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.

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VALLEY AT SECANQUIM, ALTA VERA PAZ, GUATEMALA, THE SCENE OF EXPERIMENTS WITH WEEVIL-RESISTING COTTON.

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B. T. GALLOWAY,

Pathologist and Physiologist, and Chief of Bureau.

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INVESTIGATIONS IN THE AGRICULTURAL ECONOMY OF TROPICAL AND SUBTROPICAL PLANTS.

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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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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 Linnæus 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.

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[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

[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.

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[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 Retalhulen 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-

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[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

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[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 for 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

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[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

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[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.

[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

[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 "canch 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.

PLATES.

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.)

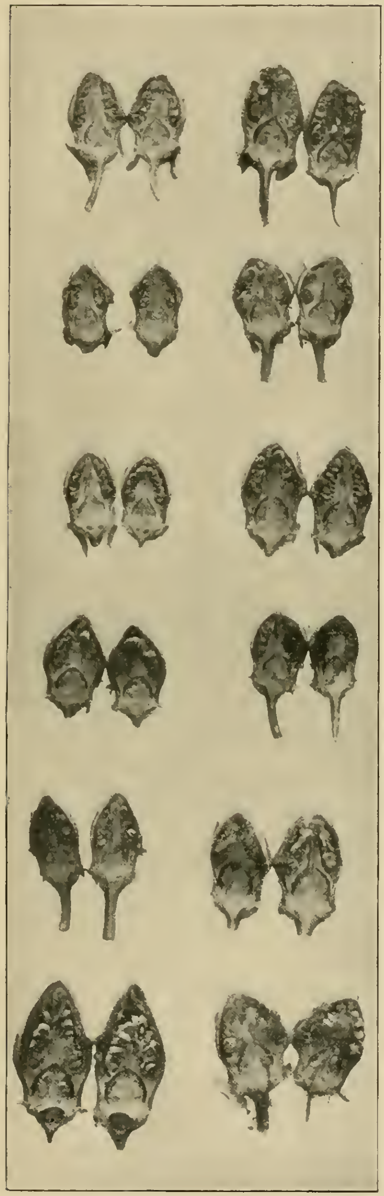


FIG. 1.—YOUNG BUDS OF KEKCHI COTTON WITH WEEVIL PUNCTURES.

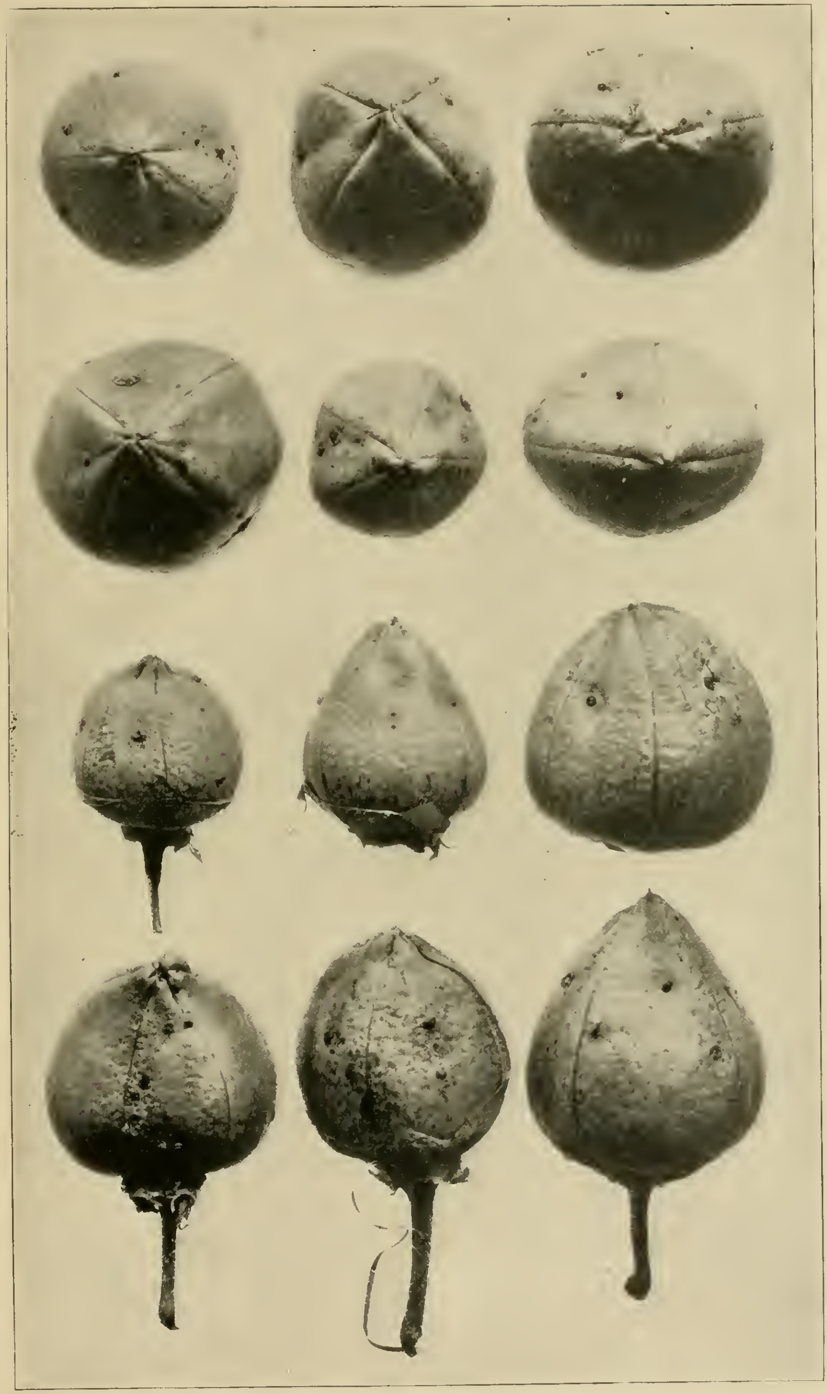
(Natural size.)

FIG. 2.—BUDS OF KEKCHI COTTON WITH PROLIFERATION.

(Natural size.)

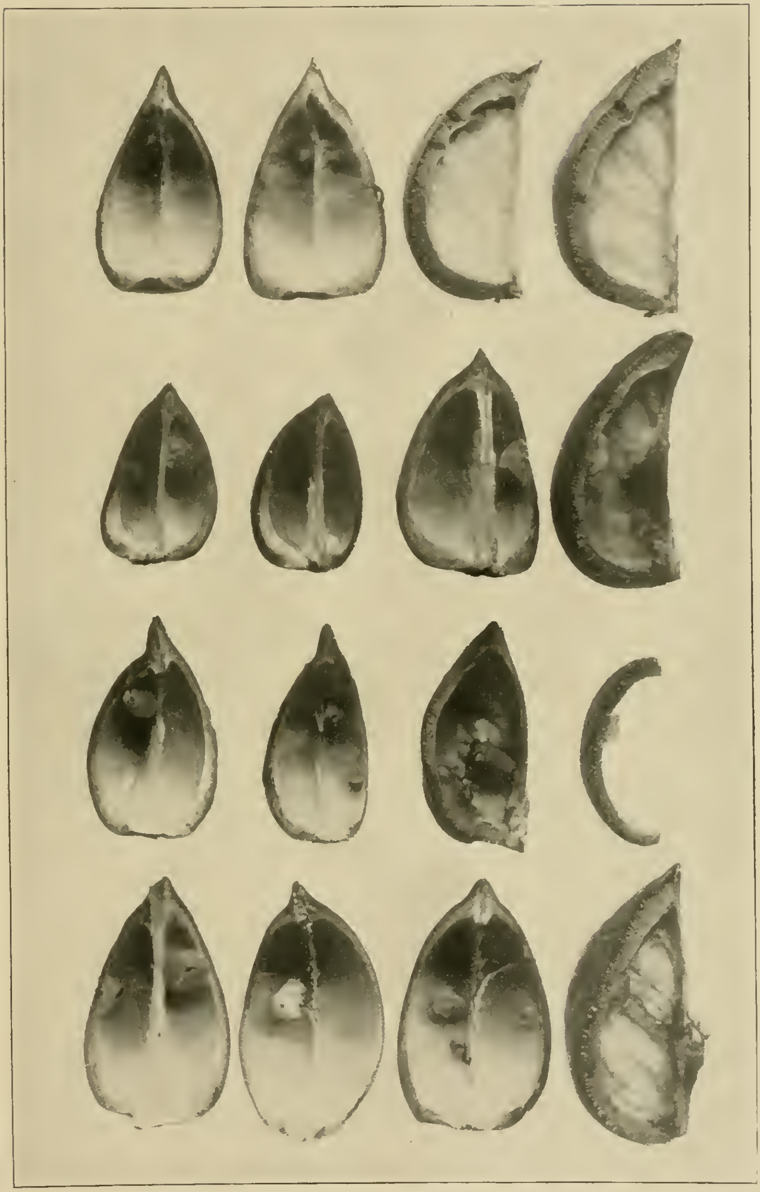
LARGE BUDS OF KEKCHI COTTON WITH PROLIFERATION.

(Natural size.)



WEEVIL-INFESTED BOLLS OF KEKCHI COTTON.

(Natural size.)



CARPELS OF KEKCHI COTTON, SHOWING PROLIFERATION.

(Natural size.)

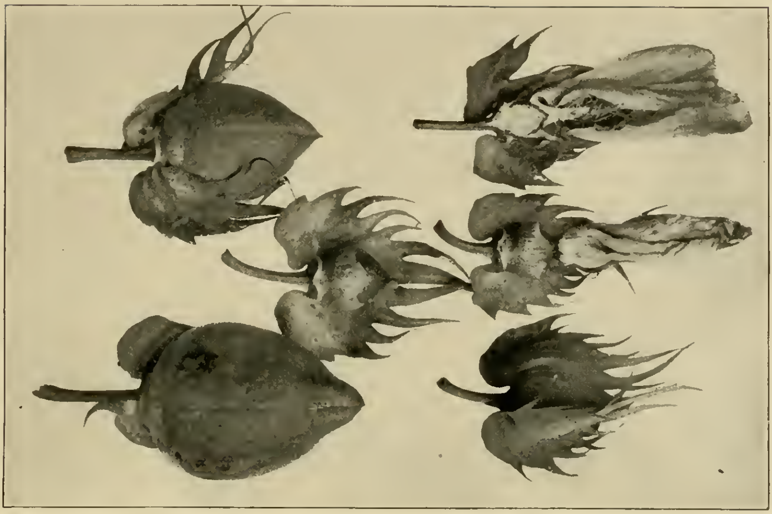


FIG. 1.—KEKCHI COTTON, SUCCESSIVE STAGES OF THE BOLL.

(Reduced.)

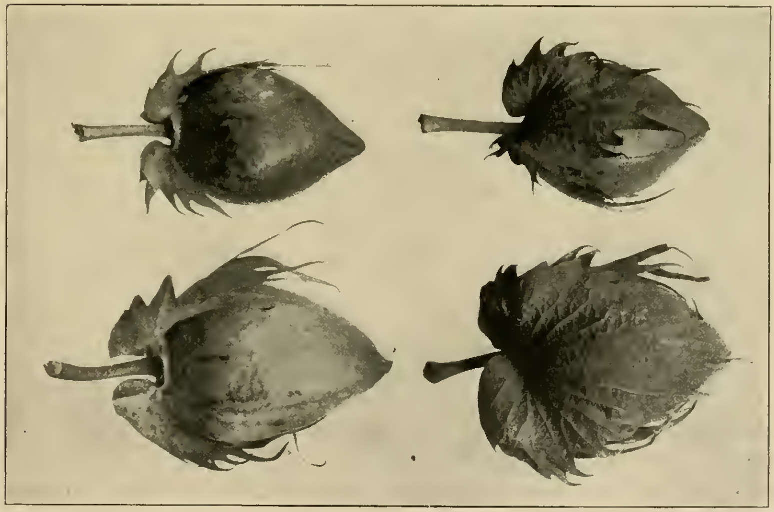


FIG. 2.—KEKCHI COTTON BOLLS (RIGHT) COMPARED WITH KING BOLLS (LEFT).

(Reduced.)

FIG. 1.—RABINAL COTTON WITH BOLLS.

(Reduced.)

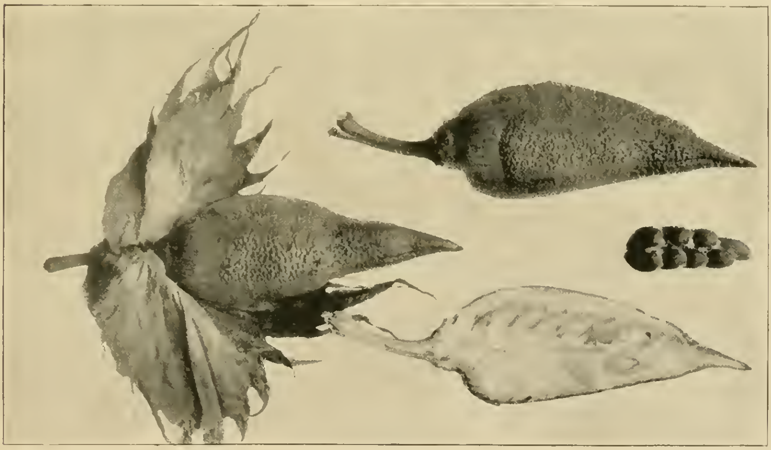


FIG. 2.—BOLLS AND SEEDS OF KIDNEY COTTON.

(Reduced.)

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