormseed. See *Chenopodium anthelminticum.*

Wormseed, American. See *Chenopodium ambrosioides.*

Wormwood. See *Artemisia absinthium.*

Wormwood, Roman. See *Ambrosia artemisiaefolia.*

Xanthium spinosum L. **Ragweed family (Ambrosiaceae).**

Spiny clotbur; spiny burseed; thorny clotweed; thorny burweed.

An annual weed, 1 to 3 feet high, naturalized from Europe or Asia; in waste ground, Ontario to Florida, westward to Missouri and Texas.

Part used.—Leaves (nonofficial).

Xanthorrhiza apiifolia L'Her. **Crowfoot family (Ranunculaceae).**

Shrub yellowroot; southern yellowroot.

Low, shrubby, indigenous perennial, 1 to 2 feet high, growing in woods and along river banks, southwestern New York to Florida, chiefly in the mountains.

Parts used.—Rhizome and roots (nonofficial).

Xanthoxylum. See *Fagara clava-herculis* and *Xanthoxylum americanum.*

Xanthoxylum americanum Mill. **Rue family (Rutaceae).**

Synonym.—*Xanthoxylum fraxineum* Willd.

Xanthoxylum; northern prickly ash; toothache-tree.

Indigenous shrub or small tree, maximum height about 25 feet; common in woods and thickets and along river banks from Virginia, Missouri, and Nebraska northward to Canada.

Parts used.—Bark of this or of *Fagara clava-herculis* official under the name "Xanthoxylum." Berries (nonofficial).

Xanthoxylum clava-herculis L. Same as *Fagara clava-herculis.*

Xanthoxylum fraxineum Willd. Same as *Xanthoxylum americanum.*

Yam, wild. See *Dioscorea villosa.*

Yarrow. See *Achillea millefolium.*

Yellowroot. See *Coptis trifolia*, *Hydrastis canadensis*, and *Jeffersonia diphylla.*

Yellowroot, shrub. See *Xanthorrhiza apiifolia.*

Yellowroot, southern. See *Xanthorrhiza apiifolia.*

Yellowthorn. See *Fagara clava-herculis.*

Yellowwood. See *Fagara clava-herculis.*

Yerba buena. See *Micromeria chamissonis.*

Yerba reuma. See *Frankenia grandifolia.*

Yerba santa. See *Eriodictyon californicum.*

Youthwort. See *Drosera rotundifolia* and *Heracleum lanatum.*

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 90, PART I.

B. T. GALLOWAY, *Chief of Bureau.*

THE STORAGE AND GERMINATION OF WILD RICE SEED.

BY

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ISSUED SEPTEMBER 7, 1905.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

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THE STORAGE AND GERMINATION OF WILD RICE SEED.[a]

INTRODUCTION.

The seed of wild rice, sometimes called Indian rice or water oats (*Zizania aquatica* L.), has always been a very valuable food among the Indians, especially those of the upper Mississippi Valley. Of recent years wild rice has found a place on the menu cards of some of our best American hotels. The rich and highly nutritious grains, together with the slightly smoky flavor it has when properly prepared, make it an extremely palatable article of diet. If it were not for the difficulties of harvesting the seed and preparing the finished product for market it is probable that wild rice would find a place in many American homes.

At present, however, the greatest interest in wild rice is created by the value of the seed as a food for wild waterfowl, particularly wild ducks. As a result of this interest the propagation of wild rice from seed has become a question of considerable importance, especially to the members of the gunning clubs throughout the United States and Canada.

DISTRIBUTION.

The distribution of wild rice is now reported from New Brunswick and Assiniboia south to Florida, Louisiana, and Texas. There are, however, comparatively few localities in which it grows abundantly.

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[a] Wild rice is considered one of the most important foods for wild ducks and other waterfowl, and a large number of inquiries have been received from members of gunning clubs throughout the United States asking where good, germinable seed can be secured. It is quite generally recognized that wild rice seed loses its vitality if allowed to become dry, and better methods of storing the seed during the winter have long since been demanded.

The results of investigations begun two years ago show that wild rice seed can be handled without any deterioration in vitality if it is harvested and stored according to methods outlined in the present paper.

J. W. T. Duvel, *Acting Botanist in Charge of Seed Laboratory.*

Seed Laboratory,
Washington, D. C., July 20, 1905.

Good reasons exist for assuming that this area can be extended to include all fresh-water lakes, as well as swamps and river bogs, where the water does not become stagnant, throughout the whole of North America south of latitude 55° north. Wild rice also grows luxuriantly along the lower parts of many of the rivers of the Atlantic Coast States, the waters of which are affected by the action of the tide to a considerable degree, and consequently contain an appreciable quantity of salt. It has been shown[a] that the maximum degree of concentration of salt water in which wild rice plants can grow successfully is equivalent to a 0.03 normal solution of sodium chlorid. This concentration corresponds to 0.1755 per cent by weight of sodium chlorid, which is sufficient to give a slight salty taste to the water.

HABITAT.

While it is well recognized that the habitat of the wild rice plant is in shallow fresh water, it is now known that it will grow luxuriantly in water containing little less than two-tenths of 1 per cent of sodium chlorid. Occasional plants have been found growing in water which contained, for short periods at least, nearly double that amount of salt. These facts indicate the possibility of a much wider range of conditions to which this plant may be subjected without hindering its development. It is not beyond the range of possibility—indeed, it is quite probable—that by careful selection plants may be obtained which will thrive on soil that is comparatively dry, at least in places in which the water can be drawn off gradually during the latter part of the growing season.

In September, 1904, Mr. G. C. Worthen, of the Bureau of Plant Industry, collected a cluster of wild rice plants which were growing on the Potomac Flats, near Washington, D. C., in soil which was sufficiently dry to permit the use of a 2-horse mowing machine for cutting down the rank growth of vegetation. This was newly made land, and in all probability the seed giving rise to this cluster of plants was pumped in with the dirt from the Potomac River the year previous.

This amphibious type once established, it will undoubtedly carry with it a strain of seed which can withstand considerable drying without any marked injury to its vitality. Such being true, the methods and difficulties of propagation from seed would be greatly simplified.

Simultaneous with establishing an amphibious type should come the selection of seed plants which are capable of retaining their seed until the larger part of it has reached maturity. These two steps once made, the future of wild rice as a cereal will be assured.

[a] The Salt Water Limits of Wild Rice. Bulletin No. 72, Part II, Bureau of Plant Industry, United States Department of Agriculture, 1905.

GERMINATION OF THE SEED.

The greatest difficulty to be overcome in extending the area for growing wild rice is the poor germination of the commercial seed. Inasmuch as wild rice constitutes one of the most important foods of wild ducks and other wild waterfowl, many individuals and most of the gunning clubs east of the Rocky Mountains have been asking the question, How can we propagate wild rice from seed in order to establish better feeding and fattening grounds for our game birds?

The many failures in the propagation of wild rice from seed have been due to the use of seed that had become dry before sowing, or to the fact that the seed when sown fresh in the autumn had been eaten by ducks or other animals or was carried away by heavy floods before germination took place.

It is now very generally known that the seed of wild rice, if once allowed to become dry, will not germinate, save possibly an occasional grain. In its natural habitat the seed, as soon as mature, falls into the water and sinks into the mud beneath, where it remains during the winter months, germinating the following spring if conditions are favorable.

Heretofore the plan generally followed, and the one usually recommended by those who have given some attention to the propagation of wild rice, was practically that of natural seeding; that is, to gather the seed in the autumn, as soon as thoroughly mature, and, while still fresh, to sow it in 1 to 3 feet of water.

FALL SEEDING VERSUS SPRING SEEDING.

It must be remembered that the bulk of the seed remains dormant during the winter, germinating first the spring after maturing: consequently, with but few exceptions, fall seeding is unsatisfactory and unreliable. Fall seeding is likely to prove a failure for three reasons: (1) Wild ducks and other animals of various kinds eat or destroy the seed in considerable quantity before it has had time to germinate the following spring; (2) much of the seed is frequently covered so deeply with mud that washes in from the shore during the winter that the young plants die of suffocation and starvation before they reach the surface; (3) in some cases a large quantity of the seed is carried away from the place where sown by the high waters and floating ice prevalent during the latter part of the winter and early spring.

In exceptional cases these difficulties can be overcome; under which circumstances autumn sowing may be preferable to spring sowing. In the majority of cases, however, much better results will be obtained if the seed is properly stored and sown in the early spring, as soon as the danger of heavy floods is passed and the water level approaches normal.

In sowing the seed considerable care must be exercised in selecting a suitable place, securing the proper depth of water, etc. Good results can be expected if the seed is sown in from 1 to 3 feet of water which is not too stagnant or too swiftly moving, with a thick layer of soft mud underneath.[a] It is useless to sow wild rice seed on a gravelly bottom or in water where the seed will be constantly disturbed by strong currents.

Previous to this time, save in a few reported cases, the seed which was allowed to dry during the winter and was sown the following spring gave only negative results. It is now definitely known that wild rice, if properly handled, can be stored during the winter without impairing the quality of germination to any appreciable degree, and that it can be sown the following spring or summer with good success.

DIRECTIONS FOR STORING THE SEED.

The vitality of wild rice seed is preserved almost perfectly if kept wet in cold storage—Nature's method of preservation. This method of storage implies that the seed has been properly harvested and cared for up to the time of storage. The seed should be gathered as soon as mature, put loosely into sacks (preferably burlap), and sent at once to the cold-storage rooms. If the wild rice fields are some distance from the cold-storage plant the sacks of seed should be sent by express, and unless prompt delivery can be guaranteed it is not advisable to send by freight even for comparatively short distances. It is very important that the period between the time of harvesting and the time when the seed is put into cold storage be as short as possible. If this time is prolonged to such an extent as to admit of much fermentation or to allow the seed near the outside of the bags to become dry during transit, its vitality will be greatly lowered.

It is not practicable to give any definite length of time which may elapse between harvesting and storing, inasmuch as the temperature, humidity, and general weather conditions, as well as the methods of handling the seed, must be taken into consideration. Let it suffice to say, however, that the vitality of the seed will be the stronger the sooner it is put into cold storage after harvesting.

As soon as the seed is received at the cold-storage plant, while it is still fresh and before fermentation has taken place, it should be put into buckets, open barrels, or vats, covered with fresh water, and placed at once in cold storage. If there is present a considerable quantity of light immature seed or straw, broken sticks, etc., it will be profitable to separate this from the good seed by floating in water

[a] Wild Rice: Its Uses and Propagation. Bulletin No. 50, Bureau of Plant Industry, United States Department of Agriculture, 1903.

preparatory to storing. The storage room should be maintained at a temperature just above freezing—what the storage men usually designate as the "chill room."

When taken from cold storage in the spring the seed must not be allowed to dry out before planting, as a few days' drying will destroy every embryo.

Seed which was stored under the foregoing conditions from October 19, 1903, to November 15, 1904, 393 days, germinated from 80 to 88 per cent. Another lot of seed, which was stored on October 6, 1904, and tested for vitality on April 17, 1905, germinated 79.8 per cent.

Plate I shows the luxuriant growth made by the seed which was kept wet and stored at a temperature of 32° to 34° F. for 393 days.

DETAILED CONDITIONS AND RESULTS OF STORAGE EXPERIMENTS.

The foregoing conclusions are based on the results obtained from two series of experiments, as follows:

In October, 1903, a box of wild rice seed was received from Ontario, Canada. This seed, as soon as gathered, was loosely packed in moist sphagnum and sent by express to the Seed Laboratory of the United States Department of Agriculture. After a few days, while it was yet moist and before any fermentation had taken place, the seed was divided into four lots for special treatment, as follows:

(1) Seed submerged in water and placed in cold storage at a temperature of 32° to 34° F.

(2) Seed submerged in water and placed in cold storage at a temperature of 12° F. The seed was soon embedded in a solid mass of ice and remained so until samples were taken for test.

(3) Seed, without the addition of water, put into cloth bags and kept in cold storage at a temperature of 32° to 34° F.

(4) Seed, without the addition of water, put into cloth bags and kept in cold storage at a temperature of 12° F.

In October, 1904, a second consignment of seed was received from Minnesota, and the following additional storage experiments were made by Mr. C. S. Scofield, of the Bureau of Plant Industry.

(5) Seed submerged in water and placed in cold storage at a temperature of 32° to 34° F., as in No. 1.

(6) Seed submerged in water and placed in cold storage at a temperature of 12° F., as in No. 2.

(7) Seed submerged in water in a galvanized-iron bucket and stored on the roof of the laboratory building. The water was changed daily when not frozen.

(8) Seed submerged in water in a galvanized-iron bucket and stored on the roof of the laboratory building, as in No. 7. In this case the water was not changed save to replace the loss due to evaporation.

(9) The conditions for No. 9 were the same as those for No. 8, except that air was forced into the water daily when not frozen solid.

Samples of seed were taken from the different lots and tested for vitality at irregular intervals throughout the time of storage, which, in the former series, extended over a period approximately thirteen months and in the latter series over a period of little more than six months.

Experiments Nos. 1 and 5.—The seed which was submerged in water and stored in the "chill room" showed no deterioration in vitality. The results of the final tests gave a germination varying from 79.8 to 88 per cent. This is practically Nature's method of preserving the vitality of the seed during the winter.

Experiments Nos. 2 and 6.—The seed which was submerged in water and stored at a temperature of 12° F. was all killed before the spring following the date of storage. Soon after being placed in storage the water was frozen solid and the seeds were embedded in a mass of ice, in which condition they remained throughout the experiment, a portion being cut out from time to time for germination tests. The complete loss of vitality in these two lots of seed is attributed not to the freezing directly, but to the thorough desiccation as a result of the continuous low temperature.

Experiments Nos. 3 and 4.—The samples of seed which were stored in cloth bags at the temperatures of 32° to 34° F. and of 12° F. had, for all economic purposes, entirely lost their vitality. The average percentage of germination, as shown by the 37 tests made from each of the two lots, was less than five-tenths of 1 per cent.

Experiment No. 7.—The seed which was submerged in water and stored on the roof of the laboratory building, the water being changed daily, showed a good percentage of germination when the last vitality tests were made. If only a small quantity of seed is desired for the spring planting and cold storage can not be readily secured, good results may be obtained by this treatment; but it is much less certain and probably more expensive than keeping the seed in cold storage, and for this reason is not recommended. The success of this method will likewise depend largely on the temperature of the water.

Experiments Nos. 8 and 9.—On April 22, 1905, samples taken from each of these two lots of seed showed a marked deterioration in vitality. Thoroughly mixed samples from No. 8 showed a vitality of only 58 per cent, while No. 9 had deteriorated to 14.3 per cent.

PACKING FOR TRANSPORTATION.

Too much care can not be given to the matter of packing the seed for transportation, for unless the packing is properly done the vitality of the seed will be destroyed during transit. What is here said applies to fresh seed which is to be sown in the autumn, as well as to seed which has been kept in cold storage during the winter. It must not be forgotten, however, that the vitality of cold-storage seed is more quickly destroyed on drying than that of fresh seed.

For transportation the seed should be carefully packed, with moist sphagnum, cocoanut fiber, or fine excelsior, in a loosely slatted box. If the time of transportation does not exceed five or six days no special precautions need be taken as to the temperature. During the period of transportation it is quite probable that some of the seed will germinate, but if sown at once growth will not be retarded and the roots will soon penetrate the soil and anchor the young plants.

If the time of transportation is necessarily long, it is recommended, if the best results are desired, that some provision be made for a reduced temperature. The nearer the temperature approaches that of freezing the better. It has been demonstrated, however, that a fair percentage of seed will remain germinable for a considerable time if packed as above described.

On October 10, 1904, Mr. C. S. Scofield sent a small quantity of wild rice, packed in moist sphagnum moss in a well-ventilated box, to Doctor De Vries, of Amsterdam, Holland. On October 14 or 15 this box was placed in cold storage on the steamer in New York Harbor. The box of seed was received by Doctor De Vries in good condition on November 2, twenty-one days after the seed was packed for shipment.

METHODS OF MAKING GERMINATION TESTS.

The samples were tested (1) between folds of blotting paper—our regular method for testing the germination of most seeds—and (2) in water, Nature's method of sowing wild rice seed. The latter method gave much better results and was the one finally adopted for the laboratory tests. The seed should be covered with water, the water in the dishes to be changed daily.

Plate I shows the importance of making the germination tests in water, as described in the foregoing paragraph. The seed was covered with water and placed in a germinating chamber maintained at an alternating temperature of 20° C. (68° F.) for eighteen hours, and 30° C. (84° F.) for six hours, until the majority of the seeds had germinated. At this stage the dish containing the seeds was transferred to the worktable, which was exposed to the temperature of the laboratory—approximately that of a living-room. The water in the dish was changed daily during the period of germination, and water was afterwards added at irregular intervals to replace the loss by evaporation.

Plate II shows somewhat in detail the different stages in the germination of wild rice seeds. The seeds and seedlings are shown in natural size. In *b* and *c* the first sheath has just burst through the seed coats, taking a position at right angles to the seed proper. The lateral roots begin to emerge when the first sheath leaf has attained a length of ½ to 1½ inches. From this time growth continues rapidly, and by the time the seedlings are 2 or 3 inches long the root system is very well developed (*f* and *g*). At this stage under favorable conditions the plants have a good hold in the soil and will not be washed away by an ordinary freshet. The relative position of the actively growing seedling is always at right angles to that of the old seed, as shown in *f* and *g*.

EFFECT OF TEMPERATURE ON GERMINATION.

Germination tests were made at constant and alternating temperatures, ranging from 15° to 35° C. (59° to 95° F.). While no effort was made to show the minimum and maximum temperatures of germination, the percentage was somewhat reduced at a constant temperature of 35° C., and the maximum is not much above that. All of the other temperatures gave good results. The lower temperatures, however, were slightly more favorable than the higher. These facts are valuable to show that the wild rice plant can thrive in either warm or cold water, but better, perhaps, in northern than in southern latitudes.

SUMMARY.

(1) Under no circumstances should wild rice seed which is intended for planting be allowed to dry. Dried seed will germinate but rarely and should never be sown.

(2) Wild rice seed can be stored without deterioration if it is gathered as soon as matured, put into barrels or tanks, covered with fresh water, and, before fermentation has set in, stored at a temperature of 32–34° F. Seed treated in this way germinated as high as 88 per cent after being in storage 393 days. Fresh seed seldom germinates better, and usually not so well.

(3) After the seed is taken from cold storage it should not be allowed to dry. The vitality of cold-storage seed is destroyed on drying even more quickly than that of fresh seed.

(4) For transportation the seed should be packed in moist sphagnum, cocoanut fiber, or fine excelsior. If not more than five or six days are required for transit, no special precautions need be taken for controlling the temperature; but if the time for transportation exceeds

six days, provision should be made for a temperature sufficiently low to prevent marked fermentation. A temperature approximately freezing will give the most satisfactory results.

(5) Wild rice can be sown either in the autumn or in the spring. Spring sowing is preferable, thus avoiding the danger of having the seed eaten or destroyed by wild ducks or other animals during the fall or winter, or of its being buried or washed away by the heavy floods of late winter or early spring.

(6) Wild rice should be sown in the spring in from 1 to 3 feet of water which is neither too stagnant nor too swiftly moving, as soon as the danger of heavy floods is passed.

(7) Wild rice is of the greatest importance as a food for wild waterfowl, likewise a delicious breakfast food for man, and the area in which it is extensively grown should be extended. It will grow luxuriantly in either warm or cold water; furthermore, it can be grown successfully in water which is slightly salty to the taste.

(8) In determining the vitality of any sample of wild rice seed the germination tests should be made in water—the condition under which the self-sown seed germinates.

(9) The seed will germinate well at temperatures ranging from 15° to 30° C. The maximum temperature of germination is above 35° C. (95° F.), but better results are obtained at lower temperatures.

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PLATES.

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DESCRIPTION OF PLATES.

PLATE I. Wild rice growing in water. This seed was submerged at a temperature of 32–34° F. for approximately thirteen months. In making the germination test the seed was covered with water and placed in a germinating chamber maintained at a temperature of 20° C. (68° F.) for eighteen hours, and at 30° C. (86° F.) for six hours. After the majority of the seeds had germinated the dish was transferred to the worktable of the Seed Laboratory.

PLATE II. Progressive stages in the development of wild rice seedlings; *f* and *g*, seedlings showing the relative position of the growing seedlings and the parent seed, which take a position at right angles to each other when grown normally in water. (Natural size.)

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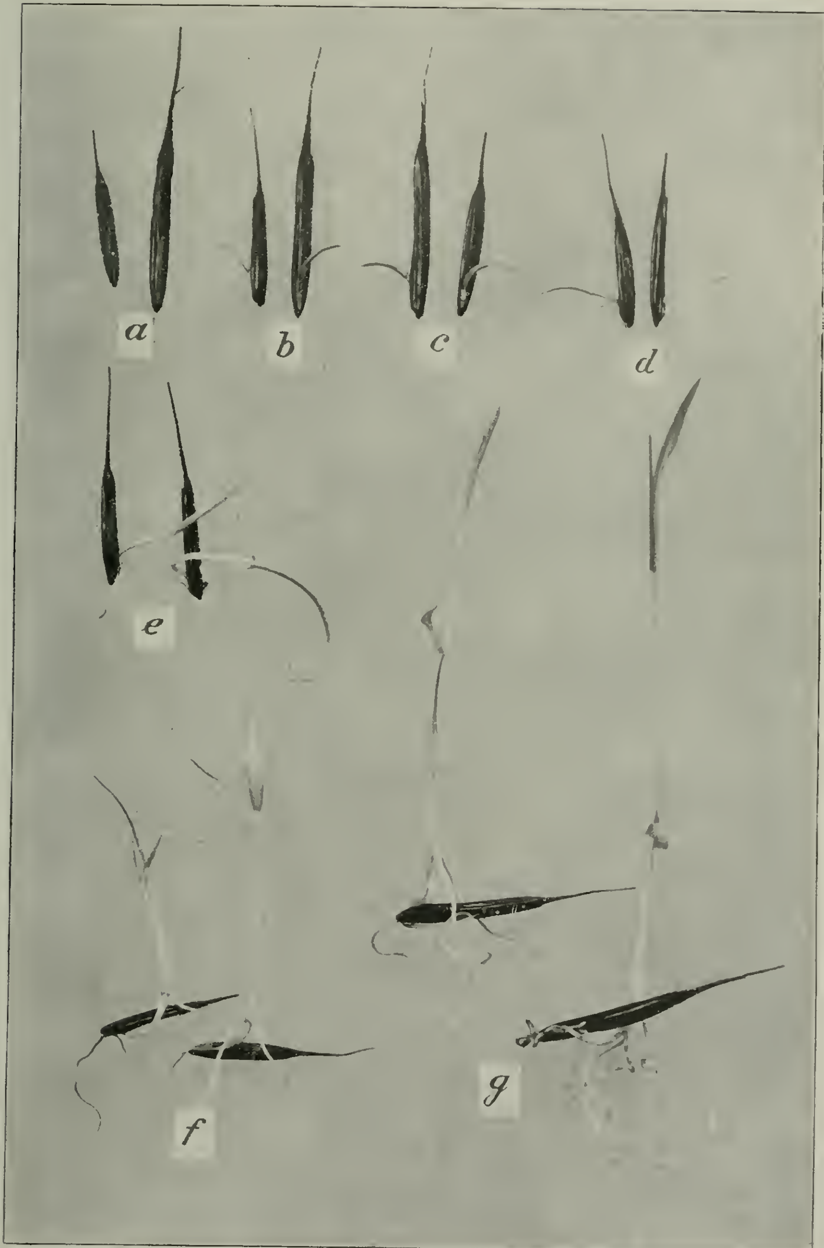
WILD RICE GROWING IN WATER AFTER BEING KEPT WET IN COLD STORAGE AT A TEMPERATURE OF 32-34° F., FROM OCTOBER 19, 1903, TO NOVEMBER 15, 1904.



STAGES OF GERMINATION OF WILD RICE, SHOWING THE DEVELOPMENT OF THE ROOT SYSTEM AND THE RELATIVE POSITION OF THE SEEDLING AND THE PARENT SEED. NATURAL SIZE.

U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 90, PART II.
B. T. GALLOWAY, *Chief of Bureau.*

THE CROWN-GALL AND HAIRY-ROOT DISEASES OF THE APPLE TREE.

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ISSUED NOVEMBER 17, 1905.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

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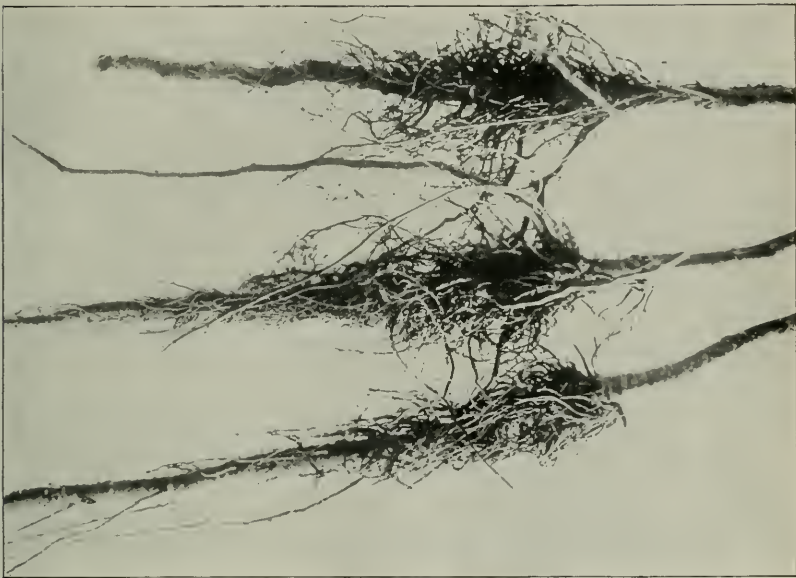

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THE CROWN-GALL AND HAIRY-ROOT DISEASES OF THE APPLE TREE.

INTRODUCTION.

The diseases of the apple which have been classed under the name crown-gall have, during the last few years, attracted much attention, due partly to an increase of these diseases and partly to the enacting of more stringent State laws governing the shipment and inspection of trees.

A series of investigations into the nature of crown-gall upon the apple, pear, raspberry, peach, almond, grape, rose, and other plants has been in progress for some time in the Mississippi Valley Laboratory of the Bureau of Plant Industry at St. Louis, Mo., and also at other points in the Mississippi Valley. It is not to be assumed, however, that such diseases are more common in this locality than in some other portions of the United States. Apple crown-gall and hairy-root have been found in all nurseries that have been examined in various portions of the country.

This preliminary report is sent out, not with the intention of giving the results of all our investigations, but for the purpose of calling the attention of apple-tree growers to the different diseases hitherto known as apple crown-gall, and to endeavor to interest them in the collection of data regarding the predisposition of varieties to these diseases.

TWO DISTINCT DISEASES, CROWN-GALL AND HAIRY-ROOT.

Our investigations have resulted first in separating apple crown-gall into two diseases, which are considered distinct. The disease now designated as crown-gall is a callous-like gall growth of hypertrophied tissue following wounds on some portion of the root system of the tree, which rarely occurs above the ground on parts of the trunk or limbs. (See Pl. I, figs. 1 and 2.)

The malady now called the hairy-root disease is evidently the same as the one first given this name by Stewart, Rolfs, and Hall in Bulletin 191 of the New York State Experiment Station. It is characterized both in seedlings (Pl. II, fig. 1, and Pl. III, fig. 2) and in grafted or budded trees (Pl. I, figs. 3 and 4) by a stunted root system, accompanied with an excessive production of small fibrous roots, often originating in clusters from the main root, or taproot. Galls often occur in connection with hairy-root, but these are a result of wounds rather than a form of this disease. Seedlings of the hairy-root type, unless wounded, remain free from galls.

TYPES OF APPLE CROWN-GALL.

Apple crown-gall is of two types. A hard callous form is common on grafted trees at the union of the root and scion, and at any other point of the root system where wounds occur in either the cultivation or transplanting of trees (Pl. I, fig. 1). The results of extensive inoculations with this type have failed to prove that this disease is of a contagious nature.

A second type is a soft form more common on seedlings (Pl. II, fig. 2), occurring more rarely on grafted trees (Pl. I, fig. 2). These softer galls resemble those of the raspberry and peach, in that they are soft and often rot off. It is not certain, however, that they, like the latter, are replaced the following year by a new gall growth from the adjacent live tissues of the host, nor is there proof yet that they are of a contagious nature.

EFFECT UPON THE LENGTH OF LIFE OF THE APPLE TREE.

Careful data are being collected from orchards and nurseries as to the effect of these diseases upon the life and fruitfulness of trees. Any information as to the locality of orchards in which diseased trees have been planted will be highly appreciated. In our crown-gall orchard there are more than 200 trees diseased with the hard type of crown-gall, and 200 healthy trees of the same grade planted under similar conditions. After two years' growth six of the crown-gall trees and nine of the healthy ones have died. No difference in the growth of the trees is noticeable. However, it can not be assumed from the results so far that, on the one hand, the disease may not yet shorten the life of the trees, or, on the other, that the trees may not entirely overcome its effects. A tree having crown-gall on its roots, however, can never be correctly graded with a smooth-rooted tree. The root system of a healthy fibrous-rooted apple tree is shown in Plate III, figure 1.

SUGGESTIONS TO NURSERYMEN.

Nurserymen are advised to be careful in the selection of seedlings for grafting and budding. All rough, warty, or galled seedlings should be thrown out, for most of them will form rough-rooted trees. Seedlings with tufted or hairy roots should also be rejected, for these, as shown by our experiments, develop into hairy-rooted trees with a very deficient root system. The hairy-root disease, as it appears from the results of two years' experiments, is not contagious. It is hoped in the near future to be able to offer some practical means of reducing the percentage of trees affected with these diseases in the nursery.

DATA DESIRED.

The hearty cooperation of nurserymen and orchardists in securing data is desired. It is hoped to secure the help of the leading nurserymen of this country in getting an accurate count from each nursery of the number of diseased trees in at least one row of every variety in all fields where the trees are all dug in one season. Such data are desired from every locality where apple trees are grown. Printed blanks with directions for tabulating such data have been provided and these will be sent to all who request them. Address the Mississippi Valley Laboratory, St. Louis, Mo.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 90, PART III.

B. T. GALLOWAY, *Chief of Bureau.*

PEPPERMINT.

BY

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ISSUED DECEMBER 28, 1905.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1905.

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PEPPERMINT.[a]

DESCRIPTION.

One of the most important essential oils produced in the United States is distilled from the peppermint plant and its varieties. The three kinds of mint grown in this country for the distillation of peppermint oil are the so-called American mint (*Mentha piperita* L.), the black mint (*Mentha piperita vulgaris* Sole), and the white mint (*Mentha piperita officinalis* Sole), the two last named being varieties of the American mint.

The American mint, although introduced from England many years ago, is so called from the fact that it has long been cultivated in this country, and the name "State mint" has been applied to it in the State of New York for the same reason.

The peppermint, or American mint, is now naturalized in many parts of the eastern United States, occurring in wet soil from the New England States to Minnesota, south to Florida and Tennessee. It is an aromatic perennial belonging to the mint family (Menthaceæ), and propagates by means of its long, running roots (fig. 1). The smooth, square stems are erect and branching, from 1 to 3 feet in height, bearing dark-green, lance-shaped leaves, which are from 1 to 2 inches long, and from one-half to 1 inch wide. The leaves are pointed at the apex, rounded or narrowed at the base, sharply toothed, smooth on both sides, or with hairy veins on the lower surface. The flowers are borne in whorls in dense, terminal spikes; they are purplish, with a tubular, five-toothed calyx, and a four-lobed corolla. (Fig. 2.)

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[a] In response to a steady demand for information relating to the peppermint industry, Miss Alice Henkel, Assistant in Drug-Plant Investigations, has been requested to bring together the most important facts regarding the history, culture, and utilization of the peppermint plant. The information here presented has been obtained in large part from scattered articles on the subject, and in part from experience with the plant in the Testing Gardens of the Department of Agriculture.

RODNEY H. TRUE, *Physiologist in Charge.*

OFFICE OF DRUG-PLANT INVESTIGATIONS,

Washington, D. C., October 14, 1905.

The two varieties mentioned are closely related botanically, although in general appearance they are quite different. The variety known as black mint (*Mentha piperita vulgaris*) has purple stems and slightly toothed, dark-green leaves, while the white mint (*Mentha piperita officinalis*) has green stems, with brighter green leaves, which are more lance-shaped and more deeply toothed. Black mint is much more hardy and productive than either the American mint or the white mint, and is grown on nearly all peppermint farms in this country. The white mint, which produces a fine grade of oil, is rarely cultivated on a commercial scale in this country on account of its inability to withstand the climate and its smaller yield of essential oil.

FIG. 1.—Peppermint "runners," showing method of propagation.

The oils spoken of as Japanese and Chinese "peppermint" oils are not obtained from the true peppermint plant, but are distilled from entirely different species, namely, *Mentha arvensis piperascens* Malinvaud and *Mentha arvensis glabrata* Holmes, respectively.

COUNTRIES WHERE GROWN.

The most important peppermint-producing countries are the United States, England, and Japan. Peppermint is grown on a smaller scale in Germany, France, Italy, Russia, China, and southern India.

In Japan, peppermint cultivation is said to have been undertaken before the Christian era. The plant grown there is not, as already stated, the peppermint cultivated in our country, but *Mentha arvensis piperascens*, which is entirely dis-

FIG. 2.—Leaves and flowering top of peppermint.

tinct from the true peppermint, not only botanically but also in taste and odor.

Peppermint is cultivated on many drug farms in England, especially at Mitcham, the middle of the eighteenth century marking the beginning of peppermint cultivation in that country. Up to 1805, however, there were no stills at Mitcham, and the crops obtained there were sent to London for distillation. About 1850, at which time the peppermint industry in England was at its height, the effect of American competition began to be felt, and caused a decided check in the production.

PEPPERMINT CULTIVATION IN THE UNITED STATES.

Wayne County, N. Y., in 1816, was the first locality in this country to distill peppermint on a commercial scale. The supply of rootstocks was obtained from the wild plants found growing along the banks of streams and brooks. Adjacent counties soon undertook the cultivation of peppermint, but Wayne County was then, and is now, the principal peppermint district in New York.

The cultivation of peppermint was extended to Ashtabula, Geauga, and Cuyahoga counties in Ohio, and also to northern Indiana. Roots were taken from Ohio into St. Joseph County, Mich., the first plantation being made on Pigeon prairie in 1835. Other plantations in St. Joseph County were established the following years, and adjoining counties soon took up the cultivation of peppermint, and southwestern Michigan has been for thirty-five years or more the greatest peppermint-producing section in the United States.

About 1844 an interesting peppermint-oil monopoly[a] was undertaken by a New York firm, which seems to have put an end to peppermint cultivation in Ohio, for none of the counties just mentioned has since been heard from as a peppermint-producing section.

The first step taken by this New York firm in its efforts to control the peppermint-oil market was to send a representative to Liverpool, England, to ascertain the amount annually demanded by that market, which was found to be about 12,000 pounds. This done, another agent was sent West to determine the amount produced annually, with the result that it was found that the farms in New York did not produce enough oil for their purposes, the plantations in Ohio too much, while those in Michigan seemed to produce just about the right amount to satisfy the Liverpool demand. A contract was then entered into by this agent with the producers in New York and Ohio "whereby he bound them under heavy penalties to plow up their mint fields and destroy the roots, and not plant any more mint, or sell or give away any roots, or produce or sell any mint oil for the

[a] Proc. Amer. Pharm. Assoc., 7: 449–459 (1858).

period of five years." For this wholesale destruction of their mint fields the producers received a bonus of \$1.50 per acre. Next a contract was made by the agent with the producers of St. Joseph County, Mich., agreeing to pay them \$2.50 a pound for their mint oil, every ounce of the mint oil to be delivered for a period of five years to the agents named in the contract. They also were prohibited during this period from extending their plantations and from selling roots to anyone. The producers held to these contracts for about three years, after which period the New York firm was not so anxious to enforce them, having, in the meantime, acquired a large fortune through its peppermint-oil monopoly.

Since that period the area devoted to peppermint cultivation in Michigan has steadily increased, and northern Indiana, with its principal centers of production in St. Joseph, Steuben, and La Grange counties, continues to place on the market a considerable quantity of oil. Ohio seems to have abandoned peppermint cultivation, at least on a commercial scale, and New York, for a number of years and until very recently, had greatly reduced the area under peppermint, thousands of acres formerly devoted to this crop having been given over to sugar beets, onions, and celery. In 1889 Wayne County, N. Y., had 3,325 acres of peppermint, whereas in 1899 there were only 300 acres. In 1905, about 933 acres were under cultivation.

Special canvassers appointed by the State of Michigan[a] made a canvass of 299 growers in the peppermint district in that State, covering 39 townships in nine counties (Allegan, Berrien, Branch, Cass, Kalamazoo, Oakland, St. Joseph, St. Clair, and Van Buren), and the total number of acres under peppermint cultivation, the number of pounds of oil distilled, and the average number of pounds per acre, as ascertained by this canvass, for the years 1900, 1901, and 1902, are as follows:

Items.	1900.	1901.	1902.
Total number of acres grown	2,112	2,782¼	6,400¾
Total number of pounds distilled	47,628½	63,718¾	82,420¼
Average number of pounds per acre	22.5	23.9	12.8

CULTIVATION.

Peppermint cultivation is most profitable on muck lands, such as are now used in Michigan for this crop and for celery and cranberry culture. These muck lands were formerly marshes and swamps, which have been reclaimed by draining, plowing, and cultivating, the swamp vegetation having been thus subdued, and the decayed

[a] Twentieth Annual Report of the Bureau of Labor of the State of Michigan, 1903, pp. 438–447.

vegetable matter resulting in a very black soil which is most admirably adapted to mint cultivation. Formerly peppermint was grown exclusively on upland soil in Michigan, but it is a very exhausting crop on such land. Only two crops can be obtained from upland plantations, and after the second year's harvest the land is plowed and a rotation of clover, corn, etc., is practiced for five years before peppermint is again planted. But on the rich muck land peppermint can be grown year after year for six or seven years, the land being plowed up after each crop is harvested, and the runners turned under to form a new growth the succeeding year. The ground is harrowed in autumn and again in spring, and carefully weeded. Peppermint will grow, however, on any land that will produce good crops of corn, the ground being prepared by deep plowing and harrowing.

In Michigan[a] the land is plowed in the autumn, and early in spring it is harrowed and marked with furrows about 3 feet apart. The roots selected for planting are from one-eighth to one-quarter of an inch thick, and from 1 to 3 feet long; and the workmen engaged in "setting mint," as the process is called, carry these roots in sacks across their shoulders and place them in the furrows by hand, covering the roots with one foot and stepping on them with the other. The roots are planted so close together in the furrow as to form a continuous line. An expert workman can plant about an acre in a day.

In about two weeks the young plants will make their appearance, and are carefully hoed and cultivated until July and August, when the plants have usually sent out so many runners as to make further cultivation difficult. The crop is cultivated with horse cultivators, but if the land was very weedy in the first place, the weeds will have to be pulled by hand. It is very necessary that the land be free from weeds, as any collected with the peppermint crop will seriously injure the quality of the oil.

It may be interesting to note here that on muck lands, when necessary, the horses are usually provided with mud shoes to prevent their sinking into the soft, wet ground, these mud shoes consisting of wide pieces of iron or wood about 9 by 10 inches, fastened to the hoofs and ordinary shoes by means of bolts and straps.

CONDITIONS INJURIOUS TO CROP.

Cold and wet weather or extremely dry periods have a very unfavorable effect on the mint crop. Insect enemies also tend to cut down the mint harvest—grasshoppers, crickets, and cutworms sometimes doing considerable damage. A rust, causing the foliage to drop off

[a] Twentieth Annual Report of the Bureau of Labor of the State of Michigan, 1903, pp. 438–447.

and leaving the stems almost bare, is apt to follow if very moist weather occurs toward the latter part of the season. Weeds are especially to be avoided in a mint field, since, as stated, the quality of the oil will be seriously impaired if these are harvested with the peppermint. The weeds generally found in a peppermint field are Canada fleabane (*Leptilon canadense*), fireweed (*Erechtites hieracifolia*), giant ragweed (*Ambrosia trifida*), pennyroyal (*Hedeoma pulegioides*), Eaton's grass (*Eatonia pennsylvanica*), June grass (*Poa pratensis*), and other low grasses.

HARVESTING AND DISTILLATION.

The first crop of mint is harvested in the latter part of August, when the plants are in full flower, and the gathering continues until about the middle of September, the stills running night and day until all the mint is disposed of. The first crop is usually cut with a scythe, as mowing machines do not work well on soft cultivated land. The succeeding crops are cut with a mowing machine or sweep-rake reaper. The highest yield per acre and the best quality of oil are obtained from the first year's crop. Sometimes, if the weather conditions have been very favorable, a second cutting is made. The yield of oil from peppermint obtained from the same field sometimes varies very much, the condition of the atmosphere seeming to exert an influence upon it, as it is said that mint cut after a warm and humid night will yield more oil than that cut after a cool and dry night. It requires about 330 pounds of dried peppermint to produce 1 pound of oil, and the yield of oil from an acre ranges from 12 to 50 pounds.

If the mint crop has been grown on muck land, all that is necessary after the crop has been harvested is to plow up the land and turn the runners under for a new crop. If grown on upland, after the second year's crop is in, or, at the most, after the third year's harvest, the land is plowed and then given up to other crops. Peppermint exhausts the land, and it is necessary to practice rotation of crops for about five years in order to put the land in condition if it is desired to use it again for peppermint cultivation.

After the plants are cut they are usually placed in windrows until they are dried, but are not allowed to become so dry as to permit the leaves to shatter off, and are then taken to the distillery. Some growers believe that if the plants are allowed to dry there will be a smaller oil content owing to the escape of some of the oil into the atmosphere, and so have the plants brought to the distillery in the green state; but Mr. A. M. Todd[a] is of the opinion that no loss of oil will result

[a] Amer. Jour. Pharm., 60: 328–332 (1888).

from drying, his experiments along this line showing that the dry plants can be distilled three times as rapidly as the green plants, and that a larger quantity of oil may be obtained. He states that—

> To obtain the best results, both as to quality of essential oil and economy of transportation and distillation, the plants should be dried as thoroughly as possible without endangering the loss of the leaves in handling. Distillation should then take place as soon as convenient to prevent the oxidation of the oil in the leaf by atmospheric action.

The smaller producers, who have no stills of their own, have their mint crop hauled to the nearest peppermint distillery, where it is distilled for them at a cost of 25 cents per pound of oil.

DESCRIPTION OF STILL.

The apparatus used in peppermint distillation in the early years of the industry in this country consisted of a copper kettle, from the top of which a pipe connected with a condensing "worm." Water was placed in the kettle and the plants were immersed in it, and direct heat was applied to the bottom from a furnace. With such a still only about 15 pounds of oil could be obtained from a charge. In 1846, large wooden vats were substituted for the copper kettles, and the plants were distilled by steam passing through them. The kettle formerly used as the still was now employed to generate steam, a long pipe conveying the steam to the bottom of the vats. With this method of distillation from 75 to 100 pounds of oil could be obtained from a charge without much additional expense.

A modern peppermint still (fig. 3) may be briefly described as follows: The apparatus required consists of a boiler, a pair of large circular wooden vats, a condenser, and a receiver. The boiler, of course, is used for the generation of steam.

Two wooden vats are used in order that they may be filled and emptied alternately. These vats are about 6 feet high and about 5 feet in diameter, with tight-fitting removable covers and perforated false bottoms. Steam pipes are led from the boiler into the bottom of the vats.

The condenser consists of a series of pipes of block tin, either immersed in tanks of cold water or over which cold water is kept running, the condenser being connected with the top of the distilling vats. The condensed steam, together with the oil, flows into a metallic receiver, in which the oil, being lighter than the water, rises to the top and can be drawn off.

The perforated false bottoms with which the vats are supplied permit the passage of steam. A strong iron hoop is placed about this false bottom, and two pairs of stout chains, which meet at the top of the vat in a pair of rings, are attached to it. After the charge has been distilled it is drawn from the vats by means of this arrangement.

The plants are thrown into the vats and are closely packed by two or three men tramping upon them, and as the vat becomes about one-third full the packing is still further assisted by turning in a small supply of steam, which softens the plants. When the vat is filled the tight cover is replaced and a full head of steam turned on. In the largest distilleries the vats have a capacity of from 2,000 to 3,000 pounds of dried plants each.

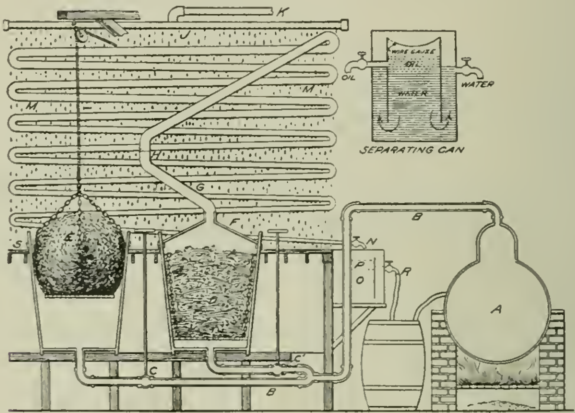

FIG. 3.—Peppermint still. (After Dewey, in Bailey's Cyclopedia of American Horticulture.)

A, boiler; *B*, steam pipes leading to vats; *C*, valves for shutting off steam; *D*, mint packed in vat ready for distilling; *E*, mint being lowered into vat; *F*, tight-fitting cover used alternately for both vats; *G*, pipe from top of vat, joined at *H* so as to swing to other vat; *J*, perforated pipe, from which cold water drops over condensing tubes; *K*, supply pipe for cold water; *M*, condensing pipes; *N*, outlet for condensed oil and water; *O* and *P*, water and oil in separating can; *R*, outlet for water; *S*, floor of distilling room.

Large tanks are used for storing the oil, and cans holding 20 pounds each are employed for shipping, three of these cans being placed in a wooden case.

The peppermint hay which remains after distillation is used as a fertilizer or is fed to stock.

PEPPERMINT OIL AND MENTHOL.

Peppermint leaves and flowering tops are official in the Eighth Decennial Revision of the United States Pharmacopœia, as are likewise the following products and preparations derived from these parts: Oil of peppermint, menthol, spirit of peppermint, and peppermint water.

The United States Pharmacopœia describes oil of peppermint as "a colorless liquid, having the characteristic strong odor of peppermint and a strongly aromatic pungent taste, followed by a sensation of cold when air is drawn into the mouth." It is largely used in medicine, internally as a stimulant and carminative, and externally to relieve neuralgic and rheumatic conditions. It is also used for flavoring and scenting confectionery, cordials, and cosmetics. There is a slight difference in the odor of white and black peppermint oil, the black being more pungent and less agreeable in fragrance than the white, which has a much finer odor, but, as already indicated, the white mint is less hardy than the black and yields a smaller quantity of oil.

The Japanese oil of peppermint, which, as pointed out elsewhere in these pages, is obtained from a different species of mint than that which produces the true oil of peppermint, is very inferior to the last named. It has a very unpleasant odor and a bitter, disagreeable taste, but it is a heavy oil and contains a higher percentage of menthol and, being a very much cheaper oil, it is liable to be used as an adulterant of true peppermint oil.

Menthol, formerly known as peppermint camphor, is the solid constituent of oil of peppermint, obtained by subjecting the distilled oil to an exceedingly low temperature by means of a freezing mixture. Its properties are about the same as those of oil of peppermint, only somewhat intensified. It is very largely made up into cones or pencils, which furnish a popular remedy, to be applied externally or inhaled, for the relief of headache, neuralgia, catarrh, asthma, and kindred affections. It is also largely employed in other forms of medication. The name "pipmenthol" has been applied to the menthol obtained from the American oil, to distinguish it from the Japanese menthol. Pipmenthol is said to have a distinct odor of peppermint, while the Japanese menthol has but a slight peppermint odor.

EXPORT OF PEPPERMINT OIL.

The exports of peppermint oil during the fiscal year ended June 30, 1904, amounted to 42,939 pounds, valued at $124,728. Germany and the United Kingdom were the largest consumers, the former receiving 22,372 pounds, valued at $65,505, and the latter 11,558 pounds, worth $31,798.

The following tables show the export of peppermint oil, by countries, for the fiscal year ended June 30, 1904, and the quantities and values of peppermint oil exported for a period of ten years, from July 1, 1894, to June 30, 1904, inclusive:

Exports of peppermint oil, by countries, for the fiscal year ended June 30, 1904.[a]

Country.	Quantity.	Value.
	Pounds.	
Belgium	473	$1,585
France	3,054	10,059
Germany	22,372	65,505
Italy	826	2,471
Netherlands	590	1,934
United Kingdom	11,558	31,798
Dominion of Canada:		
Nova Scotia, New Brunswick, etc	85	234
Quebec, Ontario, Manitoba, etc	1,165	3,306
Newfoundland and Labrador	94	204
West Indies:		
British	183	700
Cuba	29	87
Danish	17	55
Dutch	20	61
Argentina	1,237	3,504
British Guiana	10	31
Peru	50	175
British Australasia	1,176	3,019
Total	42,939	124,728

[a] The Foreign Commerce and Navigation of the United States for the year ending June 30, 1904, vol. 1, p. 531, Bureau of Statistics, Department of Commerce and Labor.

Quantities and values of peppermint oil exported during the fiscal years 1895 to 1904, inclusive.[a]

Fiscal year.	Quantity.	Value.	Fiscal year.	Quantity.	Value.
	Pounds.			*Pounds.*	
1895	87,633	$194,616	1900	89,558	$90,298
1896	85,290	174,810	1901	60,166	63,672
1897	162,492	257,484	1902	36,301	54,898
1898	145,375	180,811	1903	13,033	34,943
1899	117,462	118,227	1904	42,939	124,728

[a] From The Foreign Commerce and Navigation of the United States for the year ending June 30, 1902, vol. 2, p. 309, Bureau of Statistics, Treasury Department; and The Foreign Commerce and Navigation of the United States for the year ending June 30, 1904, vol. 1, p. 192, Bureau of Statistics, Department of Commerce and Labor.

PRICES OF PEPPERMINT OIL.

The price of peppermint oil was very low for a few years prior to 1900, the enormous production of 1897 resulting in a great drop in price. The lowest price paid for it was in 1899, when it brought only 75 cents per pound. As a result of the low price a great many mint farmers restricted the area of their mint plantations or altogether abandoned peppermint cultivation. The smaller output of the following seasons again sent prices up, and in 1902 the oil sold as high as $4.75 a pound, which price was maintained until early in 1903, when it gradually declined, until toward the end of that year it reached $2.20 per pound.

The following table[a] gives the highest and lowest prices of peppermint oil in bulk from 1873 to September 16, 1905:

Year.	Highest.	Lowest.	Year.	Highest.	Lowest.	Year.	Highest.	Lowest.
1873	$3.15	$3.15	1884	$3.00	$2.50	1895	$2.00	$1.70
1874	5.25	3.75	1885	4.37	2.75	1896	1.85	1.20
1875	5.50	3.20	1886	3.60	2.75	1897	1.25	.90
1876	3.75	2.40	1887	2.75	1.90	1898	.90	.80
1877	3.00	1.75	1888	2.40	1.75	1899	.90	.75
1878	2.00	1.50	1889	2.30	1.80	1900	1.10	.80
1879	2.65	1.45	1890	2.40	1.80	1901	1.80	1.10
1880	2.87	2.60	1891	2.50	2.45	1902	4.75	1.70
1881	2.85	2.35	1892	2.50	2.15	1903	4.75	2.20
1882	2.50	2.25	1893	2.45	2.15	1904	3.75	2.65
1883	2.60	2.20	1894	2.45	1.70	1905*	3.45	2.25

* To September 16.

The good prices of the past few years have caused many farmers to look again to peppermint as a profitable crop, as noted in increased areas under cultivation in many localities. This is the case not only in Michigan and Indiana, but also in New York, where for many years the peppermint industry has been declining. Thus, if favorable conditions of growth prevail, an increased production may be looked for within the next few years, which will have the effect of again depressing prices.

As is the case with other products the prices of which are subject to great fluctuations, the condition of the market for peppermint oil needs to be closely observed. The cost of cultivation per acre has been stated at from $12 to $14, and, with a charge of 25 cents per pound of oil for distillation, the market price may easily fall below the cost of production.

[a] From Oil, Paint, and Drug Reporter, September 18, 1905, p. 7.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 90. PART IV.
B. T. GALLOWAY, *Chief of Bureau.*

THE POISONOUS ACTION OF JOHNSON GRASS.

BY

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ISSUED JANUARY 17, 1906.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1906.

THE POISONOUS ACTION OF JOHNSON GRASS.[1]

Johnson grass, which was introduced from Turkey into this country about 1830,[2] has spread so that in many places it is considered as a weed and pest.[3] Some farmers, however, have utilized the dried grass as hay with advantage, either alone or combined with other food material,[4] and chemical analyses have proved its value as feed. Recently reports have come to this office from California of the death of cattle under such circumstances as to point to Johnson grass as the causative agent—the cattle dying in thirty minutes after eating the grass. Johnson grass belongs to the same genus of the Gramineae as sorghum. This group has been partially investigated chemically, and it has been found that the fresh green plants of various members yield hydrocyanic

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[1] This office has from time to time received communications from stockmen, especially in the lower part of California, Arizona, and adjacent territory, expressing a suspicion that the eating of Johnson grass had caused the death of stock with rather sudden and violent symptoms. There has seemed to be little ground in poisonous-plant literature to support such an explanation. Last summer, however, convincing observations were reported from California by a stockman who had lost heavily, and a supply of the grass in question was obtained. The result of the study of this material was so positive, and the possibility of damage due to this unsuspected forage plant so clear, that this preliminary notice is put out in the hope of getting observations and material for study from many sources, in order, if possible, to determine the conditions under which the poisonous properties are developed and over how wide an area they are likely to appear.

RODNEY H. TRUE, *Physiologist.*

OFFICE OF POISONOUS PLANT INVESTIGATIONS,
Washington, D. C., December 11, 1905.

[2] Ball, C. R. Johnson Grass. Bul. No. 11, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1902.

[3] Spillman, W. J. Extermination of Johnson Grass. Bul. No. 72, Part III, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1905.

[4] North Carolina Agr. Expt. Sta. Bul. 97, p. 92.

Vasey, G. Grasses of the South. Bul. No. 3, Division of Botany, U. S. Dept. of Agriculture, 1887.

Report of the Commissioner of Agriculture for 1881, pp. 231, 232, 239, 241; Report of the Secretary of Agriculture, 1890, p. 381.

acid as a result of the action of enzymes on more highly complex bodies.[1]

Ball[2] in 1902 stated that at that time there had been no official reports to his office of cases of poisoning by Johnson grass, but that there were some newspaper statements to that effect. He thought these accounts were probably not authentic, but stated that "since Johnson grass is closely related to sorghum, which is known to be poisonous under some circumstances, it would not be surprising if Johnson grass should also be poisonous under like conditions. * * * In comparison with the great number of cattle fed or pastured in Johnson grass, the reported cases of poisoning are extremely rare."

The first report of the poisonous action of Johnson grass which reached the Department came from Miles City, Mont. Mr. William Story reported that he and a neighbor had lost several head of cattle after they had eaten small quantities of the grass, and that they had died very suddenly. Mr. Story suggested that there was "something peculiarly poisonous about the grass." The Commissioner of Agriculture in publishing this report stated that "although the grass has been cultivated in the South for forty or fifty years, no similar charges have been made against it."[3]

In India this plant is widely used as a fodder for cattle,[4] and the natives make use of the seeds for food. It has been noted there that deaths in cattle frequently occur when, on account of the failure of rain, the plants which have reached a certain size become stunted and withered. The toxic principle appears simultaneously over a wide area, but soon disappears if a rainfall occurs.[5] The deaths of cattle have been attributed by some to an insect living upon the plant, and in Australia it is the belief that *Sorghum vulgare*, which also yields hydrocyanic acid, becomes more poisonous when attacked by an insect during a drought. A similar observation has been made with *Sorghum vulgare* in the Sudan. Balfour[6] found that one specimen of the plant

[1] Dunstan, W. R., and Henry, T. A. The Nature and Origin of the Poison of Lotus Arabicus. Phil. Trans. Roy. Soc. London, 1901, vol. 194, B., p. 515.

Dunstan, W. R., and Henry, T. A. Cyanogenesis in Plants. Phil. Trans. Roy. Soc. London, 1902, vol. 199, A., p. 399.

Slade, Henry B. Prussic Acid in Sorghum. Jour. Amer. Chem. Soc., 1903, vol. 25, pp. 55–59.

Slade, Henry B. Study of the Enzymes of Green Sorghum. Fifteenth Ann. Report, Agr. Expt. Sta. of Nebraska, 1902, pp. 55–62.

Brünnich, J. C. Hydrocyanic Acid in Fodder-plants. Jour. Chem. Soc., 1903, vol. 83, part 2, pp. 788–796.

[2] Loc. cit., p. 23.

[3] Report of the Commissioner of Agriculture, 1885, p. 71.

[4] Duthie, J. F. Fodder Grasses of Northern India, 1888, p. 41.

[5] Pease, H. T. Poisoning of Cattle by Andropogon Sorghum. Jour. Compar. Med. and Vet. Arch., vol. 18, 1897, p. 679. See also Agr. Ledger, 1896, No. 24.

[6] Balfour, Andrew. Cyanogenesis in Sorghum Vulgare. First Report, Wellcome Research Laboratory, at Gordon Mem. College, Khartum, 1904, p. 47.

which harbored aphids yielded more hydrocyanic acid than a second one without parasites. Pease has lately claimed that the deaths from Johnson grass in India were really cases of nitrate poisoning, as he found 25 per cent of nitrate of potassium in the stem of the plant and was able to produce somewhat similar symptoms in animals by feeding them this salt. Johnson grass is being introduced into Australia as a fodder plant, but as yet no reports of its poisonous action there have been noted by the writer.[1]

There has been some chemical study of Johnson grass, but not with reference to any poisonous principle.[2]

A fresh, green, mature, nonflowering specimen of Johnson grass, moistened with a little water and preserved with chloroform, was sent from Santa Rosa, Cal., in sealed glass vessels, to this laboratory. This was botanically identified here as Johnson grass. This specimen was not immediately worked up, but remained in the jars for about a month. At that time on opening the jars a marked odor of hydrocyanic acid, together with that of chloroform, was detected. The ground-up plant, with the water in which it came, was distilled, and the distillate was caught in sodium hydrate solution. This distillate, on mixing with ferrous sulphate and acidulation with hydrochloric acid, gave a heavy blue precipitate with ferric chlorid. Yellow ammonium sulphid was added to the same filtrate, and the mixture was evaporated to dryness on the bath. The dried residue was then taken in hydrochloric acid water, and on the addition of ferric chlorid the fluid gave the characteristic red reaction for hydrocyanic acid. The nitro-prussid, picric acid, and silver nitrate reactions were all positive for hydrocyanic acid. The aqueous fluid in which the plant was shipped was filtered off from the plant and gave on distillation all the above reactions for hydrocyanic acid.

According to our California correspondent, this plant is poisonous when grown on irrigated as well as on nonirrigated lands, but especially so when grown on irrigated soil and the growth has become rank.

Recently Dunstan[3] has shown that Lima beans (*Phaseolus lunatus*), which when grown wild in Mauritius yield sufficient hydrocyanic acid to produce poisoning, when cultivated in Burma lose this toxicity almost entirely, although it may return most unexpectedly.[4] He was unable, however, to determine the condition which increased its poisonous properties.

[1] Maiden, J. H. Useful Australian Plants. Dept. Agr. New South Wales, Misc. Pub. No. 22, 1896.

[2] Annual Report of the Commissioner of Agriculture, 1878, p. 168.

[3] Dunstan, W. R. Phaseolus Lunatus. Agr. Ledger, 1905, No. 2.

[4] Church, A. H. Food-Grains of India. 1886, p. 155.

Watt, George. Dictionary of the Economic Products of India, vol. 6, part 1, 1892, p. 187.

It is interesting to note, besides this production of hydrocyanic acid from complex glucosids, that proteids, when subjected to oxidation under certain conditions, also yield it.[1] In fact, hydrocyanic acid may exist in plants in two forms, either as the acid or as one of its salts, or in the form of complex glucosids.[2] Under the circumstances, the conclusions of Brünnich[3] should be held in mind, viz, that "all fodder plants related to sorghum must be used with discretion in either the green or the dried state, and should not be given in large amounts to animals which have fasted for some time."

In reference to other forage plants, Avery[4] says that "Kafir-corn leaves also contain this poison, but other forage plants—clover, alfalfa, grasses, and corn—give no test for prussic acid," and Brünnich also found it in Guinea grass or *Panicum maximum* and *P. muticum*. Many facts have been collected relative to the distribution of hydrocyanic acid in plants, yet its exact significance in their metabolism is unknown.[5] The question as to the relationship of parasites[6] to the production of hydrocyanic acid remains to be solved.

Later investigations will be carried on to determine the nature of this cyanogenetic compound, to determine whether hydrocyanic acid is present in all stages of its growth, but disappears on drying the plant, whether the hydrocyanic acid production occurs under all conditions or only when grown on certain soils, and the amount produced. Hydrocyanic acid will also be looked for in other members of this genus.

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[1] Plummer, R. H. A. The Formation of Prussic Acid by the Oxidation of Albumins. Jour. Physiol., vol. 31, 1904, p. 65; vol. 32, 1904, p. 50.

[2] Les Nouveaux Remèdes, vol. 14, 1898, p. 272.

[3] Loc. cit., p. 792.

[4] Avery, S. Laboratory Notes on Poison in Sorghum. Jour. Compar. Med. and Vet. Arch., vol. 23, 1902, p. 705.

[5] Czapek, F. Biochemie d. Pflanzen, 1905, vol. 2, p. 259.

[6] Literature on some parasites of the sorghum family can be found in Bot. Gaz., vol. 28, 1899, p. 65. Also in Busse, W., Untersuch. u. d. Krank. der Sorghum Hirse, Arb. a. d. biol. Abtheil. f. Land u. Forstw. am kaiserl. Gesundheitsamt, 1904, vol. 4.

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