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PRINCIPLES OF AGRONOMY

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THE PRINCIPLES OF AGRONOMY

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THE PRINCIPLES OF AGRONOMY

A TEXT-BOOK OF CROP PRODUCTION FOR HIGH-SCHOOLS AND SHORT-COURSES IN AGRICULTURAL COLLEGES

BY

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PREFACE

Agricultural instruction in the high-school has extended so rapidly within the last few years that the demand for suitable text-books has become insistent. The variation in the teaching in different schools is so great that several texts are required. Some high-schools give but one year in agriculture, while others give four.

This book is designed for schools giving more than one course in agriculture; its study should probably precede instruction in horticulture or animal husbandry. A knowledge of botany and chemistry, although not presupposed, will assist in a better understanding of some, perhaps all, of the chapters.

Although written primarily for a text-book, the discussion ought to be useful to the practical farmer who will find treated in non-technical language the principles underlying many of his practices.

Those wishing more information will find help in the list of supplementary readings at the end of each chapter. A complete list of references has not been given; only the most accessible publications are mentioned. Constant reference has been made to the Cyclopedia of American Agriculture by L. H. Bailey, to Farmers' Bulletins of the United States Department of Agriculture, and to a number of standard works on each subject, all of which should be in the library of every school where agriculture is taught. Very few references have been made to state experiment station publications, since many of them are not available.

The teaching of agriculture is valuable only as it is made practical. It is suggested, therefore, that students work in the laboratory and field as much as possible in order to become directly familiar with soils, crops, and applications of principles instead of relying solely upon what the text says about them.

The authors are indebted to a number of their colleagues at the Utah Agricultural College for encouragement and friendly criticism during the preparation of this book. They are under special obligation to President J. A. Widtsoe, Director E. D. Ball, Professor N. A. Pederson, and Messrs. A. F. Bracken, C. L. Anderson, and N. I. Butt, all of whom have read the manuscript and offered valuable suggestions.

FRANKLIN S. HARRIS,
GEORGE STEWART.

LOGAN, UTAH,
May 1, 1915.

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THE PRINCIPLES OF AGRONOMY

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CHAPTER I

INTRODUCTORY

AGRICULTURE is so broad in its scope and practice, that it is related to almost every branch of human learning. All the industries and professions of man are in some way connected with the land and its products. The welfare of manufacturer, merchant, railroad man, lawyer, and doctor is so dependent on agricultural prosperity that these men are necessarily interested in this great subject. Since agriculture embraces such a wide field, it is necessary to define and subdivide, in order to obtain a clear idea of its various branches.

1. What is agriculture? — Agriculture may be defined as the art, the science, and the business of producing plants and animals for economic purposes.

As an art, it embraces a knowledge of the way to perform the operations of the farm in a skillful manner, but does not necessarily include an understanding of the principles underlying farm practices. The ability to plow well, to make a good stack of hay, and to handle live-stock indicates training in the handicrafts of agriculture.

The science of agriculture deals with the principles underlying the production of plants and animals, without regard to skill in the practices of farming. A person may understand the methods by which hay is digested in the stomach of a cow, and how milk is secreted; he may be familiar with the composition of milk and the processes it undergoes in the manufacture of butter or cheese; and still he may not know how even to milk a cow. He has training in the underlying scientific principles of agriculture, but not in the art or handicraft.

Agriculture is a business, since it is practiced primarily as a means of securing a living. Usually a farmer is not interested in the art and science of agriculture except as they contribute to his making a better livelihood. Science helps him to understand why he does certain things, and gives him a foundation for his practices; he acquires skill in the practices in order to increase production and, through it, to extend his income.

2. Agriculture and the sciences. — The assertion is sometimes made that if a person were familiar with all the sciences, he would not need to study agriculture. This is probably true, but no one person is able to master all the sciences; even if he were able to do so, he would need to learn some of the applications of science to the land before finishing his studies of pure science.

The real condition, however, is that those who have most to do with the land have little time for extensive study of science, although they desire a brief knowledge of some of the principles underlying the industry in which they are engaged. This justifies the teaching of agriculture even to those who have had little training in the so-called pure sciences. The better one understands the natural and social sciences, however, the better will one be able to comprehend the principles and problems of agriculture.

3. Agriculture and the industries. — Agriculture is at the very foundation of all industries. Manufacturing, mining, and commerce are dependent on the products of the soil for their existence; indeed, the very life of man himself would be impossible if the soil did not directly or indirectly yield him food. The advance of civilization and the development of industrial enterprises are limited by the agricultural conditions of the world. Agriculture, instead of being a problem merely for those engaged directly in its practice, is a world problem affecting all the activities of man. It is evident, therefore, that it merits serious consideration.

The farm, in addition to being a place where a great industry is conducted, is a home for those engaged in this industry. It should, therefore, be considered not entirely from the point of view of economic efficiency, but of social efficiency also, as the home of that part of the coming generation which will probably have most to do with the future welfare of the nation. Agriculture, as a consequence, has social and educational aspects quite as important as its scientific and economic phases.

4. Opportunities in agriculture are varied. — The most important opportunities are those connected with the work on the land in its various phases. Never in history has the land called with a louder voice than at present, for young men of intelligence, industry, and training. There are opportunities on every hand for him who knows how to use the forces of nature, and who can secure joy and satisfaction in being a direct producer.

Other phases of agriculture, such as teaching it in the schools, engaging in demonstration and experimental work for the states and the government, and working as an expert adviser for corporations, are assuming greater importance every year, and offer good opportunities to young men of ability and training.

5. Division of agriculture. — Agriculture may be subdivided in many ways. It may be classed as intensive or extensive, specialized or diversified, exploitive or restorative, tropical or temperate; or it may be divided according to the source of income. For instructional purposes in agricultural colleges, it has often been divided into three main parts: agronomy, animal husbandry, and horticulture.

The subject of agronomy has usually included a study of soils, field crops, and farm management. Under animal husbandry, the various phases of the live-stock industry, including dairying, have been studied. The study of horticulture has included the production of fruits, vegetables, and flowers.

In addition to these three applied divisions, there are also a number of scientific divisions, such as entomology, chemistry, and plant and animal pathology. Each of these bears a relation to all three of the applied divisions. It is difficult, therefore, to find a subdivision of agriculture that is logical and at the same time entirely practical, since the different branches are so closely interrelated.

6. Phases of agronomy. — The present volume deals with that phase of agriculture sometimes called agronomy. The meaning of this word is not widely known outside of the schools, and even there it is used somewhat loosely. It comes from two Greek words meaning "the use of fields." At present, it is usually understood to mean the management of the land in the production of field crops. It is sometimes divided into three distinct phases: soils, crops, and farm management. The term "agronomy" may be applied to any one of these branches.

7. Scope of this book. — To give the beginner in agricultural study a general idea of the principles of successful production of crops, and to furnish him a basis for study in the other branches of agriculture, is the object of the present volume.

Part I discusses the principles of plant growth, and will be of service to students who later take up horticulture as well as to those studying agronomy. In Part II, a study is made of the soil and its management. This part is likewise fundamental to horticulture as well as to agronomy. Part III is devoted entirely to the study of field crops; and in Part IV, numbers of problems relating to field management are discussed. Some of these also apply to other phases of agriculture.

PART I

THE PLANT

CHAPTER II

THE PLANT AND ITS ENVIRONMENT

On every side are evidences that plants bear more or less definite relations to the nature of their surroundings. An environment that favors one crop may prevent the culture of another. Tropical plants do not thrive in temperate or frigid zones; neither do lilies grow in deserts, nor roses on barren cliffs.

Great forests spread for hundreds of miles over certain sections; wide grassy plains stretched almost endlessly east of the Rockies before settlement; valleys in the West were covered with sagebrush, except for patches of willows or cottonwood along the streams, or for rushes and sedges in the sloughs. In many sections scrub oak covers the foothills; groves of quaking aspens line the swales in the mountains; pines and spruces cover the shady sides of higher ridges. This grouping has not come by chance. Colonies of plants grow up only where conditions are so favorable to the particular plant that others are crowded out.

Farmers plow and harrow because plants grow better in tilled soils. They apply irrigation water and manure to aid plant growth. Weeds are removed that the crop may have more room. The plant as well as the physical conditions in which it lives deserves attention in this respect.

8. Factors of plant growth. — In general, there are six factors which must be favorable in order for plants to make the best growth. These are: (1) a home, or place in which to find lodging and support, (2) water, (3) heat, (4) light, (5) oxygen, and (6) plant-food. The general environment determines the character of the vegetation (Figs. 1–3).

Fine soil is the medium of growth for agricultural plants, though some species flourish in water or on rock. The quantity of available water determines the kind of plant that may grow in a given spot and the degree of development it may attain. A proper degree of warmth is essential to germination and to growth. Most plants require sunlight, though a few do better in the shade. All living cells must have oxygen in order to carry on their functions. Lack of air in over-wet soils kills some plants. Certain soils lack mineral plant-food in a soluble condition and, therefore, produce poor yields if not fertilized. Carbon dioxide, a gaseous plant-food, comes from the air.

Of these six factors, man can control but two: (1) the water supply of soils, and (2) the plant-food available. As regards a given spot, man can do little that will influence heat, light, oxygen, and depth or texture of soil. His method of control in respect to these depends on his power to change his place of abode and, by so doing, to select a district having desirable climate and soil. Length of season and daily temperature, together with the kind of soil, determine the degree of warmth. Clear or cloudy weather regulates the sunshine and light. Rainfall and winds supplemented by irrigation, drainage, and tillage are the factors controlling the water supply. The fineness, depth, uniformity, and fertility of the soil measure both the plant-food and the opportunity for root development.

Fig. 1. — Effect of environment on the distribution of vegetation in the bottom of a canyon.

Cropping systems aid materially in causing plants to respond properly, while the plant is the subject on which these forces interact.

Insects, rodents, weeds, and plant diseases are pests to be reckoned with in crop production. They are nuisances, and as such are counted negative or hindering factors.

9. Length of season. — Of the factors controlling the distribution of crops in the United States, length of season is one of the most powerful. Between the Gulf of Mexico and Canada are several well-marked belts of production. Of course, no single factor alone accounts for this. Although moisture, soil, and daily range of temperature count for much, they cannot overcome the injurious effect of a short growing-season that causes crops from the South to fail when moved into the North. That wheat, oats, and barley have shorter periods of growth than potatoes and corn is well known. Cotton requires seven or eight months without a frost, while barley or rye can get on with a season having only two or four months between frosts. Oranges and bananas are not grown save in semi-tropical climates where the growing-season lasts almost the whole year. Coconuts are produced only in tropical regions; corn extends over a rather broad area, from the tropics well into the temperate zones. This power of adaptability comes largely from the power of corn to adjust itself to shorter growing-seasons. By the selection of early-maturing plants, corn-growing has gradually extended well up toward the Canadian boundary. All crops have some power of changing the time of growth to suit the seasons of a new district into which they are carried. A crop that thrives under certain conditions will usually grow under others less favorable. Cotton and cowpeas are confined almost entirely to the section of the United States south of the thirty-seventh degree of latitude. Timothy and red clover are widely grown north of this parallel, but not in the South. Potatoes are grown in every state, but profitable potato-growing is limited to the states in the North; corn does best in the central part. The question of seasonal adaptability is one of profitable production rather than of successful growth. Although corn grows well north and south of the "corn belt," other crops pay better at the extremes and they replace it. In the intermediate regions, corn is the most profitable crop to grow. It is not so much that one crop does not pay, as that another pays better. Economical problems enter into agriculture and disturb our survey of crop response. An examination of the areas in which a crop is grown extensively will show the general boundaries of climate and soil that cause one crop to supplant another.

Abbe[1] estimates that variations in climate over areas of 100 square miles have never caused more than a 50 per cent fluctuation in crop yields, and not over 5 per cent for the whole United States. Though in moving a crop from one section to another length of season counts for much, very little can be attributed to it in a given section. This is largely due to the tendency of a climate to vary little when long periods are considered. Occasionally, however, abnormal seasons occur and crops that have done well are killed by untimely frosts. Tender plants, if not killed, are nipped and retarded in growth.

10. Frost. — Many succulent plants, such as corn and melons, are frost-bitten when the temperature drop is but slightly below freezing. Hardy crops like rye, barley, and wheat are not readily injured even by rather sharp

[1] Weather Bureau Bul. 36, p. 364.

frosts. Alfalfa and potatoes droop after a slight frost, but grass and wheat show no sign of injury. Many orchardists, maintaining that it is not the frost but sudden thawing that kills fruit buds, choose land that slopes away from the morning sun in order to avoid immediate thawing; but this is probably an error. Large bodies of water hold latent heat; breezes prevent cold air from settling in one spot; large running streams seem to carry away the cold air. At any rate, frosts are less likely to occur in sections with good air drainage.

When stems or buds freeze, water is drawn out of the cells into the spaces between and there frozen. Sometimes a sudden drop in temperature will freeze the whole plant just as it is. Death from freezing is the result of the withdrawal of water from the plasma membrane to form ice crystals. When extremely severe, frosts may rupture the bark, exposing wood. Frozen plants have a wilted or blighted appearance as if injured by excessive drouth or heat. A day or so after a frost, the injured leaves look as though they had been scorched by a fire that was too close.

Records of a district for a number of years show about how late in the spring and how early in autumn frosts may be expected. These will vary some, but, as already pointed out, not so widely as to prevent a new settler from anticipating what crops will mature; provided, of course, that he knows how long the crop requires and how hardy it is. General farm practice in the locality will gradually readjust itself to meet climatic demands. Farmers in established districts do not go far wrong in regard to time of planting and choice of crops.

11. Temperature. — After length of season, daily range of temperature is the chief consideration affecting

Fig. 2. — Type of vegetation found on a rocky hillside.

heat supply. Days are practically as warm in the Great Lakes region or in the Great Basin as they are at New Orleans, but only for a few hours. Mornings, evenings, and nights are much cooler, whereas in the South nights as well as days keep warm. Many plants are sensitive to a lowering of temperature even though it remains several degrees above freezing. On this account, daily fluctuations are of considerable importance.

Some evidence seems to indicate that total heat found by multiplying the temperature by the length of the season determines the growth of some plants. Duggar[1] cites one case in which yields of date palms increased with the total heat. Fall and spring wheat seem to use about the same quantity of heat for ripening. Spring grain has a shorter but warmer growing period.

As elevation increases, temperature decreases. Going from low to higher land is nearly equivalent to moving northward or southward from the equator. High mountains in the tropics show all gradations of vegetation found in passing from tropical to arctic regions. Many peaks near the equator are covered with perpetual snow. Aside from the temperature change produced, increased elevations seem to have little influence on plant growth if soil and moisture relations are equally favorable.

12. Water. — Every person at all familiar with plants has noticed the effect of abundant moisture on them. How green the foothills are in early spring, and how brown they become in summer after extended periods of drouth. When lawns begin to lose their uniform green color, they need water. A hose is essential to a good lawn almost everywhere. House-plants must be watered frequently; greenhouse plants are usually sprinkled in order to keep

[1] Duggar, *Plant Physiology*, p. 406.

the air as well as the soil moist. Outdoors, particularly in arid regions, plants require water. When rains are infrequent, irrigation is practiced wherever water is to be had at reasonable expense.

Hunt [1] cites an Illinois record of the influence of water on the yield. One year when the rainfall during the growing-season was 13 inches, the yield of corn was 32 bushels an acre; the next season with $22\frac{1}{2}$ inches gave 94 bushels. The same land was used in both instances and other conditions seemed equal. Green growth continues in moist glades after higher lands have become dry. Too much water, however, fills up the soil spaces and shuts out the air necessary to plant roots. Very wet soils are fatal to many plants, but others do not thrive unless almost immersed in water. Cresses and seaweeds are examples of water-loving plants. Some crops, such as rice, cane, cranberries, and redtop, do best in soaked soils. On the other hand, alfalfa and the potato suffer quickly from standing water. Neither, however, is a drouth-lover, though long roots enable alfalfa to be drouth-resistant. Cacti, some grasses, and many weeds are able to endure extremely hot, dry weather for long periods. All plants, then, must have water in varying quantities. Cultivated plants, in general, require moderate amounts.

Since either too little or too much moisture injures ordinary crops, irrigation is practiced to supplement the rainfall when it is insufficient for profitable yields, and drains are laid to remove excess water from the soil. So important has irrigation become in dry sections, that immense reservoirs, long canals, expensive diversion dams, and tunnels have been built to get water to farming lands. Throughout arid regions, scarcity of water, more than anything else, limits crop yields. Dry-farming is an

[1] *Cereals in America*, p. 207.

unending struggle against evaporation, and heavier rainfall is a theme of constant prayer.

Not all the effects of low rainfall are harmful. Irrigation enables the farmer to apply water to one crop and withhold it from another, thereby hastening maturity or controlling the size and quality of the harvest. Wheat long accustomed to dry, hot weather loses part of its hardness when grown in moist climates. Excessive water injures the cooking quality of potatoes, and causes many other crops to be too succulent.

Lands wet in late spring do not warm up sufficiently to permit sowing to early crops. Drying the soil cools it because of the heat used in evaporation. Conversely, soils that are dry and bare, especially sandy ones, heat to abnormal temperatures which are harmful to ordinary plants. In addition, then, to influencing plants directly, water affects them by changing the temperature and length of the growing-season.

13. Sunlight. — Nearly every lawn with trees on it has weak sod and pale green grass in the shady spots. This is most marked under trees with dense foliage, such as low-growing evergreens. Lack of sunlight causes this injury. Plants vary as to their sunlight requirements, however, as they do in regard to heat and moisture. The best quality of celery and lettuce, and the finest tobacco leaves grow in half-shade. Orchard-grass is named from its fondness for shady spots. Rhubarb stems can be made long and tender, and asparagus stems white, by " blanching " with boards or earth. Forest trees do not have low branches because lack of light kills the shaded limbs. The height, branching, and coarseness in flax and other crops are controlled by thickness of planting.

Crops that store great quantities of starch or sugar, such as sugar-beets and potatoes, are benefited by clear weather. Sunlight is essential to starch and sugar production. Therefore, in very rainy regions where the sky is overcast with clouds much of the time, sugar-beets, at least, do not thrive so well as they do in sunnier sections.

14. Wind. — One reason why large trees must have strong trunks is that heavy winds exert enormous pressure on leafy tree-tops. Weak plants and even gigantic forest trees are broken down or uprooted in tornadoes. Vines and clinging plants lie close to the ground or cling to the branches of trees, or to walls. This prevents air currents from getting under or behind them.

Sometimes strong wind shifts the surface soil so badly that roots of young plants are uncovered. Tender leaves, stems, or flowers may be rasped by the wind-borne sand grains. Plants with tough coverings, such as cacti and some grasses, suffer less. The formation of sod greatly aids the farmer in preventing this injury and in reducing that caused by contact with blown soil particles. Where hot, dry winds blow for several days continuously, evaporation and transpiration are increased to such an extent that plants are "burned" from sudden drying. Crops subjected to such winds present a dry, blasted appearance not far different from frost or fire injury.

Winds are temperature regulators, for they mix the air, preventing cold or warm air from remaining in one place long enough to do injury.

15. Soil. — Crops do not thrive in hard, dry soils impervious to water, air, and roots. Soils may be loose enough to blow readily, or sticky enough to "bake," or puddle, when wet. Soils that are shallow or underlaid with gravel are likely to dry out easily, thereby diminishing the supply of available moisture. The principal soil factors that influence plants are fertility, depth, uniformity, and water-holding power. Sometimes a plant

Fig. 3. — Type of vegetation found on alkali land.

cannot get enough mineral food to enable it to grow; abnormal arrangement or size of soil particles may prevent proper root development. As already pointed out, moderate moisture in the soil is more favorable than extreme wetness or dryness. Decayed leaves, stubble, and manure render soils capable of holding more water, thus insuring a steady, reliable supply. To create these desirable conditions and to control weeds, insects, and plant diseases are the chief virtues of cultivation and manuring.

16. Pests. — Great numbers of weeds hinder growth by shading, by stealing moisture and plant-food, and by usurping room both in the ground and above it. Insects that eat leaves, flowers, roots, and stems of the growing plant or that suck sap not only retard development, but in some cases kill the crop entirely. Plant diseases which do likewise usually feed upon the sap preventing proper nourishment. Smut of wheat or oats injures the quality of the grain or prevents its maturity. Potato diseases hinder the crop almost more than any other single factor. Control of these pests is at some time a problem in every locality. In Texas, for example, the cotton boll-weevil is driving cotton from some lands and compelling better culture methods everywhere. Fire-blight of pears has almost ruined the pear industry in much of the West. Attention to these negative factors may be as important as to the positive ones, for the farmer loses all the labor put on a crop which he cannot harvest.

17. Adapted crops.—Only those crops that mature in the growing-season of any section are grown there to advantage. Some varieties will prove more thrifty than others. Grimm alfalfa thrives much farther north than ordinary varieties; alsike clover resists much wetter soils than red clover; and Turkey red wheat is adapted to dry climates.

Finally, a variety of any plant long cultivated in a particular section develops resistance to frost, water, heat, or drouth. Desirable strains may be started from single plants that have resisted some hardship more successfully than other plants. This is only a part of the constant attempt of plants to adjust themselves to their surroundings. Environment has modified the plant and will continue to do so. Meantime, it gradually becomes better and better adapted to the section. This is the chief argument for home-grown seed. By this means, man lends a helping hand to the plant struggling to fit itself for its surrounding.

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CHAPTER III

PLANT STRUCTURE

Just as a locomotive engineer needs to know the parts and arrangement of his engine to keep it working smoothly, so the farmer must understand the mechanism and function of plants in order to remove obstacles in the way of their best development. Plant structure determines in a large measure plant functions, and economic production depends on the unobstructed activity of life processes. Therefore, a clear understanding of the kind and location of activity that goes on within the plant will enable the farmer to handle his crop more satisfactorily. This is particularly true under abnormal conditions such as plant diseases, the nature and location of which must be understood for effective control.

18. Cells (Fig. 4). — Roots, stems, leaves, bark, and flowers are so readily distinguished that everybody knows about them. Rings in wood, rind of melons, bran of wheat, and pith of corn are likewise matters of common observation. Neither pores in the skin of animals nor openings in the leaves of plants can be seen with the unaided eye, yet every wide-awake schoolboy knows of them.

Under the microscope, not only the stomata of the leaves can be seen, but a vast number of minute parts which seem to be more or less independent of one another in that they are separated by walls of compact substance. In the outer bark of trees, nothing remains but the walls which seem to be built of a vast number of small, box-like structures. When cut across, they resemble to some extent the cells of a honey-comb. Because of this resemblance, the name cell was chosen.

Originally, "cell" was used to designate only the inclosed space within the box-like walls. Examination of living plants showed that neither the opening nor the wall was so important in the make-up of the plant as the mass of living substance occupying the inclosure. It was found that this living substance instead of being uniform was composed of several parts differing chiefly in compactness. Moreover, it was discovered that each cell took in food and oxygen independently of other cells; that one cell might live or die without materially affecting others; that growth consisted in an increase of the size and number of individual cells; and that when work is done, the cells do it.

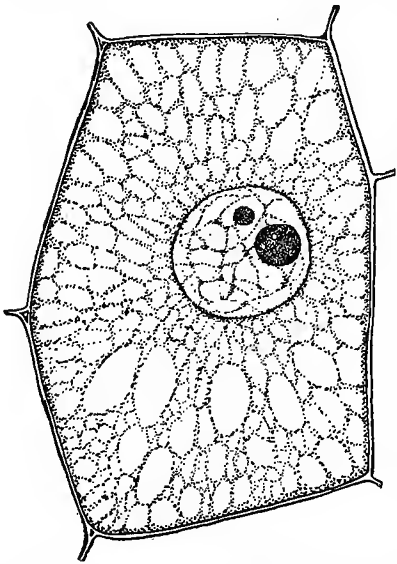

FIG. 4. — Plant cell showing cell-wall, cytoplasm, nucleus, and vacuoles. (After Duggar.)

Since the cell is the primary consideration in the life processes of the plant, the substance composing it was named protoplasm from *proto*, meaning the first, and *plasma,* meaning substance. As previously indicated, the cell is composed of several unlike parts. Beginning at the outside, there are (1) the compact protective wall known as the cell-wall; (2) a membranous covering known as the plasma membrane which incloses the plastic cell-contents; (3) a semi-transparent, semi-fluid substance something like the white of an egg known as the cytoplasm; (4) a more concentrated part of the cytoplasm called the nucleus which refracts light and is stained by certain chemicals; and (5) a number of smaller bodies known as *plastids,* of which there are three kinds: (1) green, (2) white, and (3) other colors, such as red, yellow, or brown. Seldom, if ever, does the protoplasm fill the entire cell. Every cell contains spaces interspersed within the cytoplasm known as vacuoles. These sometimes contain solid substances, but they are usually filled with a solution of water and salts known as cell-sap.

19. Tissues. — All parts of the animal or plant body are made up of cells. Skin consists of flattened cells with rather tough walls; muscle is made up of fibrous cells that fit closely; bone cells are heavily laden with mineral matter; and the brain is composed of layers of variously-shaped nerve cells, some white and others gray. A group of cells much alike and serving in a particular way is known as a tissue.

The epidermis or peel of an apple, the flesh, the seed, the seed-coats, and the stem are plant tissues. Leaves, stems, roots, buds, flowers, and seeds are all composed of several tissues. It is by means of united cells specialized to some end that the plant performs its functions of taking in water, manufacturing starch or sugar, and storing food. Tissues comprise the plant structure in much the same way that walls, plaster, floors, windows, and doors make up the house.

20. Kind of plant. — Only higher plants have well-developed tissues. The structure in one class of plants, the bacteria, consists of one cell or at most a few which are not grouped into tissues. Each cell performs all functions for itself. As the scale of plant life ascends, cells group themselves into more and more complex tissues until in seed plants each tissue or organ is highly specialized and performs only one function.

Plants alike in all essential points are said to belong to the same species; closely related species belong in the same genus. Genera (plural of genus) that resemble each other comprise a family. Families in turn form orders, and these, sub-classes or classes. A final grouping of classes gives rise to four great groups which make up the plant kingdom. Among the seed plants known as spermatophytes, all the crop plants occur. Thallophytes, bryophytes, and pteridophytes which are represented by seaweeds, mosses, and ferns, respectively, are the other great groups. Beginning with thallophytes and ending with spermatophytes, these plants show a gradually increasing complexity. There is no exact place where a species or genus, or even a group, ends with absolute certainty. It is hard to tell whether certain organisms belong to the plant or to the animal kingdom.

Though even botantists sometimes disagree in regard to the species to which some plants belong, these classes are sufficiently definite and the names are sufficiently well chosen to enable students of plants to identify them rather accurately by the names of the genus and the species. These Latin names are necessary because the same plant is popularly known by different names in different countries, and even in different parts of the same country.

21. Crop plants. — Plants in the same group or species are much like each other. The tissues of all seed plants (spermatophytes) resemble each other enough to be described as a group. In method of growth, there are two kinds, monocotyledonous and dicotyledonous. Grasses are monocotyledonous, that is, they have undivided seeds. They grow largely by increase in size of cells; dicotyledonous plants have split seeds and grow by laying down rings of new tissue. Practically all crops, save only the grasses and grains, grow by adding tissue in rings. Though differing in growth habits and in appearance, they do work by similar means.

FIG. 5. — Root-hairs on radish. (After Duggar.)

22. Plant parts. — Crop plants have roots, stems, leaves, flowers, seeds, and buds which are simply leaves or flowers in protective coverings. The roots anchor the plant in the soil and take up water and mineral plant-food in solution. Stems hold the leaves and flower up into the sunlight, transport to the leaves the water and mineral salts, and carry elaborated food from the leaves to the roots. Some plants use them as a place in which to store food. This elaborated plant-food is manufactured by the leaves in the presence of sunlight, when moisture, carbon dioxide, and mineral salts are available. The flowers are forerunners of the seed by which the plant transmits life and reproduces its kind. Each crop plant is composed of a number of tissues which enable it to perform its functions.

23. The root (Figs. 5–7). — A careful examination with a microscope of a longitudinal section of a living root shows the growing section to be a short distance behind the tip. The very tip is the root-cap composed of a group of firm cells which push aside the soil particles as the root lengthens. The tender growing cells could not make their way through the hard, compact soil.

Just behind the growing area and still on the thread-like rootlets are the root-hairs. These are extremely

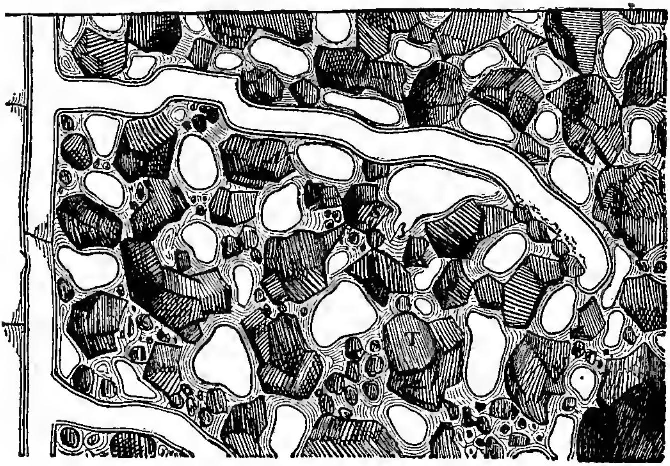

FIG. 6. — Root-hair in the soil.

small projections that radiate outward from the root to take in water and dissolved plant-food. The root-hairs are cells extending out from the small roots into the soil. They contain within a thin cell-wall, plasma membrane, cytoplasm, nucleus, plastids, and vacuoles. A concentrated solution of numerous salts known as cell-sap fills the vaculoes.

Considerable adjustability as to shape permits root-hairs to force themselves into close contact with soil particles and to fit into every space and around every angle.

Wherever contact with a solid body is made, a mucilaginous substance develops on the outside of the cell-wall causing it to cling tightly. Very close contact between the root-hairs and soil particles makes possible a rapid absorption of film moisture and plant-food.

Root-hairs may be half an inch long, though they are usually much less. They are short-lived, old ones dying

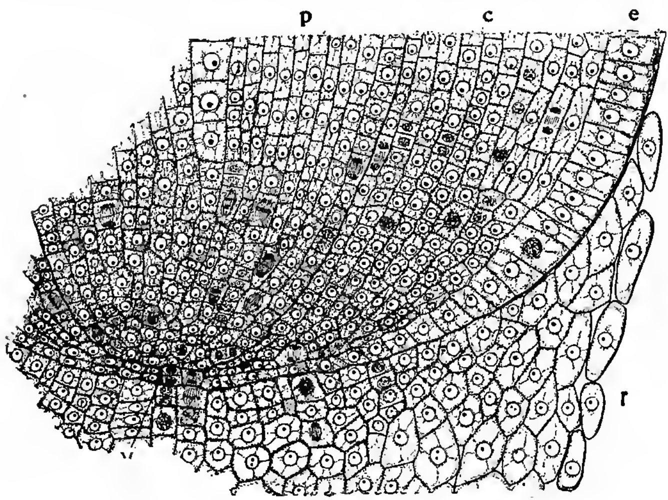

Fig. 7.— Root-tip of corn. (After Curtis.)

and new ones forming continually. As the root gets older, root-hairs cease to form and the epidermis takes on a nearly water-proof coat. Beneath this protective epidermis, various tissues form in layers. One of these, the xylem, takes up water and carries it toward the stem in small tubes known as tracheal tubes or in elongated cells known as tracheids. Between this water-transporting tissue and the epidermis lies the endodermis, a layer of cells rich in starch, and the cortex, a layer of corky cells.

Water passes between these cells reaching the xylem, which lies partly inside and partly outside of the phloëm in roots, though in stems the phloëm is always outside. This alternating arrangement permits water to enter the tracheal tubes without passing through the phloëm, which carries the true sap downward from the leaves. Water, after ascending the roots, passes into the stem, still going upward in the tubes of the xylem.

All the roots and root-branches of a plant form a root-system. If the central root grows faster than the others, subordinating the side roots, the plant has a tap root-system, of which alfalfa, carrots, and red-root pigweeds are examples. In other plants, the side roots keep pace with, or outgrow the central roots giving rise to a fibrous root-system, such as those of grasses and cereals.

24. The stem (Figs. 8–9). — The xylem of the stem, into which water passes from the root, connects with the xylem of roots affording a somewhat continuous passage to the leaves. The tracheal tubes, by means of which this transfer from roots to leaves is effected, are minute tubes with thickened walls. In formation the end walls of cells directly above each other gradually dissolve out leaving a continuous opening sometimes an inch or more in length. The walls are thickened spirally or have pits in woody walls. This thickening strengthens the stem, while the thin places permit a more ready passage of liquid into and out of the tubes. At the end, one tube does not connect directly with the next, but is slightly to one side making a lateral movement of water necessary. In this way, a straight lift is avoided.

Examination of a xylem cross-section under a microscope shows the enlarged tracheal openings arranged in a row alternating with a row of more fine-grained wood tissue which supports the weaker tube area. These wood cells

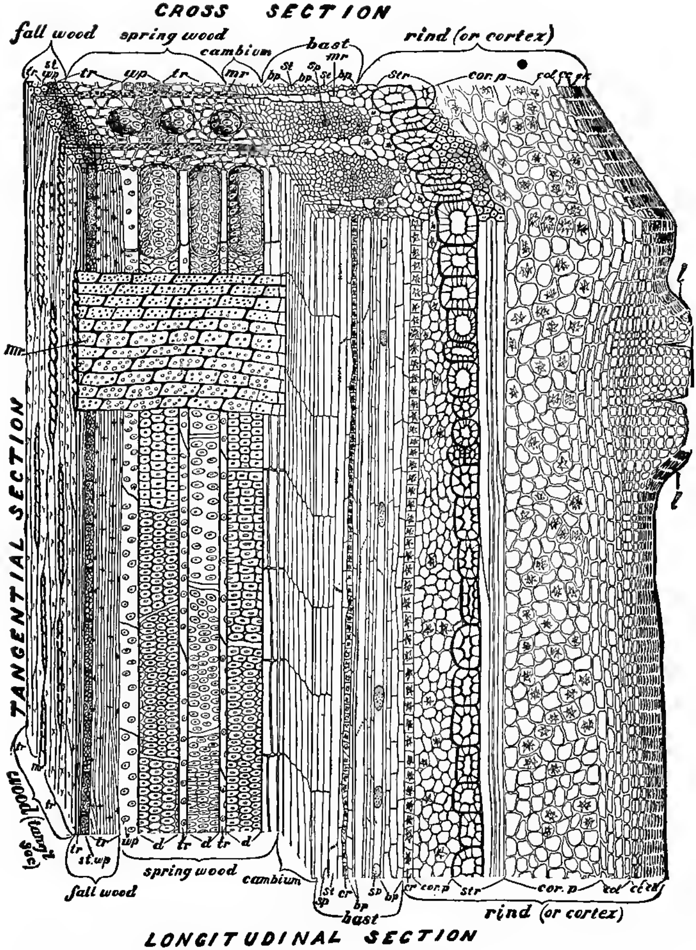

FIG. 8.—Section of oak branch showing longitudinal and cross-section tissues. (After Osterhout.)

die leaving only heavy cell-walls. Just at the outer edge of the xylem is a layer of thin-walled cells that grow and divide leaving new tubes and new wood fiber on the inner, or xylem side; while on the outer side it lays down a smaller quantity of less compact tissue known as the phloëm.

Xylem, phloëm, and the growing layer, cambium, form what is known as the fibro-vascular bundles of the plant. These are small at first, but if the plant is perennial and completes a ring of new growth each year, they increase in size until they form a series of wedge-shaped bundles radiating from the central pith. Medullary rays pass radially between these bundles dividing them from each other. Along these medullary rays, food, air, and water move to deeper tissues. When bark is stripped from a willow, for example, it parts from the wood at the cambium exposing a smooth, moist surface. The rings of the woody part mark a division between the tubes and the finer, more compact wood cells; the radial markings are medullary rays; and the pith is a region of broken-down cells that originally composed the first stem of the plant.

Several distinct layers come off in the bark. On the outside is a membranous tissue, the epidermis, which is composed of flattened cells with tough walls and which is covered with a substance that renders them water-proof. Beneath this is a region of thickened walls, and still farther beneath is an area of corky cells known as the cortex. Stone cells are scattered throughout this tissue. A layer of cells rich in starch, called the endodermis (*endo*, inner, and *dermis*, skin), divides the cortex from the pericycle. This last ring is composed of thin-walled cells and more or less regular areas of strong-walled, fibrous cells known as bast. Finally comes the phloëm, which lies next the cambium and just in from the xylem.

Within the phloëm is a series of cell passages, which are known as sieve tubes. These do not lie directly above each other, but slightly to one side. Down the sieve tubes flows the true sap, which is a solution of elaborated plant-food manufactured in the leaves from the water, gases, and mineral. This tissue extends into the roots, where, instead of lying outside the xylem, it alternates position with it, thus permitting water to enter the xylem

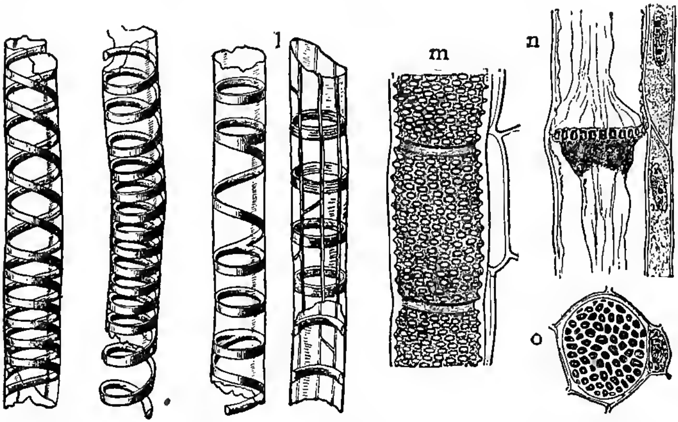

FIG. 9. — Conducting cells of the fibro-vascular bundles. (Adapted from Duggar.)

without first passing through the phloëm. In both root and stem, this sap leaves the phloëm at intervals and diffuses outward in spaces between the cells and inward along the medullary rays. Old trees are mostly xylem with epidermis broken off, exposing the corky cortex.

In most monocotyledonous plants the entire tissue is in a firm rind in the outer rim of the stem, which is usually jointed and hollow save at the joints, or nodes. Since no cambium exists, there can be no rings of growth. On this account, members of this group — grasses and palms — are usually slender for their height. In some, such as corn, the internodes are filled with pith interspersed with the strands of the fibro-vascular bundles. The stem is much harder at the nodes than at the internodes, and it is smaller in each successive internode that is farther from the ground.

25. The leaf (Figs. 10–11).— Water-conducting tissue of the xylem joins the leaf-veins which distribute the

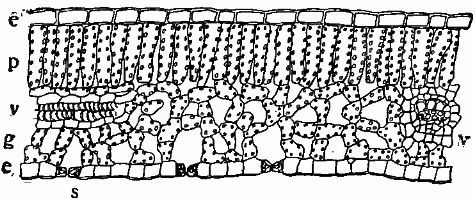

FIG. 10. — Section of leaf showing cellular structure.

water throughout the leaf, finally leaving it in the spaces between the cells. The cells absorb the water and also carbon dioxide taken in through the stomata, as the small openings in the epidermis of the leaf are called.

The cross-section of a leaf shows a layer of flattened cells with stomata at intervals on both the upper and the lower epidermis. With most ordinary plants, the number is greater on the under side. On each side of the opening is a small cell so placed that when the leaf wilts, it falls across the opening partly closing it, and thus reduces the loss of water. Beneath the upper epidermis is a group of cells containing many green plastids. If the chlorophyll cells are elongated vertically and lie side by side, as they often do, they are known as palisade cells. Below these cells lie others called sponge cells which are less closely knit together, thereby allowing more space between.

Just above an opening, the sponge cells spread apart leaving a larger chamber (Fig. 11).

Leaf-veins may branch at the base as in grapes, or from a midrib as in alfalfa. In this case the veins form a sort of net-work called netted venation. This is typical of all dicotyledons. Grasses and grains are parallel-veined, that is, have the veins side by side either with or without a large central one known as the midrib. This kind of venation is typical of monocotyledons.

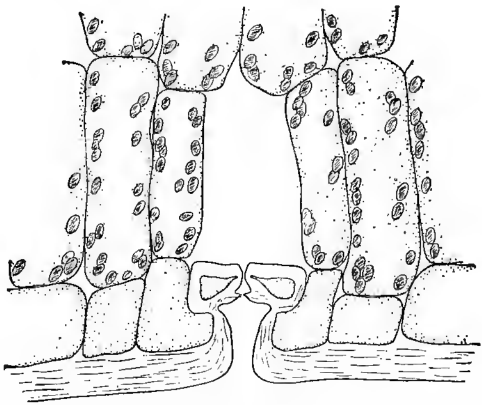

Fig. 11. — Stomata of carnation leaf. (After Duggar.)

Leaves may be borne on a leaf-stem, or petiole, or attached directly to the plant. They may be compound as with clover, alfalfa, and the potato, or simple as in the case of beans. They may be two-ranked as in the case of grasses and the grains. A leaf grows from a node, wraps closely about the stem for a distance, and spreads outward. The part that clasps about the stem is the leaf sheath, and the part that grows outward the leaf blade.

26. The flower. — Seed production seems to be the prime purpose of all functions of the plant, which dies or discontinues growth as soon as mature. The flower is the fore-runner of the seed, in that the seed is a product of a union of the floral parts. These floral parts are the corolla, calyx, stamens, and pistil. The corolla, the showy part of the flower, consists of petals, single or united, regular or irregular in shape and size, and usually of delicate texture. The calyx is composed of firmer tissues, single or united, usually regular in size and shape, and nearly always green. The calyx is an envelope for the remainder of the flower and the petals attract insects useful in cross-pollination.

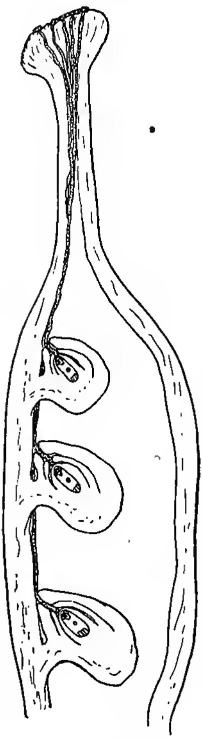

FIG. 12. — Pistil of legume showing fertilization.

Each stamen consists of a slender stalk and a hollow receptacle bearing powdery pollen. There are from three to twenty or more stamens on a flower and they are situated inside the corolla, usually surrounding the pistil. The pistil consists of a roughened or divided stigma supported on a style that reaches upward from the ovule or ovary at the base (Fig. 12). When pollen grains reach the stigma they germinate and send long, slender tubes down the style to the ovule. Dissolving its way to the ovule, this tube comes in contact with the egg cell, which it fertilizes causing a seed to begin development.

Flowers are borne singly or in clusters. If the cluster is a close, compact one, such as red or white clover, it is called a head. A cluster arranged like oats with long, slender branches connecting the separate flowers is called a panicle; while one with the branches shortened to the extent that the flowers are in a compact, elongated mass is called a spike. Wheat, barley, and timothy are spikes.

27. The seed. — As maturity approaches, the seed gradually assumes a characteristic shape, size, and appearance. Some are smooth and nearly bare as alfalfa seed; others, such as some grasses and barley, are covered with a hull; still others are large and protected only by a membranous covering as with corn, peas, and beans.

Within the seed is (1) an embryo, or germ, which is a miniature plant; and (2) a food supply to nourish the plantlet until it can gather nourishment. Some kind of covering or hull surrounds the seed protecting it from injury until germination time, when water is absorbed through the hull to start growth.

28. Buds and branches. — Budding leaves and flowers must have some protection until they are strong enough to expose themselves to the weather, and until conditions favor growth. A series of scales coated with a resinous or gummy substance makes up this protective covering called a bud. Some buds are lined with soft, fluffy material to protect the tender leaves or flowers from cold wind, and to prevent excessive drying.

Branches begin growth from a bud in the axil of a leaf. At first the union extends only to the cambium, but as rings of growth are added the branch is embedded in deeper tissue. Thus, knots are formed in timber. Just at the base of a branch the stem is usually enlarged.

29. Underground stems. — Potatoes and onions are modifications of enlarged stems. They show the various tissues described, but lack much tissue that is composed of strong-walled stone, wood, or bast cells. Many grasses and weeds send rootstocks horizontally beneath the surface soil. These contain buds which will start both stems and roots of new plants. By this means, sod is formed and plants spread underground.

Many plants, such as beets, carrots, alfalfa, and dandelions, form root-crowns, which are closely united stem and root. Buds necessary to sending up new plants can develop only in stem parts. Root-crowns and rootstocks are simply modifications adapted to perform this function.

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CHAPTER IV

PLANT FUNCTIONS

Specialization in higher plants has given rise to a great number and variety of structural tissues. This difference presupposes different functions, that is, each tissue performs a definite kind of work. Moreover, it is highly probable that tissues slowly developed on account of the necessity of the work. In the struggle for existence, the individual plant with best-adapted means of doing essential work thrived best. Gradually plants with structures best fitted to carry on the activities have crowded out others. Since specialized work is more effective, plants more and more differentiated, have gradually been evolved. This seems to have been much more true on land, where conditions varied more than they did in the ocean. The greater number of forces, such as light, soil texture, varying moisture, and temperature differences, naturally demanded greater complexity in response. This, in turn, required expression in a way conducive to the best good of the plant.

30. Growth. — Though higher plants are complex at maturity, they have but few tissues just after germination. As growth proceeds, the original sprout develops into leaves, stem, and roots. Buds, branches, flowers, seed, and rootstocks or tubers come later. A rapid differentiation of tissues accompanies increase in size, and in some cases runs ahead of it. Many plants develop tracheal tubes, sieve tubes, cambium, cortex, and epidermis while the plant is still small.

Growth, whether measured by the increase in size or by the development of new tissues, can come only from enlargement, or increase in the number of cells. Each process is partly responsible. At first, the original cells increase in size, but soon they reach a point where little more growth results unless the cell divides. In all crop plants, both processes go on at the same time.

Thin-walled cells in growing parts of a plant constantly divide and redivide forming new cells. The first sign of cell-division is in the nucleus, which begins to change from a granular to a fibrous mass. Shortly it seems to be composed entirely of strands. These split lengthwise and then crosswise forming pairs of small bodies which arrange themselves in two parallel rows across the middle of the cell. Fine thread-like strands gradually pull these, half to one end, and half to the other end. Here they partly unite. The two move farther apart and become distinct. Following this, the cytoplasm begins to show signs of separation by developing a concentrated layer near the middle and between the two nuclei. When this has hardened into a cell-wall, cell-division is complete and two cells have come from the original one. In a few hours, or a few days, the two new cells may divide giving rise to more new cells, each behaving as the first so long as growth continues in that region of the plant.

Young plants at first grow throughout, but soon dicotyledonous plants develop a cambium and growth discontinues in other parts except at the tip of elongating branches. All later thickening results from cambial growth. This ring of cells remains thin-walled and active, building first one side to the xylem and then on the other to the phloëm. Just what determines which cell remains active in the cambium and which becomes permanent tissue in the xylem or phloëm is not understood. Early growth usually produces abundant tracheal tubes in order to get water to the leaves. This is followed by a ring of smaller, more compact cells for support.

Monocotyledonous plants lack this power of secondary thickening, because they have no cambium. Cereals and grasses gain most of their thickness in early growth. Later increase in size is largely increase in length or storage of food in the seed or stem.

31. Respiration. — Of the various needs of plants or animals, none requires more instant gratification than that of oxygen. A person can live days without food, hours without water, but only a few minutes without air. So it is with the plant. Fruit in storage not well ventilated soon suffers from storage scald. Alfalfa dies in waterlogged soils largely because air cannot pass through the water to the roots. A layer of clayey sediment may cause the same result if it packs tightly.

Although an abundance of air is at hand, it must reach the separate cells to be of service. Therefore, the oxygen must not only be in the soil or be in contact with the plant, but it must get inside the plant and circulate with sufficient freedom to carry a supply to living cells deep within the tissues. Some oxygen is taken into plants in water, some through pores or lenticels in the epidermis, but most through the stomata. Once inside, spaces between the cells afford channels of movement. Sometimes these intercellular spaces occupy more volume than the cells. A plant-cutting thrust through a cork until the cut's end is under water gives off bubbles of air if there be another hole in the stopper to prevent pressure. This shows that air passes through the plant.

Growth also requires oxygen. Seeds in air-tight vessels will cease to grow when the air is used up. A coat of oil over water containing seed greatly delays germination, because oxygen is unable to penetrate the oil. On the other hand, seeds germinate freely in water not so treated.

Actual respiration takes place inside the cell which partly decomposes in doing work. Oxygen is necessary to the proper breaking down of cellular compounds. Food and water are also necessary to repair the wear. Cells are constantly losing weight as protoplasmic substances become gas and pass off; they are likewise gaining weight as food is made into protoplasm. This exchange of worn-out protoplasm for food which becomes new body tissue is respiration. Carbon dioxide is excreted along with water and other products of slow combustion.

Potatoes and apples soon wilt if kept in a light, fairly warm place, because of the loss of water and carbon dioxide due to respiration which increases much in rapidity as temperature and light increase. Again, if a plant be made to grow in distilled water in the dark, it also loses weight. In this case, the water supplies no food, and darkness prevents the plant from manufacturing any. Only respiration is active; it has used substance which through lack of food it is prevented from replacing.

32. Photosynthesis. — Ordinary plants growing in dark places do not gain in weight; their leaves lack the characteristic green color of normal crop plants; and the building of tissue can go on only for a short time. Both sunlight and the green substance known as chlorophyll are essential to increase of dry weight. Young seedlings grow in darkness if other conditions are favorable, yet no increase takes place, for they move food from the seed storehouse to growing tissue. The quantity of food available must last until the roots can supply water and mineral salts, and until leaves have reached into light and air and become green. Under favorable conditions the plant can then feed itself.

Water, dissolved salts, and gases are taken in by the plant. From these raw food products it is able to make grain, straw, leaves, fruit, and roots composed of sugar, starch, cellulose, protein, fats, ash, and various other substances. Carbon dioxide, present in a very small percentage in the air, enters the leaves through the stomata. Diffusing in the spaces between the sponge and palisade cells, it comes in contact with water that is making its way in the opposite direction. Chlorophyll with the help of sunlight unites water and carbon dioxide into sugar. Considerable oxygen is liberated in this process — infinitely greater quantities than the plant uses in respiration. In consequence of this, oxygen is given off by the plant. This oxygen comes not from the breathing of the plant, but from the manufacture of food in the leaves which is called photosynthesis (from *photo*, light, and from *synthesis*, to put together). Chlorophyll, in an unknown way, accomplishes this manufacture of plant-food after which the plant nourishes itself. The following chemical reaction shows the different beginning and end products:

$$6\,CO_2 + 6\,H_2O = C_6H_{12}O_6 + 6\,O_2.$$

Sugar, under the action of certain chemical ferments, called enzymes, changes to starch and this to oil or cellulose, and in some plants, to wood. But nitrogen, calcium, potassium, phosphorus, sulfur, iron, and magnesium are brought from the soil. Nitrogen and sulfur together with a little phosphorus are united into another class of compounds called proteins, a general term for any organic product containing nitrogen.

Such is the way in which plants manufacture the raw inorganic elements into products they can use. All these compounds find use in various parts of the plant. This union of raw elements into usable compounds is essential to the existence of all life.

33. Osmosis. — For a long time it was known that water and nourishment are taken from the soil by plants, yet no clear understanding existed as to how they enter or what part they take in plant growth. Some thought the plant feeds entirely on water, and others that soil particles, as such, enter the plant. Jethro Tull, about 1674, advocated that intertillage be practiced to fine the soil in order that it might enter the plant. Just how he expected this entrance to be made is not clear. Soon came discoveries showing that neither water nor soil alone is plant-food, but that certain soil elements, water, and carbon dioxide are united by photosynthesis to form the materials out of which plants build their tissues. The intake of carbon by leaves was established; the entrance of water with mineral salts in solution by osmosis was proved. Knowledge of these basic principles enabled the science of plant production to advance with hitherto unknown rapidity.

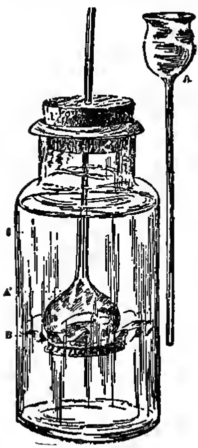

FIG. 13. — Apparatus used to demonstrate osmosis. (From Bailey.)

Kernels of grain, germinated on wet cloth or paper over a box of wet sand or sawdust, develop root-hairs for the absorption of water and mineral food. The seedlings will grow and use water, as will a geranium cutting passed through a stopper with the cut end under water. Roots will develop, the plant will continue to grow, and the quantity of water in the bottle will diminish though openings around the stopper and plant be sealed to prevent evaporation. Since there was no other way of escape for the water, it must have been taken into the plant and passed upward through the stem. The process by which the plant accomplishes osmosis is complex. Liquids and gases — even solids in some cases — are driven through membranes or caused to diffuse into one another by a gigantic force spoken of as osmotic pressure.

When copper sulfate (blue vitriol) crystals are covered with water, solution begins and a blue color gradually creeps throughout the water until a uniform color exists. Samples taken from any part of the vessel would show nearly equal concentrations of copper sulfate, which, at the beginning of the experiment, was confined to the immediate vicinity of the immersed crystals. This diffusion, or mixing of the salt throughout the water, was impelled by the power of diffusion or osmotic pressure.

If the vessel containing water be divided by a partition of parchment or piece of animal bladder, a change in the final result is apparent. After awhile the water on one side of the membrane rises and lowers on the other. Since the membrane admits the free passage of water but not of salt, fresh water is driven through in an attempt to make the liquid of uniform concentration. Some salt passes through into the fresh water, but the chief movement is made by the water.

To demonstrate osmosis, a strong solution of common salt may be placed in a thistle tube, over the large end of which a piece of parchment paper or bladder is tied tightly to shut out air (Fig. 13). If the solution stands high enough to reach into the small tube above the bulb, a piece of string or an elastic band can be used to mark the height. After immersion in fresh water from a few minutes to a few hours, the solution rises in the tube showing the intake of water. Osmosis, agriculturally, is the process by which water from the dilute solution flows through a semi-permeable membrane into the more concentrated, in an attempt to equalize the strength of the solution.

It is by osmosis and due to osmotic pressure that roots take in water. Root-hairs contain concentrated solutions in the cell-sap which set up a difference in osmotic pressure between the cell and the water outside. Students of physical chemistry have found that this pressure is enormous, amounting in many cases to tons, and that it increases as the difference in solution-concentrations increases, and as the temperature rises. So long as the cell-sap is more concentrated than the soil solution, water passes inward. If strong solutions are brought in contact with the root-hairs, osmosis ceases or goes in the opposite direction and the cells become flabby and wilt. This is one injury caused by strong alkali.

Plants seem able to exercise a power of selective absorption; that is, if salts are not used by the plant, they enter only in small quantities; while the useful elements go in rather freely. This careful adjustment helps to keep out harmful substances and to take in the raw mineral plant-foods. Plant cells full of water are rigid and hold their shape. As one loses water, osmotic pressure causes more to enter. Throughout the plant there is some movement of water due to osmosis.

34. Transpiration. — Not only do roots take in water enough to maintain the plant in a rigid condition, but they must, in addition, maintain a stream that passes entirely through the plant. Because the water evaporated from the leaves is in the form of vapor, it cannot be seen under ordinary conditions. On cool mornings, however, droplets of moisture are often visible on the surface of leaves. Water vapor, escaping by means of the stomata, partly condenses when cooler air is reached. Even on hot days, in living or school rooms, transpiration — as this giving off of water is called — can be demonstrated by covering a leafy house-plant such as a geranium with a clean glass jar or open-mouthed bottle. In two or three hours the transpired water will collect on the glass in drops, and under favorable conditions with a healthy plant will drip down the sides.

Plants transpire enormous quantities. For each pound of dry substance they add to their weight by growth, over 200 pounds of water have passed through the plant. Measurements of transpiration show that about 300 pounds of water are required for one pound of growth in corn and about 500 pounds for one pound of growth in wheat (Fig. 14). A pint of wheat weighs a pound, but 60 gallons of water are necessary to produce it. If the straw weighs as much as the grain, three 40-gallon barrels full of water are transpired in growing the pint of wheat. This quantity of water used in growing a pound of dry substance is called the water-cost of dry matter for the particular plant.

Fig. 14. — Comparison of water used with wheat produced. (After Widtsoe.)

Crops growing in hot, sunshiny regions transpire more water than in humid regions. Dry air, winds, poor soil, weak plants, and an abundance of water in the soil cause more water to be used for dry matter produced. Desert plants and drouth-resistant crops have the power to hold so much water in their tissues against the forces of transpiration that they do not die from wilting. Some plants also have the power of developing few or many stomata according to whether they have small or large quantities of water at their disposal. Some plants transpire much more water than others; most plants seem to be wasteful during the period of bloom; and quick-growing crops use more water than steady-growing ones. Darkness also diminishes transpiration considerably.

35. Translocation. — Since all the starch and other plant-food is elaborated in the leaves, this must be moved or the leaves would be the largest part of the plant. Enzymes change sugar into starch for storage, and then to sugar again when moving is begun. The solubility of sugar allows the sap stream to carry it to the fruit, stem, or root for use or for storage. For example, great quantities of sugar or starch are stored in roots of carrots to be moved to the flowers and seed when the plant matures and seed is set. Fruit trees move food from wood to the fruit. Seed and fruit often grow so rapidly that storage in early summer is necessary. This movement of elaborated food from one part of the plant to another is called translocation. Most crop plants becomc more or less porous in stem or roots, or in both, during the seed-setting period owing to the transfer of food material.

36. Transportation. — Water is transported upward through the tracheal tubes and sap, downward through the sieve tubes, or radially along medullary rays. Sap can flow down largely by gravity and radially by capillarity, or wick action. Both these forces aid osmotic pressure in forcing the water upward. Whatever factors are at work, the water seems to have little more trouble in reaching leaves on a tree-top 200 feet above ground than those on a strawberry plant.

A geranium-cutting with the cut end immersed in red ink will soon show red stains moving upward. They will finally extend along the leaf-veins causing red blotches in the leaves where the liquid is released into the spaces between the cells. A plant stem several inches in length will be traversed in a few minutes. The rate of movement varies from a few inches to several feet an hour.

37. Response. — Nearly all plants tend to grow vertically, even on a steep hillside where it would seem that growth at right angles to the slope would afford the firmest root attachment. Most plants in windows lean toward the light, and must be turned every few days to prevent their becoming one-sided. Roots, in wet soils, nearly always grow in the surface layer, while on dry, well-drained soils, they penetrate deeply. It is counted a good practice to withhold irrigation water as long as possible in order to promote deep rooting. Oxygen as well as water limits the growth in swamped soils. Many plants do not thrive save on soils rich in lime. Alfalfa is a notable example.

SUPPLEMENTARY READING

Any textbook of botany.
Plant Physiology, B. M. Duggar.
Plant Physiology, L. Jost.
Plant Physiology, G. J. Peirce.
Cyclopedia of American Agriculture, Vol. II, pp. 11–22.

CHAPTER V

THE PLANT AS A FACTORY

NOTWITHSTANDING their complexity, plants are simple in their purpose if they can be said to have such. All their energies are bent toward seed production or toward some other means of continuing the species, that is, of transmitting life and characteristics to another generation. Singleness of aim seems to show the organization of the plant and the variety of ways in which it attempts to preserve itself in the struggle for existence. Power to gather raw foods and elaborate them into tissue-building compounds, storage of these products in some part of the plant against the time of greater needs, and adjustment to surroundings are nothing more than manifestations of the struggle to perpetuate the species.

In the products of the plant, man is vitally interested. Sometimes it is the roots, sometimes the stem, the seed, or the fruit containing stored starch, sugar, oil, or protein that draws his energy in producing and harvesting. Often it is just the dead cell-walls, such as wood, cork, or straw; but other times he takes the plant in the midst of life to get immature stems for forage, sap for rubber or turpentine, or cell-contents for sugar. Every part of the plant has been put to use; roots, stems, leaves, flowers, seeds, and sap, all furnish useful products. For example, beets and carrots are roots, hay is both stem and leaf, grain and beans are seeds, some perfumery is made of blossoms, and cane-sugar is a sap product. Drugs and stimulants, such as opium, tobacco, and quinine, come from substances known as alkaloids that may be found in any part.

38. Interdependence of plants and animals. — If only plants were upon the earth, then the provision of nature for plants to give up oxygen and use carbon dioxide and for animals to reverse these processes, would be useless. Animals feed upon plants, directly and indirectly; directly when they are plant-eaters, and indirectly when they are flesh-eaters; for the prey of carnivorous animals either ate plants, or animals that ate plants. On the other hand, decayed bones, flesh, and manure restore to the soil and air substances upon which the plants feed either directly or indirectly; directly when plant-food is at once taken from the broken-down tissues, and indirectly when these decaying substances promote the growth of soil bacteria which take atmospheric nitrogen and make compounds that the plant absorbs. Soil devoid of organic matter — decaying plant and animal substance — is almost useless on account of its being compact. It can hold water for only a short time; air and heat cannot pass through it readily.

Many plants require limestone soils for development. Part of the limestone ledges supplying lime is composed largely of shells of small animals that extracted lime from the water in which they lived. These animals probably fed on water plants, and breathed oxygen released as by plant processes. In the economy of nature, plants and animals need each other.

39. Dependence of man on plants. — Since animals depend on plants for their food, man, who in turn depends on plants and animals, may be regarded as being ultimately dependent on plants. It is not difficult to see that almost all human food, save only a few minerals such as salt, comes entirely as a result of life processes. Milk, cheese, butter, flesh, and eggs are body products of animals; bread, fruit, vegetables, and "greens" are plant contributions. Furthermore, they are produced almost entirely by domesticated plants and animals.

Clothing, likewise, comes largely from the same sources. Cloth made from wool, hair, cotton, or flax fiber is just as truly the product of animals and plants as are the skin garments of the Eskimo or the leaf and bark raiment of the tropical savage; furs, gloves, shoes, and straw hats are made directly from products of the life processes.

Formerly, most dwelling places were built of wood and leaves or of skins. Modern buildings consist largely of brick, stone, concrete, and metal, but wood is used in lathing, for floors, door and window frames, for roofing, and for walls in many cases. Furniture and useful tools will for years to come, if not always, be composed largely of wood. Attention to forestry indicates that man realizes this and is making an effort to preserve his timber resources. Moreover, far back in the history of cement, brick-clay, some rock, and some metals, life has played a part. Especially is this true wherever carbonate compounds exist, since others as well as limestone have resulted from an organic process somewhere in the chain of interaction of the elements.

The carbon dioxide used in photosynthesis was the original source not only of all carbonate products, but of all substances such as wood, coal, petroleum, and natural gas. Combustion of these materials yields heat energy used to warm dwelling and office, to furnish power for driving the engines of factory and transportation, and to generate electricity for both power and light.

Animals themselves are direct bearers of burdens and drawers of loads. Horses pull tillage implements and haul farm products to market; camels, llamas, and burros carry man and goods in regions inaccessible to wagon and locomotive. Horses and dogs assist in tending herds; cats and birds in the control of mice and insects; bees and other flying folk pollinate flowers. Not only are the labors of man lessened by dumb beasts that live on plants, but his pleasure is also increased by them. Riding and driving are healthful recreations; ponies, dogs, and birds gladden the hearts of children who have them for pets; zoölogical gardens and aquariums are places of beauty; and caring for and breeding fancy animals are avocations of many. Flower gardens and house plants also beautify the home. Vegetable gardens and ornamental plants satisfy some men in the same way that good animals do others.

Many raw products that are transformed by factories into new forms, whether food, clothing, tools, or books, are of plant or animal origin. Books, pictures, and newspapers, so essential in education and in national and artistic well-being, are made of paper or cloth, both plant products. Medicines, dyes, and chemicals are supplied in part by plants. Finally, more people earn their living by the culture of plants and the rearing of animals than by any other pursuit. Plainly, man cannot live in and of himself; he must be fed, clothed, warmed, and sheltered from the weather. Since he cannot dispense with plants, let him not scorn them.

40. Domestication. — When the people who are now civilized were savages, they lived much as present-day savages do. Wild fruits, nuts, roots, and tender shoots fed, clothed, and sheltered them. In the wild, enemies were frequent and they often prevented man's obtaining food. Rigorous winters and dry summers also caused suffering to some, while those in better provided areas were less disturbed. Stern necessity drove man to domesticate plants for food and shelter, and animals as assistants in hunting and in moving about. Originally, all tame creatures came from native haunts. If they were useful, the most savage brutes were gradually brought under subjection by man who alone could use fire and make machines to throw arrows or stones. Weaker than many animals and plants, he studied their ways and found ways of subjecting the useful ones. Seed was planted in protected places and other plants were kept out. Then tillage began and man took up a fixed habitation.

Some plants and animals have been so long cultivated that wild relatives have disappeared. The earliest records tell us that wheat, barley, and alfalfa were cultivated at the dawn of civilization. Constantly new plants are being used for crops. In the cases of plants recently domesticated, the wild relatives are still in the fields. Wild plums and roses, native grasses, and vetches may still be found, but the plants from which wheat and corn came have disappeared. Plants not yet known could doubtless be found that would serve man, and as new varieties appear, many useful plants will be developed.

41. Plant compounds. — Hundreds of kinds of substances are found in plants. Some of these man finds useful and appropriates for his own use. So closely related are these compounds that they may be included in eight groups: (1) water, (2) carbohydrates, (3) proteins, (4) ash, (5) fats and oils, (6) aromatic substances, (7) medicinal properties, and (8) acids. In importance the last three rank far below the first five, yet even these are not to be neglected.

42. Flavors, perfumes, and other characteristic odors, such as lemon, mint, and rose-water, have various uses.

Flavors of fruit and nuts serve to distinguish them. Carbon, hydrogen, and oxygen in various quantities and arrangement compose these substances. The drugs and stimulants, such as morphine, strychnine, and quinine, usually contain nitrogen in addition; while the acids of fruits, such as malic acid in apples and tomatoes, citric acid in citrus-fruits and currants, and tartaric acid in grapes, consist of carbon, hydrogen, and oxygen. These three classes of compounds promote palatability, give variety, increase healthfulness, or stimulate the nervous system rather than serve as constructive foods.

43. Water composes from 60 to 90 per cent of the weight of green plants. (1) It forms a part of the cell content keeping the cells full and rigid; (2) it acts as a solvent which carries mineral salts and distributes elaborated plant-foods; (3) it regulates the temperature of plants by maintaining a constant stream from root to leaf where evaporation, which uses much heat, reduces the temperature to normal. In the animal body, water performs similar functions. The extra succulence caused by water in plant tissues increases palatability. Dry feed and water seem to lack something that green feeds possess, particularly for the use of milch cows.

44. Carbohydrates consist of carbon, hydrogen, and oxygen usually in the ratio $C_x(H_2O)_y$. They comprise from 80 to 95 per cent of the dry weight of plants and are made from water and carbon dioxide. Starch, sugar, and cellulose occur in the plant, scattered widely throughout the tissues. Cellulose makes up all woody tissue and the strong cell-walls. Starch is the usual form of storage, while sugar is ordinarily the temporary form, though in sugar-cane and sugar-beets it is one of the storage compounds. When carbohydrates are digested by man and beast, they supply work and heat energy and may be made into fat. Never, however, do they become a part of the muscle, ligaments, and connective tissue. Slow combustion in the cells uses these foods. Starch and sugars are easily digested, but cellulose, often designated as crude fiber, is but partly digested. However, it furnishes bulk, which is necessary.

45. Protein compounds contain nitrogen and sulfur and sometimes phosphorus. Out of these foods, muscular, connective, and vital tissues of the body are formed. Flesh, stomach, intestines, lungs, nerves, and brain use these in direct composition. Man eats meat to supply these needs because plants are not usually rich in nitrogenous substance. Animal bodies must first get them from plants which contain them in storage. Leaves, embryo of seeds, and a layer of cells just beneath the seed-coat are rich in nitrogen. Leguminous plants are much richer in protein than grasses or cereals; and legume seed, such as peas and beans, are composed largely of protein compounds. Proteins, then, are both scarce and vital; they cost about three times as much as carbohydrates if ordinary prices are considered.

46. Ash comprises from a fraction of one to several, but usually less than 2 per cent, of the dry matter. It is scattered through the plant as stone cells of the stem and leaf, in the cell-sap to promote osmosis, and in the protoplasm itself. A small quantity enters into the composition of protein. It is called ash because it remains so after burning. Animals concentrate this mineral, in the bones and teeth, and use it in smaller proportions in blood and flesh.

47. Fats and oils are simply carbohydrates rich in carbon and poor in hydrogen and oxygen. Seed embryos and the flesh of nuts are the storage tissues. All grains contain some: corn about 5 per cent; seed of flax, sun-flowers, cotton, mustard, rape, and poppies are about one-third oil; peanuts, palm-nuts, and coconuts contain from 45 to 67 per cent. Fats and oils, in the animal body, produce fat and supply energy. In computing rations for live-stock, they are counted 2.4 times as valuable for energy production as sugar and starch.

48. The plant factory. — Since plants and animals use the same foods, and since the animal is not able to compound its own, the animal draws its food from the plant. True, the elements are the same and in the same quantity before and after photosynthesis, but they are in entirely different relations. Iron made into pig-iron and then into watch springs is the same substance in different forms; but just as the watch-maker could make no use of the pig-iron, so the animal — and the plant for that matter — can make no use of carbon dioxide, potassium, nitrogen, phosphorus, or iron until they have passed through the factory of the leaf and been made over into sugar, starch, protein, or oil. Water alone is used in the compound that exists in nature.

As described in paragraph 32, carbon dioxide and water are united into sugar by the chlorophyll of the leaf. This green substance is found throughout the green part of the plant, but it is abundant in the palisade cells of the leaf. Small green bodies arranged along the side walls of these cells intercept rays of sunlight and make use of this energy to do the work of combining water and carbon dioxide. The water within the cell touches the chlorophyll bodies on one side, while the carbon dioxide comes into intimate contact with them on the other, as it diffuses against and through the cell-walls from the stomata. Chlorophyll, by means of energy in the sunlight, causes this chemical combination to take place. Plants make no outward demonstration, yet, in quietness, they have caused the most important reaction known. This is the beginning of the food which feeds all. The whole problem of feeding the world must ultimately be solved by chlorophyll and sunshine. Figure 15 represents apparatus showing aëration of the leaf.

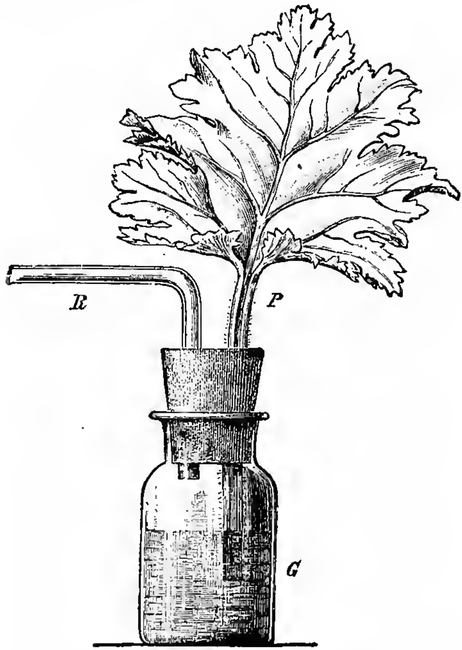

FIG. 15. — Apparatus showing aëration of the leaf. (After Detmer.)

Without green plants, it would be simply a matter of time until life could not exist on earth. First plants would die and animals would feed upon them. Gradually these would use up the food and then die. Equally essential is sunshine, which not only enables plants to grow, but vaporizes water, lifting it into clouds which return the water as rain, letting it run down hillside and hollow. In this journey, it washes soil and grinds rock, it floods meadows and turns water-wheels, it grinds grain and saws lumber, it dissolves mineral for plants and generates electricity. Sunshine, then, is the source of water power as well as the original power of warmth and food. In this whole world, only chlorophyll is able to make use of it for food manufacture.

Just what this strange substance is, has not yet been found out. Plants growing in the shade continuously have none, but as soon as they are exposed to sunshine, it develops. Sunshine and the living cell can bring this vital substance into action and perhaps into being. Truly the plant is a factory: sunshine furnishes the power to do work; chlorophyll seems to be the machinery; and water, dissolved salts, and carbon dioxide are the raw products.

49. Animal concentration. — Proteins occur only in small percentages in plant tissue. When the plant is eaten and digested, carbohydrates and oils are "burned" in doing work and the refuse excreted. Water is the same in plant, animal, and stream. Some ash is used, but save in young animals, it is mostly discarded in the manure. Protein is also partly excreted when fed in abundance, but part of it is retained and made into flesh, blood, and sinew. The animal has gradually accumulated a body composed largely of the vital tissue. When it is butchered, man gets a concentrated food which began in the plant cell, but which was refined in the plant and in the animal, and when cooked is adapted to his use. Brain and brawn, which have so changed the world, must look far back to find the beginning of their working power and of their tissues.

50. Storage. — Man and other animals must do something besides eat; hence they eat a quantity and gain reserve energy to carry them till the next meal. Should the following meal and still others be omitted, they live on stored food. Finally, fat and muscle waste away and starvation results.

Something quite similar to this occurs in the plant when storage is made. During the fruiting period, plants use food more rapidly than they manufacture it. Perhaps it would be more accurate to say that the plant moves the food, or part of it, to the seed from the stem, root, or leaf. In annuals and biennials, the seed gets most of the food, while in perennials, it gets only part. The method of storage is almost identical whether in the seed, root, or stem.

When sugar is first made it changes into starch. At night, starch can usually be found in healthy leaves, but usually not early next morning. Enzymes have changed it to sugar and the plant has transported it to the place of storage. Here it is again changed by enzymes into starch which now fills the white plastids of the cell just as chlorphyll did the green. A microscope shows this starch to be in rings with the center of formation on one side in the potato, and in the middle in beans. Plastid after plastid may be laden until the whole cell seems to be composed of starch. Here it remains until transloca-tion to the seed begins, when enzymes turn it to sugar and the plant carries it upward through the tracheal tubes.

Proteins are deposited in the cytoplasm as crystals or globules, or as both. Less storing is done than in the case of starch, but it is handled in nearly the same way. Fats and oils usually enmesh themselves in the cytoplasm. Much seed storage is in the form of oil since most energy can be so stored in a given space. Embryos are rich in oil, supposedly on this account.

Plants that store sugar deposit it as false crystals in the vacuoles when the cell-sap dries, leaving the sugar too concentrated to remain dissolved. Less soluble sugars are found in storage than in the sap of the same plant. This is natural, since insoluble starch and cellulose, and slightly soluble saccharose (cane sugar) are much less easily disturbed than the highly-soluble glucose (grape sugar) of the sap.

51. Harvest. — Plants vary in composition as age advances because nitrogen and ash are taken up early and carbohydrates are manufactured later. The place of storage changes, leaving a plant part rich in food at one time and almost devoid of it at another. Man must know for what he wishes the plant. He must also know what part he wishes to harvest and when he will find what he wants in that part. Wheat makes the best hay at bloom or in the soft dough, but is useless for grain until nearly mature. Beets and carrots yield roots at the end of the first year, but seed only at the end of the second. It is rather general for stems, roots, and leaves to lose food material rapidly as the seed forms.

If hay is the crop, let the grass or legume be cut when the leaves and stems are rich in delicious, digestible food. They must be cured in such a way as not to lose value by leaching with rain or by shattering. When seed is desired, the plants advance to maturity. Care that seed does not shell out is all that is necessary. If roots are required, biennials are harvested the first autumn; if seed, then the tops are cut the second. Fruit is picked when full grown and mature enough to be delicious, yet when firm enough to withstand handling. Cotton is picked after the bolls break, but before the lint weathers from the seed.

Man cuts short the life of the plant when it is in the condition that will best fit his purpose. Curing begins at once and goes on in sunshine or shade, hastily or gradually, by air or by heat according to the product expected. Considerable knowledge of plants and effects of treatment are required. He who does this work must know his ground and work with precision.

52. Control of the harvest. — As civilization has advanced, man has gained more and more control over nature. More and better machines, propelled more effectively, have given him an enormous power to harvest large fields within a short time. Orchard-grass must be cut within a few days of bloom; timothy may be mown any time within two or three weeks. American farmers have chosen to grow timothy. This enables them to tend much larger hayfields. Some wheats shell more easily than others; some potato varieties ripen earlier than others; and alfalfa is richer in protein than grass. All these factors enable man to control the harvest by choosing his crop wisely.

Better cultivation, more thorough manuring, and wiser irrigation produce greater yields. The Utah Station found that the time of application and the quantities of irrigation water affected the proportion of stem, leaves, and grain, and also the chemical composition of these parts. It was found that moderate irrigation produced better qualities of grain, potatoes, and fruit than did excessive water which promoted woodiness and stem development.

Thick planting yields slender, straight flax stems bearing long fiber but little seed; thin planting, which allows branching, begets short fiber but much seed. Pruning may direct food from small useless growth to fruit, and thinning gives fewer but larger fruits.

If man will but learn the ways of his crop, he may have largely within his grasp the power to get what he desires from the plant world. He may set certain forces in action; and then, at the right moment, gather a harvest superior in yield and quality to that of his less diligent neighbors. The Bible says:

"And God blessed them and God said unto them, Be fruitful, and multiply, and replenish the earth, and subdue it; and have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moveth upon the earth.

"And God said, Behold, I have given you every herb bearing seed, which is upon the face of the earth, and every tree, in which is the fruit of a tree yielding seed; to you it shall be for meat" (Genesis i. 28, 29).

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PART II

THE SOIL

CHAPTER VI

WHAT THE SOIL IS

THE soil is not only the foundation of agriculture, but it is also the basis of all human prosperity. It is the most common, and yet the most precious, thing in the world. The fact that this productive blanket covers practically the entire land area of the globe makes it possible for man to get a living almost anywhere; but in places where the soil is scanty the dwellings of man are few.

53. Definition. — The soil is the loose material of the earth's crust in which plants find a home for their roots and from which they are able to secure certain foods necessary for their growth. Almost the entire land surface of the earth is covered with a layer of soil, which varies in thickness from a few inches to hundreds of feet, and in nature from fragments of rock on which weathering has scarcely begun, to muck soil composed almost entirely of organic matter.

Some soils are rich in all the foods required by plants; some are rich in certain elements but deficient in others; some are low in practically all of the necessary foods; while some soils in arid regions contain excessive quantities of soluble salts. This great variation makes clear the fact that what is called " soil " is by no means a definite thing, but may have almost any composition or structure.

The soil may be considered as the waste heap of nature, since almost everything eventually finds its way into the soil where it is mixed and remixed with all sorts of substances to make a blanket-covering for the earth. Fragments of all kinds of minerals and rocks and the remains of all the plants and animals are brought together in the soil to make of it a home in which plants may thrive.

54. Permanence of soils. — The soil cannot be absolutely destroyed or removed from the earth. It will always remain as a heritage to mankind and furnish him a means of making a living. Floods may rage, fires may sweep over the land, man may be at war, dynasties may rise and fall, but the soil will remain an ever-present means of producing food. It may be abused and have its fertility lessened, but it cannot be entirely destroyed; and, if left to the reviving action of nature, it will in time have part of its lost fertility restored.

55. Economic importance of the soil. — The soil is at the very foundation, not only of agriculture, but of all human welfare. The industries of man would cease, and he would be left without food and clothing if the soil should fail to produce its bounties. Mines would close, railroads would cease to operate, factories would stop their wheels, in fact, every human activity would in time be discontinued if the soil should lose its producing power.

The growth of all cultivated plants is dependent on the soil, and the yield of crops is a direct reflection of its condition. Since livestock are maintained by crops, the livestock industry also depends for its existence on the productivity of the soil.

56. Conservation of the soil. — Of all the national resources, the one most in need of conservation is the soil. Forests may grow in the lifetime of man, and waterfalls will continue after he is gone; but the soil — the product of ages of nature's work — when depleted, can be renewed only at great expense. The most important conservation movement, therefore, for any nation to undertake is the preservation of the fertility of its soils.

57. Need of better soil management. — As a rule, soils are tilled by methods handed down from previous generations. These may, or may not, be the best methods. Most of them were devised at a time when but little was known of the real nature of soils or the food of plants, and as a result, they do not take into account the factors of crop production which are to-day known to exist. Many of the present methods of handling soils are out of date and are not well founded; while other methods are known which, if adopted, would add greatly to the profits of farming. Since the welfare of the nations is based on the productivity of the soil, nothing could be of greater importance to a country than the discovery of better ways of handling its soils and the prompt dissemination of this information to tillers of the land.

CHAPTER VII

ORIGIN AND FORMATION OF SOILS

THE material of which the soil is made has been derived largely from the rocks and minerals composing the crust of the earth; but in some soils a considerable part is made up of vegetable matter from the bodies of dead plants. All agricultural soils contain a certain quantity of organic matter which is intimately mixed with the mineral matter. It is difficult to tell in all cases just the kind of rock from which a given soil is derived, since the great amount of weathering and mixing often causes it almost to lose its original identity.

58. Minerals and rocks. — A mineral may be defined as any solid substance of inorganic origin, occurring in nature, and having a practically definite chemical composition and usually a definite crystalline form. A rock may be composed of a single mineral; but it is usually made up of an aggregate of minerals associated with some impurities. Granite is a rock which contains the minerals quartz, feldspar, and mica. Different kinds of granites vary considerably in their mineral content. Elements unite to form compounds; compounds are united to form minerals; aggregates of minerals compose rocks; and rocks disintegrate to form soils.

59. Soil-forming minerals. — It is probable that every known mineral occurs somewhere in the soil, since weathering has been going on for ages, and since every mineral that has been exposed to weathering action has been carried into the soil in great or small quantities. The main soil-forming minerals are the following: quartz, the feldspars, hornblende and pyroxene, mica, chlorite, talc and serpentine, the zeolites, calcite, dolomite, gypsum, apatite, and the iron minerals.

60. Quartz is composed of silicon dioxide, or silica, which makes up about 60 per cent of the crust of the earth. Both silicon and oxygen are found in a great many other minerals, and are present in most rocks. Quartzite is composed of fine grains of quartz firmly held together. Hornstone and flint, sandstone, jasper, and opal are composed mainly of silica. Some soils contain more than 90 per cent of quartz, which is almost entirely insoluble.

61. The feldspars are compounds of silicates of potash, soda, or lime, one or all, in combination with the silicate of alumina. They are prominent ingredients of most crystalline rocks. Potash feldspar (orthoclase) with quartz and mica forms granite gneiss. Soda and lime feldspars form many rocks such as basalt, diabase, diorite, and most lavas. The feldspars are decomposed with comparative ease by weathering agencies, and are the chief sources of clay and potash in the soil. Orthoclase contains nearly 17 per cent of potash, while leucite from lava contains over 21 per cent.

62. Hornblende and pyroxene are of nearly the same composition, being silicates of lime, magnesia, alumina, and iron. They appear to be black, but are in reality of a dark green color. They are easily decomposed because of two properties: (1) their cleavage, and (2) the fact that their iron is readily oxidized. These minerals are usually deficient in potash and hence go well with orthoclase feldspar.

63. Mica is similar in composition to hornblende and pyroxene, but its relative insolubility makes its plant-food elements unavailable. It occurs most abundantly with quartz in mica schist which usually forms soil of a poor quality. The soils derived from granites and gneisses, however, even when rich in mica, are usually excellent on account of their feldspar and associated minerals.

64. Chlorite is a silicate of alumina and iron. It forms part of chlorite schist which is similar, but inferior, to hornblende schist. Talc and serpentine are hydrous silicates of magnesia. They form an important part of the soils of some regions, but are very insoluble and are usually poor in plant food.

65. Zeolites are hydro-silicates containing as bases chiefly lime and alumina, usually with small quantities of potash and soda, and sometimes magnesia and baryta. Water is combined in the basic form and not merely as water of crystallization. The zeolites proper are not original rock ingredients, but are formed in the course of rock decomposition by the atmosphere, heated water, and other agents. Although zeolites rarely form a large proportion of the rock-forming minerals, they are of interest because of the continuation within the soil of some of the processes that bring about their formation in rocks. They are common cementing materials for holding together sand grains.

66. Calcite, or lime, is an important soil-forming mineral, which is but slightly soluble in pure water, although much more so in the presence of carbon dioxide. It is dissolved readily by acids. Limestone comes partly from the shells and framework of marine and fresh water animals and partly by concretions of lime directly from water; hence much of it has been dissolved and precipitated many times. The old saying that "A limestone country is a rich country," has, on the whole, but few exceptions.

67. Dolomite, a mixture of calcium carbonate and magnesium carbonate, is more easily affected by weathering agents than pure limestone. An excess of magnesia tends to impoverish soils.

68. Gypsum, or the sulfate of lime, although widely distributed, is not so abundant as limestone. Few naturally gypseous soils are very productive, probably because of the heavy clays which usually accompany this compound. Gypsum favors the action of certain desirable bacteria, and it is sometimes used to correct black alkali.

69. Apatite, the phosphate of lime, is found in many soils. Unless accompanied by organic matter, it is rather unavailable.

The most important iron minerals in the soil are siderite, limonite, hematite, and magnetite. Since iron is always present in sufficient quantities for plant growth, the iron compounds need receive but little attention.

70. Soil-forming rocks. — The individual minerals, not usually occurring separately, are combined and mixed with the various igneous and sedimentary rocks. Rocks rich in feldspar are said to be feldspathic; in clay, argillaceous; in silica, siliceous; in lime, calcareous; and in sand, arranaceous, according to the minerals composing them. These various rocks in decomposing form soils which differ greatly.

Soils from granite with potash feldspar are rich in potash and usually contain an ample supply of phosphoric acid from small apatite crystals. Gneiss soils are more siliceous and less strong than those from true granites. Eruptive rocks as a class usually form very productive soils, but decompose slowly. Hard limestone dissolves slowly, but the softer varieties go into solution readily. Limestone soils from which much of the lime has been leached form some of the very richest soils. The Kentucky blue-grass region is an example of soil formed in this way. Sandstone soils are often poor, but this depends on the material cementing the grains together. Claystone soils are usually rich in plant-food material, but are too heavy for the best growth of crops. Hard-pans are formed where an excess of alkali accompanies the clay.

71. Methods of soil formation. — Soils are formed from the minerals and rocks, already discussed, by the various chemical and physical agencies of rock decay known as weathering. The most important of these agencies are: (1) heat and cold, (2) water, (3) ice, (4) the atmosphere, and (5) plants and animals. Their action is both mechanical and chemical, the mechanical causing a breaking up of the rock into finer fragments, and the chemical causing a change in the actual composition of the materials.

72. Action of heat and cold. — All of the weathering agents may be ultimately traced back to the heat of the sun, the source of energy for the earth. Wind, rain, and organisms are all directly dependent on this source of heat. In addition to this general work, heat and cold are strong factors working directly in breaking down rock masses. This is very apparent in the granites, gneisses, and mica-schists, each composed of a number of minerals which expand unevenly when heated, causing a break in the rock. This allows water to enter. When cold weather comes the water freezes, and, in freezing, expands about 9 per cent of its volume. This widens the crevice and shatters the rock. Thus, nature uses heat and cold as charges of powder which are constantly being discharged to assist in the constant effort to crumble the rock-masses into soil.

73. Action of water. — Water through its physical and chemical action is perhaps the most important of

Fig. 16. — Streams wear gorges, grinding rocks into fine particles.

the weathering agents. In mountain torrents, bowlders are rolled along, knocking and rasping in their ceaseless effort to loosen the banks and gouge out the bottom of the stream. In the meantime, the rolling bowlder is ground into countless particles, which in the course of time are scattered over as many acres of land. The gorges of the Columbia and Colorado rivers, which, in places, are thousands of feet deep, are good examples of abrasive action. All this earthy material is carried downstream. The Mississippi River annually carries into the Gulf of Mexico enough earth to cover a 640 acre field 286 feet deep. In addition to this, it deposits immense quantities of silt along the lowlands above its mouth. Effects of water action are shown in Figs. 16 and 17.

The ability of water to carry suspended material varies as the sixth power of its velocity; hence, as the grade of a stream changes and the quantity of water varies, there is a constant unloading and reloading of transported materials. Rains, by their constant pounding, also exert considerable action on rocks, especially in loosening and shifting small fragments.

Water is called nature's universal solvent. Its power to dissolve is greatly increased by the presence of carbon dioxide which it takes from decaying organic matter while percolating through the soil. Waves and tides along the sea-shore move sand and other materials in and out, up and down, and by their continuous pounding often wash out great caverns.

74. Ice. — In mountainous countries, where there is considerable snowfall, snowslides are of common occurrence. One of these slides often contains thousands of tons of sliding and rolling snow and moves everything in its way. Trees, rocks, and all kinds of débris are jammed into the cañons below to be taken out by swollen streams.

Ice in the form of glaciers is in certain regions a powerful agent in the making of soils. Glaciers are both disintegrators and transporters; lateral, medial, and terminal moraines are formed from the transported material,

FIG. 17. — Soils are often deposited and moved many times before being used for crop production.

and the rock over which the glacier moves is ground into a very fine powder, which is often carried away by the streams resulting from the melting ice. The river from the Aar glacier carries away 280 tons of solid matter in suspension daily. The Justedal, which covers an area of 820 square miles, discharges on a summer's day 1968 tons of sediment besides the material in solution. The Vatnajökull glacier in Iceland discharges annually about 14,763,000 tons of earth.

These glaciers of to-day are mere babies when compared with those that existed during the great ice age, when the ice sheet covered 2,500,000 square miles. The effects of this ice sheet are apparent all over the northern part of America, Europe, and Asia. The soils of these regions are of glacial origin, and are very fertile in potential plant-food, but often lack in oxidation and tilth. Glacial soils are very different in structure from those formed by the slower process of disintegration. They are usually uniform to considerable depth. In the northern part of the United States and over a large part of Canada, there is a layer of this well-mixed soil resulting from the North American ice sheet.

75. The atmosphere. — The atmosphere exerts both physical and chemical action. Its physical work is done mainly through winds, which are most effective in regions of little vegetation. In parts of China, the wind-formed soils, or loess, are from 1500 to 2000 feet deep. The chemical action of the atmosphere is due almost entirely to oxygen and carbon dioxide. The action of the latter in increasing the solvent power of water has already been explained. Oxygen, working as an oxidizing agent, affects most of the minerals composing the soil. The minerals containing iron are oxidized when brought in contact with air, with the result that their rocks are softened. Feldspar, in the presence of air, oxidizes to kaolin; and certain rocks containing large quantities of feldspar often crumble to a depth of forty or fifty feet by the action of the atmosphere.

76. Plants and animals join with other agencies in breaking up rocks and mellowing soils. Some of the lower forms of plants are able to begin their growth on almost smooth rock surfaces, and by the dissolving action of their juices, soon make sufficient impression to enable other plants to start and to permit the entrance of water. This, by its dissolving and freezing action, hastens decay. Roots of higher plants readily penetrate any small crevice and by their gigantic strength are able to break even large bowlders. The smaller roots of plants penetrate every particle of earthy material and by their physical and chemical activities promote the formation of a good agricultural soil.

Burrowing animals and earthworms are constantly at work mixing the various soils, incorporating organic matter, and assisting in the free movement of air. Plants and animals are constantly dying, and their bodies contribute to the organic matter of the soil, which ceases to be just a mass of dead matter. The decay of these organic bodies assists, not only in mellowing the soil and placing it in a better physical condition, but also in the making available various plant-foods.

77. Classification of soils. — Soils may be classified according to their origin as either sedentary or transported. Sedentary soils are of two kinds: those which over-lie the rock from which they were formed, and those formed in place largely by the accumulation of organic matter, as in swamps. Transported soils vary with the agent used in carrying the materials of which they are composed. Those transported by running water are called alluvial; by ice, glacial; by wind, æolian; and by the ocean, marine. Each of these kinds of soils has its own peculiar properties, although the composition is dependent largely on the kind of rock from which it was formed.

In addition to classification according to origin, soils are sometimes classified by their chemical composition, the native vegetation growing on them, the crops to which they are suited, the size of particles composing them, and a number of other properties. Any adequate method of classifying soils, however, should take account of all the factors which affect their value.

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CHAPTER VIII

PHYSICAL PROPERTIES OF THE SOIL

THE soil is composed of fine rock particles of different sizes thoroughly mixed with varying quantities of organic matter in different stages of decomposition. For practical purposes, it is divided into the surface and sub-soil, the sub-soil being the part below the plowed zone. Soils vary greatly in their general make up, some being but a few inches deep and overlying solid rock, while others are hundreds of feet deep and fairly uniform throughout. Every gradation between these two is found, including clay surface soil with gravelly sub-soil or gravelly surface with clay below. In arid regions the difference between the surface and sub-soil is not great, the sub-soil being in many cases just as fertile and mellow as the upper layer. In humid regions, however, the sub-soil is often compact and, on account of its lack of aëration, seems "dead" when brought to the surface. Such soil sometimes requires a number of years to become friable.

78. Soil texture. — Soils vary greatly in the size of particles composing them. Some are made up almost entirely of coarse particles; others are composed entirely of fine. Most soils, however, contain some fine and some coarse grains, the relative number of each determining the texture, which cannot be modified by the farmer. The texture of a soil has a great influence on the method of tillage as well as on a number of its properties, such as the water-holding capacity, the circulation of air, and the availability of plant-food. These all help in determining the kind of crop that should be grown. For example, peaches and cherries do best on soils having a coarse texture; the small grains prefer a "heavier" soil. Soils having an intermediate texture, such as the loams, are fairly well adapted to the raising of any ordinary crop. Hence, in selecting land, the farmer who knows what crops he wishes to grow should give considerable attention to soil texture.

79. Groups according to texture. — The soil may, by mechanical analysis, have its particles separated in such a way that all grains of approximately the same size are gathered together. Where this is done, arbitrary groups are arranged for convenience in expressing the sizes. A number of different methods of grouping have been employed, but probably the one finding widest use in this country is that of the Bureau of Soils of the United States Department of Agriculture. In this grouping the various sizes are given the following names:

Name	Diameter in Millimeters	Number of Particles in Gram of Soil
1. Fine gravel	2.000–1.000	.252
2. Coarse sand	1.000–0.500	1,723
3. Medium sand	0.500–0.250	13,500
4. Fine sand	0.250–0.100	132,600
5. Very fine sand	0.100–0.050	1,687,000
6. Silt	0.050–0.005	65,100,000
7. Clay	less than 0.005	45,500,000,000

It is impossible to get a soil composed entirely of particles of any one size; hence, the name given to a soil type must depend on the relative mixture of these various sizes. The terms most commonly used for these mixtures are: (1) coarse sand, (2) medium sand, (3) fine sand, (4) sandy loam, (5) loam, (6) silt loam, (7) clay loam, and (8) clay. Farmers, speaking in a general way, usually call their soil sand, loam, or clay.

80. Relation of texture to water-holding capacity. — Of the properties of soils affected by texture, probably none is of greater practical importance than the water-holding capacity. Moisture is held in thin films around the soil particles and the quanity that can be retained depends largely on the surface, which in turn is dependent on the size of particles. King gives the surface of soils of different sizes as follows:

Diameter of Grains in Millimeters	Sq. Cm. Surface to a Gram of Soil	Sq. Ft. Surface to a Lb. of Soil
1.0	22.64	11.05
.1	226.41	110.54
.01	2,264.15	1,105.35
.001	22,641.51	11,053.81
.0001	226,515.14	110,538.16

With such a great variation in surface, it is easy to see why a clay soil may hold 45 per cent of water when a coarse sand will scarcely hold 15 per cent. The understanding of this fact is important in such branches of agriculture as dry-farming, where success depends on the storage in the soil of large quantities of water.

81. Soil structure. — Structure refers to the arrangements of soil particles. Just as sticks may be piled in a box in various ways, so the soil grains may be grouped in numerous different arrangements. Sticks may be piled evenly all one way and fitted together in such a manner that there is little air space between; they may be arranged with one layer crosswise, the next lengthwise, or in other designs, each arrangement having a different volume of air space between the sticks. The same soil particles may, in a similar manner, have many different groupings. The numerous sizes of particles present in every soil make an even more complex arrangement possible. The grains may be wedged tightly together so that air is almost excluded, or they may be flocculated into loose-fitting groups with considerable air space between.

The tilth of a soil, known by farmers to be of such great practical importance, is determined by its structure, or the grouping of its particles. Soil grains packed tightly together form a soil of poor tilth. When plowed, such a soil breaks up into clods instead of falling apart in granules or floccules. A loose structure gives lines of weakness extending in every direction through the soil. Where such a condition exists, it cannot be made to hold together; but where the opposite condition exists, the soil crumbles only when considerable force is applied. A hardpan structure in arid soil is shown in Fig. 18.

82. How to modify structure. — The structure of a coarse-grained soil cannot be greatly affected, since it is always fairly good; but with a clay, constant care is necessary to prevent its becoming puddled. Many a farmer has learned through sad experience that he can, by cultivating a clay soil when too wet, so injure the tilth that several years are required to get the soil back into good condition.

The structure of a soil is affected by almost everything that causes a movement of soil particles. Among the most common factors are the following: (1) tillage, (2)

Fig. 18. — Hardpan in arid soil three feet below surface.

the growth of roots, (3) freezing and thawing, (4) alternate wetting and drying, (5) organic matter, (6) soluble salts, (7) animal life, and (8) storms. The tilth is the result of the combined action of a number of these factors, all of which improve it except certain kinds of storms like hail, and certain soluble salts like sodium carbonate.

83. Specific gravity of soils. — The weight of a soil may be expressed as the real or the apparent specific gravity. The real specific gravity, referring to the weight of the individual particles in comparison with water, is not affected by the pore-space. The apparent specific gravity, on the other hand, refers to the relative weight of a given volume of soil and the weight of the same volume of water. This is greatly affected by pore-spaces.

Clay is often spoken of as a "heavy" soil; sand is said to be "light." This does not refer to weight, but means that clay is difficult, and sand easy, to till. An average sand weighs about 110 pounds to the cubic foot, but clay weighs only about 80 pounds.

84. Air in the soil. — Since air is necessary to the growth of all plants, it is impossible to have a fertile soil without spaces through which air can circulate. Seeds in germinating, and plant roots in growing, require oxygen which is absorbed while carbon dioxide is given off. The decay of organic matter requires oxygen and forms carbon dioxide, which accumulates in the soil-air with the depletion of oxygen. If the condition of the soil does not favor the free movement of air, the oxygen supply soon becomes reduced to the point where plant growth is retarded. The aëration of the soil is dependent on its texture, structure, drainage, and a number of other factors. In a coarse sand air moves readily, but in a clay, especially if compact, the movement is slow. Puddling a soil greatly reduces its aëration, while flocculating its particles into groups promotes the ready movement of air. The size of particles cannot be changed, but their arrangement is affected by plowing and harrowing, which thereby indirectly influence aëration.

A water-logged soil usually has its producing power reduced by lack of oxygen; and the free circulation of air, resulting from placing tile drains under such a soil, is in part responsible for the increased yields following drainage. The beneficial nitrifying and nitrogen-fixing bacteria of the soil require an abundant supply of oxygen for their best growth, and their action is practically discontinued when the air supply is reduced below a certain point. In some soils the aëration may be so great as to result in the loss of excessive quantities of water. This condition, however, is rarely met, and may be remedied in most cases by packing.

85. Heat of the soil. — The temperature of the soil is important because of its influence on the germination of seeds and on the growth of plants; also because of its effect on chemical changes and bacterial action in the soil. When the soil is cold, its life is dormant and all chemical action is reduced. The earlier a soil is warmed in the spring and the later it is kept warm in the fall, the longer is its growing-season. This may have considerable practical importance in regions where early crops bring the best prices and where the season is so short that crops do not fully mature.

Soil heat comes largely from the sun, the rays of which are most effective when striking perpendicularly. A south slope, therefore, is considerably warmer than one facing the north, and a sandy soil is much warmer than clay. The high specific heat of water makes it slow to warm, and as a consequence, a wet soil is usually late in starting the growth of plants in the spring. The excessive evaporation from a wet soil also reduces its temperature. Such factors as color, specific heat, tillage, and a number of others play a very important rôle in regulating the temperature of a soil.

86. The organic matter of the soil is without doubt one of its most important parts since it influences so greatly the physical, chemical, and biological changes that take place. The tilth of a soil, its water-holding capacity, its temperature, and a number of other physical properties are improved by the presence of organic matter, which, on decaying, increases the availability of mineral matter in the soil and hastens desirable chemical changes. Bacteria, which are so important to the soil, could not do their work without organic matter, since they secure their energy by its decomposition. The fertility of a soil, therefore, depends as much on the presence of organic matter as on any other factor; and the maintenance of fertility must include the keeping up of this important constituent.

87. Maintaining the organic matter. — The organic matter of soils is derived largely from the decay of roots, leaves, and stems, although a part of it comes from the remains of animals. For ages, accumulation has been going on until some soils have a large percentage of organic material. In arid soils, however, where the growth of vegetation has been light, the organic content is low; hence, one of the chief problems in the management of arid soils is to increase the proportion of organic matter.

Organic matter in the soil is maintained by the addition of farm manure and other organic refuse, and by the raising of crops to be plowed under. The wise farmer will, if possible, apply large quantities of manure in order to maintain organic matter as well as to add plant-food. The continuous raising of grain crops on the same land year after year and the burning of straw and stubble is a procedure most ruinous to land. The regular use of green-manure crops, preferably the legumes, and the returning of all plant residues to the land will serve to maintain the proper proportion of organic matter in the soil.

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CHAPTER IX

THE WATER OF THE SOIL

All plants and animals require water for life and growth. Plants may live for considerable time without receiving any outside supply of mineral food, but if water is withheld, they very soon wilt and cease to function. The yield of crops during any particular year is usually a reflection of the moisture conditions during the growing-season. Even in humid regions, the lack of available moisture often reduces crop-yields. Over more than half of the earth's tillable surface, the shortage of moisture is the chief limiting factor concerned in crop growth; while in parts of the humid regions, the excess of water in the soil prevents the cultivation of vast areas of otherwise fertile soil. On the whole, therefore, no factor connected with agriculture needs to be more carefully studied and more thoroughly understood than the water of the soil.

88. Origin of soil water. — The water of the soil has at some time been precipitated from the atmosphere. That contained in the soil of any given field may have come in by percolation, or by flooding the surface; but it has at some time been vapor. The quantity of moisture in the soil of any large area, therefore, will be dependent on the precipitation of that region. The rainfall cannot be influenced by man, but he can do much to save water after it falls. In dry regions he may increase the amount of soil water by irrigation, or he may reduce it by drainage when there is too much for the best growth of the crops. He may also increase the efficiency of the moisture in the soil by certain tillage operations.

89. Variations in soil moisture. — The quantity of moisture in the soil is not so stable as the phosphorus, lime, or silica; but it varies from season to season and from day to day. It seldom remains the same even for a short period. More is being added from time to time, and losses occur through a number of channels. Even if for a short period no water is added or lost, there is a constant movement from place to place with a tendency to establish an equilibrium which is seldom, or never, reached. Many forces are at work making it difficult to determine all the laws by which soil moisture is influenced.

90. The condition of the soil moisture depends largely on the quantity present and the nature of the soil. If the soil is saturated, the action is not the same as if only a small quantity of water is present. The soil is able to hold only about a certain amount of moisture and when more is added it percolates rapidly. As the quantity decreases, the tenacity with which it is held increases. A sandy soil reaches the point of saturation with much less water than does a clay soil. The condition of the moisture, therefore, will not always be the same with a given percentage, but will vary according to the nature of the soil.

The water of the soil is usually divided into three classes, determined by the percentage present. These are: (1) free, or gravitational, (2) capillary, or film, and (3) hygroscopic water.

91. Free water. — When the soil becomes saturated with water, a part of it drains away, due to the action of gravity. This drainage water is known as free, or gravitational, water. The attraction of the soil for it is not so great as that of gravity. This water is found between the grains of soil, taking the place of air. Gravitational water, held in surface soil for any great length of time, excludes the air needed by roots. Normally, after a heavy rain, the top soil has its air spaces filled with water, but this rapidly sinks to moisten the drier soil below, in which case it ceases to be free water. Drainage is practiced to remove the free water that cannot drain away unaided.

92. Capillary water. — After all the free water has drained out of the soil, there is still remaining a great deal of moisture that is held in a thin film around each soil particle. Most of the water in ordinary cultivated soils under field conditions is of this nature, and it is this form that supplies water to plants. The quantity of capillary water that can be held by a soil depends on the surface area of its particles. Since many fine particles have more surface than a large one occupying the same volume, a fine-grained soil, such as clay, will hold much more film water than a coarse-grained soil like sand.

Capillary water moves by going from the wetter to the drier particles in the soil. The films on different soil grains tend to become of the same thickness, thus exerting a pull on the thicker films.

93. Hygroscopic water. — A part of the moisture is retained by the soil even when it seems to be dry. Road-dust, on being heated, will give off water vapor which may be condensed on a cold body. This last moisture which a soil retains is called hygroscopic water. If a soil is dried completely with heat and then allowed to stand in the open, it will absorb moisture from the air. This water is held in a thin film around the particle in a way similar to that in which capillary water is held, only much more firmly. It does not move from particle to particle as does the capillary water. Hygroscopic water is of no direct use to plants, since the soil has a greater attraction for it than have the plants.

94. Other critical points. — It has been shown in late years that there are a number of critical points in the percentage of soil moisture besides those already mentioned. For example, there is a point at which plants wilt. This occurs when there is a small quantity of capillary water in addition to the hygroscopic water. There is another point in the capillary water below which the movements are very slow. Above this point the capillary movement is much more rapid.

95. Quantity of water in field soils. — The quantity of moisture found in field soils depends on a number of conditions. Of these, the amount and frequency of rainfall is perhaps most important. In arid regions, the soil is seldom near the point of saturation, while in regions of great rainfall, it is kept constantly wet. Every gradation between these extremes is found. The amount of moisture that a soil will hold depends almost entirely on the size of particles and the amount of organic matter which it contains. The finer the soil the greater its water capacity. A clay that seems fairly dry really contains more water than a moist sand. In one experiment the maximum water-holding capacity of different classes of soils was as follows:

Sand	8 per cent
Silt loam	25 per cent
Clay	40 per cent

The clay was able to retain five times as much as the sand. Organic matter, or humus, greatly increases the power of soils to retain water. This is one reason why much humus is desirable.

96. Methods of expressing the quantity of water. — Soil moisture is usually expressed in percentage of the soil by weight. This may be based either on the total weight of the soil and water, or on the dry soil alone. For example, if on heating 100 pounds of soil there was a loss of ten pounds, there would be 10 per cent of water on the wet basis, there being ninety pounds of soil and ten pounds of water. On the other hand, since ten pounds is 11.1 per cent of ninety pounds, there would be 11.1 per cent of water in the soil on the dry basis. The quantity of water may also be expressed in percentage of the soil by volume. The depth of water over the surface of a given area of land is a common method of expressing quantity in an irrigated district.

97. Loss of soil moisture. — The water that falls on the soil can be lost in three ways: (1) run-off from the surface, (2) percolation through the soil, and (3) evaporation from the surface.

In arid regions, it is desirable to reduce run-off to a minimum, but it may be necessary to increase it in sections of excessive rainfall. Too much run-off under any condition is undesirable, as it is likely to cause destructive erosion. This loss is diminished by keeping the soil open and receptive in order that it may absorb the rain as fast as it falls. Percolation can be reduced only by increasing the water-holding capacity of the soil. This is done by keeping the soil loose and increasing its organic matter.

The loss by evaporation is, in part, under the control of man. When moisture is once in the soil, it should be held there until needed by plants. This is accomplished by some protecting cover such as a mulch.

98. Need for preventing evaporation. — The plant gets its moisture from that stored in the soil; hence, if the supply runs short, the plant suffers. Even in humid climates, rain is so uncertain that it is not safe to let the soil become dry by evaporation. In arid regions, it is absolutely necessary to store all the water that falls, or there will not be sufficient to produce crops (see Fig. 19). Almost the whole practice of dry-farming is founded on the prevention of this loss. Evaporation from the soil is affected by the same factors as evaporation from a water surface. Heat, wind, sunshine, air humidity, and

Fig. 19. — Reservoir for the storage of irrigation water.

altitude all play their part. With soil, an important consideration is the wetness of the surface. Drying the surface quickly is one method of preventing loss.

99. The water-table is the level in the soil at which free water is encountered. In digging a well, the place where water is found is known as the water-table. The depth of the water-table below the surface varies — from a few inches in swamps to many hundreds of feet in some arid sections. It is undesirable to have water too near the surface, as roots cannot penetrate below water level. A changing water-table near the surface is especially bad, since roots no sooner get established than water rises and kills them, thereby weakening the entire plant. The chief reason for draining soils is to lower the permanent level of the water-table or to prevent its rising to injurious heights during wet seasons.

100. The movements of soil-moisture are due to a number of distinct forces. Gravity is constantly pulling the moisture down wherever there is free water. After this has been removed, however, gravity does not have much effect. The capillary water is moved by force of surface tension which works to make the films on soil particles of equal thickness. When water is removed from part of the soil, the film thickness is reduced and there is a gradual movement in that direction. If there is evaporation at the surface or if roots remove moisture from below, this force of capillarity, or surface tension, draws water from other parts. When there is much film water present, the movement is comparatively rapid; but as the soil approaches dryness, it greatly diminishes, and finally ceases. A little water is moved from place to place in the soil by what is known as thermal action. There is an evaporation of water from one place in the soil and a condensing of it in another. Movements by this method are slow and of little importance.

101. Uses of soil water. — The principal use of the soil water is to supply the needs of plants — crops cannot be produced without it. Soil water also acts as a carrier of plant food. The plant can take up only food that is in solution; consequently, without a proper amount of water no other food can be obtained. Water also increases the chemical action that goes on in the soil, making soluble the substances used by crops.

102. Quantity of water used by plants. — A plant may use two or three times as much water each day as its own weight. Every living, active plant-cell contains a large quantity of water, and the process of photosynthesis calls constantly for it. The greatest use plants have for water, however, is for transpiration. For each pound of dry substance produced, there must be a number of hundred pounds of water transpired. This intimate relationship existing between the soil moisture and the life of the plant makes water the most important, as it is also the most variable, factor in crop production.

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CHAPTER X

THE CONTROL OF SOIL WATER

In agriculture it is often desirable to change the amount of water present in the soil. Where it is necessary to remove the excess of water, this is done by drainage, while if the land is dry, its water content may be increased by irrigation. Under arid conditions, where irrigation water is not available, it becomes necessary to adopt methods of conserving a scant precipitation in the soil for the use of crops. This is accomplished by the methods of dry-farming.

IRRIGATION

103. Increasing the soil moisture. — In all arid, and even in some humid, regions there are times when the soil moisture is not sufficient for the best growth of crops. Where this condition exists during any great part of the time, it is often advisable to add water to the soil by irrigation. Methods of conducting this water are shown in figures 20 to 24.

This method has many advantages as well as some disadvantages. A person would think himself very fortunate if he could cause it to begin and cease raining at will, yet with irrigation water at his disposal, a farmer can do even more. He can not only have water when needed, but he can apply it to one crop and at the same time

FIG. 20. — Water being taken to the land.

FIG. 21. — Cement lining prevents seepage.

withhold it from another such as newly-cut hay that might be injured at the time by water. The rain, even supposing it to be under the farmer's control, would fall on the entire farm if it came at all.

Among the disadvantages of irrigation are the cost of installing the system and the expense of applying water.

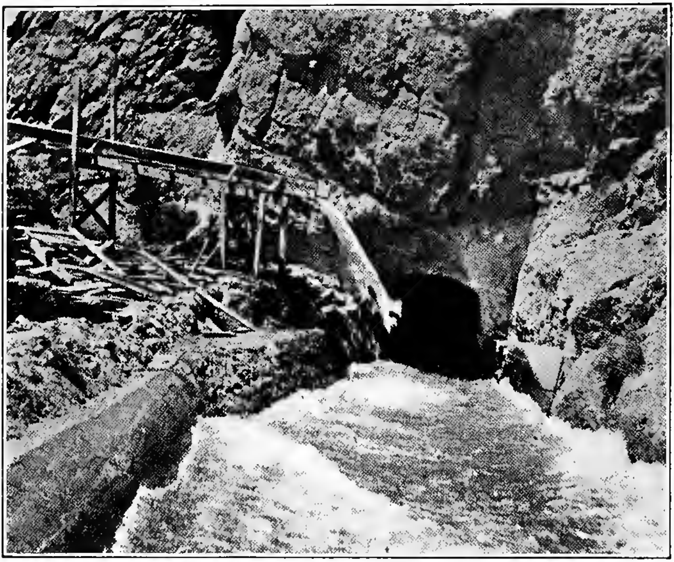

Fig. 22. — Water diverted from reservoir through tunnel in rock.

In arid regions, however, these expenses are justified by increased profits when the water is used with wisdom.

104. Sources of water supply. — The most common and least expensive source of water for irrigation is found in running streams. A suitable dam is placed across the bed of a stream to turn water into the canal, which carries it to the land that is to be served. The head of such canals is sometimes many miles from the farm, and at other times the land to be irrigated is along the banks of the stream.

Where irrigation water is secured directly from a river, only part of the water can be used, since the season

Fig. 23. — A good type of weir for measuring irrigation water.

of irrigation is but three or four months out of the year, while the stream usually flows continuously, often having its greatest flow while the water is not being used. In order to make more water available, storage reservoirs are built. These receive the water at times when it is not being used and hold it for the cropping season. As more land is taken up and water becomes less plentiful, storage usually increases and methods for accomplishing it become complex and thorough. The pumping of underground water from wells for irrigation is rapidly increasing in many sections.

105. Measurement of water. — Irrigation water, as well as land and crops, should be measured. In the past it has been the custom to guess instead of taking accurate

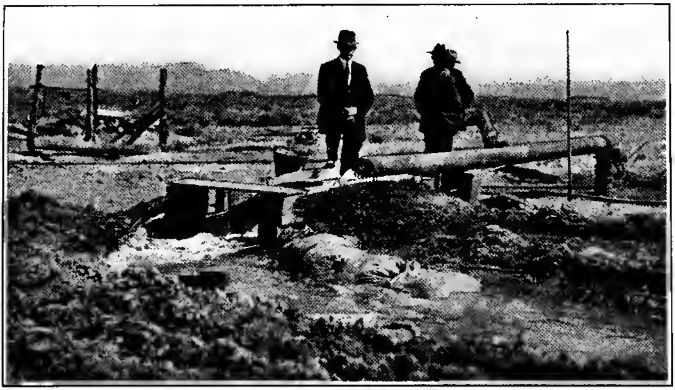

Fig. 24. — Artesian water is often used for irrigation.

measurements. This has led to endless disputes and trouble. In the future it will be necessary for those concerned with the use of water to be familiar with methods of making measurements and expressing quantities.

The two principal devices for measuring flowing water are the weir and the current meter. With the former a measuring gate of a known size is placed in the stream and the height of water flowing over it determined. From standard tables the discharge is found. When the current meter is used, the velocity of the stream flow is obtained, together with its cross-section, and from these the amount of water is calculated.

Of the many ways of expressing quantities of water, the ones in most common use are the second-foot and the acre-foot. A second-foot represents one cubic foot of water flowing each second; an acre-foot is the amount of water required to cover an acre of land one foot deep, that is, 43,560 cubic feet. A second-foot flowing for twelve hours will flow almost exactly an acre-foot.

106. Methods of applying water. — The four principal methods of applying water to land are: (1) furrow, (2)

Fig. 25. — Irrigation water being distributed by furrow method.

flooding, (3) overhead, and (4) sub-irrigation. The first two are by far the most important, but the last two are extremely valuable sometimes. The furrow method of distribution is shown in Fig. 25.

In the first method, water is run in furrows and allowed to soak the ground between the rows. It can well be used on crops that are intertilled and has the advantage of not wetting the entire surface. This reduces evaporation greatly as compared with flooding. A small stream of water can irrigate a greater area of land by this than by other methods, but more labor is required.

The flooding method is used most on pastures, meadows, and the small grains. This method leaves a soil that bakes in a crusted condition, and can be used only on land with an even slope. Overhead-irrigation is used for lawns and gardens, but is never practiced on a large scale. Its disadvantages are the high cost of installing and the large evaporation. It has the advantage of supplying water evenly over the surface in a condition similar to rain that leaves the air as well as the soil damp.

Sub-irrigation is practiced by filling deep ditches on the sides of the field with water and allowing it to soak through the soil and saturate the sub-soil without wetting the surface. It may also be distributed through underground pipes. The latter method is probably the most economical way of using water, since it reduces evaporation to a minimum.

107. The amount of water to use will depend, to a considerable extent, on the amount available. As a general rule, however, if there is an abundant supply, most farmers will apply more than is good for either the crop or the soil. They try to make up for lack of tillage and manure by the application of water.

Crops vary in their water requirements, and even the same crop does not require the same quantity of water in all climates and on all soils. These factors must be taken into account in determining how much to use.

It is probable that two feet of water applied during the year is enough for most crops if the rainfall is as much as twelve inches. The yield may be slightly increased if more than this amount is used, but the cost of applying the extra water is probably more than the increased yields justify. The practice of putting from six to eight feet of water on land in a season cannot be too strongly condemned. It wastes water, injures the quality of the crop, and reduces the value of the land.

108. When to irrigate. — It is probable that there is a definite amount of moisture that is best for each crop. The ideal condition is to maintain this degree of wetness, but it is impossible to do this exactly. Crops have cer-

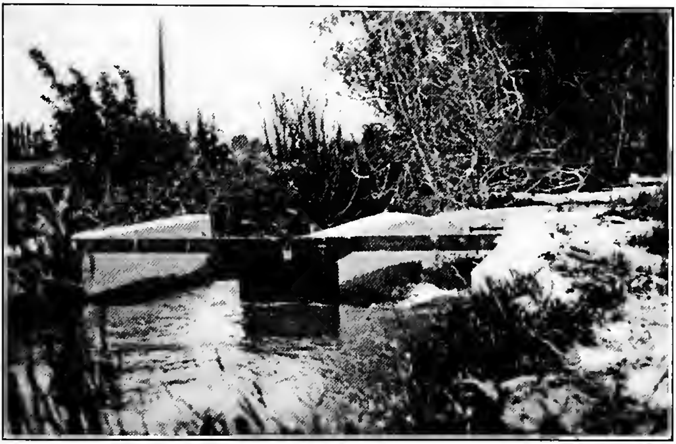

Fig. 26. — Cement dividing gates save trouble.

tain periods in their lives when they are especially affected by drouth. With grain crops, this sensitive period comes when the heads are forming and filling. Sufficient water should be supplied at these critical periods.

Good germination and a good start are very important. If sufficient moisture is supplied at first to make this possible, plants can often go without much additional water till they are preparing to fruit. Forage crops, in order to produce a large amount of succulent material, should be kept fairly moist all the time. If a soil is deep and retentive, a few heavy irrigations are usually better than many light ones; but, on a shallow, sandy soil, it is necessary to apply water often. Deep-rooted crops can go without water much longer than those keeping their roots near the surface.

Under irrigation, it is a good thing for a farmer to have a number of crops in order that the water may be used on one when the other does not need it. When but one crop is grown, it may require the irrigation stream for only a small part of the season, leaving the water to waste at other times; hence, a larger area can be served by a given stream of water if it is used on a number of crops.

109. Over-irrigation. — The farmer who irrigates every time he gets a chance whether his land needs it or not is as bad as the boy who went to the theater every night and slept during the performance. On being asked why he attended, if he was not sufficiently interested to stay awake, he replied that he had to go because he had a season ticket.

To irrigate when not necessary is a waste of time and water, both of which are precious. Too much water reduces actual yields and, in addition, ruins the land by washing out fertility. It would not be so bad if the offender alone had to suffer, but his folly causes injury to his neighbor located on lower land by water-logging the soil and causing alkali to rise. There should be laws to prevent the excessive use of irrigation water.

110. Need for economy. — There is very much more land in arid regions than can be served by the available water; hence, the factor limiting crop production is not land, but water. It is important, therefore, from the standpoint of the community, that all water be used to the best advantage. Six acre-feet of water will produce many times as much if applied to five or six acres of land as it will if applied to one. As the available water becomes less plentiful, methods of greater economy will be introduced. These will be of benefit to the individual farmer, as well as to the general community. Economy in water distribution (note Fig. 26) becomes a prime requisite.

DRAINAGE

111. Removing excessive water. — There are many million acres of land in the United States containing so

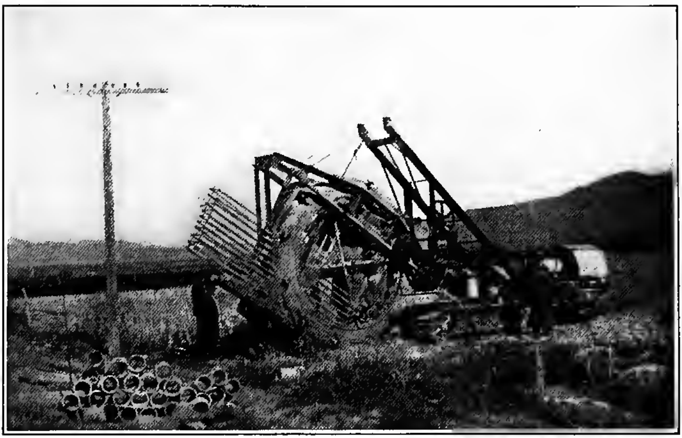

Fig. 27. — Machine for digging drainage ditches.

much water that crops cannot be successfully raised there. Part of this land is in permanent swamps, while some of it is dry during a portion of the year, being water-logged only at certain seasons. There is also much land having a fairly dry surface appearance, but with ground water so near that roots cannot penetrate to any great depth.

The chief difficulty in the way of successful agriculture on all such fields is the surplus water. The only way to make them suitable for crops is to drain them. Drainage practices are shown in Figs. 27 to 29.

112. Removing alkali. — In most arid regions, much of the land contains a high percentage of soluble salts. This often accumulates in such large quantities that the growth of plants is prevented. Drainage is the only method of permanently removing the alkali, which is gradually

FIG. 28. — Draining an orchard.

carried away by percolating waters. Much of the land that is at present valueless, on account of its high alkali content, would be of excellent quality if its excess salts were removed.

113. Benefits of drainage. — The drainage of wet land improves it, in many indirect, as well as direct, ways. Lowering the water-table gives plants a larger zone from which their roots can draw plant-food and moisture. This lessens the need of fertilizers and the susceptibility to drouth. The increased aëration of the soil resulting from drainage promotes the growth of desirable organisms, increases favorable chemical action, and makes the soil a much more desirable home for plants. It warms the soil earlier in the spring, thereby increasing the growing-season of crops.

Drainage improves the sanitary conditions of a region by drying the breeding places of disease germs and disease-carrying insects. It lessens the winter-killing of

FIG. 29. — Drainage outlet that is likely to clog.

crops by reducing heaving of the soil; and it very decidedly improves structure and tilth. All of these benefits working together result in a good net profit in almost every case where drainage is properly done. It is a common experience that when twelve or fifteen dollars an acre are spent in drainage, the value of the land is increased from twenty-five to fifty dollars.

114. Kinds of drainage. — Any one method of drainage is not suited to all conditions, nor is it always practicable to employ the method that might seem best. The entire set of conditions must be taken into consideration before deciding just how to drain a piece of land.

Open ditches are probably the cheapest method of carrying away the water. They are used to advantage in draining ponds and other surface accumulations. The chief advantages of the open drain are, (1) the cheapness with which it can be constructed, and (2) the ease with which it can be cleaned. Some disadvantages are that it renders waste the land occupied, and cuts the land area into small fields that are difficult to get at. The open ditches become filled with falling earth and weeds and are a source of constant danger to farm animals.

Some form of covered drain is usually preferable for ordinary purposes. With the covered drain, a trench is dug and some material placed in the bottom that will allow water to pass through. This is later covered with earth. Some of the materials used for such drains are rock, brush, lumber, clay tile, and cement tile. The last two are, by far, the most common. Where tile can be had, it is recommended under almost all circumstances.

115. Installing the drains. — The first step in draining land is to lay out the system. Some kind of instrument for getting levels must be used in determining the contours and deciding where to place the drain lines. A level is also necessary to find the proper depth for the trenches. After the system is laid out, the ditches are dug either by hand or by machinery. In early days, they were practically always dug by hand, but modern machinery, where it can be had, now does the work much more cheaply. Tile should probably not be placed nearer the surface than two feet, or farther than five or six feet except in unusual cases. Usually about four feet is a good depth.

The bottom of the ditch should have an even grade, otherwise the flow of drainage water will be uneven and silt will be deposited in low places. In certain sections, where there is a tendency for roots to clog the drains, they must be placed deeper than would otherwise be necessary. Care should be taken to have the joints of the tile fit well together to avoid filling with dirt. The work of covering can usually be done with a team. The outlet should be screened to keep out small water-loving animals, and should be so constructed that it will not be easily clogged.

DRY-FARMING

116. Scope of dry-farming. — More than half of the land surface of the earth receives less than twenty inches of annual precipitation. Consequently, this vast area is handicapped in its crop production by a shortage of moisture. A relatively small part of this total area can be reclaimed by the use of irrigation water; but the greater part of it, if tilled at all, must have applied to it every possible method of water conservation. The raising of crops without irrigation where there is less than about twenty inches of annual rainfall, has come to be called dry-farming. It does not differ essentially from any other farming, except that every process is directed toward utilizing economically all of the available moisture.

117. The question of rainfall. — The total amount of rainfall is not the only consideration. Its distribution throughout the year, the quantity falling at one time, and the evaporation all modify its effectiveness. In some regions with a comparatively high total precipitation, most of the water falls in the autumn after the crops are harvested. A large percentage of this is lost before the next summer when it is needed. In other places the rain comes in great torrents at a few times during the year. In such cases comparatively little of the moisture sinks into the soil; most of it runs off. The intensity of evaporation is also important, since it so greatly modifies the soil moisture. Hot regions, with many clear, windy days, challenge man's best effort. It is difficult to store water in the soil from which several times the total rainfall would evaporate. If, however, there is but little wind and, at the same time, a high humidity of the air, the loss by evaporation is relatively low.

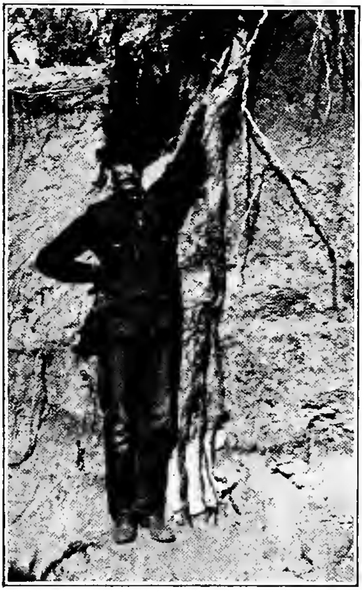

Fig. 30. — A deep, uniform soil, well adapted to dry-farming.

Twelve inches of precipitation, well distributed in a region of low evaporation, would doubtless make dry-farming more successful than twenty inches falling in such a way that most of it is lost.

The dry-farming areas of the United States are sometimes divided into the following five areas according to the seasonal distribution of rainfall:

(1) Pacific type, which extends west of the Sierra Nevada and Cascade ranges receiving most of its rainfall from October to March with but little during the summer;

(2) Sub-Pacific type, which extends over Utah, Nevada, and eastern Washington, having a high winter and spring rainfall;

(3) Arizona type, which prevails over Arizona, New Mexico, and a small part of Utah and Nevada, having least rainfall in early summer and most during July and August;

FIG. 31. — Clearing dry-farm land of brush.

(4) The Northern Rocky Mountain and Eastern Foothills type, with the main part of the rainfall coming during the late spring;

(5) The Plains type, with most of the rain falling during May, June, and July.

118. Dry-farm soils. — In dry-farming, the soil must constantly be used as a reservoir for moisture; hence, the necessity for a soil with high water-holding capacity. A soil that is shallow is entirely useless for a dry-farm, since it cannot hold sufficient water to supply crops between rains. A soil with coarse texture, like sand, is not able to hold more than a small quantity of moisture;

hence, it cannot be used in dry-farming. The ideal dry-farm soil is at least eight or ten feet deep and loamy. It

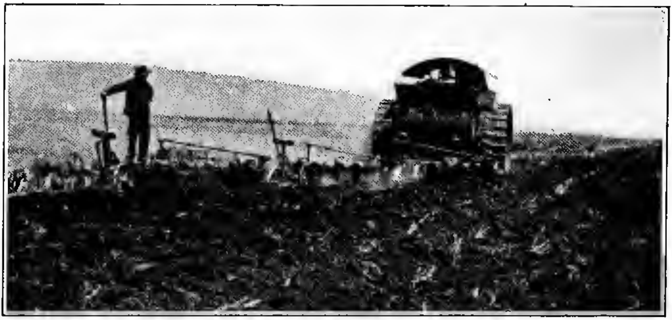

Fig. 32. — Plowing stubble on a dry-farm.

should be easily tilled and readily mulched. A good type of soil for dry-farming is shown in Fig. 30.

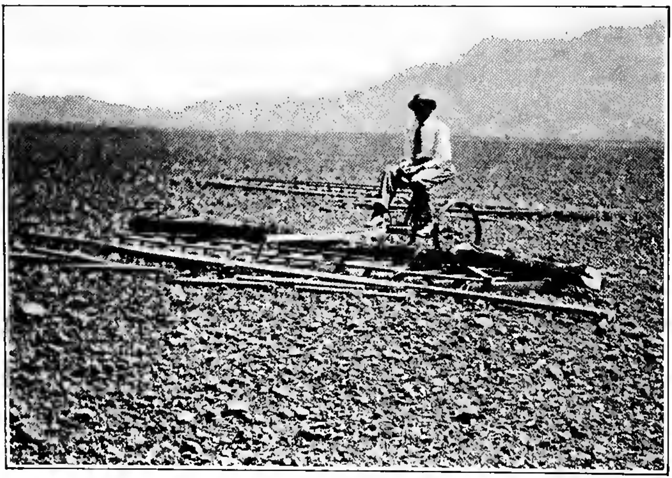

Fig. 33. — A large mulching implement used in dry-farming.

119. Dry-farm crops. — No set rule can be given for the best crops to be grown on the dry-farm. The problem must be worked out for each climatic and soil condition. Up to the present, however, the cereals have been most widely as well as most successfully grown. Of these,

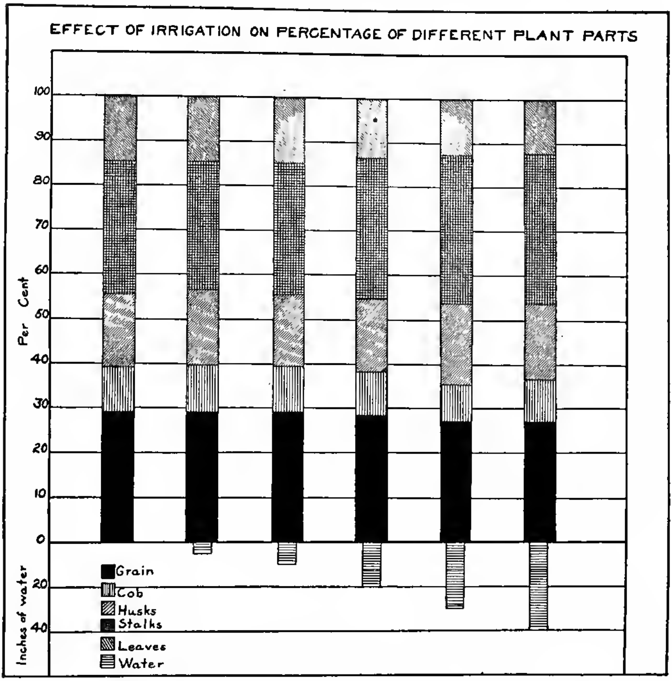

FIG. 34. — The amount of moisture which the plant has affects the proportion of different parts.

wheat is king. In regions where the major part of the precipitation comes during the winter, fall wheat has done best; but where the rain falls during the summer or where winter-killing is severe, the spring-planted varieties have been most successful. Barley, oats, emmer, and rye have been raised with varying success depending on conditions. In hot climates, the grain-sorghums have become important dry-farm crops. Corn has been successful over a wide range of conditions, and has the advantage of being planted in rows, which permits it to be cultivated during growth.

It has been difficult, up to the present, to find forage crops that grow well under extreme drouth. Alfalfa,

FIG. 35. — Experiments to determine the amount of water used by crops. (Utah Experiment Station.)

field peas, and smooth brome-grass have been used to some extent. Potatoes and a number of vegetables have done well. Trees for shade and fruit are grown in some sections, but usually it is difficult to get them started.

120. Tillage methods. — Though the same tillage methods are not successful in all dry-farm areas, most of the fundamental principles hold for all conditions. The objects of tillage are to make the land receptive to rain and to prevent loss after the moisture is once in the soil.

Deep plowing, usually in the fall, and considerable subsequent tillage have been found best to accomplish this end. Thin seeding is almost always practiced on such farms. Every precaution must be taken to prevent the growth of weeds, as they consume the moisture needed by crops, in addition to being in the way at harvest and reducing the value of the crops. Over the greater part of the dry-farm region, summer fallowing is a successful practice. It makes possible the use of two years' precipitation in the production of a single crop and aids greatly in the control of weeds. The great amount of tillage required in dry-farming has made necessary the development of special machinery which can utilize a relatively large amount of power. Clearing and village operations on dry-farms are shown in Figs. 31 to 33. The effects of irrigation are graphically shown in Figs. 34 and 35.

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CHAPTER XI

PLANT-FOOD OF THE SOIL

THE method by which plants secure their food from the soil was not discovered until comparatively a few years ago. From the time of the ancient Greeks and Romans down to the beginning of the nineteenth century, investigators sought to find some one substance in the soil that was the real food of plants. At different times it was thought to be fire, water, nitre, oil, and many other materials; and the idea was rather generally held that plants fed on a single substance. During this period all plant-food was supposed to come from the soil; it was not known that the greater part comes from the air. One theory that was held for a long time was that humus, or organic matter, furnished the material from which growing plants secured their food. After it became known that the carbon of plants is derived from the carbon dioxide gas in the air and that only ash comes from the soil, it was easy to find the real function of the soil and how to control its plant-food.

121. What plants use from the soil. — Of the ten elements required by plants seven, in addition to those obtained from water, come from the soil. These are potassium, phosphorus, calcium, magnesium, iron, sulfur, and nitrogen. A number of non-essential elements, including sodium, chlorine, and silicon, are also taken up by most plants. Elements are not used by plants in their elementary condition, but they are taken from the soil minerals, each of which is made up of a number of elements. All crops require the same elements for their growth, although they do not all use them in the same proportion. Potatoes and sugar-beets use relatively large quantities of potassium, the grain crops require considerable phosphorus, while alfalfa and clover use more calcium than do most other crops. This is one, but only one, of the reasons for practicing rotation.

Water, which furnishes the elements oxygen and hydrogen, is also taken from the soil. Only a small quantity of water would be required if its sole function were to furnish these elements, but it is used as a carrier of foods in the plant and is also transpired in large quantities; hence, the quantity used by crops is much greater than that of all the other foods combined. The method of supplying and conserving the soil moisture has been discussed in Chapter X.

122. Composition of soils. — Soils are made up largely of insoluble material of no food value for plants. The amount of actual plant-food in the soil is comparatively small, but since plants do not use large quantities of this food, the supply is sufficient for crop production. Hilgard has compiled in the following table a great number of analyses of typical soils.

These analyses show that less than 5 per cent of humid soils is composed of plant-food and that the remainder is largely made up of material insoluble even in strong acid. In arid soils, the proportion of plant-food is somewhat higher, but even there, it comprises less than 10 per cent of the total soil.

The organic matter in humid soils is usually much higher than that in soils of arid regions; but the low organic matter of the arid soils is relatively high in nitrogen.

TABLE 1. — CHEMICAL COMPOSITION OF HUMID AND ARID SOILS. STRONG HYDROCHLORIC ACID ANALYSIS

	HUMID REGIONS AVERAGE OF 696 SAMPLES	ARID REGIONS AVERAGE OF 573 SAMPLES
1. Insoluble residue	84.17	69.16
2. Soluble silica (SiO_2)	4.04	6.71
3. Alumina (Al_2O_3)	3.66	7.21
4. Ferric iron (Fe_2O_3)	3.88	5.48
5. Sulfuric trioxide (SO_3)	0.05	0.06
6. Manganese (MnO_2)	0.13	0.11
7. Phosphoric acid (P_2O_5)	0.12	0.16
8. Lime (CaO)	0.13	0.43
9. Magnesia (MgO)	0.29	1.27
10. Soda (Na_2O)	0.14	0.35
11. Potash (K_2O)	0.21	0.67
12. Humus	1.22	1.13

123. The analysis of soils. — In order to determine the plant-food in a soil, the chemist takes a sample to a laboratory, where he analyzes it. He does the sampling very carefully, since the accuracy of the analysis depends on the accuracy of the samples. If, for example, he should analyze just the surface inch, his results would not apply to the lower depths of the soil where roots often feed; frequently the soil varies much in composition at these different depths. Again, if the sample should be taken from a low place containing considerable organic matter, it would not represent the entire field. In sampling, therefore, the chemist takes soil from a number of places in the field and at various depths and mixes all together in order to get an average sample for analysis.

After the sample has been prepared, the method of analysis depends on the information desired. If the total plant-food is to be determined, the soil is treated with certain acids which dissolve the soluble matter, after which the chemist can determine the quantity of the various elements in it.

124. Available and reserve plant-food. — Only a small part of the total plant-food of the soil is available to crops during any one year. Roots penetrate every part of the soil, but they can absorb only material that is in solution. Through the carbon dioxide which they give off, the roots assist in dissolving the minerals of the soil. Their action is slow, consequently only a small portion of each compound can be used in any one year. This is very fortunate, since, if all plant-food were readily dissolved, it would be leached out by rains or floods. The potassium found in such minerals as mica becomes available only after years of weathering, while that in kainit can be immediately dissolved. It is impossible, therefore, from a chemical analysis, to tell how much of a given element is available to plants for immediate use without knowing in what minerals it is contained.

125. Making plant-food available. — The making available of reserve plant-foods as fast as needed by crops is one of the chief problems of soil management. This is done (1) by tillage, which aids weathering agencies in their action on soil particles; (2) by drainage, which allows air to circulate more freely through the soil; (3) by plowing under organic matter, which, in decaying, helps to make the minerals soluble; and (4) by numerous other less important means. The nitrogen present in the soil is made available by nitrification, which is favored by tillage and by a desirable moisture content.

126. Quantity of plant-food removed by plants. — Each crop uses plant-food in varying quantities. The quantity of mineral foods taken from the soil by different crops is expressed by Warington in the following table, which includes the material found in the entire harvested crop.

TABLE 2. MINERAL FOODS REMOVED FROM THE SOIL BY CROPS

		TOTAL				
Crop	Yield	Ash	Nitrogen	Potash	Lime	Phosphoric Acid
Wheat . .	30 bu.	172 lb.	48 lb.	28.8 lb.	9.2 lb.	21.1 lb.
Barley . .	40 bu.	157 lb.	48 lb.	35.7 lb.	9.2 lb.	20.7 lb.
Oats . .	45 bu.	191 lb.	55 lb.	46.1 lb.	11.6 lb.	19.4 lb.
Maize . .	30 bu.	121 lb.	43 lb.	36.3 lb.	——	18.0 lb.
Meadow hay	$1\frac{1}{2}$ T.	203 lb.	49 lb.	50.9 lb.	32.1 lb.	12.3 lb.
Red clover	2 T.	258 lb.	102 lb.	83.4 lb.	90.1 lb.	24.9 lb.
Potatoes .	6 T.	127 lb.	47 lb.	76.5 lb.	3.4 lb.	21.5 lb.
Turnips .	17 T.	364 lb.	192 lb.	148.8 lb.	74.0 lb.	33.1 lb.

The table shows the variation in the relative quantities of nitrogen, potash, lime, and phosphoric acid used by different crops.

127. Plant-foods that are scarce. — Of the ten elements required by plants, only three may be considered as scarce. These are nitrogen, phosphorus, and potassium. In a few soils calcium and sulfur may be deficient, but they are usually present in sufficient quantities to supply the needs of crops for centuries.

Nitrogen is, without doubt, the element most likely to be lacking in soils, and it is the most expensive element when purchased; but the fact that it can be added to the soil by the growth of leguminous plants makes its maintenance possible in every soil. Phosphorus, which is used in large quantities by the grain crops, is present in exceedingly small quantities in many soils. On this account, it becomes necessary to use phosphorus fertilizers in order to maintain the fertility of these soils. Potassium is usually present in fairly large quantities, but since it is, in the main, not available to plants, soils usually respond to potassium fertilizers. It is probable, however, that proper methods of increasing the availability of reserve potassium will do much toward making unnecessary the heavy use of this fertilizer.

128. Exhaustion of the soil. — The possible exhaustion of the soil has been discussed for many years; numerous different opinions have been held. Some have contended that the plant-food supply is rapidly being used up and that it will not be long before the soil is so impoverished that crops will not grow. Others have maintained that the soil is being constantly renewed and as a result will never be exhausted. Experience has demonstrated, however, that, if the productivity of the soil is to be maintained at a high standard, part of the plant-food removed by crops must be returned either as farm manure or as commercial fertilizers. Since plant-food is rendered available but slowly, it is probable that crops never can entirely exhaust the soil. A lessened supply of available food, however, greatly reduces yields of all crops.

129. Losses in plant-food result primarily from the removal of crops from the land, but in regions of heavy rainfall large quantities are also removed by leaching and by surface washing. In some of the limestone areas of the eastern part of the United States, the rock and soil have been leached so much that the greater part of the original material has been removed, leaving only the more insoluble minerals. Naturally, during this process the more available compounds have been carried away. In many sections, surface erosion is responsible for the destruction of much valuable land. The soil is, in some cases, washed entirely away, while in others, the main part is retained, but the soluble material is leached from the surface.

130. Plant-food in organic matter. — The organic matter of the soil is composed almost entirely of dead plants in various stages of decomposition. These dead tissues contain a quantity of mineral matter that has been once in solution, and is, therefore, more likely to be available to growing plants than the minerals. Nitrogen is particularly important in this connection, since practically all of the nitrogen of the soil is found in the organic matter. Besides furnishing directly a part of the plant-food, organic matter assists, by its decay, in rendering available the mineral matter of the soil.

131. Relation of plant-food to value of a soil. — In order that a soil may be valuable, it must have an ample supply of plant-food; but this is by no means the only consideration. Farmers sometimes submit a small sample of soil to a chemist with the request that he analyze it and tell what the land is worth. Those who are familiar with soil study understand that it is impossible by merely knowing the total quantity of plant-food to tell the exact value of any land. Such questions as drainage, aëration, mositure supply, texture, and many other things help to determine what a soil can produce. All these factors must be taken into consideration in estimating the value of land and in outlining methods of management.

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CHAPTER XII

MANURES AND FERTILIZERS

Plants require for their growth an available supply of various mineral foods. These should be present in the soil in a balanced condition in order that the plants may find the most congenial environment. Crop yields are decreased if any one of these necessary elements is present in exceptionally small quantities. Even if all other conditions are favorable, the producing power of most soils could be materially increased by simply changing the available supply of one or two elements. The addition of a fertilizer may effect this readjustment.

Where crops are raised continuously on land and removed each year, a certain amount of plant-food is carried away. An unreplenished deposit of money in the bank, no matter how large, will in time be exhausted if continually drawn out. The plant-foods in the soil may be considered in much the same way, and while this analogy is not entirely true, yet the same principle holds.

Some soils contain a very great store of plant-food, but even such will not continue to endure abuse without protesting by giving reduced yields. If a permanent system of agriculture is to be maintained on any soil, no matter how rich, at least a part of the mineral matter that is removed must be returned either in the form of farm manure or commercial fertilizers.

Materials are often applied to the soil for their indirect action as well as for the plant-food which they add. Farm manure improves the physical condition of the soil; lime corrects acidity and flocculates the particles of fine clay; other fertilizers help to render available the reserve store of plant-food in the soil.

132. Types of fertilizers. — The materials added to the soil either as direct or indirect fertilizers are numerous. By far the most important of these is farm manure, which is composed largely of animal excreta mixed with litter. Of the fertilizers purchased from the outside, the most common are those applied for the nitrogen, phosphorus, and potassium they contain. These are usually, but not always, in the form of mineral salts. Other materials called amendments are used for their indirect action on the soil rather than for the direct plant-food they furnish. In addition to these substances, which must be hauled to the soil, it is a common practice to grow certain crops which serve a similar purpose. These are usually the legumes. In order for them to be of use as a fertilizer, they are plowed under.

133. How to determine fertilizer needs. — In the United States, more than one hundred million dollars are spent each year for commercial fertilizers in addition to the billions of dollars worth of farm manure that is used. It is probable that nearly half of this commercial fertilizer is wasted on account of lack of judgment in applying it. One of the most important problems connected with the use of fertilizers is to know the needs of the soil and to be able to supply these needs in an intelligent and economical manner.

This is no simple matter. It is impossible by any single means to say just what is the best treatment for a soil, but by combining the knowledge of science and the wisdom of the practical farmer, a partial solution of this problem can be reached. A chemical analysis of the soil is very useful in determining the needs of soil, but it is not sufficient. Such analysis must be compared with field tests of fertilizers, and with practical tests of crops in order to determine soil needs. Where all this information is brought together and carefully studied a fairly accurate judgment of the soil requirements can be made. The practice of simply applying any kind of fertilizer the dealer may have for sale, without making a thorough investigation, cannot be too strongly condemned.

134. Nitrogen fertilizers. — Nitrogen is the most expensive of all the fertilizer elements, and the world's supply of this compound is limited. Formerly, it was obtained from guano, which is manure and decayed bodies of birds, but this source of supply is now practically exhausted. At present the chief source is the beds of sodium nitrate, or Chile saltpeter, found in Chile. It lies near the surface of the ground in great beds, but is so mixed with rock and earth that leaching out of the salt is necessary before it is ready for market. Nitrogen in the form of sodium nitrate is directly available to plants.

Ammonium sulfate is another important source of nitrogen. In the making of coal-gas by the distillation of coal, a quantity of ammonia is given off. The gas is passed through sulfuric acid, where the ammonia is removed and ammonium sulfate formed. This salt is about 20 per cent nitrogen.

It is possible, by means of electricity and in other ways, to combine the nitrogen of the air in such a manner that it can be used as a fertilizer. The chief products of these processes are calcium nitrate and calcium cyanamid. The main difficulty in the way of using these fertilizers more widely is the lack of cheap power which is required in the manufacture of them.

A great many animal products are used, chiefly for their nitrogen. Dried blood, dried flesh, ground fish, tankage, hoof and horn meal, leather meal, and wool and hair waste are all used. The availability of the nitrogen in these compounds diminishes about in the order given. In dried blood the nitrogen is available at once, while in leather and hair it can be used but slowly.

135. Nitrogen-fixation. — While the use of some commercial nitrogen may always be necessary, it is probable that the best husbandry will direct the farmer to add the necessary quantity of nitrogen to his soil by the growth of legume crops which are capable, through the nodule-forming bacteria on their roots, of fixing the nitrogen of the air. Thus, when these crops are plowed under they enrich the soil on which they were grown. The details of this operation are described at greater length in Chapter XIII.

136. Phosphorus fertilizers are obtained from both organic and mineral sources. Bones in various forms are extensively used. Formerly, they were used chiefly in the raw condition, both ground and unground; but now most of the bone is first steamed or burned to remove fat and nitrogenous materials which are used for other purposes. Fine grinding of bone makes its phosphorus more easily available. Tankage that is relatively high in bone is used largely for its phosphorus, and if high in flesh scraps, it is valuable for its nitrogen. Bone is sometimes treated with sulfuric acid to render its phosphorus more available.

Mineral phosphorus is found in several kinds of rock which usually have the phosphoric acid in combination with lime, iron, and aluminum. The presence of the last two elements reduces the availability of phosphorus. Rock phosphates are used in various ways. Formerly, the rock was practically all treated with sulfuric acid to form super-phosphate, or acid-phosphate as it is often called; but of late years, the use of finely-ground raw rock-phosphate is increasing, especially on soils rich in organic matter. The acid-phosphate is doubtless more immediately available than the raw rock, but it is also much more expensive.

In the manufacture of steel from pig-iron, much phosphorus is removed with the slag. This is called Thomas slag; it is often ground and used as fertilizer.

137. Potassium fertilizers. — Most of the potassium fertilizers used in the world come from the Stassfurt deposits in Germany. Here, a great many minerals containing a high percentage of potassium are found. Some of these are ground and put on the land direct, while others are leached with water to concentrate them before they are used. Kainit and silvinit are among the most common of these minerals.

Wood ashes have, for generations, been known to be high in potash. They are often applied directly to the land, but they are sometimes leached to obtain the potash in a more concentrated form. In some countries where there is abundant sunshine, sea water is evaporated and potassium obtained by fractional crystallization. Many rocks such as orthoclase feldspar and others contain a comparatively high percentage of potassium. These rocks have sometimes been ground and used as fertilizers, but their potassium is so unavailable that their use is of doubtful value.

138. Lime. — Many soils, particularly in humid regions, have an acid reaction which is not conducive to the best growth of most crops. It is necessary to neutralize this acidity before such crops as alfalfa and clover will thrive. This is best done by the use of some form of lime. Burned lime has been used very extensively, but it is gradually giving way to finely-ground limestone which is much easier to handle. The effectiveness of limestone depends to a great extent on the fineness of grinding.

139. Indirect fertilizers. — Many substances are added to the soil because of their indirect or stimulating action. Among the most common are gypsum, common salt, iron sulfate, soot, and manganese salts. While it may be advisable to use some of these materials for special cases, their general use is not recommended, since they add no real plant-food and their temporary benefit may have a reaction.

140. Home-mixing of fertilizers. — Many farmers would rather pay more for fertilizers that are already mixed than to take the trouble of mixing them. This is largely because they do not realize how much more they have to pay for the various elements when purchased in the commercial brands of fertilizers than if obtained as the simple fertilizing materials such as sodium nitrate, acid-phosphate, and potassium chloride.

Fertilizer manufacturers possess no special secrets that cannot be learned by any farmer who will give the subject a little study. It is a poor policy to pay hundreds of dollars every year for fertilizers about which nothing is known save what is told by the salesman. Better economy would lead the farmer to spend a few dollars buying books on the subject, as the information obtained from one book may make possible the saving of from 25 to 50 per cent on the fertilizer bill. Any farmer can at very little expense prepare a place in which to mix fertilizers; then, by purchasing the materials best suited to his conditions, he can mix them himself and thereby obtain a much more effective fertilizer at the same expense. Self-reliance in this and other respects is often a great advantage.

141. Value of farm manure. — The use of farm manure is the surest means of preserving soil fertility. Practically

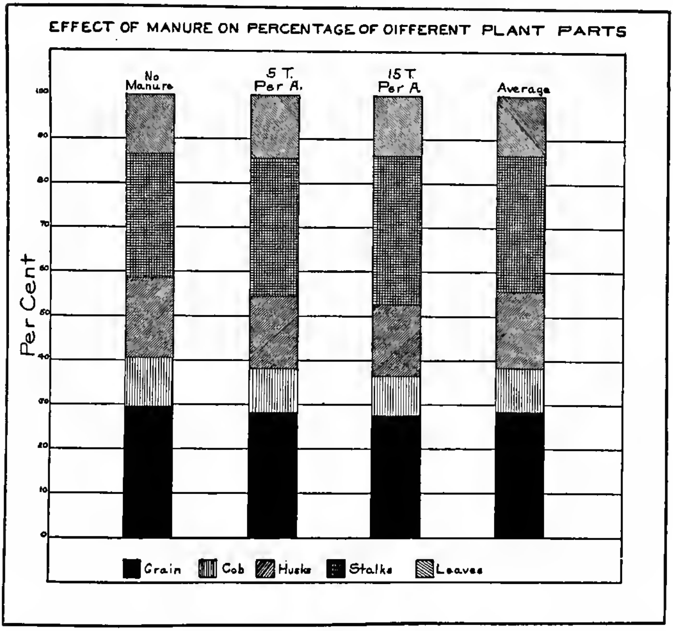

FIG. 36. — Effect of manure on proportion of different parts of corn plant.

every farm produces a quantity of this by-product of animal husbandry; and a wise use of it is at the foundation of permanent agriculture. Since the very dawn of history, the excreta of animals have been used as fertilizer. For a long time, little was known of the way in which it improved the soil, but the increase which it made in the yield of crops was very evident. Manure is now known to benefit the soil by adding directly a quantity of plant-food, by increasing the organic matter, and by aiding the work of desirable soil organisms. It may not in all cases be a complete and well-balanced fertilizer for every soil, but its use can always be recommended with safety. Manures have an effect on the porportion of different parts

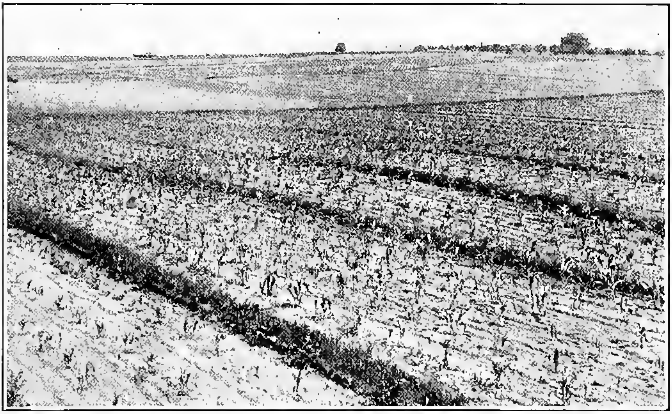

FIG. 37. — Fields used in famous fertilizer experiments. (Penn. Experiment Station.)

of the plant (Fig. 36). Fig. 37 shows the way in which a field is laid out to test the value of different fertilizers.

142. Kinds of farm manure. — The manure from each kind of farm animal is different. That produced by poultry and sheep is concentrated and dry, while that produced by cattle and horses contains more water and coarse material. The manure of any animal is influenced by the kind of food it eats, its age, work, and several other factors. Old animals, that do but little work and eat much rich food, produce the best manure.

Liquid manure is richer in plant-food elements than the solid, but it lacks the organic matter which is so beneficial to most soils. Good husbandry requires the saving of both the liquid and the solid manure, which can easily be kept together if sufficient bedding material is used to absorb the liquid.

143. Losses in manure. — Losses occur in manure by leaching and by fermentation (Figs. 38, 39). Experi-

FIG. 38. — Manure piled where its plant food will be leached.

ments have shown that, when left carelessly exposed to the weather for six months, manure loses about half its value. This loss can be overcome in large measure by proper methods of storage even without expensive equipment. The plant-foods contained in manure are readily soluble and but little rain is required to dissolve and carry them away. If manure is left scattered in an open yard, it is wet through by every rain and the greater part of its plant-food is washed out before the season is over. If manure has to be stored for any length of time it should be so piled that it cannot be leached. This may be done by putting it under cover or by making the pile of proper shape.

Manure is filled with bacteria and fungi which are constantly at work. Some of these tend to make the manure heat, causing a loss of considerable nitrogen. Since these destructive organisms work best in manure that is loose and fairly dry, their action can most easily be

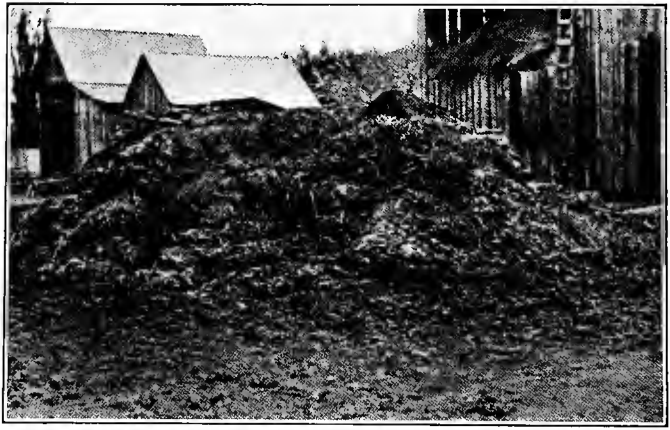

FIG. 39. — Manure pile in an unsightly and inconvenient place.

prevented by compacting the manure to exclude air and by keeping it moist.

144. Handling farm manure. — Experience has demonstrated that the best way to handle farm manure is to haul it out and spread it on the land when fresh. This prevents any serious loss from either leaching or fermentation. Many farmers haul manure on to the field and leave it standing for months in small piles. This is not a good practice, since its loose condition allows destructive fermentation to go on readily. Moreover, the leaching of the piles causes an irregular distribution of plant-food over the field. Fig. 40 shows a common manure carrier.

During parts of the year there is no vacant land on which manure can be spread, and hence it must be stored. This can be done in special manure pits, under sheds, or in the open yard. Expensive pits probably do not pay, but simple devices to assist in handling manure are with-

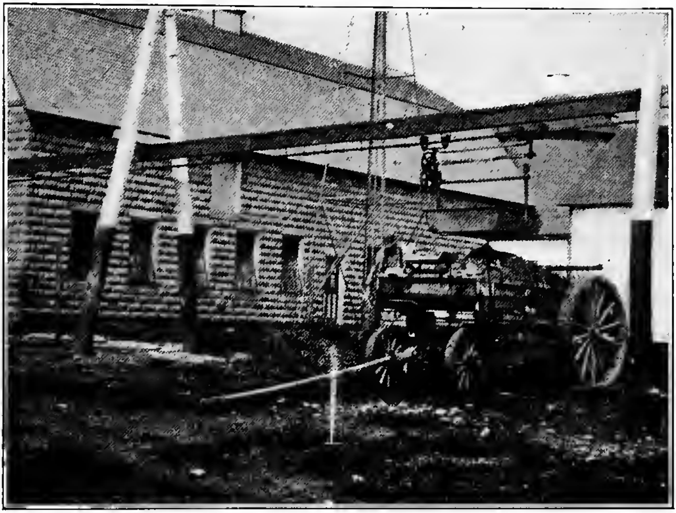

Fig. 40. — Manure carriers are becoming almost a farm necessity.

out doubt a good thing. It has already been stated that by proper piling, the loss due to leaching and fermentation can be practically overcome. Where an open yard is used the neatest and most sanitary kind of pile, as well as the one allowing least loss, is a square pile with vertical sides and with edges slightly higher than the middle. The manure that is produced each day should be put on the pile and should be kept compact and moist.

A manure spreader is a great time-saver, and makes possible a more even distribution than can be made by hand. The amount of manure that is applied is usually limited by the quantity that can be obtained. Few farmers are in danger of over-manuring their land. Most soils will use forty or fifty tons to the acre every few years without suffering any injury.

145. How to fertilize different crops. — While each crop uses exactly the same plant-food elements, the relative quantities used by different crops vary. Potatoes and sugar-beets use relatively large quantities of potassium; the grain crops require considerable phosphorus; while the legumes use relatively more lime and nitrogen. Each crop also has different rooting habits. These facts must all be taken into consideration when applying fertilizers. In pastures an early growth of succulent forage is desired. This calls for the application of some form of available nitrogen. The needs of each crop and the quality of product desired should be carefully studied before deciding just how to fertilize. It is, of course, necessary to have the fertilizer conform to the needs of the soil.

146. Green manures. — The plowing under of growing plants to increase the organic content of the soil has been practiced for centuries. The decay of these plants helps to make available the mineral foods of the soil, and helps to correct defects that exist in its physical nature.

Legumes make the best green-manure crops, since they increase the nitrogen supply of the soil by taking this element from the air and combining it in such a way that it can be used by other plants. The clovers, vetches, cowpeas, soybeans, field peas, and alfalfa are all plowed under as green manures. The small-grains are also much used for this purpose. A worn-out or poor soil will usually produce a fair growth of rye which, when plowed under, puts the soil in a condition to raise other crops.

In arid regions where water is scarce, the use of green-manure crops is somewhat limited; but in humid climates, especially where soil erosion has to be contended with, green-manure crops are necessary in building up the soil. It is often possible to raise a fairly good green-manure crop after the regular crop is harvested.

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398. Farm Practice in the use of Commercial Fertilizers in the South Atlantic States.
406. Soil Conservation.

CHAPTER XIII

ORGANISMS OF THE SOIL

THE soil is not a mass of dead matter, but is filled with living organisms which are constantly transforming its compounds and renewing its productiveness. These organisms work on the dead bodies of plants and animals and make the materials composing them useful to growing plants. All life on the earth is dependent for its continuance on the unseen organisms which swarm in the soil. If it were not for their renewing action, the available plant-food would in time be consumed and plant growth would cease. A soil composed merely of dead mineral matter unable to support life would be valueless. Fortunately, the soil is not in this condition, but teems with myriads of microscopic organisms of many forms, each contributing its share toward making the soil productive.

147. Kinds of soil organisms. — A great diversity of life exists in the soil. Animals, such as squirrels and gophers, burrow in the ground and are important in mixing the soil. Earth-worms are continually making the soil more mellow by mixing mineral and organic matter and by increasing the availability of many of the plant-foods. Their work is particularly important in heavy, wet soils, where they improve aëration. The higher plants increase the circulation of air and add organic matter by sending their roots into every part of the soil; certain of the higher fungi assist in the decay of organic matter; and last, but not least, come the bacteria, which are the most important of all the soil organisms in the influence they exert.

148. Bacteria. — The existence of bacteria was discovered by Leeuwenhoek in 1695, but little was known of their real nature until a few years ago. They belong to the plant kingdom, and are composed of single cells about $\frac{1}{25000}$ of an inch in diameter, although they vary considerably in size as well as shape. Increase is rapid, since under favorable conditions one may divide in about a half hour. At this rate, the number that might be produced from a single individual in a week is almost beyond computation. Bacteria cause many of the common diseases of animals and plants. The discovery of this fact made possible a new era in the treatment of disease. All bacteria are by no means harmful; some seem to be neutral in their action; others are decidedly beneficial. Most soil organisms are helpful in one way or another.

149. The number of bacteria in the soil is probably about as large as can be supported under existing conditions. Desert soils low in organic matter, water-logged soils, and sandy soils have comparatively few bacteria; while loamy soils, especially if manured, have many. Cultivated soils of the ordinary type usually have from 1,000,000 to 10,000,000 bacteria in each gram of soil. Where conditions are exceptionally favorable the number often runs as high as 100,000,000 to the gram; however, this varies greatly during the different seasons of the year, and is affected by soil moisture, crops, temperature, organic matter, and a number of other factors.

150. Kinds of bacteria. — The size and shape of bacteria vary greatly. They are classified as spherical, cylindrical, and spiral and are often compared in form with billiard balls, lead pencils, and corkscrews. They may occur singly or in aggregates of two or more. The spherical forms differ from the others in being able to multiply in a number of planes; hence they may make chains, flat layers, or cubical masses. The rod-shaped and spiral-shaped forms increase in but one direction; they elongate and separate into two parts. The three main types are not always distinct, and some forms are intermediate. Hair-like flagella borne by some bacteria aid in locomotion.

151. How bacteria grow. — The fact that bacteria are colorless makes them unable to use the energy of sunlight; but they, like animals, must depend on the decomposition of organic foods for a source of energy. Organic material, therefore, is commonly needed for food. Saprophytic forms obtain their foods from dead plant and animal bodies, while parasitic forms get their food from living plants and animals. A few forms can live without organic matter but subsist entirely on mineral matter.

Oxygen is needed by most bacteria for their growth; others can grow either in the presence or in the absence of oxygen; still others grow only in the absence of free oxygen. None of the higher plants or animals have the ability to live without free oxygen.

Bacteria respond to temperature changes in much the same way as do other living things. At very low temperatures their activities cease, while at very high temperatures they are killed. The temperature of best growth varies greatly with the species. Some grow best at about 70° F., while many prefer 95° F., and a few species require as high as 140° F. for their most rapid growth. At a temperature of 160° F. most bacteria are quickly killed, although spores of bacteria will often live after being heated for a short time at 212° F.

The proper amount and balance of food is one of the most important considerations. Soluble carbohydrates are used by many for food. Their own products are usually detrimental and must be removed or growth ceases and death may result.

152. Relation to humus formation. — Tillage ventilates the soil, thus removing these excretions. Practically all plant residues eventually find their way into the soil, where they undergo changes of some kind. They may decay entirely and, with the exception of a small quantity of mineral matter, become gas which passes into the air; they may undergo transformations resulting in the formation of humus in the soil; or they may remain preserved in almost their original form. The greater part of the organic matter that gets into the soil undergoes some process of humification, and as a result, it is of great benefit.

The changes occurring in the organic matter of the soil are largely the result of bacterial action. Some fungi begin the decay of woody matter, but the decomposition is completed by bacteria. The carbon of the organic matter, by its decay and union with oxygen in the formation of carbon dioxide, furnishes food energy to the microorganisms. In addition to carbon dioxide, many other compounds are formed, some of them being rather complex. Many of the compounds resulting from organic decay act as solvents in making mineral matter more available to growing plants. The humus remaining in the soil as a result of decay is usually lower in carbon and higher in nitrogen than the plant residues from which it was formed. This is particularly the case in arid climates where decay has gone on with but small quantities of moisture.

153. Relation to nitrogen. — Of all the plant-food elements of the soil, nitrogen is probably the one needing most attention. It must constantly be worked over and changed from one form to another. A part is lost from the soil as free nitrogen and ammonia, which escape into the air, or as soluble nitrogen salts which are leached out. To prevent these losses and maintain in the soil a supply sufficient for the needs of crops, is one of the greatest problems of agriculture.

The atmosphere contains a vast store of nitrogen, but this is in an uncombined form and is, therefore, not in a condition to be used by plants. The supply of combined nitrogen in the soil, on the other hand, is limited. It was thought for some time that, on account of losses which occurred, this supply would in time be entirely exhausted and that it would eventually be impossible to raise crops. This was before the action of bacteria was understood. We now know that, under proper conditions, these organisms are able to combine the nitrogen of the air with other elements in such a way that it can be used by plants. The discovery of this process known as nitrogen-fixation is responsible for a change of ideas regarding soil fertility.

Other kinds of bacteria are able to change the nitrogen contained in dead animal and plant bodies into a form that can be used by living plants. This general process which takes place in a number of distinct stages is known as nitrification. When available forms of nitrogen, like the nitrates, are transformed into non-available ammonia or free nitrogen the process is known as denitrification.

154. The fixation of nitrogen was first found to occur in connection with little nodules which are found on the roots of legumes such as peas, beans, alfalfa, and clover. It was observed that where these plants grew, the nitrogen content of the soil was increased. Investigation showed that the nodules were caused by bacteria working on the roots. The bacteria living in these nodules are able to use free nitrogen of the air and combine it into the organic compounds of their bodies from which it may later become available to the higher plants. The fixation of nitrogen in connection with the growth of legumes makes these plants desirable in all crop rotations. They make it possible to maintain the soil nitrogen. It was later found that certain bacteria and fungi working independently of plants are also able to fix nitrogen from the supply in the air. The quantity of nitrogen they fix in the soil is large in some cases, though fixation by means of legumes proceeds more rapidly.

155. Nitrification and denitrification. — Most of the soil nitrogen has once been held in plants where it was one of the important constituents of protoplasm. When plants die, their nitrogen returns to the soil as complex protein compounds and, as such, it cannot again be used until the compounds are broken down. Some bacteria and fungi attack dead plants and cause decay, during which at least a part of the nitrogen is converted into ammonia compounds. Ammonia is then attacked by a group of nitrous bacteria which change the nitrogen into nitrites, which are in turn converted into nitrates by the nitric bacteria. In the form of nitrates, the nitrogen is again available to crops. Thus the nitrogen cycle is carried on by a number of different forms of organisms.

In this cycle, nitrogen is taken up as nitrates by the higher plants. In their bodies it becomes a part of the complex protein compounds. When the plant dies, these compounds are broken down into ammonia, which by the process of nitrification, is converted into nitrites and finally into nitrates, when it is again ready to be used. Nitrification requires a good supply of oxygen, a proper amount of soil moisture, a favorable temperature, and a number of other conditions.

In the soil there are denitrifying organisms which change the nitrates back into nitrites and ammonia. These work in conditions just the opposite to those favorable for the nitrifying bacteria. Poor drainage and a lack of soil air are among the conditions favoring their action. In ordinary well-tilled soils these nitrate destroying organisms have but little effect. Only where large quantities of nitrate fertilizers are applied to poorly aërated soils do they have great economic importance.

156. Bacteria and the farmer. — Soil bacteria will go on doing their work in spite of anything the farmer does; but he may, by proper methods, increase their usefulness to him. By the introduction of leguminous crops into his rotations, he is able to keep up the nitrogen supply, and by the plowing under of organic matter, he furnishes carbon for the formation of humus which assists in making available the various mineral plant-foods. By draining wet lands, by adding limestone to soils that are acid, by the liberal use of barnyard manure, and by proper tillage methods, the farmer is able to get the greatest good out of these invisible, but powerful, workers in his behalf.

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CHAPTER XIV

TILLAGE AND CROP ROTATIONS

New reasons for cultivating soils and rotating crops are constantly being found; but tillage and rotation were practiced long before any reason was known except that the yields of crops were increased by these practices. Before any modern implements were made, the soil was stirred with bent sticks and rude devices of various kinds. These methods served the purpose of the time; but as knowledge increased and better implements were invented, the tillage of the soil was completely transformed. To-day, instead of being confined to a mere scratching of the land, it may include the intelligent use of a number of specialized implements during a season. Although there are many reasons why cultivation of the soil is desirable, the following are probably the most important: (1) to improve the structure, or tilth of the soil, (2) to control the growth of weeds, (3) to cover manure, stubble, and other plant residues, and (4) to conserve soil moisture. Almost every tillage operation effects one or all of these.

157. Improving soil structure. — Every plant requires for its best growth a looseness of soil that permits a free passage of air and an easy penetration of roots. When left undisturbed for a number of years, the soil becomes compact and is not in the best condition for crop growth. It is necessary, therefore, to loosen it by the use of some tillage implement. In cultivating the soil to improve tilth, attention must be given to the amount of moisture present. When a very wet soil is stirred, its particles are wedged together and the result is puddling, which is much more unfavorable to plants than is the merely compact condition of virgin land.

Plowing should mean more than the mere turning over of the soil. If well done, every clod will be shattered and every particle have its relation to every other particle

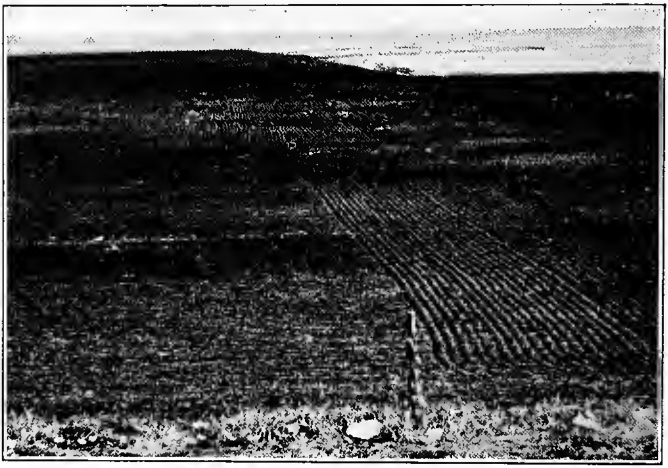

Fig. 41. — Field in good condition for crops.

changed through the shearing action which should take place when the plowed slice is turned over. As the soil falls into the furrow, it should be a granular, mellow mass of loose particles. The kind of implement that will best produce this condition varies with each soil. Sand or loam may be made mellow with almost any kind of plow, but a heavy clay without organic matter can be given a good tilth only when everything is favorable. Soil in good condition is shown in Figs. 41 to 43.

158. Controlling weeds. — Weeds are a menace to every farm. They thrive under all conditions that produce crops, and it is impossible for ordinary crops to compete with them without the farmer's aid. Weeds are injurious, since they consume available plant-food and moisture needed by crops; they shade and crowd out

FIG. 42. — A good seed-bed.

the more desirable plants; and they often reduce the market value of crops. In arid regions where crop production is limited by lack of moisture, successful farming cannot be practiced unless weeds are kept in check; indeed, the quality of farming in any region may be judged by the thoroughness with which weeds are controlled.

Some one has said that weeds are a good thing for the farm since they keep the farmer cultivating. Be this as it may, it is probable that a large part of the tillage operations are performed in order to kill weeds; but the soil receives other benefits at the same time. Much energy is wasted in trying to control weeds which are allowed to grow and begin seed production before the cultivator is used. It takes a great deal of work to kill big weeds, and if their seeds have been scattered a new crop of trouble may be expected. The best time to kill weeds is just after they have germinated and before they have become well established in the soil. A mere stirring of the soil at this time is all that is necessary, but if they are allowed to get well established, a number of hoeings or cultivations are often required.

The implement used to kill weeds depends on the crop grown, the kind of land, and the kind of weeds. On fallow land, an implement covering considerable area can be used to advantage. The spike-tooth, disk, and spring-tooth harrows, and implements with blades running just beneath the surface of the soil are effective. For tilled crops such as corn and potatoes, some sort of cultivator is used to advantage; while in crops like alfalfa, the spring-tooth harrow is a good implement to eradicate weeds. The great secret of weed control with any tool lies in doing the work at the right time.

159. Covering manure and plant residues. — Organic matter accumulates on the surface of any soil that is cropped. In the orchard, leaves fall to the ground; in the grain field, stubble is left after harvest; and in meadows that are to be followed by another crop, a sod must be disposed of. These plant residues cannot decompose readily if left at the surface. They need to be turned under and mixed with the soil in order to decay and give up their plant-foods as well as to assist in making available the mineral matter of the soil. Farm manure is constantly being applied to the land, and must be covered and mixed with the soil if it is to do the most good. Practically all of this covering must be done with some kind of plow, although the disk harrow finds occasional use where the land has recently been plowed.

160. Conserving moisture. — One of the most important reasons for cultivating the soil is the conservation of moisture. Even in regions of abundant rainfall, there are times when it is necessary to save soil mois-

Fig. 43. — Orchard soil in good tilth.

ture; and in arid regions, the very life of agriculture depends on conserving the scant supply of water (see Fig. 44).

If the soil is compact and hard, rain water will run off the surface rather than penetrate the soil where it can be used by plants. The soil must, therefore, be loosened in order that it may absorb moisture. The water that is in the soil moves by capillarity from particle to particle, and if the surface particles are pressed tightly together, the water will rise to the surface where it is lost by evaporation. This loss can be prevented by stirring the surface and forming a loose, dry mulch of earth which does not allow moisture to escape readily. This mulch may be preserved by many implements, such as harrows and cultivators of various kinds.

Rolling the land is often practiced to make the surface smooth and to break clods. Compacting the surface soil by the roller increases capillary movement toward the surface and thereby the loss of moisture. The fact

FIG. 44. — Cultivation while the crop is young greatly influences the yield. Delaware.

that the soil seems more moist after a roller is used often misleads farmers who think they are actually saving water.

161. Tillage of various crops. — The implements of tillage may be divided into three main classes — (1) plows, (2) cultivators, and (3) crushers and packers. The primary purpose of the plow is to loosen and pulverize the soil and make it more fit for the growth of plants. Plows are of numerous designs; no one kind is suitable for all conditions. The disk plow has given good results in many places, but the moldboard plow is doubtless suited to a much wider range. The old walking plow is rapidly giving way to some form of riding plow.

Many different kinds of cultivators are used in preparing the seed-bed, in eradicating weeds, and in tilling crops during growth. Every farm should be equipped with several kinds of cultivating implements. A very useful and simple device used to smooth the land and to break clods without compacting the soil is made by attaching a number of planks together with their edges overlapping. This planker, or float, is especially useful to precede the grain drill, since it scrapes off little elevations and fills depressions, thus insuring a more uniform depth of planting.

162. Reasons for rotation of crops. — Some sort of crop rotation has been practiced for many centuries. The reasons for this practice were probably not at first understood, even to-day all the effects of alternate cropping are not known; but so many reasons are now known that there seems no good excuse for not practicing some kind of rotation on almost every farm. All crops do not require the various foods in exactly the same proportions; some use more potash or nitrogen, while others need relatively more phosphorus or lime. If one crop is grown continuously on the same land, the available supply of certain elements is reduced and the yield will finally decrease; but if crops with different requirements are alternated, the food supply of the soil is kept in a more balanced condition. Each kind of plant has a different rooting system and manner of growth. If shallow-rooted crops are grown continuously, only part of the soil is used, while an alternation of deep- and shallow-rooted crops overcomes this difficulty.

One of the chief reasons for crop rotations is the improvement of the soil. This is made possible by the use of legume crops, which fix nitrogen from the air (Fig. 45). The nitrogen fixed by these crops can be used by others which follow in the rotation, but it would be practically lost if the legumes were raised continuously. The control of plant diseases, insect pests, and weeds is made possible by the rotation of crops; indeed, such considerations often cause the farmer to change his crops when he would not otherwise do so. Economy in the use of man-labor, horse-labor, machinery, and irrigation water results

FIG. 45. — Every rotation should include a nitrogen-gathering crop.

from the raising of a number of crops on a farm. These considerations alone, without any of the other benefits, would be sufficient reason for practicing rotations.

163. Methods of crop rotation. — Careful planning is required in making a good rotation. The first essential is to decide on what crops can best be grown under the conditions. When this is done the quantity of each crop to raise and the placing of it can be determined.

The following principles should be kept in mind in planning a rotation: (1) raise about the same acreage of each crop every year; (2) have at least one cash crop; (3) include a legume crop in the rotation; (4) alternate tilled and non-tilled crops; (5) alternate deep- and shallow-rooted crops; (6) alternate exhaustive and restorative crops; (7) follow the best sequence of crops; and (8) add manure to the right crops in the rotation. It is not always possible to conform to all of these principles, but they are useful guides.

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CHAPTER XV

SPECIAL SOIL PROBLEMS

EVERY region has certain special soil problems not found in other places. Some of these are merely local; others apply to a comparatively large area. On each farm, soil conditions are found that are not identical with those found on other farms of the same neighborhood. These special conditions make it necessary for each farmer to study his own soil in order to solve the problems which it presents. It is not possible to discuss, or even to understand, all the special soil problems.

ALKALI

In arid regions, there are millions of acres of land containing excessively high quantities of soluble salts which are usually spoken of as alkalies. The soil is rendered valueless by these salts if they are present in quantities that prohibit crop growth. Many soils, however, containing considerable alkali will raise good crops until strong concentrations of salt are brought near the surface by the evaporation of large quantities of water. In judging arid soils, it is necessary to know the amount of soluble salts present and their relation to the quantity causing injury to crops. In the management of such soils, the farmer should know how to prevent the accumulation of salts in the strata of the soil that is used; and in regions where large quantities of alkali are already present, he should know how to reclaim the land. Effects of alkali on vegetation are shown in Figs. 46 and 47.

164. Kinds of alkali. — Any soluble salt present in the soil in injurious quantities may be considered an alkali. The salts that most often cause injury are: sodium chloride, or common salt; sodium sulfate, or Glauber's salt; sodium carbonate, or sal-soda; and magnesium sulfate, or

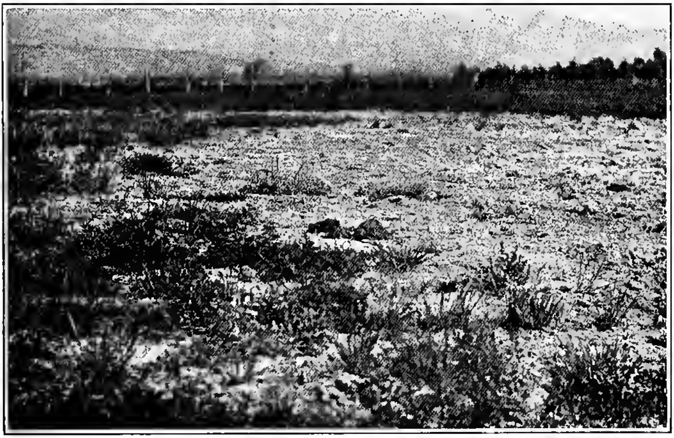

Fig. 46. — Alkali spot with vegetation killed.

epsom salt. In addition to these, sodium nitrate and a number of other salts do damage in some districts. Sodium chloride is injurious to vegetation when present in lower concentrations than any of the other salts mentioned; sodium carbonate, or black alkali, injures the soil when present in low concentrations by dissolving the organic matter and causing a hard crust to form. Plants will grow in the presence of relatively large quantities of the sulfates.

165. Effect of alkali on plant growth. — The injury done to vegetation by alkali salts results largely from the shutting off of water from the plant on account of the soil solution having a greater concentration than the plant cells. By the law of osmosis water passes from the dilute to the more concentrated solution. In a normal soil, the root has a cell-sap with a higher concentration than the soil solution; hence, water passes from the soil into the

FIG. 47. — An orchard being killed by the rise of alkali.

plant. When the soil solution is made too concentrated, on the other hand, water passes out of the roots into the soil and the plant dies.

166. Reclamation of alkali lands. — The permanent reclamation of alkali lands rests on a removal of excessive salts by drainage. Other means may give temporary relief, but drainage is the only certain cure. In draining, the principles discussed in Chapter X are to be followed. Where the accumulation of alkali results from over-irrigating higher lands, the remedy is obviously the prevention of percolating water which carries soluble salts from above and concentrates them in the lower lands. Any practice which reduces evaporation, such as cultivation, cropping, or the use of manure, tends to reduce the accumulation of these salts.

ACIDITY

Most crops require for their best growth an alkaline, or basic, reaction, although some grow better if the soil is slightly acid. Such important crops as the legumes can hardly be made to grow on an acid soil, since the bacteria which fix nitrogen in connection with growth on the roots of these crops require a basic reaction. Acid soils are most often found in humid regions where the basic elements of the soil-minerals have been leached out, leaving the acid part behind, and in swamp lands where the decay of large quantities of vegetable matter results in the accumulation of organic acids. The continuous application of ammoniun sulfate as a fertilizer to cultivated soils also finally results in an acid condition.

167. Indicators of soil acidity. — An acid soil is indicated by the growth of a number of plants, among which are common sorrel, sour dock, horsetail, and corn spurry; also by the failure of alfalfa and other legumes to do well. Blue litmus paper and a number of laboratory tests may be resorted to in determining acidity and the amount of lime necessary to correct the condition.

168. Correction of soil acidity. — Acidity is best corrected by the use of some form of lime; and acid soils usually pay handsomely for the expense of applying lime. Swamp lands high in organic matter often contain so much acid that it does not pay to correct the sour condition, especially since these soils usually contain an abundance of nitrogen. The kind of lime to use depends on conditions; burned lime and ground limestone both accomplish the result. Ground limestone, however, is usually cheaper and if fine enough, it is very effective. Ground limestone also has an additional advantage of destroying less organic matter than the burned, or caustic lime.

EROSION

One of the chief difficulties with which farmers of certain sections have to contend is the erosion of the soil, during which fertility is washed out and at times the entire soil carried away. Some erosion goes on normally in all parts of the world; indeed, it is by erosion that cañons and ravines have been formed. It is much more intense, however, on land that is under cultivation. Many factors influence the amount of erosion that will take place. Among these are the quantity and season of rainfall, the slope of the land, the texture of the soil, the organic matter in the soil, and the crops raised.

Where the precipitation is light, erosion does not take place to any great extent unless the water falls in a few heavy storms and then only local damage is done. Erosion is more serious where the land has considerable slope and damaging streams are formed. A loose, coarse-textured soil is in more danger of erosion than a fine one that is compact. Organic matter in the soil reduces erosion by increasing its water-holding capacity and its absorptive power.

169. Methods of preventing erosion. — Erosion cannot be avoided by the same methods under all conditions. One way of preventing it in hilly regions where the precipitation is excessive is to keep the land continually in crops. As soon as one crop is harvested something else is planted. This may later be plowed under as a green manure before the regular crop is seeded. Parts of the land most likely to wash are kept constantly planted to grass.

Erosion usually begins by the formation of small furrows across the field. These rapidly increase until in time they become great washes. This condition may be avoided in the beginning by making regular channels with less slope to take care of all the run-off. The construction of terraces and plowing at right angles to the slope are useful devices for counteracting this tendency to wash. Large quantities of stable manure are also beneficial in reducing erosion. On some soils one or two of the methods given will successfully prevent washing, but in some sections every practice in soil management has to be directed toward reducing erosion.

BLOWING

In many sections, considerable difficulty is experienced with soils being blown away, leaving fields bare to the bottom of the plowed zone. After the land is plowed and a crop planted a wind-storm may carry the plowed soil and seed to a neighboring field. This condition, particularly serious in certain parts of the Great Plains, is also found to a lesser degree in many other regions having an arid or a semi-arid climate. In places where the soil drifts readily, farms have been abandoned over large areas. Houses, barns, and trees have been almost completely covered with soil and the entire surface of the land transformed by dust storms.

In regions where the soil blows in this way, every operation has to be directed toward holding the soil in place. The greatest care must be taken in plowing and harrowing. If the soil is left loose and fine, it is sure to be carried away. A fine, dry mulch such as is most effectual in preventing evaporation of moisture cannot be used at all, but it is necessary to leave a surface of small clods which cannot be readily moved by wind. Plowing is usually done at right angles to the direction of wind. In this way the ridges break the force of the wind next to the ground, and the soil does not easily get into motion.

170. Prevention of blowing. — It is on the long stretches of barren soil that the greatest injury is done. Where a large tract is left summer fallowed in dry-farming districts, blowing may begin and the whole district be affected. When the soil begins to move, it rapidly cuts the ground over which it passes. The great problem, therefore, is to prevent the first blowing. One effective means is the alternate cropping and fallowing of long strips of land. A crop, say corn, is planted in a long strip a few rods wide at right angles to the wind. Next to this comes a strip of fallow land, and then another of crop. In this way there is no large area of fallow land in one body and the soil does not start to blow. Seeding to grass or to some other permanent crop is sometimes necessary in places where drifting is worst. The methods to be used vary with conditions; sometimes one measure will be sufficient, while at other times every known means must be used to prevent the soil's being carried away by the wind.

METHODS OF JUDGING SOILS

Since there are so many factors entering into the value of land, it is very difficult to tell just what it is worth. The amount of money involved in land transactions is so great that considerable care should be exercised to determine as nearly as possible its true value. Often in one transaction there is sufficient money wasted to pay a man's expenses through an entire course at an agricultural college. The value of old land that has been farmed for a generation can be determined rather accurately; but new land in a district where agriculture has not been practiced is more difficult to appraise. It is necessary on such lands to use every available means to aid in making a proper judgment. Among the things that must be taken into consideration are: (1) the native vegetation supported by the land; (2) the topography; (3) depth and structure of the soil; (4) chemical analysis; (5) crop yields obtained in the neighborhood; and (6) external factors such as rainfall and nearness to market. The importance of rainfall is discussed in Chapter X, while Chapter XXXII considers market problems.

171. Indicator value of native vegetation. — The vegetation that grows naturally on a soil in its virgin state is one of the best indicators of its value. Certain plants show a condition of drouth; others show an excess of moisture; a number of species indicate an acid condition; while others are a sure indication of the presence of large quantities of soluble salts. Since the entire flora of various sections is different, it is necessary to become acquainted with the plants of each region and determine what their growth indicates. When this is done the judging of virgin soils is greatly simplified.

172. Topography of the land. — In many sections of the country, the topography of the land must be given considerable attention in judging its value. Where irrigation water is to be used, the land must be so situated that it can be reached by ditches. In regions where erosion does damage, the slope of the land is very important; and in sections likely to be affected by frosts, the land should be so located that it has a good air drainage. The expense of tillage may be greatly increased if the surface of the land is rough, but the need of drainage is probably less on land of this kind than where the surface is flat. Under some conditions a rolling surface may be desirable, while under others smoother land may be preferred. Under practically all conditions, however, the topography of the land must be given consideration in judging of its value.

173. Depth and structure of the soil. — The depth of the soil and its general make-up are very important elements entering into its value. A soil may be nearly perfect at the surface, but if it is only a few inches deep, it is of little value for some classes of farming. A shallow soil has a low water-holding capacity and its root-zone is not sufficient to give the best results for certain crops. The presence of a hardpan or of a streak of coarse gravel near the surface greatly reduces the value of any piece of land. Too often land is purchased on a surface examination merely. This is a dangerous practice, since it is impossible by looking at the surface to tell what lies below. The condition of the sub-soil can best be studied by examining washes, railroad cuts, and wells, or by using a soil auger. It is impossible to make a sound judgment regarding land without knowing its nature to a depth of at least eight or ten feet.

174. A chemical analysis of the soil tells the amount of plant-food contained, and gives some index to the best methods of handling the land. It shows which elements are likely to be deficient and which are abundant. It may also tell the reaction of the soil as well as the presence of excessive quantities of soluble salts. Special skill and considerable time are required to make a chemical analysis; hence, this item is often overlooked by practical farmers in judging land. If the chemical composition of a soil is not known, however, any judgment made of it must be somewhat superficial.

175. The mechanical analysis of a soil shows its texture, or the size of particles composing it. After a little experience the texture can be judged with fair accuracy without an analysis simply by feeling it. There is no difficulty, for example, in distinguishing between a coarse sand and a fine clay; but in determining the texture of an intermediate soil, a mechanical analysis is useful. Since the texture of a soil helps to determine what crops to grow, it should be known.

176. Productivity. — The real value of land is determined by what it will produce. Its chemical composition and texture may seem favorable, but they count for little if crops do not thrive. For this reason it is not wise to judge hastily the value of land in a new project before crops are tried, even though chemical analyses and other indicators are available. So many factors enter into crop production that it is easy to overlook some of them, but all must be right if yields are to be satisfactory. Natural vegetation, topography, depth of soil, and chemical and mechanical composition are all good indicators of the value of land; but the real "proof of the pudding is in the eating," and the best indicator of the value of land is its productivity.

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PART III

FIELD CROPS

CHAPTER XVI

WHEAT (*Triticum sativum*)

THE word "wheat" comes to us, Dondlinger[1] says, from the Middle English "whete," which in turn came from old English "hwaete." To this day the Germans call it "weizen." Strange though it may seem, both these words are related to others which mean white. Dondlinger further suggests that perhaps wheat was called white on account of rye and other grains being darker in color.

Wheat is one of the oldest cultivated plants. Far back beyond the time when the first histories were written, this plant was nurtured. It seems to have been cultivated about thirty centuries before Christ, in China. It has also been found in the Lake dwellings of the Swiss, which discovery throws its history back into the prehistoric Stone Age. The Bible speaks of wheat harvest in very early times (Genesis xx. 14). Without intermission this plant has served men down to the present day.

Geographically, its origin is equally uncertain. The supposition that the Tigris-Euphrates valley is its birthplace is favored by de Candolle, Dondlinger, and Hunt. At any rate, when recorded history began, it was cultivated widely over the earth from China to Egypt. Perhaps the search for a center of spread suggested the Euphrates region.

[1] *Book of Wheat*, p. 1.

177. Relationships. — The Gramineæ is the botanical family to which wheat belongs. Many species of this family have become valuable for the production of seed which supplies food to both man and animal. These plants are designated as cereals, or grains. Into this category fall wheat, oats, barley, rye, rice, corn, the sorghums, and the millets. The Gramineæ include not only all of the cereals but also the common tame and wild grasses. The general field conditions for good wheat are well indicated in Figs. 48–53.

178. Roots. — When wheat kernels germinate, they send out three roots which gather food from the soil to supplement that stored in the kernel. From these two sources, comes sufficient nourishment to keep the young plant growing until it can establish itself.

Once the green leaflets push into the sunlight, food manufacture begins. In the meantime roots grow out in all directions from a node, or joint, about an inch beneath the surface, leaving the first ones to die because they are of no further use. These new roots grow outward from eight to twenty inches and then turn downward, rapidly reaching into deeper soil which is both a reservoir for water and a storehouse for plant-food. The depth to which they penetrate and the number of branches they send out depend on the looseness, the dampness, and the warmth of the soil; on the time of the year; and on the kind of wheat. The limits of variation are wide, yet under the most unfavorable conditions, the extent of the root-system far exceeds what the ordinary person thinks it to be.

One plant, showing roots seven feet two inches long profusely branched, was dug up at the Utah Experiment Farm at Nephi. The Minnesota Station reports finding a branch root every eighth of an inch for eighteen or twenty inches. Naturally many of these rebranch, thus forming a complete network in the soil. Moreover, many broken-off roots remained undisturbed. A total length of 2000 feet would probably be obtained

FIG. 48. — A good stand of wheat.

if all of these thread-like branches were placed end to end.

179. The plant above ground. — Like all other members of the grass family, the wheat stem, known as a culm, has four or five distinct joints, or nodes, from two to ten inches apart in the mature plant. These nodes are solid, while the straw between, in most cases, is hollow and sometimes partly filled with pith. In the young plant, nodes are close together. Growth consists in a lengthening and thickening of the internodes at a point just above the nodes. If the plants are so few that they do not fill the ground in which they are planted, underground nodes send out more culms, that is, the plant stools.

Leaves grow upward from the nodes along the stem, clasping it closely half or two thirds of the way to the next joint. This part of the leaf is called the sheath; that which springs away from the stem is called the blade. The leaves have parallel veins, a prominent one in the middle forming a midrib. Leaf blades may be large or small, smooth or rough; some have edges so sharp as to cut the skin when brought in contact by a sliding movement.

The head, or spike, consists of smaller sections borne alternately upon the rachis, a zig-zag stem, which may be studied in a picture or by carefully pulling off the spikelets, as the sections are called. On each side of the spikelet is a coarse chaff, or glume. Between are two to five flowers so completely inclosed by other chaff, that pollen seldom escapes. This causes the flowers to be self-fertilized. Generally two of these flowers, but sometimes only one or even three, bear a kernel, or berry.

180. The kernel, dry and fairly smooth, has a deep groove running lengthwise, a number of fine hairs at one end, and a crumpled irregularity at the other. This wrinkling betrays the location of the embryo, or germ, which is not more than one fourteenth of the entire berry. The embryo is oily and can easily be removed with a pin or the point of a knife blade. The remainder of the berry is endosperm. Cut in two across the groove, the grain shows plainly under a hand lens three distinct layers; the bran outermost and the starchy part inside, with a layer of dark aleurone cells between.

When wheat is milled, flour comes from the white interior, the outer two layers making bran. In big

FIG. 49. — A good yield of wheat, Pennsylvania.

mills the germ is separated from the endosperm and made into flour, though this weakens the flour and also lessens its keeping qualities to a slight extent.

181. Varieties. — Like all living things, wheat varies under different climatic and soil conditions. This is but natural, for included within the vast range of the crop are many distinct environments, to which nature and man attempt to fit plastic plant organisms, particularly if they are useful. East of the Mississippi, where the winters are mild and the rainfall abundant, soft winter wheats are grown. Between this river and the Rockies, north of Nebraska, where the summers are dry and hot, and the winters severe, having little snow, alternate freezing and thawing injure fall-planted grain; hence, the farmers grow hard spring varieties. Because the winters are less rigorous and because snow protects the young plants from freezing, winter wheats do best on the Great Plains south of Dakota. The hot, dry ripening period favors hard grain. On the Pacific coast hard wheat tends to soften and amber wheat to whiten in response to mild winters and wet springs. Both the winter and the spring varieties are soft and starchy. The types of wheat in these districts neither begin nor end sharply, but blend into one another.

All told there are upwards of 1000 so-called varieties. In 1895, the United States Department of Agriculture selected about 200 as being best fitted to various regions. As already indicated, no single choice could be made for the Great Plains alone. Clearly, then, no one variety is best for all localities. There are now existing eight distinct types. Once merely variations, their characteristics have become fairly fixed on account of continuous selection for one part of the earth.

Certain definite qualities are, however, desired with reference to which varieties may be improved. Chief among these are: (1) high yield to the acre, (2) high weight for a bushel, (3) hardness accompanied by high nitrogen content, and (4) resistance to drouth, insects, or plant diseases. Better varieties may be secured by three methods: (1) by selection of the most desirable plants from ones now grown; (2) by cross-breeding; and (3) by the bringing of superior species from some other part of the world that has climate and soil reasonably like the one in question. Better cultural methods will also improve the health and consequently the yield of the crop.

182. Distribution and adaptation. — Although wheat is primarily adapted to growth in the temperate zone, it is by no means confined there. It has followed the Caucasian race into every continent and clime, and has also been cultivated by other races, for example, by the Chinese and other Asiatics. It is the bread-stuff of civilized man, having accompanied the spread of learning and implements. It was first cultivated, as we have seen, by the Egyptians; all peoples have grown it except some in the Far East, where a similar grain, rice, supplants it.

Wheat has matured from the equator to within two hundred miles of the Arctic circle at Dawson and on the Mackenzie River, both fully a thousand miles north of the United States. It is a common crop in Brazil, Peru, Egypt, India, Australia, United States, Russia, and Canada. Being best adapted to low plateau regions, it has spread round the world from east to west, wherever suitable conditions and opportunities have presented themselves. Nor is production closely limited by elevation. In Russia and Palestine, regions fifty to one hundred feet below sea-level produce abundantly, while Ecuador and Peru show profitable crops at 10,000 feet, and in the Himalaya mountains wheat is produced at an elevation of 11,000 feet. About three-fourths of the crop, however, grows between 500 and 1500 feet above sea-level.

At the equator the areas of production are high, with but little growing near sea-level. Near the extremes of height and latitude, no profit is made from the crop, production being entirely experimental. The elevation and latitude of the best regions indicate the desirability of moderate climates as regards both temperature and rainfall. With the perfection of dry-farming methods, wheat has spread rapidly into drier districts until it is the principal crop on the dry-farm. It is only of late years that crops of higher acre returns have driven it from irrigated farms.

Whether a crop yielding at best only a few dollars to the acre can be profitably grown on high-priced land is

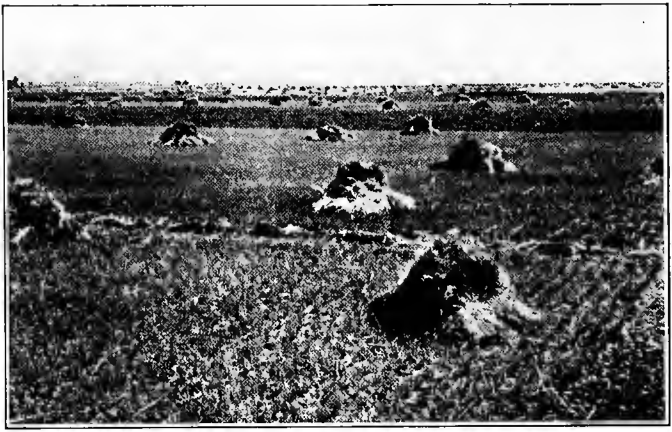

FIG. 50. — Wheat farms should be large to be most economical.

questionable. The opinion of the best informed men seems to be that wheat should gradually pass to the less valuable areas everywhere, making room for the higher producing crops on land that bears high rent. About all it requires as to soil is fair fertility and tilth. It grows on sands, loams, clays, and silts, avoiding the muck soils, which are too rich in organic matter. Deep, uniform loams, however, generally give the best yields where there is about twenty-five inches of rainfall. Good fields of wheat are shown in Figs. 48, 49, and 50.

Hard and soft spring, hard and soft winter, and white wheats have adapted themselves to climatic conditions. These variations illustrate only a few of the attempts of the crop to suit more rigorous climates. Strains are continually becoming adapted to drier or to colder districts, where they were not successfully grown before. It is because of this widely increasing variation coupled with its manifold uses, that wheat has become such a general crop.

183. Preparation of seed-bed. — The preparation of land for planting differs with the region. The chief difference is in amount of seed and time of sowing; the methods of cultivation are primarily the same.

In general, the methods include plowing in the autumn or late summer as soon after the crop is taken off as possible; leaving the land rough over winter so as to prevent run-off of rain or melting snow and to permit frost to break clods or sod into finer particles; and harrowing in the early spring to prevent loss of moisture by evaporation and to keep down weeds. Fall-plowing ought to be as deep as the machinery and the horses or other power at the farmer's command will permit. Increased depth of plowing makes a better home for the plant and stores a greater quantity of moisture. In regions where spring planting is practiced, deep fall-plowing is still valuable, but in most cases the grain is not sown until it becomes warm the next spring.

184. Seed and seeding. — Farmers had better use seed that is adapted to their system of farming. The stubble ought to be turned under as early as possible after harvest. Sometimes the land should lie through the winter without harrowing. If farmers disk it, and harrow after every rain that crusts the land or starts weeds, they have a loose, moist seed-bed free from weeds when planting time comes.

Fig. 51. — The header at work in a wheat field.

The grain ought to be screened to remove weed seed, rubbish, and shrunken kernels. Large, plump kernels give better yields than small or shrunken ones, because of the better start they give the young plants. But more than screening is necessary. For smut, the grain should be treated with formaldehyde, one pint to fifty gallons of water, or with blue vitriol (copper sulfate), one pound to five gallons of water. A good way is to dip a bag of wheat into a solution contained in a half barrel. About ten minutes is required to wet all the grain. In the meantime, another sackful might be screened and filled to economize time.

From three to six pecks of seed have given the best crops where no irrigation is practiced, while under irrigation four to eight pecks are used. For spring-plant-

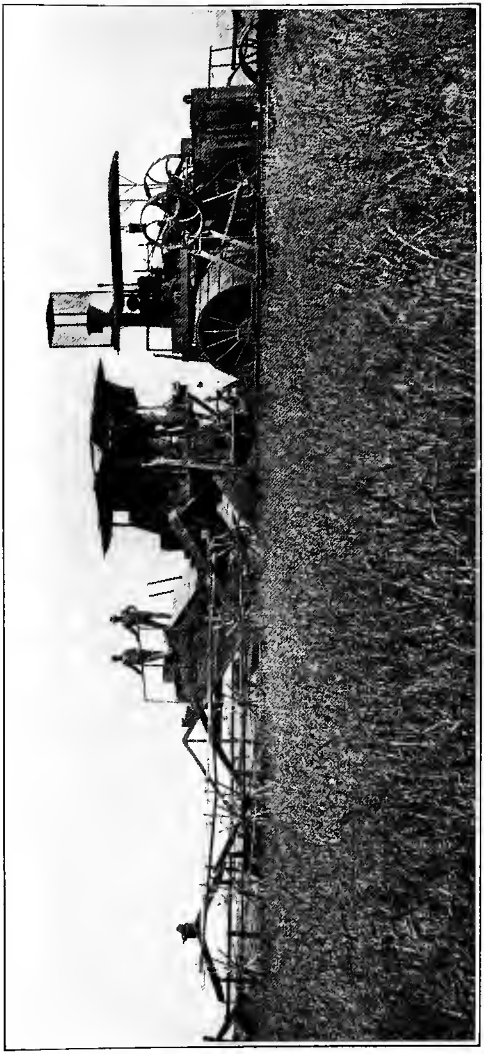

FIG. 52. — Another form of header, illustrating the possibilities of large-area cultivation.

ing, earliness is essential. Fall-plowing makes possible earlier seeding, since disking is then all that is necessary before planting. During growth about all that can be done is to harrow.

185. Harvesting. — There is no month in the year that is not a harvest season in some part of the earth. The season varies in the United States from May in Texas, to September in parts of the Northwest. Fall-planted grain ripens carly and spring-planted grain late where the weather is cool or moist.

Methods differ as widely as seasons. In many parts of the world, peasants still use the sickle or old-fashioned

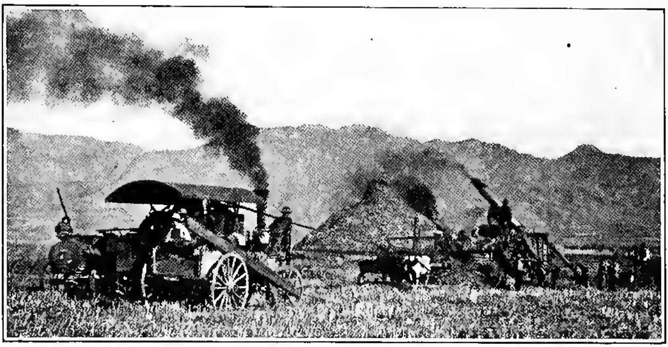

FIG. 53. — Thresher at work.

cradle, but modern harvesters are rapidly winning in all progressive countries. In parts of western United States the binder has given way to the header, which removes the heads and elevates them into tight wagon-beds to be hauled off and stacked until ready for threshing. The header has been supplanted on some large farms by the combined-harvester, a machine that cuts, threshes, and sacks the grain in one operation.

Binder-cut grain is shocked in the field where the straw dries sufficiently to permit easy separation of the grain from chaff. In some localities the wheat cut green is ripened by the translocation of starch from the straw, for which a long time in the shock is necessary. When threshing time approaches the farmer hauls and stacks the bundles, or he hauls directly to the thresher. When grain is stacked, the bundles are usually placed with heads in, so as to shed rain and resist the attack of fowls or rodents.

186. Diseases. — Wheat is attacked by glume spot, wheat scab, rust, leaf blight, powdery mildew, and loose and closed smut. Of all these, however, rust and closed smut are most serious.

187. Closed smut is a black, thread-like fungus which is spread by tiny, black spores that fly through the air and attach themselves to the wheat kernel. Sprouting about the same time as wheat, the long, slender tube of the smut enters the young plant and grows inside. It follows up the green, growing plant, dying in the lower part of the stem, as the straw hardens. At the time the heads form, the smut enters the kernel and grows inside. Infected kernels are like sound ones except they are dull in color, light in weight, and hollow. They break easily during threshing and when handled later, they scatter spores which cling to the sound kernels. On account of the resemblance in appearance to clean grain, the farmer may not notice this smut, though he finds when threshing a loss of from 10 to 40 per cent of the crop. This loss can be prevented by treatment described (Par. 184). Care should be taken that the formalin is 40 per cent formaldehyde. After the grain is treated, it is hung up in bags or spread out on the barn floor to dry before planting.

188. Loose smut enters the plant at flowering time, and lives inside of the kernel. The disease is less prevalent than is that caused by closed smut. Treatment, however, is more difficult, since the spores are inside the kernels and cannot be reached by poisons. The only method is one known as the hot-water treatment, which is extremely hard to use successfully since, if the water be a few degrees too warm, the germination quality of the wheat is injured or destroyed. The grain is soaked for four hours in cold water, since heat more readily penetrates wet grain. To kill the smut, the wheat is immersed for ten minutes in water maintained at 133° F. The addition of the cold wheat makes constant heating necessary. Because of the difficulties, only small quantities of seed can be treated. This is then sowed on a seed plat which will yield clean seed for next season.

189. Rust is a fungous disease which attacks the stem and leaf; that on the stem is the more serious. The spores live over winter in the standing straw or even in some other plant. In the spring, after germination, the fungi attack the wheat at any time. The injury consists in a failure of the grain to fill. Although considerable loss results, about all that can be done is to choose rust-resistant varieties, to rotate crops, to drain the land, and to avoid over-irrigation.

190. Insects. — Hessian flies and chinch-bugs are the worst of the insect enemies of wheat. The chinch-bug attacks other crops, while the Hessian fly confines its work mostly to wheat. The latter is a fly which lays its eggs in the young plant. When the maggots hatch they rasp the young tissue and drink the sap. The chinch-bug is a beetle that eats the tender plants. They pass through no true larval stage, but hatch continuously throughout the early summer. Altogether these insects cause a loss of 10 per cent of the wheat crop. Spraying and catching in plow furrows are advocated, but perhaps clean farming and rotation are the better methods of control.

In some districts, wheat suffers considerable loss from the wheat straw worm, which lays its eggs in the head and stem of the plant. The wheat joint worm works in the joints causing the grain to grow in bent positions, and therefore to be missed by the header.

191. Weeds. — There are a few plants that have become such nuisances to wheat that they have gained reputations as pests. They steal plant-food and moisture, shade and crowd out the crop, hinder harvest, and lower the value of the grain by adding impurities. The weeds most common in wheat-fields of the Mountain states are the mustards, Russian thistle, sweet clover, and June grass (*Bromus tectorum*). Chess or cheat is common in some parts of the East and middle West.

The mustards cause considerable trouble in some districts. Since the seed lies for years in the ground, it accumulates strength under single-cropping. Rotation with intertilled crops is, therefore, an effective method of combating it.

Russian thistle, a tumbleweed, and, for a long time, almost master of the Nebraska wheat farms, is now spread widely throughout the country. It scatters great numbers of seeds by rolling them before the wind. Railroads introduce it into new localities; irrigation water carries it to the fields; sheep carry it in their wool; and soon the whole region is sown. It is especially troublesome on the dry-farm, but no matter where it exists it is a pest to be reckoned with. For protection, it is covered with sharp, spiny leaves.

Sweet clover and June grass are easily controlled by thorough tillage, but they bother in haphazard farming, often increasing the labor and unpleasantness of harvest. Careful seed selection and proper tillage will lessen injury from chess.

192. Quality in wheat consists of the ability its flour has to absorb large quantities of water thereby producing larger leaves. This is because of the presence of a nitrogenous substance called gluten which, when wet, becomes sticky. Generally, the more gluten present and the more nearly it consists of 65 per cent gliadin and 35 per cent glutenin, the lighter is the bread made from a flour. Manifestly, however, stickiness cannot of itself cause bread to rise. Hard wheats produce angular flour particles rather than spherical or flat ones as does soft wheat. The edges permit the sticky gluten to take hold of the flour grains and to hold them more firmly together. When the yeast added to the dough "works," it produces carbon dioxide. Any substance in changing from a solid or a liquid to a gas expands. As carbon dioxide is liberated it needs more room; hence, it pushes the dough aside, making it porous. Thus bread "rises," that is, the loaf increases in size but not in weight. The size and the lightness of the loaf depend largely on the quality of the wheat furnishing the flour.

Considerable skill is required to pick out the best wheat from a number of samples. A clear, semi-transparent amber color and a horny, brittle interior indicate high percentage of protein. High nitrogen content gives any cereal a greater food value, and it gives wheat flour more desirable bread-making qualities. Shrunken kernels contain much protein, but the gluten is poor. Maturity, then, is also an essential characteristic of best quality in wheat. High nitrogen and low moisture content in a soil tends to produce wheat that is rich in nitrogen.

Millers and bakers know that some varieties of wheat are much more valuable than others for flour-making. Hard varieties often bring increased prices on the market. The most important factor in determining quality in wheat is climate. Regions having cold winters followed by hot, dry summers which cause wheat to ripen rapidly grow hard grain. Excessive rainfall as well as mildness causes wheat to soften, thereby lowering its gluten content. Starchy grain taken to a hard-wheat district hardens in a few years, just as hard ones moved to soft districts gradually lose their horny texture. Accompanying changes in chemical composition likewise result.

193. Uses and value. — The principal use of wheat is for human consumption in the form of bread. Flour, carefully graded in the large mills, is handled by wholesale dealers who distribute it to homes or bakeries. Bread is the chief diet of all highly civilized nations.

Besides being used for bread-making, flour is made into pies, cakes, crackers, doughnuts, pancakes, and a number of other common foods. In addition, many cereal breakfast foods are made from wheat. Formerly, only flour was saved at the mill. A waste-spout carried the bran, shorts, and other by-products into the stream that turned the water-wheel. Now these comprise a valuable part of the output. Bran and shorts are among the most valuable of stock-feeds. Even the dust brushed from the wheat kernels before grinding is collected and mixed with the bran.

Cracked, or broken wheat is better, especially for swine, than whole wheat, which in some cases escapes mastication and does not digest. The price of wheat, however, generally compels the use of cheaper grains, such as corn and barley. The dependence on wheat for such a variety of food products gives it a value higher than dollars and cents. Nearly twice as much wheat is ground for dietetic purposes, as of all other grains combined.

In cash value as well as in total yield, it is second to rice which alone feeds over half of the inhabitants of the earth. In the United States corn is the largest crop, with wheat second. For the world, however, corn, oats, and wheat each produce about four billion bushels, while rice totals five billion.

Potatoes, other root crops, and fruits all feed a greater number of persons for a given area than wheat, but maintain them at a lower standard of living. Wherever the standard of living is increasing, as it is in Germany, Russia, and parts of India, the use of wheat is spreading.

Dondlinger[1] says: "The great intrinsic food value of wheat; its ease of cultivation and preparation for use; its wide adaptation to different climates and soils; its quick and bountiful return; and the fact of its being paniferous and yielding such a vast number and variety of products are all factors that enhance the value of the wheat grain. Its combined qualitative and quantitative importance gives to wheat a great superiority over any other cereal, and causes it to be dealt in more extensively upon the speculative markets than any other agricultural product. As an essential part of the food of civilized man it assumes an importance so vital as to be dominating."

194. Storage. — The easiest way to store wheat, or any other grain for that matter, is to put it in sacks as it comes from the thresher, and to pile them on the ground. The owner uses this method as a makeshift until he can do something else with the grain: either sell it or store it permanently in a place where it will be protected from the weather. Sometimes the sacks are left

[1] *Book of Wheat*, p. 8.

exposed; sometimes they are covered with pieces of canvas having weights tied to the corners to hold them down.

As such storage permits considerable damage in wet storms, the farmer generally uses it only for that part of the crop that he intends to sell. Whatever he keeps over winter, he puts in bins in granaries. Since frost does not injure wheat, the granaries are exposed as much as possible to cold, thereby reducing to a minimum damage from mice and vermin, which cannot stand extreme cold.

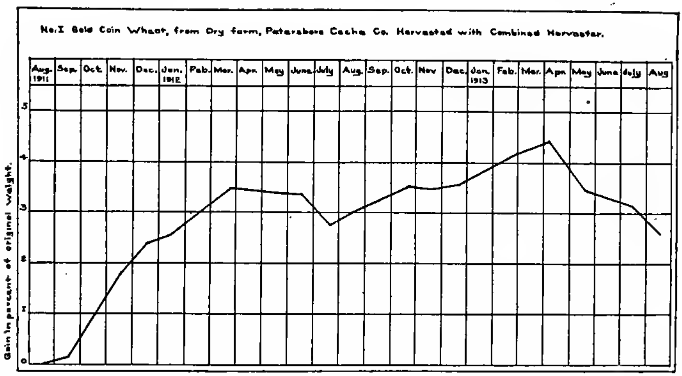

Fig. 54. — Gain in weight of wheat after harvest in arid regions, Utah.

To further ward off attacks of these destructive pests, some farmers set their granaries on posts three or four feet above ground. On top of the posts, before the joists are laid, they place inverted tin pans, which prevent mice, rats, and squirrels from climbing up the posts. Tight doors also deny them admittance.

The grain that is sold has very different treatment. The part that goes to the Pacific Coast is left in sacks, either being piled up on the wharves in heaps several blocks long by a hundred feet high, where it waits shipment, or else being stored in warehouses, some of which cover several acres. Still another part of our local export stops in the neighboring towns to be ground into flour. These mills have large bins holding from one thousand to fifty thousand bushels, storehouses which are really miniature elevators.

195. Elevators. — Particularly in the region of the Great Lakes, elevators are becoming more common. Here sacks are not used, and men handle the loose grain almost entirely by machinery. It pours directly from the thresher into dump wagons. The loose grain finds its way into cars which carry it to the elevator platforms. Trap-doors open chutes, down which it pours into vast cellars. Endless carriers elevate the grain and distribute it to bins from which it runs like water down chutes into cars, boats, or mills. Not once is it moved by hand. Terminal elevators are immense affairs, occasionally holding three million bushels of grain. Scattered far and wide over the country are smaller structures sometimes tributary to the large concerns and sometimes independent. One of the great elevators used in the handling of the grain crop is shown in Fig. 55.

Any grain containing excessive moisture molds and ferments in storage thus losing much of its value. Formerly, a considerable amount of grain was lost in this way in the close holds of ships that carried it from the United States to Europe. Grain must be well-dried before being stored anywhere. In arid regions, it is so dry at harvest time that it can be stored at once without danger. Indeed, it gains in weight by the absorption of moisture, eliminating shrinkage. Wheat shipped from California gains enough in weight before it reaches London to pay the cost of hauling.

Wheat is often bought and stored to await a rise in price. Small storage charges are made for rented space in elevators, about two cents a bushel for the first thirty days and a half cent for each additional thirty days. Sometimes farmers store grain independently; occasionally a number coöperate and run an elevator. By far the greatest number sell at threshing time. Much

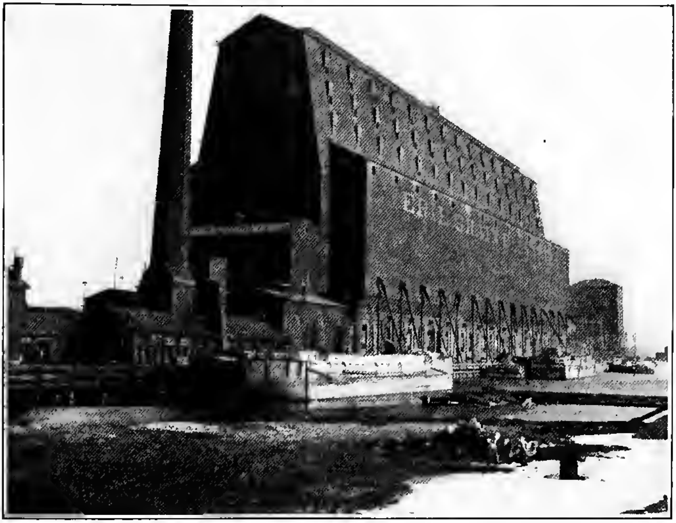

Fig. 55. — Large terminal elevators help to handle the world's grain crop.

grain, however, is contracted in the spring before it is even planted.

196. Marketing. — It is difficult for the ordinary farmer to know whether to sell at harvest or during the following winter. Often he needs the money and must dispose of part or all of the grain at once. To sell the entire crop at the same time saves him labor and storage expenses, but he loses any advantage from subsequent rise in price. This rise sometimes does not pay the expense; indeed, there may be a drop instead of a rise. The intelligent farmer studies the markets. "Will it pay to store?" is the question he must answer in consideration of the time to sell.

Local merchants and mills buy from growers and sell to shippers. Large companies also keep agents in the field who contract for grain with the individual farmers. In well-developed districts most of the grain is handled in this way. A few coöperative farmers' companies ship their own products. When successful, these net large returns, but the undertaking is attended with much risk as a business venture.

A great avenue for advance in marketing is a more systematic grading. In the grain trade of Chicago wheat is graded as follows:

White Winter Wheat, Nos. 1, 2, 3, and 4.
Long Red Winter Wheat, Nos. 1 and 2.
Red Winter Wheat, Nos. 1, 2, 3, and 4.
Hard Winter Wheat, Nos. 1, 2, 3, and 4.
Colorado Wheat, Nos. 1, 2, and 3.
Northern Spring Wheat, Nos. 1 and 2.
Spring Wheat, Nos. 1, 2, 3, and 4.
White Spring Wheat, Nos. 1, 2, 3, and 4.

The grades are based on soundness, cleanliness, weight, color, and uniformity, No. 1 being best. Poor wheat is called "no grade." These grades have become so nearly standard that a buyer accepts a certificate from the inspector without looking at the grain or seeing a sample of it.

197. Prices vary a few cents according to grade. In some sections, little reliable grading is done. The grain buyer, making a shrewd estimate of the grade, knows what he can get for it, while the farmer selling simply "wheat," must take the price of grade No. 3, though his grain may be No. 2 or even No. 1. Generally, the agent will pay less than he should. Therefore, a standardization of wheat and other grain would save money for growers.

To assist in handling the grain, enormous exchanges are maintained at Chicago and smaller ones in other cities. The Exchange is a large room in which buyers and sellers meet to transact business. Much of the time, confusion prevents ordinary conversation, hence a finger sign-language is used. Only large quantities of wheat (about 5000 bushels) are considered. Speculators, who have entered these exchanges, buy simply to sell for gain — not to assist in the legitimate grain handling. They buy up certificates and hold them, expecting prices to go up.

If a man buys a million bushels and holds it for a time, he is making a "bull" speculation. On the other hand, owning no grain at all, he may sell wheat at a given price, agreeing to deliver at a future date. He expects the price to fall when he can purchase wheat to fill his contract at a lower price than he receives from his customer. Such sales are known as "futures." When a man plunges in this way he is a "bear" speculator.

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534. Durum Wheat.
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616. Winter Wheat Varieties for the Eastern United States.

CHAPTER XVII

CORN OR MAIZE (*Zea Mays*)

BECAUSE " corn " was a common term in Europe for all grains, " Indian corn " was the name applied to field corn, or maize. Early European visitors found the natives growing it in Peru, Mexico, and New Mexico. Indians taught the English settlers at Plymouth how to grow the crop, fertilizing each hill with a fish. Captain John Smith of the Jamestown settlement saved the settlers from starvation by forcing the Indian Chief Powhatan to sell him corn. It must have seemed strange to these pioneers to find in America a plant of such vast importance to them. Some of the American field conditions of corn culture are shown in Figs. 56 and 57.

198. Relationships. — Maize belongs to the grass family, but is not closely related to the common grasses or to the other cereals. So far as we know, it has no close relatives in existence to-day.

199. Roots. — The first roots sent out by a young corn plant to start growth remain, but the larger part of the root-system, like that of wheat, develops from a node about an inch below the surface of the ground. As corn is generally grown in hills, the fibrous roots, in order to occupy all the soil, grow outward for eighteen or twenty inches and then turn downward. Other roots reach downward at once, thus leaving little unused soil. While the plant is young the roots grow rapidly, never, however,

Fig. 56. — Good corn culture.

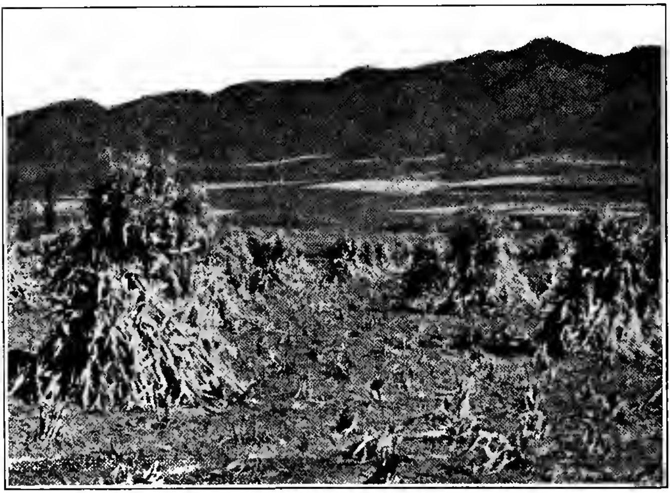

Fig. 57. — Corn on an irrigated farm, Utah.

reaching quite so large a development in proportion to the size of the entire plant as those of wheat. To anchor itself more firmly the plant sends out from the first one or two nodes above ground another whorl of roots. These enter the soil at an angle, bracing the stalk much as guy-ropes do a tall pole or derrick. Because these roots do little food gathering, but simply aid the plant in resisting wind, they are known as brace roots.

200. The culms, or stems, of maize resemble wheat culms in having nodes and internodes, but differ from them in having a stem filled with soft pith through which fibers are scattered. This pith is inclosed in a case of hard, compact fiber that serves as support. Each internode, except the top one, has a narrow groove on the side that bears the leaf. The length and diameter of the internodes vary so greatly as to cause the size of the plant to range from eighteen inches to thirty feet in height and from a half inch to a number of inches in thickness. The common range is from four to twelve feet in height and from one to two inches in diameter near the ground. One stalk grows from each kernel, sometimes sending out from a lower node branch stalks called suckers.

201. The leaves, growing from the nodes on alternate sides, clasp the stem part way to the next joint, and then send out a blade just as do the leaves of wheat. They are parallel-veined, with a distinct midrib, edges that cut, and a rough, hairy surface. As the outer part of the leaf grows faster than the inner, wrinkling is produced. The edges are thinner than the middle causing the leaf to roll when it wilts. Because the plant grows rapidly about tasseling season, a large leaf area is necessary to take in carbon dioxide for the manufacture of food. In a good stand, the total leaf area, when greatest, is about six times that of the land on which it is grown; hence enormous quantities of water are transpired to maintain growth. Wilting often takes place, but the rolling of the leaves reduces loss of water and turgidity is restored automatically.

202. The flower. — Each ear develops in the axil of a leaf from a bud in the groove, part way up the plant. Kernels develop from the ovary part of the flower on the cob. Each is fertilized by pollen borne on the tassels. This alights on the exposed end of the silk which connects with the ovary.

The wind blows the pollen about so freely that much is lost. To insure itself against this loss each plant produces from 9000 to 45,000 pollen grains for each silk, or about 2000 ovules and from eighteen to seventy million grains of pollen. Many of the silks are fertilized by pollen from another plant. In fact, the plant seems to invite cross-fertilization by ripening and letting its pollen go before the silk of the same plant is ready to receive it.

203. The ear. — Since the cob is several united spikelets, each of which bears two rows of kernels, the number of rows is even. An ear having an odd number is a great curiosity. Often an ear has more rows at the butt than at the tip, but these rows drop out two at a time. Because the tip of the ear fills last, this part of the cob is frequently bare and the kernels are nearly always smaller and more nearly round here than in the middle of the ear. At the butt they are larger but irregularly shaped. Fig. 58 shows good and uniform ears of corn.

All kernels are covered with a membranous hull that loosens when the grain is soaked in warm water. The embryo is near the cob on the side toward the tip of the ear. The remaining part, about seven-eighths of the whole, is endosperm — corneous if hard, starchy if white.

The corneous endosperm contains more nitrogen than the white and is more valuable for feed.

Abnormalities of structure occasionally manifest themselves as grain on the tassel, as divided cobs, as one ear borne at the tip of another, and as tassels borne on or between cobs.

204. Types. — The corn that Europeans first found the Indians growing in America was much inferior to the better kinds now used. Although there is but one species,

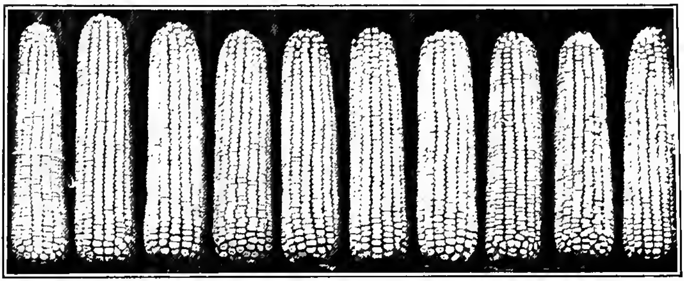

FIG. 58. — Good ears of dent corn.

this varies so widely that little difficulty is experienced in changing a variety or in improving it. It is only about sixty years since corn improvement was begun; yet within this short period has come most of the advance made since white people first grew the crop. Widely different uses of corn and varying conditions of growth have given rise to six very distinct groups of varieties better known as types. These are: (1) dent, (2) flint, (3) sweet, (4) pop, (5) soft, and (6) pod.

205. Dent corn is by far the most important, as it includes over four-fifths of the total corn crop. It is so called because the corneous endosperm, which partially incloses the soft, starchy endosperm at the crown without covering it, allows the kernel to shrink or dent in ripening. The dent may be very shallow or so deep as to give considerable roughness to the ear. The kernels are not too hard for animals to chew.

Desirable ears are six to eight inches in circumference and eight to ten inches in length, with deep, wedge-shaped kernels extending well over both tip and butt. Cylindrical ears with small butts and no bare cob at the tip are most desirable, because the shelling percentage is high.

206. Flint corn is so called on account of the hard, glossy kernels, the crowns of which are round and smooth. The dent fails to develop because hard endosperm covers the crown as well as the sides of the kernel, entirely inclosing the starchy part. The kernels are more nearly round, wider, and more shallow than dent kernels. Less corn in proportion to cob grows on the flint ear. Flint corn differs from dent in having a longer, slimmer ear, a larger shank which increases the difficulty of husking, and fewer rows of kernels.

Dent varieties usually require a longer time to mature than flint, but this is not always the case. Although next to dent in importance, flint corn produces somewhat less than one-twelfth of the total crop.

207. Sweet corn has sugar instead of starch in the endosperm. The glucose sugar shrinks evenly while ripening, giving the kernels a distinctly wrinkled appearance. In shape, the ears resemble dent. Its ripening period is medium. Sweet corn does not represent more than 2 or 3 per cent of the total crop, most of this being used in the canning industry, and for table use.

208. Pop corn is either smooth like flint or sharp on the top of the kernels, which are so very hard that animals cannot chew them easily. This, the dwarfishness of the plant, and the small size of the ears, which are generally an inch thick and four to six inches long, prevent its being used as stock-feed. Pop corn yields less than 1 per cent of the corn produced in this country. It is largely consumed as "popped corn." Popping consists of a rapid heating which causes the kernel to explode and turn inside out. The plant suckers freely, bears several ears, and matures early.

209. Soft or flour corn resembles white flint in appearance both as to ear and plant, but has no hard endosperm at all. Because it is readily ground, it was grown by the Incas of Peru for food.

210. Pod corn received this name because each kernel is inclosed in a husk. The ears are short and the plants smaller than flint. It is used to some extent for cattle feeding, but neither this nor soft maize are grown on a commercial scale.

211. Varieties. — There are nearly three hundred varieties of corn, but as already mentioned, these may be changed and improved so easily that, in many cases, the same variety has several sub-varieties called strains. Many varieties are known by different names in different localities, causing a hopeless tangle out of which little can be cleared. Improved Leaming, Reid's Yellow Dent, Boone County White, Silver King, Silver Mine, Gold Mine, King Philip, Longfellow, Legal Tender, Wisconsin No. 7, and Minnesota No. 13 are wide-spread, standard varieties.

212. Distribution. — The total production of corn from 1905 to 1909 was 3,585,418,600 bushels yearly. Austria-Hungary, Argentina, Russia, Egypt, Australia, and Mexico in the order named produced corn, though the United States grew 76 per cent of the whole, producing about two-thirds of its crop, or one-half the total output of the world, in eight states: namely, (1) Illinois, (2) Iowa, (3) Missouri, (4) Nebraska, (5) Indiana, (6) Kansas, (7) Ohio, and (8) Texas. These eight states have an area in square miles equal to 22 per cent of the area of the United States, and to one-third of 1 per cent of the total land area of the world. One-half of all the corn on earth would not be produced on one three-hundredth part of the earth's area if this particular section were not especially adapted to corn production.

213. Factors in production. — The four important factors that determine the successful production of corn are: (1) market conditions, (2) length of growing-season, (3) rainfall, and (4) soil.

If the crop, its manufactured products, or the meat produced by feeding it, did not sell to advantage, the crop could not be grown though the climate and soil were ever so favorable to its production. The corn belt of the United States has shipping facilities through a network of railroads and waterways; Chicago and St. Louis, the great meat markets of the world, are at hand; vast factories in which starch, glucose, oil, and sirup are made have grown up in the region. It is hard to conceive of more favorable marketing conditions than here exist.

214. Adaptation. — Corn is extremely sensitive to frost — so much so that the length of its growing-season is measured by the last spring frost and the first one of autumn. One slight frost in the fall injures the plant to such an extent that, although a month of warm weather follows the freeze, this first drop of the thermometer, even though of only a few hours' duration, ends its growing-season. An even temperature free from cold nights is desirable, but absence of frost for nearly five months is absolutely essential. In the corn belt there are no late spring frosts and no early fall frosts.

The water requirement in proportion to dry matter produced is less for corn than for other grains. This does not indicate, however, that corn needs less water than the small-grains. It grows very rapidly after tasseling begins. In one case it was found that 1300 pounds of dry matter to the acre was produced in a single week. Thus great quantities of moisture are needed in the growing-season. Experience has shown that the yield of corn is almost directly proportional to the moisture supply during a few critical weeks.

Corn responds very readily to the presence of organic matter in the soil. Soils that are loose, black, and rich in organic matter are common in the corn belt. The crop is grown on the heavier soils, but is at its best on the loessial soils, which are easily kept loose and friable. The physical condition of the soil is important, since good tilth allows soil moisture to move freely to the roots.

The average acre-yield for the United States from 1900 to 1910 was 24 bushels; for Connecticut, 39.9 bushels; Massachusetts, 38.3 bushels; Maine, 37.3 bushels; Ohio, 36.9 bushels; and Pennsylvania, 36.8 bushels. In the South, the yields were less, but the methods of culture were also infinitely poorer. Systematic handling of the crop, it is estimated, should in the North give a 100-bushel crop and in the South even more. The bumper crop of 226 bushels grown by a Tennessee boy is worthy of attention.

215. Preparation of the seed-bed. — Deep fall-plowing seems rather advantageous to corn because it enables winter moisture to sink into the soil, and allows frost to mellow the seed-bed. Since large quantities of organic matter cause abundant growth in corn, moderate applications of farm manure usually pay. Corn is a good crop to follow clover, alfalfa, or other sod-producers. Whether plowing is done in spring or fall, the plow should cover all the vegetable material to insure decay. In the spring the disk or spike-tooth harrow should fine the seed-bed until a loose, friable surface is ready to receive the seed.

216. Seed and planting. — After the farmer has decided upon the variety he wishes to grow, he should choose seed adapted to the climate. Seed should be selected in the field before the grain is cut in order to identify high-producing, early-maturing plants.

Because both frost and moisture injure the germinating power of corn, seed requires a warm, dry, well-ventilated place for storage. A good way is to hang the ears in strings, in such a way that they do not touch. Kernels from butt, tip, and middle of ear have equal value, although irregular butt and tip kernels may interfere with even distribution by planters. In most cases, no treatment before planting is needed.

On some large farms, machines do the planting, but on most small farms, seeding is done with hand planters. Although there seems to be no advantage in planting deeper than one or two inches in humid sections, farmers of the West consider three to six inches none too deep because they find it necessary to plant below the dry surface soil. In heavy soils, planting should not be so deep as in light, sandy ones.

Thickness of planting varies from more than a kernel for each square foot to one for each fifteen or twenty square feet. Medium thick planting, a kernel for each three or four square feet, usually gives the most grain. Seed is nearly always planted in rows and generally in hills. A common practice is to plant three or four kernels in hills two to five feet apart, with three to five feet between rows. About a peck of shelled corn sows an acre for grain production, but, for fodder or silage, thicker planting is desirable.

The time for planting is usually later than for the small-grains. Sometime in May is usual, though the late days of April and the early ones of June are suitable in some districts. No date can be set, for the frost and moisture conditions vary with the locality.

217. Treatment of the growing crop. — Before corn comes up, a harrow run over the field will break the crust

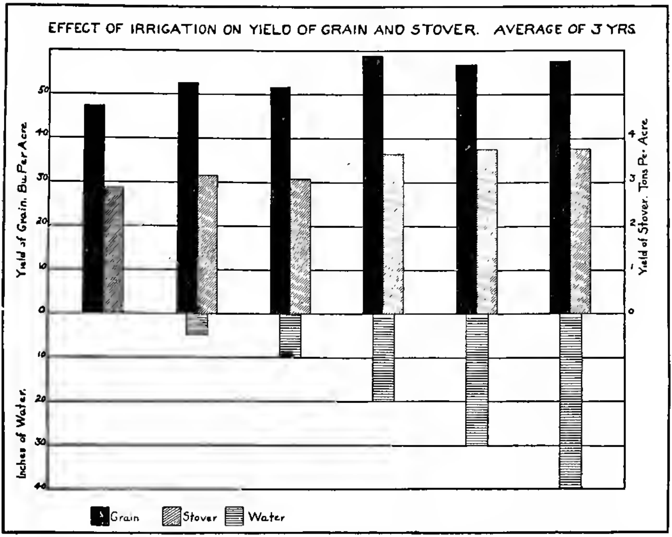

FIG. 59. — Effect of irrigation on yield of corn, Utah.

and kill weeds that have just germinated. After the hills can be seen plainly, the harrow may be used until the plants are so large that they would be injured by the implement. The cultivator may be used as soon as the rows show well and it should follow at intervals of two weeks, or thereabouts, except that, after every heavy storm or irrigation, cultivation can be given to advantage as soon as the land will permit. Some hand-hoeing may be needed to keep down weeds in the rows. Shallow is better than very deep cultivation, and frequent better than occasional.

It is usually unnecessary to irrigate corn until it has a good start, but in case the soil is too dry to germinate the seed, it is advisable to apply the water before planting

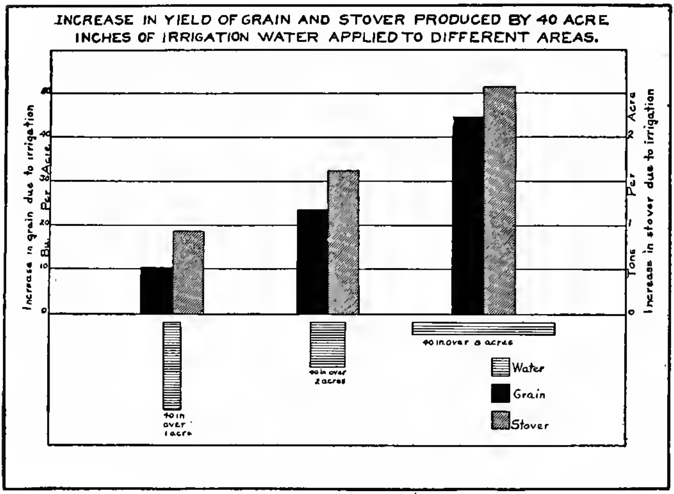

FIG. 60. — Results of irrigation on corn.

rather than after. The time for irrigation will be indicated by a dark color and by the wilting of the leaves. The amount and distribution of irrigation water will vary greatly with conditions, but it is rarely necessary to use more than thirty inches during a season. It is usually more convenient to apply water by the furrow method. The charts (Figs. 59 and 60) show the results to be secured from judicious irrigation.

218. Harvesting. — A good time to begin to harvest corn is when the grain is just hard enough to resist pressure from the thumb nail. About this time the husk turns whitish, but the fodder remains green if frost has not nipped the leaves. Nothing is gained by allowing maize to go unharvested after it is ready, and since, in many sections, frosts are likely to do considerable injury to the fodder, much risk accompanies late harvesting.

Some growers turn hogs and occasionally cattle into the corn to harvest it on foot. Rape or cowpeas sowed between the rows add much to its pasture value. The practice of "hogging-off" is increasing. Sometimes the ears are pulled by hand or machinery and the stover pastured. Again the leaves may be stripped off and saved, or the top of the stalks and leaves cut. Most satisfactory, perhaps, is the method of cutting off the stalks at the ground and stacking them in shocks in the field or in the yard to be husked later.

There are several kinds of corn-cutters, some of which bind and shock the corn. Much maize is cut with long knives and short-handled hoes. Husking is commonly done by hand, in spite of the fact that there are machine huskers and shredders. The great expense and the complicated, easily-injured mechanisms have retarded the universal adoption of corn-harvesting machinery.

219. Silage. — Corn to be made into silage is allowed to stand in the field until the grain is in the roasting-ear stage, when it is cut, usually with a binder, and hauled on a low wagon to the silo. Here it is cut into pieces a half inch long, or thereabouts, and blown into the silo. It settles into an air-tight mass and preserves itself for green feed in winter when dairy stock have no pasture, or in the hot, dry summer when succulent feed is scarce.

220. Enemies. — Weeds cause the most difficulty in corn-growing, but as already pointed out, they may be largely controlled by proper tillage. Cocklebur, bindweed, Russian thistle, milkweed, and common pigweeds all cause the corn-grower trouble. The perennial bindweed, milkweed, and ground cherry are most troublesome west of the Great Plains.

Besides weeds, maize smut and the corn ear-worm are the worst enemies to the crop. The smut masses should be picked off and burned before they burst and spread the smut spores. As smut lives over winter in soil or manure, it is useless to treat the seed. Clean cultivation and rotation of crops are the effective methods of control. This is likewise true of the corn ear-worm, billbugs, the root-louse, rootworms, and chinch-bugs, which do considerable damage, especially where corn is grown year after year on the same land, or where culture methods are otherwise poor. Fall-plowing and clean farming are the best methods of control. Sometimes remedies are used advantageously. A treatment for the chinch-bug is given in Chapter XVI.

221. Uses and value. — About nine-tenths of the crop enters the food ration of animals without first being shelled. For fattening hogs and beef it has no equal. Dairymen and horsemen also use much of it as feed. It mixes well with alfalfa, which is a flesh and bone builder, while corn furnishes energy and fat. Corn alone is not, however, a balanced food.

Green, dried, and canned corn, hominy, corn meal, cereal breakfast foods, popcorn, and corn sirup are human foods. Corn oil, starch, distiller's grain, cobs, husks, and pith find various uses, while the stalks and leaves are used for roughage.

The value in dollars of corn produced in the United

States exceeds that of any other single crop in this country or any other one country, although the world crop of wheat and rice surpass the world crop of corn in value because little maize is grown in the Old World.

The great number of uses to which corn can be put gives it a value aside from its selling price. It was particularly useful to the pioneers of the Mississippi Valley because it grew on almost unbroken land, even among

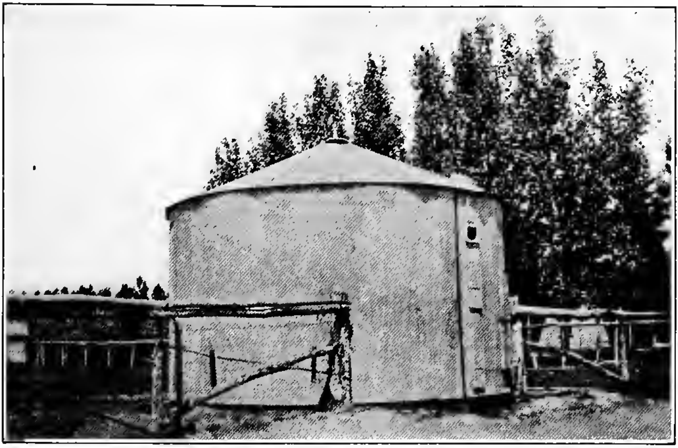

FIG. 61. — A good type of farm grain bin.

the stumps. It furnished both animal and human food and needed little care. It and meat were the chief foods of the early colonists in Jamestown and Plymouth; it accompanied the pioneers until they reached the dry plains east of the Rockies, where wheat displaced it.

222. Storage and marketing. — Because of the high percentage of moisture in kernels and cob, the grain molds easily in poorly ventilated places; hence the value of the slatted cribs. After being shelled the germination power is injured by freezing, though the feeding qualities are not hurt. On the other hand, the best way to handle fodder is to shock it on well-drained ground. The construction shown in Fig. 61 is a good type of store-house for the farm.

Corn is marketed mostly "on foot," that is, fed to animals that are being fitted for market. It does not enter into world markets so largely as other cereals, but where it does, it is handled much as is wheat except that greater precautions are taken in drying.

For big markets there are grades Nos. 1, 2, 3, and 4 in each of three classes — white, mixed, and yellow.

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CHAPTER XVIII

OTHER CEREALS

Besides corn and wheat, the cereals commonly grown in America are oats and barley. Rye is less important and rice is confined to a few districts in the South. Buckwheat, though not a true cereal, is grown to some extent for grain. Sorghums are more important for forage than for grain, and, on that account, are grouped with the millets.

OATS (*Avena sativa*)

223. Origin and relationships. — It is little wonder that oats were not used for human food until long after wheat and barley, when we consider that wheat has no husk covering the kernels and the barley has a much thinner one than oats. The Egyptians knew nothing of oats, and Greeks or Romans did not cultivate them, extensively at least, although they knew them. This is not strange, since the grain is primarily adapted for animal feed. It is not surprising that oats probably came from the region of the great central Eurasian plains — probably from the region of Tartary in west-central Asia — where cattle and horses had long been cared for. They spread over Europe later, especially in the cool, moist sections. When introduced into America by the early colonists, oats did best in the damp North.

Like corn, the oat has but few immediate relatives. Nearly all our commonly grown varieties belong to the one species, *Avena sativa*, though one or two other species yield some grain. Like all other true cereals, they belong to the grass family, but to the tribe Avenæ instead of Hordeæ, which includes all the other small-grains. Two grasses, tall meadow oat-grass and velvet-grass, belong to the same tribe as oats. Not only in the tribe but in the same genus with the oat is the wild oat (*Avena fatua*), one of the worst weeds of this grain crop.

224. Description. — The oat plant has a fibrous root-system similar to that of wheat except that it does not have such a deep rooting habit. The roots spring from an underground node generally about an inch below the surface — deeper in drier soils — and form a network as they penetrate the soil.

The culms resemble those of wheat except that they are usually both thicker and longer, varying from eighteen inches to five feet in length, with between three and four feet as the ordinary height. Lower joints have the power of sending up an erect internode even though the one below is lying flat or is inclined. The plant accomplishes this by means of a bent node.

The leaves grow from the nodes clasping the stem nearly to the next node, where they spring outward without any clasp. The absence of the clasp, together with its slightly broader leaf covered with fine hair, enables a careful observer to distinguish the young oat plant from other small-grains.

The grain-bearing head of the oat differs widely from that of other grains. These bear a compact head, or spike, whereas the oat head is a panicle, that is, the spikelets are borne on rather long and slender pedicels holding them far apart. The panicle may be nine to twelve inches long and from two to eight inches wide, with intermediate measurements most common.

The spikelets, of which there are from forty to seventy-five in a panicle, generally contain two kernels, a smaller one being tucked snugly into the groove of a larger one. Occasionally, a third grain develops, but this is rare. Since single kernels are rather uncommon, the grain appears somewhat variant in size of kernel.

Each kernel is covered with a comparatively thick husk, or hull, which breaks away from the interior grain when rolled. Some varieties known as hull-less shell free from the husk on threshing. A crooked awn occurs on the back of the husk instead of at the end as with wheat, barley, and rye. In other respects, the structure of the grain is almost identical with that of the wheat kernel save that the oat grain is proportionately much longer and covered with hair.

225. Distribution. — Oats are naturally adapted to those parts of the temperate zone that have a cool, moist climate throughout the growing-season. The crop is not sensitive to kind of soil except as it regulates the moisture supply. Heavy soils rich in organic matter favor even distribution of moisture in the soil, and, therefore, are best. Sandy soil demands frequent applications of moisture for high yields.

The countries that have the favorable climatic conditions are the best producers. A study of the rainfall and temperature of Canada, northern United States, central Russia, Germany, Austria-Hungary, France, and Great Britain reveals the reasons for their vast oat crop. Parts of Scotland and the Scandinavian countries have almost ideal conditions, but these areas are too small to enable them to count as world producers. For the five years ending with 1910, the nations produced annually as follows:

United States	932,000,000 bushels
European Russia	865,000,000 bushels
Germany	583,000,000 bushels
France	299,000,000 bushels
Canada	295,000,000 bushels

There are vast fields of oats in Manchuria and Argentina whose total crops are unreported. The total for the world is over four billions of bushels, nearly the same as for wheat and corn. These other grains, however, exceed oats in total weight.

The oat-producing areas are spread over the United States, but the northern states from New York to Washington and Oregon are situated most favorably. The leading states in order are: (1) Iowa, (2) Illinois, (3) Wisconsin, (4) Minnesota, (5) Nebraska, (6) Ohio, (7) Indiana, (8) New York, and (9) Michigan. Western Oregon and Washington have perhaps the most ideal climates, but the district is not large. Many mountain valleys in the West which are small and generally isolated also have favorable conditions.

The average acre-yield in the United States has been slightly less than thirty bushels, while in Germany and Great Britain it is much higher, being in the neighborhood of forty to forty-five bushels. By states, the leading acre-yields (1902–1911) are as follows:

Washington	47.6 bushels
Montana	43.0 bushels
Idaho	41.7 bushels
Utah	41.5 bushels

The great producing states all average less than thirty-four bushels. A good farmer may expect from sixty to more than one hundred bushels.

226. Varieties. — Oats are classified into groups according to shape of panicle, season of planting, color, and size and shape of grain. There are spring and winter oats. The South grows winter varieties principally in order to throw the growing-season in the cool part of the year. If the spikelets are borne on short pedicels and are all on one side of the culm, they are side oats, or "horsemane" oats; if the head spreads, they are spreading. These are the oat types. Further classifications according to color are described as white, yellow, black, red, whitish-yellow, etc. Some varieties are early, others late; some plump, others long-hulled. Seedsmen and growers introduce new varieties every year, and old varieties get new names. A hopeless confusion results rendering clear grouping and naming impossible. A few leading varieties for the country are Big Four, Silvermine, Clydesdale, Swedish Select, and American Banner.

227. Seeding and cultivation. — The preparation of the seed-bed for oats is similar to that for wheat. The depth of planting varies from one to four inches, just under the dry mulched soil. As soon as the land can be worked oats may be sown in quantities of from five to eight pecks depending on the yield expected and moisture supply available. In some districts as little as three or four pecks are used; in others as much as twelve or fourteen pecks. Harrowing may begin as soon as the grain is up and continue until it would injure the plant. From five to thirty inches of irrigation water may be applied in parts of the West, in one to six applications.

228. Harvesting and marketing. — Oats are usually cut with the binder, though the header finds occasional use in the regions of small rainfall. Only on very short or badly-lodged grain should the farmer use the mower. Shocking in the field follows in most regions. Although oats should not be cut until after they have reached the hard-dough stage, the straw is often so green at this stage that the bundles must be piled to permit air to pass through the shocks. Setting the bundles in ricks two at a time with the second pair just touching the first until ten or twelve bundles are in a rick, permits ventilation and drying. Careful drying in the shock prevents mold, which is detrimental to the quality of the grain. After the straw is dry, most farmers stack the oats instead of threshing at once. Well-built stacks insure the grain against storms until the thresher can be obtained. It is asserted by some that stacking seems to improve the quality by causing it to "sweat."

Tight bins to prevent insect injury and to prevent odors from stables being absorbed by the grain are essential (Fig. 61). Although some farmers sell directly from the thresher after sacking, most of the crop is stored for feeding purposes. The part sold makes its way into the elevator system to be handled and graded like wheat, except that the groups are classed as white, mixed, and red. White is standard. Four grades in each group are made.

229. Uses. — The most important use of oats is for feeding farm animals, such as cattle, hogs, and horses, horses being especially fond of them. The hull prevents formation of a pasty mass in the stomach; the grain is palatable, nutritious, and easily masticated.

Rolled oats, or oatmeal, is used as a human food. The Scotch formerly used it much. This gave rise to a clash of wit between a Scotchman and Dr. Samuel Johnson, who said he noticed that in England oats were feed for horses, but in Scotland men ate them. The Scotchman sagely remarked that the best horses grew in England and the best men in Scotland.

Oat hulls, light grain, dust, and impurities — by-products of oatmeal factories — are used for feed, as is the straw, which has more frequent use as bedding for animals, although, as roughage, the straw supplemented by some hay or grain may carry stock over winter nearly as well as wild hay. Oats alone, or mixed with peas, make fair hay if cut before the grain gets hard and while the leaves and culms are still green. Peas, of course, increase the nitrogen in the ration.

230. Enemies. — The common weeds all trouble oats. Wild mustard is bad; clean cultivation and rotation, clean seed, and spraying with iron sulfate are helpful means of eradication. Wild oats (*Avena fatua*) are very troublesome in some fields long sown to oats, because they mature ahead of the crop and shell out before harvest. Crop rotation and clean seed are preventives. Since wild oats are lighter than the cultivated grain, the fanning mill will partly clean the seed. Smut injures oats to considerable extent unless the seed is treated. The spores enter the oat at blooming time. Oats are treated in the same way as wheat, the formalin treatment being perhaps the best.

Rust causes much loss but cannot be remedied directly. Indirectly it may be partly controlled by selection of early or rust-resistant varieties, by using only well-drained land, and by using culture methods to prevent lodging.

The chinch-bug, spring grain-aphis, and the army-worm injure the growing crop. Remedies for the chinch-bug have been given in Chapter XVI. Clean cultivation and fall-plowing help to control the others. It is not usually profitable to spray or otherwise treat growing oats for insects. Grain weevils and the Angoumois grain moth are best controlled by storage in tight bins. If the bins become infested, fumigation with carbon bisulfide will kill the insects. Hydrocyanic-acid gas is also effective, but extremely dangerous, one full inhalation of it being fatal to man.

BARLEY (*Hordeum sativum*)

From the earliest dawn of civilization, man has cultivated barley continuously. It has been an important crop in all the empires of which we have record. Barley belongs to the same tribe as wheat. It has for its nearest relative barley-grass (*Hordeum jubatum*) variously called foxtail and squirrel-tail.

231. Description. — Barley resembles wheat very closely, having a fibrous root-system of less extent and having stools, culms, leaves, and spikes that are very much like those of wheat. The chief apparent differences are that it stools less, has shorter straw, and that the kernels are usually covered with a lightly-adhering husk, which breaks when the grain is crushed. Barley heads commonly have beards, although there are a number of varieties that lack them; some lack hulls, and others lack both beards and hulls. These, however, are not as yet in general use.

The spikelets are single-flowered, and, therefore, bear only one kernel. Three spikelets, however, lie side by side. In one type all three spikelets bear grain, while in another type only the middle one is fertile, giving rise to three rows or to one row, respectively, on each side of the spike, — the two sides making six and two rows; hence the name of these types: two-rowed and six-rowed barley.

Two-rowed barley is spring grain, while six-rowed is either spring or winter. These varieties of six-rowed barley are standard: (1) Oderbrucker, (2) Manchuria, and (3) California. California Feed and Bay Brewing are common in California. Of the two-rowed type Chevalier and Hanna are most popular. In the Mountain States, Tennessee Winter, Chevalier, Utah Winter, and Beardless do well. The Southern States grow winter varieties in the main.

232. Distribution and adaptation. — No other grain crop withstands successfully such wide differences of climate, elevation, and soil as barley. It is cultivated from the equator up to the Artic circle, being grown as a crop at 65° north latitude. In Peru, at 11,000 feet above sea-level it yields well. It is a leading crop on the hot, dry plains of Spain and North Africa, though it does best on well-drained loam soils with moderate moisture. It grows on almost any soil and withstands considerable drouth being, therefore, a good dry-farm crop. Since it is the most alkali-resistant cereal, it grows well in arid regions that have slightly alkaline soils. It is often grown on virgin land until other crops can be made to grow profitably.

Russia, United States, Germany, Austria-Hungary, Japan, Spain, the British Isles, and Canada in the order named are the leading producers. California, Minnesota, Wisconsin, the Dakotas, and Iowa yield over 80 per cent of the crop of the United States.

In average acre-yields, Idaho is first, with an average of about 40 bushels; Utah second, with 38.5 bushels; and Washington third, with 37 bushels. Good yields are from 50 to 100 bushels, though 125 bushels have been harvested in some districts under irrigation.

233. Sowing and cultivation. — For barley as for other small-grains, a fine, deep seed-bed is desired. This is most easily obtained by fall-plowing followed by early spring harrowing. Seed that germinates well should be chosen. This is important, because there is often much broken grain which cuts down the percentage of germination. Careful screening will remedy this. Pure varieties should always be used.

The grain drill does the best seeding, since it controls depth and distribution. Two or three inches is the best depth usually, but seed can start only in damp soil. Two bushels is the common amount of seed for an acre, but some farmers sow as much as four. In dry districts about one bushel is used. Excessively large quantities of seed should be used only for unusual conditions or purposes. A little later than for oats, April or May, seems the best time for spring sowing, and about the same time as for wheat when fall-planting is practiced.

Barley is usually left uncultivated, though one or two harrowings may be profitable in dry sections. Five to twenty inches of water in one to four applications increase yields markedly in sections where irrigation is practiced.

234. Harvesting and marketing. — Barley, having a shorter growing-season than oats, ripens just ahead of them, from May to August, depending on the section. Binders usually do the harvesting, leaving the grain to be shocked and stacked. Headers and combined-harvesters are used to some extent. Shocks of barley to be used for malting are commonly thatched with loosened bundles to prevent staining, which injures the grain by discoloring the malt and giving it a bad taste. The thatch of the shocks is threshed separately and used for feed. Malt barley also requires extra care in threshing to prevent breaking or tearing the husks, either of which causes slow germination. Rapid germination is very desirable since, to get a strong malt, all kernels must germinate within forty-eight hours of each other. The careful removal of dirt and weed seed much improves the grain for both feed and malt.

Careful storage is essential for the same reason as that stated for careful shocking and stacking. Since malt barley is all sold, it must be carefully handled. Two-thirds of all barley finds its way into the market by a course similar to that of wheat. There are two groups of grades — "barley" and "rejected." In each there are grades 1, 2, 3, and 4.

235. Enemies and uses. — The insects that attack barley are chinch-bug, grain-aphis, and Hessian fly. Remedies, where pests are present, are fall-plowing, rotation, and clean farming. Insects in the bin are controlled by carbon-bisulfide fumigation. Loose and closed smuts of barley are prevented by the formalin or hot water treatments, respectively. Where the rusts are present, selection of stiff-strawed, early-maturing varieties, and planting on well-drained land not so rich in organic matter as to cause lodging, are the methods of control.

For hogs, barley is a splendid concentrate, producing a good quality of pork. For sheep, cattle, and poultry, it is usually crushed and mixed with oats or bran to lighten it. It is much used on the Pacific Coast for horses. In the Latin countries of Europe, barley is used for bread, but not so much as formerly. In the United States, the kernel with husk removed is used as pearl barley in soup. It forms a part of the manufactured cereal foods.

The by-products are used in various ways: (1) the straw for bedding and feed, although the beards, or awns, lower the feeding value; (2) hulls and broken grain for feed products; and (3) malt sprouts and brewers' grain (remnants from malt industry), which are high in protein, for feed, particularly for dairy cows. In the West and

South, some barley is cut green for hay. Hull-less barley mixed with peas, cowpeas, or vetch makes fairly good hay, and a good pasture for hogs.

The value of barley like that of oats and corn is closely related to the livestock industry. Barley and bran are high in protein and mix well with corn, which is high in carbohydrates. There may be a growing use for barley as one of a number of grains in a mixed grain ration. An increased number of choppers on the farm should widen its use.

As a world crop, barley yields only one and one-half billion bushels and ranks far below the other grains. In the United States barley ranks ninth, oats sixth, wheat second, and corn first in importance.

RYE (*Secale cereale*)

236. Description and distribution. — Rye came into Europe later than Roman times and spread rapidly over the northern and central parts of the continent from Spain to Central Asia. It is more closely related to wheat than to any other crop. Another species occurs in Austria-Hungary and Russia.

The root-system is fibrous, but its rooting habit is not as deep as that of wheat. It stools considerably, growing longer, finer, tougher culms than other small-grain. It has few leaves and long spikes, the glumes of which always bear beards. The kernels are naked, long, slim, and dark-colored. Rye has the power of sending up new culms after being cut, a power possessed only to a slight extent by other cereals. There are but few varieties of rye, because cross-fertilization takes place so readily in the field that all strains are mixed.

Russia produces more than half and Germany more than a fourth of the crop of the world. Other countries follow in this order: Austria-Hungary, France, and the United States. In the United States, (1) Pennsylvania, (2) Wisconsin, (3) Michigan, (4) Minnesota, and (5) New York produce most of the crop. Rye, grown as a winter crop in Alaska, is more frost-resistant than even wheat or barley. It can grow on poorer soils than nearly any other crop; it is also drouth-resistant.

237. Handling the crop. — Fertile soil and a good seed-bed increase the yield. It is usually sown with drills in fall or spring at the rate of five or six pecks; dry-farms sometimes require only two or three pecks and pasture as much as eight pecks. It grows best with the shallowest planting that will enable it to sprout. Harrowing encourages stooling, but irrigation does not pay ordinarily, because yields are too small. Harvesting and threshing methods are the same as for wheat, oats, or barley.

Ergot, a fungous disease, is the only serious enemy. It is poisonous to cattle in addition to injuring the yield. Cleaning the seed and rotating each year help to overcome it. Insects trouble but little; there are no special weeds.

238. Uses. — Rye bread feeds a vast number of the people in Russia, Germany, Norway, Sweden, and other parts of Slavonic and Teutonic Europe. It is yielding place to wheat as human food. As animal food, the grain is used mostly in mixed rations. It is better for hogs and horses than for other animals. The grain also forms part of the mixtures for malt, and the by-products are used as animal food. When green, the plant furnishes second-class hay, or, if plowed under, a poor green manure. The straw is poor feed on account of being tough. Fall-planted rye is sometimes pastured by cattle or sheep. In parts of Europe the straw is more valuable than the grain, being woven into mats, carpets, plates, dishes, baskets, boxes, trunks, and various trinkets and articles of apparel. Rye cannot, at present, be an important grain crop in the United States. In Europe, it ranks high; in the United States, it is only eleventh; as a world crop, it is smaller than wheat, corn, oats, and rice.

RICE (*Oryza sativa*)

239. Description and distribution. — Rice has fed nearly half of the population of the earth for about 4000 years. In 1694, a trading vessel carried the first rice to South Carolina. It spread slowly until the last thirty years, during which time it has become a valuable crop in Louisiana, Texas, Arkansas, and Central America.

The nations producing it rank as follows:

India	70 billion pounds
China	50 billion pounds
Japan	18 billion pounds
All Europe	12 billion pounds

The high price — about three cents a pound — gives it a greater cash value than any other crop.

The plant slightly resembles oats, save that the panicles are closed. The grain is covered with a husk called paddy that must be removed before it is used for food. Upland and lowland are the two types, lowland requiring to be flooded a large part of the growing season, while upland is not irrigated.

240. Uses. — The most important use of rice is as food for man. Machinery removes the hull; rollers covered with sheepskin, one going faster than the other, polish the grain. The flour or polish is valuable stock-feed. Asiatics omit the polishing, thereby saving much food value. Rice straw has some feeding and weaving value.

EMMER (*Triticum sativum dicoccum*)

241. Description and use. — Emmer is a sub-species of wheat and differs from it chiefly in that in threshing the spikelets retain the kernels in the glumes. It is grown rather extensively in Russia, southern Europe, and east central Africa. During the last thirty years, dry-farm sections of the United States and sections that cannot profitably grow oats for feed produce constantly increasing quantities.

Rust- and drouth-resistance are qualities recommending its use. Both winter and spring varieties are grown — winter in the West and spring in the East and South. Black winter emmer is the most commonly grown variety. It is planted, as are oats, at the rate of from four to twelve pecks an acre. It yields from twenty to seventy bushels. The husk covering the grain prevents the formation of heavy, pasty masses in the stomachs of animals, thereby aiding digestion. In this respect it is like oats.

BUCKWHEAT (*Fagopyrum esculentum*)

242. Description, distribution, and uses. — Buckwheat is not a true cereal, since it belongs to the dock, instead of to the grass family. It came from Manchuria to New England, New York, and Pennsylvania, where it is still largely used as a catch-crop when other crops fail and it is too late to replant them.

The plant has a tap-root; a branched stem two or three feet in height, each branch ending in a flat-topped cluster of white flowers; and broad leaves something like those of the morning-glory. The seed is dark gray or brown, angular, and covered with a rather strong, loose hull. The growing-season is so short that a field may be planted as late as July 1, and yet mature. Its yield is small but it pays better than no crop on land where some other crop has failed to begin growth. It is cut with a binder and shocked in order to dry the succulent stems. Buckwheat is famous as the source of pancake flour. It has some value for hogs and poultry and the straw is sometimes used for feed and bedding, but it is rather coarse and unpalatable.

SUPPLEMENTARY READING

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No. 139. Emmer: A Grain for the Semi-arid Regions.
395. Sixty-day and Kherson Oats.
420. Oats: Distribution and Uses.
424. Oats: Growing the Crop.
427. Barley Culture in the Southern States.
436. Winter Oats for the South.
443. Barley: Growing the Crop.
466. Winter Emmer.
518. Winter Barley.

CHAPTER XIX

POTATOES (*Solanum tuberosum*)

Of the crops designated as "root crops," potatoes and sugar-beets are by far the most important. The methods by which they are produced, depending much on hand-labor and requiring fertilizers and constant attention, demand that these crops be handled on small areas intensively farmed. There is a noticeable absence of machines that cover ten to forty acres in a single day, although there is a promise of implements that will modify methods of culture. Planters, cultivators, and diggers have done much to relieve the farmer of slow and exhausting hand-labor. Field conditions in potato-growing are shown in Figs. 62 to 65.

243. Origin. — The potato was growing wild in the valleys of Peru and Chile when the Spaniards first visited these countries about 1542. Another kind of potato was found in Mexico and southern Colorado. This useful plant made its way into Virginia in time to be carried to England and Ireland by Raleigh's expedition in 1586. In Ireland it did so well that it soon became the principal food crop. Meantime, the Indians and whites in the neighborhood of Virginia gradually increased their dependence on it until, by the first of the eighteenth century, they used it generally. By the middle of the century, it had spread into the parts of Europe favorable to its growth and gained larger and larger footholds on account of its great acre-yields. In thickly populated districts, just such a food crop was needed.

244. Relationships. — There are about sixteen hundred species in the potato family, nine hundred of them in the same genus, but only six out of all this number bear tubers. Besides the potato, only *Solanum Commersonii* is important. It is disease-resistant, but yields poorly. Among the immediate relatives of the potato

FIG. 62. — Potato planter at work: notched-wheel type.

is the tomato, which is so closely related that parts of one plant may be grafted on the other. Tobacco, nightshade, henbane, and belladonna also belong in this family.

245. Description. — The plant originally propagated itself by means of seed, but it has reproduced by tubers that contain buds, or " eyes," for such a long time that the seed is seldom, or never, considered. The buried " set," as the cut piece of tuber is called, sends out a stem which bears leaves after reaching sunlight. The length of this underground stem depends on the depth of planting. At various places on this stem, new branches, or stolons, grow horizontally outward bearing tubers at the end. Meanwhile, from two to four roots grow from the upright stem just at the base of tuber-bearing stolons.

By the time of maturity, the fibrous roots have spread for six or eight inches and have extended four or five feet

Fig. 63. — Constant cultivation is necessary for good potato yields.

into the soil if it is loose and well-drained. Tubers from one to thirty in number, varying from the size of a pea to six pounds, have developed in a single hill. About six or seven potatoes as large as the double-fist are preferred. The angular stem, from one to five feet in length, usually about two or two and a half feet high, stands upright or droops across the open space, depending on the variety and soil conditions. The leaves are compound with small leaflets growing in the axil and scattered irregularly between the thick, pointed, oval leaf-parts, which are from one to three inches long.

Buds or eyes are borne sparsely at the stem end and close together at the bud end. A string passed round the tuber and held in position with a pin in each eye shows the spiral arrangement of eyes. Cross-sections of a tuber show three nearly concentric, and one irregular part. The outermost, the external cortical, is poor in starch and so thin as to be almost entirely removed in peeling. Then comes a thicker layer, rich in starch, called the internal cortical, surrounding the external medullary, also rich in starch. The dark colored core, the internal medullary, is watery and low in starch. A potato that contains proportionately large external medullary and internal cortical is desirable on account of high starch content, which gives the potato the quality of mashing readily when cooked. Potatoes that are yellow and soggy after cooking are undesirable in America, where they are baked or boiled, but are highly prized by the French, who serve them fried.

246. Varieties. — Potatoes are usually classed as early and late, although color, depth or arrangement of eyes, and roughness of skin might each give rise to a grouping. The early varieties yield less, but mature in about one hundred days bringing higher prices on account of reaching market early. Late potatoes comprise the bulk of the crop wherever large acreages are grown, except near city markets. Requiring about one hundred and thirty days to ripen, they cannot reach the early market, but are allowed to grow late in order to give the greatest possible yield.

Varieties originate either by variation in hills planted by sets, or from mixtures arising from the seed-planted hills, which always contain several distinct kinds of tubers.

The Pearl, for example, comes from a bud variation of Blue Victors, while the Burbank was found in a seed-sown hill. Often old varieties are given new names in order to sell them. Some confusion in different sections cannot be avoided, but should be as nearly eliminated as possible.

Bliss Triumph, Peachblow, Eureka, Early Ohio, and Early Rose are common early varieties. Rural New Yorker, Sir Walter Raleigh, Carman No. 3, Green Mountain, and Burbank are popular in the Northern States. In the Mountain States, Pearl, Idaho Rural, Rural New Yorker, Mortgage Lifter, Netted Gem, Carmen, Peerless, Majestic, and Freeman, are profitable yielders under irrigation.

247. Distribution and adaptation. — A cool, even growing-season without severe frost, and a loose, warm soil containing medium moisture throughout the season, are the conditions most favorable to potato-growing. Ideal conditions in Scotland, Germany, and Russia produce almost unbelievable yields. Eighteen hundred bushels to the acre was grown on the seed-farm of Lord Rosebery near Edinburgh. Scandinavia also has a good climate for potato production.

The large countries that lie in this section of Europe are all heavy producers, ranking as follows in total production: (1) Germany, (2) Russia, (3) Austria-Hungary, and (4) France, with the United States fifth, and Great Britain sixth.

Out of the five billion bushels produced, Germany grows about one and seven-tenths billions, while the United States produces only one-third of a billion bushels.

The acre-yield is 197 bushels in Germany; 186 in the British Isles; 140 in Austria-Hungary; 134 in France; 100 in Russia; and 90 in the United States. Maine leads

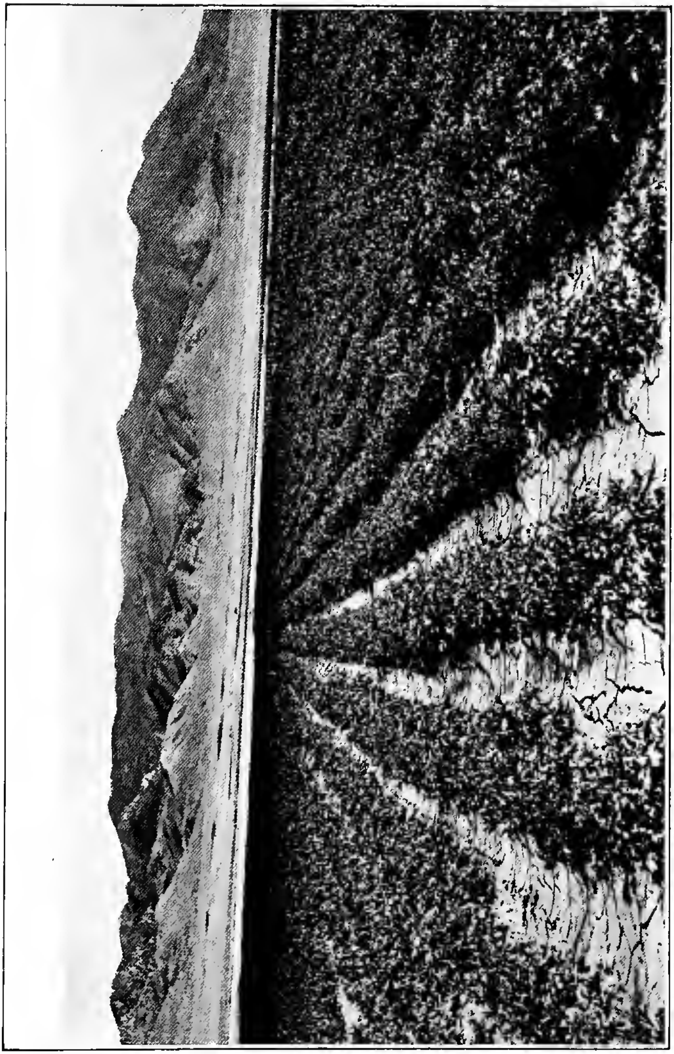

Fig. 64. — An irrigated potato field.

all states, with 225 bushels. Some other leaders are Idaho, 200 bushels; Montana and Utah, 180 bushels; Washington, 170; Colorado, 160; and Wyoming, 145. All except Maine are in the irrigated district. As total producers, the states rank: (1) New York, (2) Michigan, (3) Maine, (4) Wisconsin, (5) Ohio, and (6) Illinois, with only Maine averaging more than ninety-two bushels. In the East, four hundred bushels is a good acre-yield,

FIG. 65. — Great potato-producing section, Aroostook County, Maine.

while in the irrigated district seven hundred to eight hundred bushels are produced occasionally, and one thousand bushels under especially favorable conditions. Good farmers may expect from three hundred to five hundred bushels an acre.

248. Preparation of land. — Farmers can well afford to spend extra time and labor preparing a good seed-bed for potatoes. Heavy applications of farm manure pay, though it is well to apply it to the previous crop or in the fall preceding potatoes in order that it may be well decomposed. This helps to form a fine, moist seed-bed. Coarse manure opens up the soil permitting excessive drying, which is detrimental. The high water-holding capacity of soils due to manuring increases yields materially. To serve efficiently the organic matter must be thoroughly mixed with the soil. Old decomposed manure does this very well, but fresh manure sometimes does more harm than good. Moreover, too much coarse organic matter in limy soils aggravates potato scab. Where commercial fertilizers are used, potatoes respond readily to potash.

Deep fall-plowing is essential in loosening the seed-bed and in holding water for the next season. A rough surface left over winter prevents any run-off and gives frost an opportunity to disintegrate clods and liberate plant-food. A disk completes the fining process long before a plow could be used. This hastens the warming of the soil and reduces the enormous evaporation of early spring by the formation of a mulch. Another disking, or one or two harrowings to keep the mulch loose, will leave a deep, mellow, moist seed-bed ready for planting.

249. Seed. — Some varieties have much higher yielding possibilities than do others; therefore, the variety chosen is important. One disturbing factor in choosing potato seed is that some districts cannot use home-grown seed. The North ships to the South practically all the seed used there. Arizona also imports seed potatoes. In the West, some growers have small farms in mountain valleys which furnish seed for their large farms in the lower valley. In most cases selected home-grown seed is best.

After a good variety is chosen, the next most important thing to consider is disease, which may reduce the yield from 5 to 50, or even 100 per cent. Most diseases can be detected by examining the tubers. Absolute freedom from disease, if possible, is desired.

Sometimes varieties deteriorate, or "run out." This need not happen if proper selection is practiced. There is a tendency to use or sell the marketable potatoes, thus leaving the small ones for seed. It has been found that potato hills vary a great deal not only in the number of potatoes they produce, but also in the kind. Some hills have from four to eight tubers of very much the same size and shape containing no very large ones and not many small ones; others one large potato and a number of small ones; while still others consist almost entirely of small tubers. Since both very large and very small potatoes are undesirable on the market, hills with a fair number of medium-sized tubers are most desirable.

A set from any potato in the hill tends to produce a hill like the parent hill. A big potato from a poor hill is not so good seed as a smaller one from a good hill. It seems that any potato in a hill is as good for seed as any other and if such is true, there is no objection to using the small potatoes from desirable hills. If, however, small tubers from a bin or pit are used, most of them will be from poor hills.

Seed selection is so simple that every farmer can follow it successfully. The farmer will know which part of the patch has the healthiest potatoes. With a digging fork he can take out a few hundred hills, piling them separately. By examining the piles, he can easily select hills that contain the type he desires. For more technical work, some may desire to study the plants all summer. When such is the case, a peg may be driven close to the hills that promise well.

Selected seed requires careful storage, and protection from frost and heat. Boxes or crates holding from forty to seventy pounds are convenient, since this method prevents decay of any great number of tubers, and permits quicker shipment.

Where an early crop is desired, the seed may be soaked for forty-eight hours in lukewarm water. This seems to hasten growth a number of days. Another method is to expose well-kept tubers to the light for a few days until green sprouts show in the eyes. The long sprouts that grow when the storage place is too warm sap the strength of the seed, but are useless because they break off in planting.

250. Cutting and planting. — How large to cut the sets is a question of considerable importance. Sometimes whole potatoes are used; but usually cut sets varying from half potatoes to one-eye pieces are planted. On a mellow seed-bed, small sets may be used, but it does not pay to cut the pieces too small. A deep, two-eye set serves for ordinary planting. No core should be left after the eyes are cut out. The whole tuber seems to resist diseases in the ground more than the cut sets, in some instances at least. Careful hand-cutting has the advantage of insuring an eye in every set. Whatever the method, cutting should be done near the time of planting. Sometimes, a machine that pushes the potato against stationary knives is used.

There are several methods of planting. Many acres are planted behind the plow that turns under manure; the sets are not always thrust into the loose soil on the side of the plow-furrow but are too often dropped on the hard furrow bottom. Another way is to make furrows in prepared soil, drop the potatoes by hand, or by hand-planters, and then cover them. There are two kinds of machine planters in use, the picker type and the notched-wheel type. The picker takes the sets out of a hopper with spikes which are fastened to a revolving vertical disk and drops them down a pipe into the furrow. The other machine does the work by elevating the sets to a notched, revolving, horizontal disk which is watched by a man, who fills empty notches or removes a set if two are in one place. When the notch passes over the delivery spout, the set drops through. The picker machine requires only the driver, but misses from 5 to 20 per cent; the other requires two men and can be made to miss less than 1 per cent. The horse-power planter furrows, drops, and covers five or six acres a day. It is estimated that a farmer can afford a machine planter if he grows six acres or more.

There is no fixed depth for planting. From two to six inches is usual, while three to four is most common. Light, warm soils permit and require greater depths. Growing tubers should be surrounded by loose soil and yet not be so near the surface as to expose any to sunlight, which will injure them by causing chlorophyll to develop.

Early potatoes are planted as soon as possible, and late ones usually in May, though in some districts, early June is the best time. In the South, January to April is the time; a second crop is planted in some districts in July or August. The distance between hills and rows varies from twelve to twenty inches. Ten to fifteen bushels will plant an acre.

251. Treatment during growth. — If the ground crusts, harrowing before the potatoes are up may help them through. About two weeks later when the vines are three or four inches tall, another harrowing is advisable. The cultivator may begin work in another week or two, mulching deeper toward the middle of the space between rows if irrigation water is to be applied. This prepares for a furrow.

From five to twenty-five inches of irrigation water may be applied in one to five or six applications. Every two weeks, or so soon as possible after each irrigation or rainstorm, the cultivator should be used to stir the soil, gradually leaving a wider space untouched as the vines increase in size. This may be continued until the plants would be injured by the horse or cultivator. Then sufficient hand-hoeing to control weeds is necessary.

252. Harvesting and marketing. — Early potatoes are harvested as soon as they are large enough to be put on the market; the late crop is left as long as is consistent with approaching winter or maturity, in order to gain all possible advantage from the cool, autumn growing-season. Small patches are frequently dug with forks or turned out with the plow; but diggers are gaining in importance, particularly for large fields. A shovel blade passes under the potatoes and elevators carry the tubers upward at the same time shaking off the dirt. Some machines have rotating arms that throw out the vines; some also sort the tubers. The potatoes are picked up by hand behind the fork, plow, or digger, and sacked, boxed, or loaded loose into wagons to be hauled away and sold or stored in pits or cellars.

The potatoes that are sold go either to consumers directly, or to jobbers who ship or distribute them to retailers. Potato prices vary so much that it is hard to tell whether to sell at harvest or to store for the winter and spring markets. Because of its perishability, the crop is waste in spring if it cannot be disposed of. Some growers sell half and store half; others belong to coöperative associations that assist in marketing. Wherever shipping is practiced, carload lots of single varieties sell to the best advantage. Careful sorting and grading also help sales and prices. Both boxes and sacks are used for shipping.

253. Storage. — The part of the crop that is stored goes into pits loose or into cellars loose, in sacks, or in boxes. Pits cost less than do cellars. They ordinarily consist of a trench a few inches deep in which is set a rick heaped-up with potatoes and covered with straw and earth. As winter approaches, they are covered with more straw and earth. A stove-pipe through the covering to aid in ventilation may be closed with cloth in freezing weather. Pits should be emptied when once opened, the potatoes being sold or removed to a cellar. The important points in storage are: (1) to keep the temperature above freezing, but not over 40° F.; (2) to provide ventilation; (3) to examine for disease and condition of keeping; and (4) to be able to remove conveniently a part without disturbing the others. In these respects cellars excel pits; boxes are better than sacks; and sacks better than bins of loose tubers.

254. Weeds and insects. — All common weeds trouble potatoes, though there are none that are troublesome to potatoes alone. The intensive culture demanded by the potato should control any weed. Of the insects, the flea-beetle (*Epitrix cucumeris*) bores holes in the leaves allowing the blights to enter. Arsenate of lead aids in lessening the injury. More injurious is the potato beetle or Colorado potato beetle, which eats the leaves about the time of bloom. Paris-green spray, at the rate of one pound in one hundred twenty gallons of water; or arsenate of lead, six or eight pounds in one hundred gallons of water lessens this injury. Potato worms, potato stalk weevils, grasshoppers, and June beetles do lesser injuries. They are generally controlled by clean cultivation and rotation.

255. Diseases. — Potatoes are attacked readily by parasitic organisms, which often cause a loss in a district of from one-fourth to one-half the crop, sometimes completely destroying it. Late and early blight, Fusarium wilt

(Fig. 66), Rhizoctonia, blackleg, and scab are found in various parts of the country.

Late blight (*Phytophthora infestans*), although not prevalent in the West, is the most serious disease in the East. It caused the Irish famine of the "forties," during one year of which 300,000 people perished and thousands emigrated to America. The disease attacks the vines and tubers causing the tubers to rot. Damp weather

FIG. 66. — Potatoes killed by Fusarium wilt.

seems to encourage it. Injury is lessened by spraying with Bordeaux mixture, which is made by dissolving five pounds of quicklime in twenty-five gallons of water, and five pounds of blue vitriol in twenty-five gallons of water and mixing the two solutions. There should be sufficient lime to prevent burning.

Early blight (*Alternaria solani*) does its damage earlier in the season than late blight. It attacks the vines, turning them yellow and reducing the yield. Bordeaux mixture spray aids in its control.

Dry rot (*Fusarium oxysporum*) is widespread. It attacks the stems, causes wilting by clogging the tracheal tubes, and grows downward into the tuber, forming a dark ring which shows in a thin cross-section of the stem end. All seed showing infection should be discarded. Since this disease lives in the ground, rotation is essential to its control.

Rosette, or Rhizoctonia (*Corticium vagum*), is common and may be noted by black spots on the potatoes. It attacks the stems from the outside and eats through the phloëm, thus holding the food in the vine. This causes rosettes of leaves and small worthless tubers to form on the vines. To discard infected seed and to soak the tubers in a mercuric bichloride ($HgCl_2$) solution 1 part to 1000 of water are the remedies used. Because the disease lives several years in the soil or on other plants, clean farming and rotations are necessary.

Scab (*Oospora scabies*) attacks the tuber causing a rough appearance resembling a scab. As it survives in the soil, rotations are beneficial. The seed treatment is soaking two hours in formalin solution one pint to thirty gallons of water. Fresh manure and lime seem to encourage the disease.

Blackleg (*Bacillus phytophthorus*) attacks the vine, causing wilting, and the tuber, causing rot. Rotations, clean ground, and little water after an attack are recommended as means of control.

Seed selection for resistant strains, discarding infected seed, long rotations, and seed treatment are the most hopeful means of keeping up yields. Neglect is likely to cause the ruin of the potato industry in some localities.

Second growth is the production of new tubers when water is applied after drouth. The potatoes cannot get large and they are poor in quality. Internal brown spots are found in the interior of some potatoes, especially in the Early Ohio. It is probably not a disease, but a physiological condition which injures the odor and flavor of the potato but not its seed value. It is caused by drouth in some cases.

Growing potatoes during tuber formation are very sensitive to sudden changes of temperature. Heavy storms and irrigation, at times, cause abnormal conditions that are not easily explained.

256. Use and value. — The most important use of potatoes is for human food. Large parts of Ireland, Germany, France, Austria-Hungary, and Russia are dependent on the potato as the principal food product. A general crop failure would probably cause a famine in some districts. The per capita consumption is twenty bushels in Germany, as against five and one-half in the United States. Desiccated potatoes are valuable foods in tropical and frigid zones. Potatoes are sliced and toasted to make potato chips. In addition, potatoes are used some for stock-feed and for the manufacture of starch, sirup, alcohol, and dextrin. They are sometimes used for silage. Since potatoes are about three-fourths water, the total dry matter of the crop is less than that of the leading cereals, although in gross weight the yield exceeds any one of them.

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CHAPTER XX

ROOT CROPS

The term "root crops" is applied in a loose way to those forage crops not grasses or legumes. In addition, a number of plants used for other purposes, such as sugar-beets, are included. The classes of root crops are: (1) the beets, (2) turnips and rutabagas, (3) carrots.

These plants are usually biennial. In general a fleshy root develops the first season, which if left in the ground, sends up seed-stalks the next year and matures seed largely from plant-food stored in the root. In parts of Europe, root crops are grown extensively for stock-feed, and enter into farm rotations commonly. In America, they are just gaining foothold.

Beets belong in the family Chenopodiaceæ, which has for some of its other members spinach, and many weeds, such as common white pigweed, or lamb's quarter, Australian and other salt-bushes, white tumbleweed, and Russian thistle. In the species are four principal groups: (1) the chard, which is used for greens and which is grown in gardens only; (2) common red garden-beet, used for food, but not grown as a field crop other than in truck-garden districts; (3) mangel-wurzels, used for stock-feed; and (4) sugar-beets, used in sugar manufacture and for stock-feed.

SUGAR-BEETS

257. History. — In 1747 Professor Marggaf, a German chemist, discovered a method of extracting sugar from the sugar-beet. In 1805 one of his pupils, Achard, began the sugar industry by starting a factory in the German province of Silesia. Six years later the French planted 90,000 acres of beets at the order of Napoleon, who appropriated a large sum of money for instruction in schools and to assist in building factories. By 1825, it had become an established industry in France; by

FIG. 67. — Thinning sugar-beets, Germany.

1835, the Germans, realizing how much the French had gained both from the industry and improved culture methods, began beet-growing on a commercial scale. In 1836, France produced 40,000 tons of sugar and Germany 1400 tons. Soon the German output led, as it has done ever since. Beet-culture spread rapidly into other parts of Europe and finally extended to the United States about 1830, but it did not become important here until 1879, when a factory was built at Alvarado, California. Since that time, growth has been rapid and regular. In a century, the culture of sugar-beets has grown to such an extent that half the sugar produced in the world is beet sugar, Europe producing more than nine-tenths of the total. Sugar-beet conditions are shown in Figs. 67–69.

258. Description. — In general appearance, the beet is whitish and shaped like a long cone, broadest just below the crown from which about a dozen leaves grow out in thick clusters. These vary in length from six inches to two feet, and in width from two to six inches. On opposite sides of the root are two depressions or dimples, usually slightly spiral in shape. From the dimples and from the central tap-root of the beet, fibrous feeding roots branch off, gathering food and moisture from a rather large area, sometimes to a depth of five or six feet.

Cross-sections of a beet show a series of concentric alternating rings, mostly of soft and firm tissue. The compact rings are thought to be richer in dry-matter and sugar. A longitudinal-section shows (1) the crown, which is rough, slightly greenish in color, and watery, and (2) the root, which contains the sugar. The root should taper slowly, keep broad to considerable depth, and be single; branching roots are objectionable. The concentric rings show in straight lines converging at the bottom. The crown, removed in topping, is a part of the stem, as shown by the leaves growing from it; the lower part is an enlarged root that should weigh from one to one and one-half pounds in order to meet the demands of factory operators. During the second year, seed-stalks, from two to four feet tall and considerably branched, bear from one-fifth to two pounds of seed for each mother beet.

259. Adaptation and distribution. — Beets, like potatoes, do best in cool, moist climates that have long growing seasons. They are not sensitive to frost, being grown

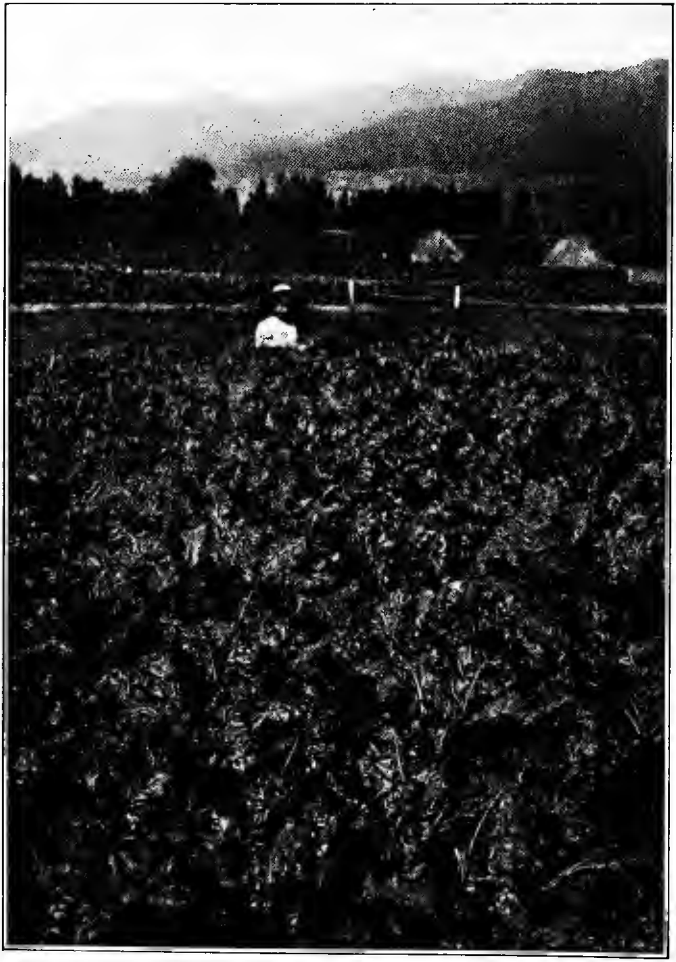

FIG. 68. — Sugar-beets require a vigorous leaf growth.

extensively in climates too cool for corn. Well-drained soils, varying through sands and loams to clay loams, are used; soils containing small quantities of alkali also yield satisfactory crops. Salt, however, causes some difficulty in the extraction of sugar. Abundant sunshine is necessary to build up the sugar which is entirely carbohydrate and, therefore, the result of photosynthesis. Where the soils are deep and can be drained, where moisture is supplied by rainfall or irrigation, and where sunshine is abundant, sugar-beet growing can become an important industry.

Northern United States from Virginia to Canada is adapted to the culture of sugar-beets, though but small parts of the section now produce them. The following states named in the order of their sugar production excel the others in this industry: Colorado, California, Michigan, Utah, Idaho, and Wisconsin. These states, in 1913 contained four-fifths of the factories. The industry is capable of almost indefinite expansion.

In Europe, the beet-growing nations are the same that lead in potato production, namely, (1) Germany, (2) Russia, (3) Austria-Hungary, and (4) France, and their rank is the order named. Nearly every nation grows some.

260. Preparation of the land, seed, and seeding. — Very light and very heavy soils are to be avoided because of poor water-holding capacity and firmness, respectively. With other soils, a good supply of organic matter is essential to maintain good physical condition, which aids materially in holding moisture, in maintaining fertility, and in promoting easy penetration of roots. Plowing may be from ten to sixteen inches deep according to power and implements. In some cases sub-soiling is practiced to break hardpans or to loosen compact sub-soils. Deep fall-plowing mellows the seed-bed and permits winter and spring rainfall to penetrate deeply. Two or three double-diskings in the spring will firm the seed-bed and conserve

Fig. 69. — Sugar-beets require a large amount of hand labor.

moisture. Factories furnish the seed and, in many cases, plant it by contract. The seed has been bred and selected for six or seven years to insure high sugar content. If a person keeps in mind that percentage of sugar is a variable character and that it has been raised from 6 to 16 per cent and as high as 25, he will appreciate that without constant selection low percentages would result in a few years.

Seed costs about fifteen cents a pound in America and is sown at the rate of ten to twenty pounds an acre, usually in April or May, though earlier in some localities and later in others. Planting is commonly done with a four-row seed drill and a team. From one to three inches is the usual depth of planting — slightly less than for small-grains — in rows from sixteen to thirty inches apart.

261. Treatment during growth. — As soon as the rows show plainly, the beets are cultivated with a four-row cultivator, which follows the rows of the planter. Weeds between the rows are removed and the soil is mulched. The beets are blocked every six to ten inches by means of short hoes. The blocks are thinned by hand to one beet in a place. Four or five sprouts come from one seed or boll. This and the thick planting to insure good stands make thinning necessary. For a time, government experts expected to develop seed with single-germs, but the experiment was not entirely successful.

Whenever the soil needs it, further cultivation is given the crop. Two or three hand-hoeings remove weeds and loosen soil in the row around the plants. Toward the end of June or in early July in most irrigated districts, furrows are made and five to thirty inches of water are applied in from one to four applications. Rather thorough soakings seem to be beneficial, as the cultivation that follows lessens evaporation, and the greater length of time between allows the water to distribute itself evenly in the soil. Water-logging must not, however, be permitted, since this causes short or branched beets, as does compact soil. Not many cultivations can be given after irrigation, as the leaves soon become so large as to be injured. Some farmers count on harrowing six or seven times early in the season.

262. Diseases. — Cultivation necessary for beets should be so intensive as to keep weeds well under control. The constant selection of beets has prevented diseases from causing widespread losses. Heart-rot, leaf-spot, and a bacterial disease, however, injure the crop materially in some sections. Both disease and insect injury increase with the age of the sugar industry and with the presence of other plants in the Chenopodium group, including white pigweed, Russian thistle, and white tumbleweed.

Heart-rot and blight (*Phoma betæ*), a distinctive disease of beets, is the worst hindrance to sugar-beet production in Germany, Austria-Hungary, and France. It has recently entered this country. Generally in August, the inner leaves and then outer ones blacken; both die leaving the bare beet crown. The disease passes down into the concentric rings and produces rot, sometimes almost ruining the crop. The destruction of all plant remnants from infested areas prevents spread, and treatment of seed with Bordeaux mixture prevents propagation of the disease in new crops.

Leaf-spot (*Cercospora beticola*) appears on the leaves as brown spots with reddish-purple borders which spread until the entire leaves become dry. The crown sends out new leaves at the expense of the root. The best precaution, some think, is to spray young plants with Bordeaux mixture.

Beet leaves are also attacked by a bacterial disease about which little is known. The disease makes its way into the roots reducing yield and percentage of sugar. Rotation and care in irrigation are the methods of control advocated.

A chlorotic condition which causes the leaves to turn white has appeared in various sections of the West. Up to the present time it is not well understood. It is thought to be a physiological condition. In general, rotation and selection will diminish the injury it causes.

263. Insects. — Leaf-miners, leafhoppers, beet army-worms, beet flea-beetles, webworms, wireworms, cutworms, and white grubs injure beets considerably in various localities.

The leaf-miner maggot (*Pegomyia vicina*) eats under the epidermis of the leaves mining out crooked grooves. Hand-picking is the only remedy; deep plowing and thorough harrowing lessen the injury the next season.

Beet leafhoppers (*Eutettix tenella*), which are very small, attack the leaves causing them to curl when it is dry and warm and the plants are not shaded. Much damage is done in some states by "curly top," as it is called.

Sugar-beet webworm (*Loxostege sticticalis*) caterpillars do damage to beets in July, August, and September by eating the leaves. Spraying with arsenicals and deep fall-plowing help to control it. The destruction of white pigweeds (*Chenopodium*), closely related to beets and on which the beet insects live, is especially important in controlling all such insects.

Caterpillars of the beet army-worm (*Laphygma exigua*) eat the leaves. Spraying with arsenicals kills many of them. Cutworms, wireworms, and white grubs increase in sod which ought to be avoided for beets the first year after plowing. Flea-beetles do considerable damage, but no control method known is satisfactory.

264. Harvesting, marketing, and storage. — Men employed by factories sample beets for sugar content and purity, telling the farmers when they may harvest. The beets are loosened and raised from their position by some sort of digger or puller, and then topped by hand.

The crown of the beet as far as it is green, that is, at lowest leaf scar, is removed. Leaves are either left on the ground or hauled off to feed cattle, while the beets are usually hauled directly to the factory, or they are loaded on cars by arrangements which dump the load from platforms. In rush seasons, however, many beets are piled in fields or yards and covered with tops to prevent frequent freezing and thawing. Freezing seems to do no injury unless thawing follows. At the factory, the beets are stored in long bins left open to the weather. The beets grown for sugar are weighed and the sugar company pays the farmer either a flat rate — so much a ton — or according to sugar content and purity, — that is, on a sliding scale.

265. Use and value. — The most important use of sugar-beets is in the manufacture of sugar, though they have considerable feed value. The tops are valuable and are often pastured on the ground because they contain most of the mineral elements of fertility. The pulp, a by-product from the sugar industry, is a valuable stock-feed, being highly succulent. Beet-sugar manufacturing can never become a farm operation because it requires much expensive machinery and many complicated operations.

Beet-culture has a decided value on the farm aside from the cash returns. The deep plowing, the intensive culture, and the fertilization necessary in successful production of beets improve farming methods materially and increase yields of other crops. Weeds are also controlled and business methods introduced into agriculture. The farmer, the soil, and the sugar company are mutually benefited in most cases.

266. Manufacture of sugar. — When the factory is ready to use the beets in a bin, the end is opened and a section of the floor in the bottom of the V-shaped bin removed. The beets tumble into a stream of water which carries them to rotating paddles or brushes, where they are washed and scrubbed. An elevator carries them to a weighing hopper, after which they are sliced into cossettes and steamed under pressure to dissolve out the sugar. The juice, or gar, is mixed with lime to precipitate impurities, whereas the pulp is run outside into vats or silos for stock-feeding. Carbon dioxide, which is now run into the juice, unites with the lime rendering it insoluble and causing it to settle and carry to the bottom much of the dark, impure substances. Filters remove the small lime particles. Lime and carbon dioxide are again added. After filtering, sulfur-dioxid gas is passed through the juice to remove dissolved lime. Surplus water is boiled off, and the juice goes to crystallizing pans for further concentration. Before going to the centrifugals, which are steel cylinders with perforated linings, the sirup is mixed. In the rapidly-whirling centrifugals, the liquid is forced through the small holes of the lining and the crystals are scraped off and dried by a current of warm air. The liquid which has not undergone crystallization is saved and again concentrated for two more yields of sugar, small ones, of course. Sacking is the last process before marketing.

MANGEL-WURZELS

267. Description. — Mangel-wurzels, or mangolds, as they are variously called, differ from sugar-beets, in that they are usually much larger, weighing from four to six pounds. Generally they grow partly out of the ground, and are very irregular in shape, being largest some distance below the crown; they are reddish in color, with yellowish or pinkish flesh; and they contain approximately 12 per cent dry matter, about half of which is sugar, whereas sugar beets are about 20 per cent solid, four-fifths of which is sugar. Beef cattle and hogs do well on this crop. Dairy cows can use them as a part ration, but they demand more solids, especially protein, than the succulent mangel can supply.

268. Use. — The mangel is the chief root crop used for feeding in the United States, although in England turnips and rutabagas rank first. The value of the mangel is in its succulence. Corn silage is displacing it to some extent, though in northern United States and Canada roots deserve more consideration. One disadvantage of roots is that for one ton of dry matter from eight to ten tons of water must be handled. The food value of the dry matter is high, however, because it is both palatable and digestible. Great quantities cannot be consumed on account of the excess of water.

269. Culture. — The land should be prepared as it is for sugar-beets. Seeding is done with one-row drills, with four-row drills, or by hand on small areas. They are planted at the rate of six to fifteen pounds to the acre and at a depth of one to two inches. Planting is usually done in April or May. The small plants grow slowly and it requires care in the first cultivation to prevent covering up the rows. Mangels require the same attention as sugar-beets in regard to thinning, except that they are left farther apart. As to cultivation and irrigation, the same methods apply.

When frost kills the outer leaves, thereby stopping growth, mangels are ready to harvest. They are sometimes pulled by hand or by plowing a furrow close to the row. Beet diggers are also used to loosen the roots.

Mangels in baked soils are especially hard to dig. Yields vary from ten to forty tons under favorable conditions. About thirty tons may be expected under irrigation.

After the tops are removed, the roots should be stored in a well-ventilated cellar where a temperature just above freezing can be maintained. High temperatures are to be avoided, particularly, to prevent heating, which is dangerous because of the high moisture content.

TURNIPS AND RUTABAGAS

270. Description. — Turnips (*Brassica rapa*) and rutabagas (*Brassica campestris*) belong to the mustard family (Cruciferæ), which include cabbage, kohlrabi, and rape in addition to several garden vegetables such as radish and cauliflower. Turnips are much smaller than rutabagas. They have a much more regular shape; and white rather than yellowish or orange flesh. They have a much shorter growing season, and since they are more watery they are a less valuable feed. They have rough foliage attached to a short, flat crown, while rutabaga leaves are borne on a neck, become smooth, and take on a bluish color. The rutabaga is long and irregular. Both have a distinct outer layer that peels free from the flesh. The root-systems of both are comparatively small.

271. Culture. — A fine seed-bed is required on account of the root-system. Sandy soils seem best, and a moist, cool climate is essential to best development. The seeds are single-germed and, on this account, require much less thinning than do the mangels or sugar-beets. The rows should be about as far apart as beets and should be thinned to six or eight inches apart in the row. Turnips may be planted for winter use as late as July, as a catch-crop after another crop is removed, or between rows of corn. Two or three pounds of seed to the acre are used; rutabagas should be sown twice as thick and usually planted in May or early June. Planting ought to be just deep enough to place the seed in warm, moist earth. Cultivation, irrigation, harvesting, and storage are the same as for mangels save that turnips must be used in early winter.

272. Value. — In England turnips and rutabagas form part of the regular farm rotation, and take the same place for stock-feed that mangels do in Germany. They are grown in Canada; in the United States, their culture is not extensive. Turnips are used also for human food.

As feed, rutabagas rank high, enabling the farmer to greatly reduce grain rations. Five to fifteen tons of turnips and ten to twenty tons of rutabagas are good acre-yields. Rutabagas are valuable for beef cattle, hogs, and sheep. Because they keep well into spring, they serve well for this purpose, particularly where silos are not used. They are easy to feed, since only slicing is necessary, and this saving of time gives them considerable additional value. Turnips are used for sheep and hog pasture. They pull up easily and the use of leaves as well as roots is possible.

CARROTS (*Daucus carota*)

273. Description. — The root of carrots may be tapering, cylindrical, or short and thick; they may be white, yellow, orange, or reddish in color. An outer layer breaks away from an irregular interior that is more watery and more palatable. A medium-sized root-system spreads outward; the leaves are finely divided; white flowers are borne the second year in dense flat umbels; the seeds are cup-shaped.

274. Culture and use. — Loose, sandy soils, in which well-rotted farm manure is incorporated, make a warm, mellow seed-bed. Seed, at the rate of four to six pounds to the acre, is sown as soon as the ground is in good condition. Since it is small, the seed requires shallow planting. Rows should be about thirty inches apart to permit use of cultivators; the carrots should stand from two to four inches apart. If thicker, they should be thinned. Irrigation, cultivation, harvesting, and storage are the same as for mangels or rutabagas.

The garden crop is used principally for household purposes. For forage, larger areas should be grown. When used for forage, carrots furnish succulence and are especially desirable for horses.

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CHAPTER XXI

ALFALFA (*Medicago sativa*)

PERMANENT agriculture must be diversified. Not only must there be a variety of crops in rotation, but livestock-raising must accompany crop production. Horses are necessary as beasts of burden; cattle, sheep, and hogs are valuable as milk- or meat-producers. Good hay is an important factor in the successful production of livestock. In this alfalfa is unexcelled. In regions that have poor shipping facilities, cattle-raising is important. Pasturage and hay are essential on both ranch and farm. In supplementing the native pastures of the West when range lands could not be used in winter or when they produced little feed, alfalfa has been of inestimable value. In fact, it made possible pioneer settlement in the West. An early start, heavy yields of delicious forage, long life, and adaptability to arid climates and arid soils promoted its spread. So marked has been the effect of all these influences that 95 per cent of the alfalfa crop of the United States is produced west of the Mississippi. Methods of handling the alfalfa crop are shown in Figs. 70 to 72.

275. Name and origin. — Of thirty or forty names by which alfalfa is, or has been, known in various parts of the world " alfalfa " and " lucern " are most widely used. " Alfalfa " seems to be gaining rapidly in popularity, largely on account of the adoption of that name in treatises and in schools. It is Arabic and means best fodder; "lucern" is a Spanish-French word taken perhaps from the name of the town Lucerne in Switzerland. A few of the other names are Mexican clover, lucern clover, perennial clover, Spanish trefoil, purple medick, cultivated medicago, medicago medica, isfist, alfasafat, and monthly clover.

From the earliest time, alfalfa has been used as forage. The Egyptians grew it; Xerxes carried it from Persia

FIG. 70. — Mowing alfalfa.

into Greece about 490 B.C., sowing it at his various encampments to feed his cavalry horses; it went to Rome; from there to France, and Spain; Arabs carried it to Algeria; finally, it reached Mexico and spread widely across parts of the Americas. In 1853, some settlers going to California by way of Cape Horn carried seed from Chile to San Francisco. It extended rapidly over California and eastward, reaching the Great Plains about fifteen years ago. Practically every state now grows it to some extent. Although alfalfa had been introduced into southern California from Mexico, and into New York from Europe nearly a century before the Chile introduction, there was no widespread cultivation. Perhaps the favorable conditions that gave the crop a good start were necessary to bring its true value to the attention of farmer and ranchman.

276. Relationships. — Alfalfa belongs to the Leguminosæ, in which are thousands of species, among which are peas, beans, clover, vetches, locust trees, lupines, sweet peas, and the little astragalus common on sagebrush lands of the mountain states. In the genus Medicago, about fifty species are found.

The legume family is easily distinguished by pea-shaped flowers, by pods that break open along both sutures, by the compound leaves, and by the tiny enlargement on the roots called nodules, or tubercles. In these live bacteria which feed upon the plant taking free nitrogen from the air, and assisting greatly in the maintenance of soil fertility. In the valleys and on the hills of the West, there are fifty or more species of native legumes which have probably had much to do with the great fertility of virgin lands.

277. Roots. — Young alfalfa plants send down proportionately long tap-roots bearing fine branching roots. The first stem is single, and lacks the crown that develops with age. The plant is decidedly perennial living from four to fifty or sixty years depending on the favorableness of the field. The roots continue to grow in well-drained soils as long as the plant lives. This results in immense root-systems. Roots fifteen to twenty feet in length are common; thirty to forty feet is occasionally reached; a cave in the gravel delta at Logan, Utah, exposed a root fifty-six feet long, while Coburn [1] reports that roots penetrated the roof of a tunnel one hundred and twenty-nine feet below the surface of an alfalfa field. Water-tables limit depth because roots will not penetrate more than six or eight inches into a soil devoid of air.

Though they are nearly always single tap-roots, three or four large roots sometimes displace the single one. About half an inch is the usual diameter below the crown. The thickness gradually diminishes until the roots are almost hair-like. These fine roots that do the feeding form a network in the soil, but they do not form sod because they are not stoloniferous. Hence, if all roots are broken, the plant dies, since there are no buds except on the crown. The fine roots bear, scattered in various places, small nodules which are either separate masses or enlargements of the roots, and which vary in size from a small pin-head to that of a pea. These may be found by carefully digging into the root-system of almost any alfalfa plant. Some plants, however, bear only a few.

278. Stems and leaves. — When the stems are harvested for hay, new shoots come out from the thickened crown near the surface of the ground. As more and more crops are cut, the crowns increase in size until some are six inches across, becoming divided into two or three distinct parts. Some make the land rough by standing four or five inches above the surface. If a harrow splits the crown without cutting the roots, separate plants may form.

In spring, young stems develop as soon as the ground is warm. These grow steadily until blossoms appear, when they stop increasing in size in order to develop seed. At this time, the stem may vary from six to sixty inches in length and from one-sixteenth to one-fourth

[1] *The Book of Alfalfa*, p. 6.

of an inch in diameter; twenty-four to thirty inches in height and one-eighth of an inch in thickness are usual. The stems are usually green, but they are sometimes marked with red; they are hollow with white pith in the center; they branch frequently in the axils of leaves which are arranged alternately. In general, first-crop stems, containing more fibrous material, are much coarser than those of succeeding crops. A longer period of growth is used by the first crop, in most cases, than by later crops.

Pinnately-compound leaves of three leaflets grow out from the main stem and branch first on one side and then on the other. Three leaves usually arise from one axis, with a middle one much larger than the two side ones; bracts indicate the presence of still other rudimentary leaves. The central vein of the compound leaf may, at any time, develop into branched stems, or simply divide to form the midrib of the leaflets, which are oval-shaped, and slightly saw-toothed at the outer end. The midrib sends out parallel side veins which show on both surfaces, the upper of which is a much darker green and the lower slightly hairy.

279. Flowers and seed. — At blossoming time, each branch and the main stem bear at least one cluster of pea-shaped flowers that are purple in common alfalfa, though some varieties bear yellow and others greenish flowers. The calyx is five-parted, compound at the base and sharply pointed at the single tips. Separate petals, nine stamens in a bundle, one alone, and a compound ovary that develops into a pod, form the other parts of the flower. Growing pods are distinctly curled, making from one to four distinct curves and bearing from one to a dozen seed. As maturity approaches, the pods take on a dark brown color and the seeds become yellowish, greenish-yellow, or brown. Though alfalfa seed is naturally kidney-shaped, a large percentage of it is angular in various ways, on account of the seeds touching each other as they grow. Peas are flattened on opposite sides due to lack of room; but curling in the pod exerts pressure on the corners, rather than on the sides or ends. Failure to mature properly leaves some shrunken seeds; others are brown with tough seed-coats. These are usually slow to germinate or may even lack the power to do so. The seeds are usually about one-sixteenth of an inch in length and half that in width and thickness.

280. Varieties. — In adjacent parts of Asia, Africa, and Europe a number of varieties of alfalfa grow wild. In cultivation, however, only two distinct kinds find use. One is erect, blue- or purple-flowered, and familiar; the other yellow-flowered, not well-known, rather creeping of stem and stoloniferous, a quality absent in the common alfalfa. The second, Siberian, has its chief value in crossing with the ordinary plant to give resistant strains.

A number of strains have been taken from regions in which they have been grown for a time long enough to become adapted to climate, soil, culture, and use of that section. These strains are: (1) "common," (2) Turkestan, (3) Arabian, (4) Peruvian, (5) variegated, and (6) Grimm. Half a century on the dry-farm has given rise to the so-called dry-land alfalfa, which probably differs but slightly from the common strain. None of these are of special importance save Grimm, which resists winter-killing to a remarkable degree. Variegated, a cross with Siberian, has variously colored flowers.

Since, in general, adaptation to a locality determines the value of a lot of seed, these cultivated varieties have little value. Perhaps we may learn enough about them to establish certain strains for particular conditions. As yet, 95 per cent of our crop continues to be "common" alfalfa.

281. Distribution and adaptation. — Western United States, Argentina, Chile, Peru, southern Europe, North Africa, South Africa, Australia, and western central Asia produce alfalfa extensively. All these sections are semi-arid, with hot, dry summers and winters either not rigorous or else snow-covered. The greatest production by states in the United States is as follows: (1) Kansas, (2) Nebraska, (3) Colorado, (4) California, (5) Idaho, (6) Utah, (7) Montana, (8) Oklahoma, (9) Wyoming, and (10) New Mexico.

A deep, fertile, well-drained soil permits the greatest development of the crop, especially when lime is present in liberal quantities, as it is likely to be where no leaching has occurred. The deep-feeding roots can then supply food and moisture abundantly. The right kind of bacteria must also be present, since in their absence the young plants grow only a few inches high and then die. Some soil from an old field scattered over the new patch inoculates it if the necessary bacteria are lacking in the new seed-bed. Porous sub-soils are desirable for root expansion; the plants tolerate some gravel.

Water-logging seriously hinders development of the plant by preventing aëration and by causing alkali accumulation at the surface. Young plants suffer quickly from salt concentrations; but when older, a corky crown enables the plant to resist girdling. Adaptability of the crop to either extensive or intensive culture strengthens its position as one of the principal crops in the West. Alfalfa responds readily to manuring, irrigation, and cultivation by increased returns; it also produces much forage on dry-farms. Then, too, it yields best when grown only five or six years on one piece of ground, but will continue to produce hay for ten, fifteen, or even twenty years when conditions are favorable. That such a crop is widespread is natural, particularly since it is most palatable and nutritious.

282. Preparation of the land and seeding. — Fall-plowing fines the seed-bed and allows rainfall to enter the soil freely; both of these are important for planting. Small seed cannot get a hold unless food and moisture are at hand. Liberal applications of well-rotted farmyard manure warm the soil and increase the available water and plant-food. After such preparation, spring-planting should give good stands. If deep cultivation is practiced the roots penetrate more easily. Lime is necessary on acid soils.

Since fall-planting gives as good results as spring-planting, farmers often plant then to save time in the spring and to get a larger harvest next season. In this case, the previous crop must come off the land generally by August in order to make possible the ready preparation of a fine, moist, porous, yet firm seed-bed. August or even July seeding permits the plants to establish themselves before winter sets in. When spring planted, alfalfa should begin growth as soon as the land is warm.

One to five pounds of seed to an acre have given full stands, though from ten to twenty are more satisfactory. From twenty to thirty pounds are required for successful stands in humid regions or on soils in poor condition. Drills are almost universally used. Nurse crops of barley, oats, or wheat may, or may not, be desirable. They are necessary only on very hard or very loose soils. In Algeria row cultivation pays, but in American hayfields it is not used, except in small plats planted for seed.

283. Treatment during growth. — Some farmers harrow with spike-tooth, spring-tooth, or disk harrows in spring or fall. Insects, disease, or weeds may necessitate special attention. Light applications of farm manure pay on some, and irrigation on all soils in arid sections.

Irrigation water up to about forty inches brings increased returns. From one to ten applications are made either by flooding or in shallow furrows which aid in leading the water over difficult patches or in covering large areas with small streams. Over-irrigation menaces some districts, since flooding for more than one day at a time may "drown" the plants and permit frost to do considerable injury. Fall, early spring, and winter irrigation are all important in regions of scarce water and mild winters. Conservation of rainfall is a fundamental economy in all dry regions.

284. Harvesting. — Under normal conditions, the best time to cut the crop for hay is in early bloom. Rakes may follow the mower almost immediately — directly on dry-farms and well-drained land. Irrigated alfalfa cures best if piled in small cocks within a few hours of cutting — the same day if possible. In this way farmers can save the leaves on the stems, which makes the hay more valuable than swath-cured hay. In rainy weather, moreover, hay suffers more in the swath than in compact piles.

When bull-rakes are used, hay cures in heavy windrows and is pushed to the stack without being loaded on wagons. Various kinds of forks and nets and several types of derricks unload the wagons, which are loaded by hand almost entirely, though loaders are used in some sections. On dry-farms, a ton to the acre pays; one and one-half to two and one-half tons are frequent. Four or five tons for the season is a good return under irrigation, though six to eight are harvested from an acre under favorable conditions.

285. Storage. — Most hay is kept out-of-doors. Stacks with upright sides with middles high and built solid from the ground up, topped with rounding slopes

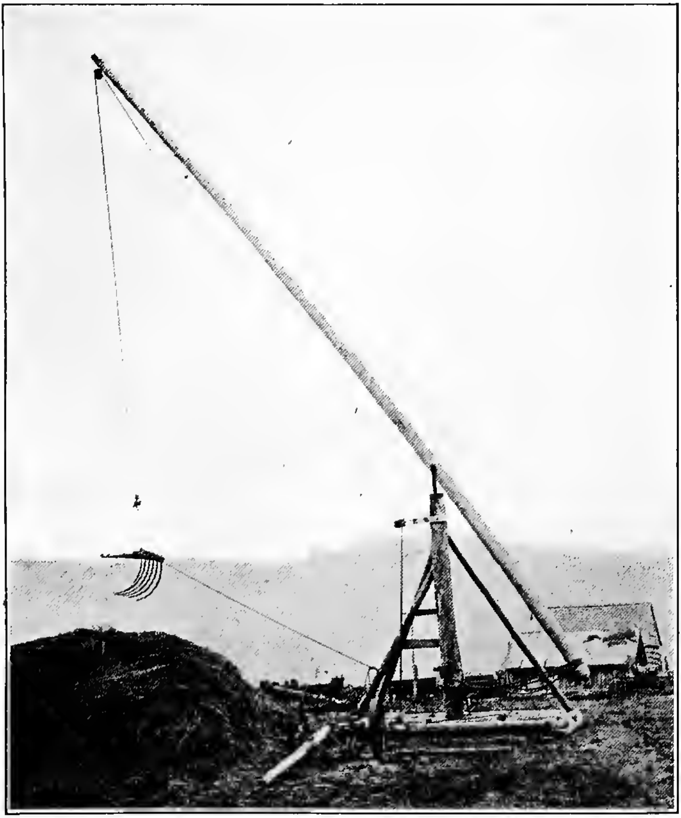

Fig. 71. — A convenient device for stacking hay.

that leave no " shoulders " for storms to enter keep well, while irregular squatty piles lose heavily. Good stacking requires much skill. Sheds are preferable, since it is not necessary to stack carefully under cover.

Most hay is fed on the farm or marketed loose in the vicinity. When shipments are made, the hay is compressed into bales weighing from 50 to 150 pounds. Baled and loose hay are usually weighed on wagons for market, although stacks are often measured. Inaccuracy in

Fig. 72. — Hay should be fed on the farm.

measuring due to variation in shape, regularity, and density cause this to be unsatisfactory in many instances.

286. Use and value. — In palatability, digestibility, nutrition, and healthfulness, alfalfa hay leads. Some horsemen prefer timothy because alfalfa is laxative for driving horses. A part of the preference for timothy is, however, due to custom. Work animals need only moderate grain ration when alfalfa is fed because of the high protein content. It excels as roughage for dairy cows, beef cattle, and sheep. As silage it has not been successful because of difficulty in compacting.

Ground hay is used in mixed feeds as alfalfa meal. It wastes less and compounds in rations more readily, but otherwise it has no advantage over hay.

Alfalfa pasturing is widely practiced in spite of the danger of bloat to cattle and sheep. Dew-covered leaves eaten by hungry stock may prove injurious. Horses and hogs may feed on alfalfa pastures any time. If cattle are left continuously on the feed night and day, danger diminishes but it never disappears. Wisdom is necessary in pasturing cattle and sheep on the growing crop. After haying, nearly all fields are grazed over indiscriminately. Withered stands need cause no alarm. Extremely close pasturing weakens the alfalfa, for it is not stoloniferous and forms no true sod.

287. Mixtures are generally detrimental in that they lessen the yield. On account of maturing at a different time, they also hurt the quality of the hay by introducing coarse, woody stems or undesirable beards. Orchard-grass, timothy, Kentucky blue-grass, and Bermuda-grass are mixed with alfalfa purposely or creep in naturally, but they are unsatisfactory and are considered weeds. Squirrel-tail, locally known as foxtail (*Hordeum jubatum*), dodder, sweet clover, yellow trefoil, June-grass quack-grass, and crab-grass all cause trouble. Thorough harrowing and occasional plowing are the remedies for almost all weeds in alfalfa.

288. Enemies. — Besides weeds, root-rot, stem-blight, leaf-spot, and several minor diseases do varying damage to the crop. Rotation and cultivation largely control them. Stem-blight, which seriously attacks the stems of the first crop only, can be controlled by cutting as soon as the disease appears.

No widespread insect does constant damage. Grasshoppers may be disregarded if fall-plowing and clean farming are practiced. Hibernations are thus destroyed.

FIG. 73. — Dodder on alfalfa plants.

Swarms from waste lands occasionally cause trouble. Various traps for catching them have been devised.

The chalcis fly has recently done much seed injury in the West. It enters the ovary at bloom, lives inside the seed, and bores out by a small clear-cut hole in the pod just before maturity. Thrips also injure the seed-crop at blooming time.

In 1905, the alfalfa leaf-weevil (*Phytonomus posticus*) appeared in Utah and has since spread rather widely over the state and into southern Idaho and southwestern Wyoming. Small green larvæ feed on the growing buds, usually of the first crop, thus delaying the second crop and causing the third cutting to be small or lacking. If the first crop is cut as soon as the larvæ appear in numbers sufficient to do marked injury, and if the land is thoroughly spring-toothed followed by a weighted brush-drag after the surface has dried, the weevil nearly disappears on that patch for the rest of the season. Besides the good which cultivation does in destroying weeds and insects, it conserves moisture by forming a mulch. Contrary to public opinion, the seed cannot carry the insect into new districts.

289. Seed production is confined almost entirely to dry regions because constant moisture encourages the growth of new shoots which lessen seed bearing. Half the seed produced is on irrigated lands where water can be withheld. Dry-farms produce most of the rest. Second-crop alfalfa bears most of the seed. Even in arid regions, seed-producing sections are isolated valleys or areas. Row cultivation has given the best yields of seed on some arid farms.

Seed alfalfa generally ought to be thinly sown. Bumble bees aid in cross pollination but much self-fertilization takes place.

Mowers or binders cut the seed stand and threshers are used to separate the straw from the seed. The straw and chaff are used for feed. From one to twenty bushels weighing from sixty to seventy pounds are harvested from an acre.

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CHAPTER XXII

THE CLOVERS AND OTHER LEGUMES

ALFALFA is the important forage crop west of the Mississippi. Red clover is similarly important north of the Ohio and east of the Mississippi, save that it has timothy for a teammate in furnishing forage. What alfalfa is to the West, and red clover to the North, cowpeas are to the South: the important legume forage. The other legumes yield seed or hay, and all are able to fix atmospheric nitrogen. They also have high-feeding value as a result of high protein.

RED CLOVER (*Trifolium pratense*)

Red clover is the most important leguminous crop grown in the United States. As a forage, it and timothy compete for first place leaving alfalfa third. The acreage of red clover diminished about 40 per cent from 1899 to 1909 due to the increasing difficulty of getting good stands on old farms. Some attribute this to "clover sickness," an abnormal condition little understood but partly remedied by long rotations.

Romans and Greeks never saw red clover. Not until the thirteenth century is there record of its use as forage. It was near the end of the eighteenth century before Europe cultivated it extensively. Early colonists carried it to Massachusetts, where mention was made of it as a crop in 1750.

290. Description. — The root-system confines itself largely within the plowed soil sending a few roots down four to six feet and occasionally eight. A small crown sends up hairy, much-branched stems bearing many palmately compound leaves which are generally patterned with white on the upper surface. Dense, globular flower-heads rise from the end of all branches. Fifty to one hundred and fifty small blossoms varying from pale pink to red comprise these heads. The whole plant presents a bushy appearance every part of which is covered with fine hair.

Cross-pollination seems necessary to seed production. Bees aid greatly in carrying pollen from plant to plant. When mature, the seeds, which are in most cases heart-shaped, vary from yellow to deep purple in color. From twenty to one hundred develop in one head.

Ordinary red clover is about a foot in height with hollow stems; a variety known as mammoth clover is large and has solid stems. Mammoth clover blooms at the same time as timothy and is better, therefore, to use in a timothy mixture than red clover, which blooms two weeks earlier. A much larger second crop is sent up by red clover. Like alfalfa, red clover has many strains named from the sections that grow them. In general the strains are much alike, with each best in its own home.

291. Distribution and adaptation. — Red clover is widely cultivated in Europe, Chile, and New Zealand as well as in the United States. In all northeastern states, it ranks with timothy as the leading forage. In acreage, the states stand in the following order: (1) New York, (2) Iowa, (3) Missouri, (4) Michigan, (5) Wisconsin, (6) Pennsylvania, (7) Illinois, (8) Ohio, (9) Indiana, and (10) Minnesota, — every large state north of the Ohio and Missouri rivers and east of the arid section. This area of production is entirely within that part of the humid section which is damp without rigorous winters. Just northward, in the Canadian provinces of Ottawa and Ontario, where similar climatic conditions exist, an immense area is planted to this crop.

The soils on which it grows vary widely. About all that is required in this respect is that they be moist and well-drained. Fertile clays produce the best yields; sand or gravelly soils that hold little water, the poorest. As both water-logging and drouth are injurious, red clover has no wide adaptation either on dry-farms or under irrigation, though it is profitable in many high valleys of the West. High temperatures prevent extensive culture of it in the South. Northern and western European countries, where it is grown extensively, have a cool, moist climate.

292. Culture. — About eight pounds of seed to an acre is planted any time from early spring to early fall, with or without nurse crops. A fine, firm seed-bed is essential. Lime and farmyard manure pay best as fertilizers. Fall-planted clover yields a hay crop the first season, but when it is spring planted, little hay grows that season, though the next two crops net good returns. The second cutting may produce seed instead of hay. Two to three tons of hay and from one to six bushels of seed is a satisfactory return.

Farmers cut, cure, and handle the hay and seed much as Westerners do alfalfa, but with greater difficulty on account of wet weather in the particular section to which it is adapted. Cutting at full bloom gives the best hay.

293. Use and value. — Red clover hay ranks high in the East. It is superior to grass, but not so good as alfalfa. As silage, it is good if cut fine and packed tightly. It makes a good soiling crop and fair pasturage, though it will bloat sheep and cattle. In rotations it fixes atmospheric nitrogen in the soil, which benefits the next crop materially. Because of lasting only two years, it enters naturally into practically every rotation where it can be grown. Disease-resistant strains and better-planned rotations seem to be much needed, at least where " clover sickness " prevails.

OTHER CLOVERS

294. Alsike clover (*Trifolium hybridum*). — Alsike is much like red clover save that it is smooth, more cold-resistant, has light pink flowers and brown seed, and can endure water-logging with much less injury. It succeeds where " clover sickness " and wet lands kill red clover.

295. White clover (*Trifolium repens*). — White clover is common in lawns and pastures. Because of its creeping habit of growth, haying machinery cannot gather it readily. Acre-yields are small when harvested for hay, since only the leaves and flower stalks can be gathered. A variety known as Ladina clover is grown for hay in northern Italy.

Since it has a creeping habit, its stems hug the ground rather closely. Roots grow out from these branches giving the plant a new start. A nearly fibrous root-system aids in forming sod, which helps to withstand tramping in pastures and lawns. Wherever cool weather prevails and plenty of moisture is present, white clover thrives. It grows from Canada to Mexico where these conditions exist, and does well in shady places.

296. Sweet clover (*Melilotus alba*) is a rank-growing biennial, having an abundance of small white flowers and coarse stems which become woody after blooming. Cumarin gives the plant a bitter taste and a characteristic odor that repel stock. Being a legume, it is rich in nitrogen. The plant is deep-rooted, resists drouth, but can also tolerate wet soils. It likewise withstands both heat and cold to a marked degree. It grows on any soil, thriving on roadsides, ditch banks, and on irrigated land not carefully cultivated. In some sections, it covers the mountain sides.

Stock feed on it in waste places. Coarse woody stems and bitter taste lessen its palatability. If cut, however, before blooming, the stems cure in such a way that they are soft and the bitterness is less intense. Stock like the hay. Its wonderful adaptability and good yields recommend its cultivation in sections, where, for some reason neither alfalfa nor red clover is profitable.

297. Crimson clover (*Trifolium incarnatum*), much grown in the middle Atlantic and Southern States for a green cover-crop, bears a flaming crimson flower, from whence its name. This clover is a winter annual in the South and a spring annual in the North, where it is occasionally found. As a hay crop, it lacks some of the valuable properties of other clovers. It bears many hairs which, in the intestines of horses, occasionally form balls causing death to the animal. Danger of bloat also accompanies its use as a pasture. Despite these undesirable qualities, it is widely used as feed; for green manure and rotation it is valuable.

Hungarian clover, Mexican clover, berseem, shaftal or Persian clover, yellow trefoil, and the bur clovers furnish some forage in small districts.

FIELD-PEAS (*Pisum arvense*)

298. Description and adaptation.—The field-pea, often known as the Canada field-pea, resembles the garden pea save that it is more thrifty and has longer stems, larger leaves, violet instead of white flowers, and smoother and slightly smaller seed. In depth, the root-system seldom exceeds three feet, while the stems vary from one to ten feet in length. The stems, which are hollow, stand upright in the early part of the season but soon flatten down on account of the length of the vines. On the whole, the plant is smooth and rather succulent, covering the ground almost completely in good growth, or climbing plant stalks and frames by means of tendrils at the terminal division of pinnately-branched leaves. Being an annual, it grows and matures rapidly in 75 to 110 days. Earliness, color of flower, shape of pods, variation in seed, and length of vine factor in differentiating about a hundred varieties, some of which are favorites in one place and some in another. All of them, however, do best in cool, moist climates and on heavy loam soils. On account of being adapted to the same conditions as oats, field-peas grow in the same sections, often in the same fields mixed with them. Southern Canada and the Northern States produce most of the crop, though many high valleys in the West yield fairly well. Ontario, Michigan, and Wisconsin, in order, lead in acreages. Excessive heat, which peas cannot withstand, prevents their cultivation south of Maryland.

299. Sowing. — The abundance of food in the large seed permits fairly deep sowing — from one to four inches, even on a coarse seed-bed. Fall-plowing in the North renders possible early sowing, since the pea has considerable frost resistance and may be seeded as soon as heavy frosts are over and as soon as the condition of the land permits.

Farmers commonly plant from one and one-half to three and one-half bushels an acre when peas are planted alone. If sown with oats, as they often are for hay, usually from one to two bushels of peas and from one-half to one and one-half bushels of oats are sown. On irrigated land, about two bushels of peas and one bushel of oats are used. Both are drilled at the same time, but some persons favor separate planting or even broadcasting.

300. Culture and harvesting. — Since the peas are sensitive to mechanical contact and not grown in rows, little cultivation is given after they come up. Three to six inches of irrigation water, where used, may be applied at intervals of from one to several weeks, depending on the physical composition and condition of the soil and on the needs of the crop. The shading and heavy lodging of the crop render over-irrigation more undesirable on clays or clay loams not underlaid with subsoil than in sandy or gravelly areas. Peas grown alone are harvested for hay by cutting with a mower before they begin to ripen, and they are cured like alfalfa. For hay, oat-and-pea mixtures are cut when the oats are in soft dough, and they are handled as other hay; for seed, mowers with attachments for piling the vines are used, or a man lifts the swath aside so that the horses and machine will not shell out the peas. Grain threshers, with teeth removed from the concaves to prevent breaking the seed, separate pods and vines from the peas.

301. Use. — Pea hay, if properly cured, is palatable and nutritious. Dairy cows, beef cattle, sheep, and hogs relish it and make rapid growth on it because of the abundant protein which it contains. Horses use it advantageously. When it is mixed with oats or beardless barley, all classes of livestock do well on it. The necessity of annual sowing prevents its more general use for hay. Then, too, the green vines are good for soiling, while hogs and other animals pasture it to advantage. The extreme palatability of the green vines makes it valuable in a mixed ration. Refuse vines and pods from factories that can garden peas are valuable feed if preserved in stacks or silos. Fruit-growers and others who want green manure find peas good in spite of the fact that shallow rooting lessens their sub-soiling value.

BEANS (*Phaseolus species*) (Fig. 74)

302. Description. — Beans belong to the same family as peas, and though there are several genera most of them belong to the genus Phaseolus. The plants have a shallow semi-tap root-system, rather erect stems, broad, hairy leaves, and long tendrils. The flowers vary through whites, yellows, and blues; the pods are generally long; the seeds may be practically any color or shape. In size they vary from one-eighth to one and one-half inches in length. Nearly all varieties are smooth.

Unlike peas, beans cannot withstand frost. They resemble corn in that a slight frost not only retards but stops growth. On this account, they are limited to sections that have four months free from frost, that is, from about the middle of May to the middle of September. Michigan and New York produce 60 per cent of the beans grown in the United States. California, Florida, and Wisconsin are also heavy growers. Cool, moist climates and rich, loamy soils promote the greatest development, but under irrigation they may resist fairly hot, dry weather. Loose, warm, well-drained soils rich in lime may be displaced by poorer ones, though at cost of high yield.

303. Culture. — Fall-plowing prepares the warm, mellow seed-bed that is best for beans. Fine manure also helps. Late planting permits spring-plowing, which ought not, however, to be delayed until just before planting as is often the case, since too much moisture evaporates and the soil does not become sufficiently firm for good

FIG. 74. — A good crop of field beans.

germination. From a peck to a bushel an acre is planted by hand, by planter, or by grain drill with the width regulated by stopping some of the holes. Planters can drop the beans in hills or in drill-rows.

As soon as the rows show well, cultivation should begin in order to loosen the soil and kill weeds, and it should continue at intervals until the vines become so large that they would catch on the cultivator. Cultivation should be given after every application of irrigation water, which may be used in moderate quantities from one to five or six times.

As soon as the beans are mature enough to prevent shrinkage, they may be cut and stacked to avoid loss from shelling, which they do at complete maturity. Two-row bean cutters make harvesting easy, while bean threshers simplify threshing. An ordinary grain thresher, slowed down to avoid splitting the beans, does satisfactory work. Beans pay fairly well but are not widely grown. They seem to have gained gradually in the last few years, having been introduced into many districts in which they were not formerly grown. Nearly all experiment stations in the West give favorable reports for some variety, but this is not surprising, because there are so many varieties that they are adaptable to widely different conditions.

304. Use. — Beans sell well on the market, dried or canned. They have considerable feeding value for stock as grain when ground and mixed with other feeds; they seem to have a laxative effect when fed alone. Sometimes the green plants are cured for hay or they may be pastured. To whatever use the plants are put after harvest, they always fix some nitrogen in the soil during growth.

COWPEAS (*Vigna Sinensis* and *V. Cat. jarg*) (Fig. 75.)

305. Description. — Cowpeas are not peas at all, but beans, differing from the garden bean in that they have long, wrinkled pods, generally long, trailing vines, and large leaves. The stems are grooved; the flowers white, violet, or yellow; the seeds small, wrinkled or smooth, and white, yellow, green, or brown. A branching tap

Fig. 75. — Cowpeas in Missouri.

root-system that fills the surface soil penetrates three or more feet into the soil.

Warm and not over-damp climates favor cowpeas; hence they do well through the eastern part of the United States south of the Ohio River. Well-drained soils promote rapid growth. Since these conditions prevail rather generally in the South, the cowpea thrives in this section where given an opportunity. In the last few years, the crop has grown much in importance. What alfalfa is to the West, and what red clover is to the North, cowpeas are to the South: a leguminous forage crop of high feeding, pasture, and rotation value. Cotton lands need a rotation badly and such a one as will support livestock. In this, cowpeas excel, for they furnish large yields, good pasture, and abundant organic matter whether fed or used as green manure. The maintenance of greater numbers of livestock, so necessary for the South, will depend largely on this crop.

306. Culture. — Well-worked seed-beds, warm and not water-logged, are essential. From two pecks to three bushels of seed an acre are broadcasted or drilled; planted alone, or mixed with sorghum, corn, Johnson-grass, millet, or soybeans. Since its chief value is for forage it is cut green and cured in the field or on racks as the weather permits. Ripened seed is hand-picked or threshed from the vines.

Cowpea hay seems equal if not superior to red clover, and is nearly as nutritious as alfalfa for cattle, sheep, and hogs. As pasture, it has considerable value, especially when planted in corn fields late in the season to be "hogged-off." Note Fig. 79.

SOYBEANS (*Soja max*)

307. Description. — Soybeans resemble other beans in general, but they are more erect, more woody, and more hairy. The root-system consists of a well-developed tap-root with few side branches. Blossoms vary in color from white to purple; the pods are usually short, flat, and tawny; most seed is flat, smooth, and oily. In height, the plant varies from six inches to several feet, but two to three feet is most common. At this height, the fields present a compact appearance on account of prolific branching. When the seed ripens, the entire plant dies, since it is an annual.

Both the climatic and soil requirements for soybeans approximate those for corn rather closely, except that frosts are not nearly so injurious. Warm, moderately moist growing-seasons and warm, loose, soils rich in lime are best. Like all other legumes, the right kind of bacteria must be in the soil to secure luxuriant growth.

308. Culture. — Well-prepared seed-beds aid materially in early germination. Seed is commonly planted during May at the rate of twenty to thirty pounds an acre in drilled rows. From two to four inches seems the most favorable depth. Shallow cultivation may begin as soon as the rows show plainly, and continue until the size of the plants prevents the use of horse and cultivator. Weeds injure the crop seriously and must, therefore, be kept out. The plan of irrigation for cowpeas is practically the same as that for field beans.

When used for hay the time to cut is just as pods form. The rake ought to follow the mower closely in order to prevent the leaves from drying too quickly. Curing is best done in the cock, because the stems do not then get too hard nor the leaves over-brittle. Cattle, sheep, and hogs, for which the crop is best adapted, do not relish the stems as they do softer food. Mixtures of corn, cowpeas, sorghum, millet, and grass increase the yield, but not the quality, which is naturally high. Hogs, particularly, do well on soybean pastures. For seed, the crop is handled as are field beans.

MISCELLANEOUS LEGUMES

309. Vetch (*Vicia*). — Of the many kinds of vetches, common vetch and hairy, or winter, vetch are most frequently grown for forage. These plants are annuals and winter annuals, respectively. The root-systems are branching and only moderately deep; the stems are long vines; the numerous leaves are finely divided ending in tendrils. Purple flowers are borne in compact masses on a pedicel; flat, broad pods bear small dark seeds which are fairly hard. Hairy vetch is covered with abundant velvet-like hairs.

Common vetch does well in cool, moist climates that do not get very cold. Pacific Coast regions are favorable. Hairy vetch does well in temperate regions that favor soft winter wheats. It seems adapted to these regions on account of being fairly drouth-resistant.

From forty to sixty pounds of seed will sow an acre whether drilled or broadcasted. Mixing with oats or grass, which help to support the tangled vines, is usually recommended for pasture and hay. The method of curing vetch hay differs but little from that of alfalfa.

The hay is fine and palatable, especially for cows and sheep. Horses like it less than clover, alfalfa, or peas on account of its extreme softness. For soiling and silage it is good. Annual planting and mediocre yields make it less valuable than alfalfa, for only one full crop can be cut. Farmers may grow their own seed, thus reducing the expense of planting.

310. Other legumes. — Peanuts are grown in the South for hog pasture and for nuts. Tangier peas, ochrus, fenu-greek, lupines, serradella, lespedeza or Japan clover, velvet beans, Florida beggar weed, jackbeans, mung beans, moth beans, hyacinth beans, guar, sanfoin, kudju, bird's-foot trefoil, astragalus, chickpeas, and grasspeas are used in various parts of the United States and the Old World for hay or pasture. They are all legumes and valuable as nitrogen gatherers and for feed, but they are of secondary importance to alfalfa, the clovers, peas, beans, and cowpeas. Vetch and soybeans seem to be growing in importance and cowpeas are much urged for the South.

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No. 224. Canadian Field Peas.
237. Lime and Clover, pp. 5–7.
260. Seed of Red Clover and its Impurities.
289. Beans.
318. Cowpeas.
323. Clover Farming on the Sandy Jack Lands of the North.
441. Lespedeza or Japan Clover.
455. Red Clover.
485. Sweet Clover.
515. Vetches.
529. Vetch Growing in the South Atlantic States.
550. Crimson Clover: Growing the Crop.
561. Bean Growing in Eastern Washington, Oregon and Northern Idaho.
579. Crimson Clover.

CHAPTER XXIII

GRASSES

To the grass family belongs a host of plants similar in structure yet varying so widely in size and usefulness as to seem unrelated. Between lawn grass and gigantic, tree-like bamboo is a wide gap partly filled with larger grasses such as timothy, sorghums, and corn, which reach

FIG. 76. — The effective use of light machinery in handling the hay crop.

great size in some climates. Thousands of species belong to this family. Among them are many of our most useful plants. In fact, the grasses are probably our most valuable plants, since with them are classed all the cereal crops, most of the forage and pasture plants except a few legumes, and most of the range and prairie plants. In addition, some species serve man as lawns, as ornamental plants, as weaving material, and as packing for furniture and other breakable commodities.

Some writers class with the grasses all hay and pasture plants, — clover and alfalfa as well as members of the

Fig. 77. — A covered haystack in the humid section.

Gramineæ, or grass family. Only the true grasses will be treated here. Among the most useful of these are the grain, the hay, and the pasture crops. Not all grasses are useful, since some are our worst weeds. The hay crops are fundamental to the nation's prosperity. Methods of handling these crops are well shown in Figs. 76 to 78.

A fibrous root-system with or without rootstocks; stems composed of nodes and internodes which are either hollow or filled with a porous pith save at the nodes; leaves clasping the culm for a distance above the node from which they spring and terminate in narrow, parallel-veined blades; a branched head bearing seed with a closely-borne covering: these are the important structural characteristics of the grass family. The forage grasses are timothy, redtop, orchard-grass, brome-grass, blue-grass, Johnson-grass, oat-grasses, rye-grasses, fescues, wheat-

FIG. 78. — A good supply of forage well stacked.

grasses, meadow-foxtail, and a few others. The first five mentioned are much more important than the others.

TIMOTHY (*Phleum pratense*)

Timothy originated in the Old World where a number of wild species are found. The name probably came from Timothy Hansen, who introduced the crop into Maryland from New England.

311. Description. — Timothy bears a slender, spike-like panicle from one to twelve inches in length on a slender culm one to six feet in height. From three to eight leaves branch off from the upright stem. As the roots are not strongly stoloniferous, the plant does not sod heavily. An enlarged stem known as a corm forms a base for the dozen or so culms. As many as two hundred stems have grown on one plant.

A patch of timothy shows purple when in bloom; green when headed completely; and whitish when the seed is ripe. During early growth, however, only the leaves show. These bend in graceful curves from a central stem. Seed of timothy is small — not over one-fourth millimeter in diameter — with a thin, transparent, adnate hull. Since germination power is high, good stands are easily obtained. The seed loses less in viability through age than does that of other grasses. Eighty per cent of two-year-old seed may be expected to grow.

312. Adaptation. — Cool, moist climates and clay or clay loam soils offer the most favorable opportunities for maximum yields. Severe drouth kills it almost immediately; hot weather, even in humid sections, lessens its vigor; cold is favorable to some extent as indicated by the fact that the plant is native in Europe as far north as the seventieth parallel. Favorable conditions exist in many high valleys in the West, especially where streams supply abundant irrigation water. In spite of its fondness for moisture the plant suffers from water-logging. In fact, timothy and red clover are mixed to a great extent because the same conditions favor both. In the United States the production of timothy ranks as follows according to states: (1) New York, (2) Iowa, (3) Ohio, (4) Missouri, (5) Illinois, (6) Pennsylvania, (7) Wisconsin, (8) Michigan, (9) Indiana, and (10) Minnesota with Ottawa and Ontario in Canada heavy producers. Red clover ranks nearly the same as timothy according to states. Every state produces some timothy.

313. Culture. — Fine, moist, firm seed-beds are essential in procuring successful stands of timothy — of any crop having very small seed. Well-decayed organic matter increases both moisture and fertility. Fall-plowing permits frost to mellow the surface; winter storms dampen and firm the seed-beds for spring planting.

About half the crop of the United States is sown in the fall with winter wheat for a nurse crop. In this case a grass seed attachment drops the seed just in front of, or just behind, the shoes of the drill. A light harrowing covers the seed, though Piper[1] thinks deeper planting would be better. The seeds must touch moist soil in order to germinate, and should be planted from a half inch to one inch in depth depending on the season and soil. Seed may also be planted in the fall without a nurse crop, and in spring with, or without, a nurse crop. Broadcasting both by hand and by means of the wheel-barrow seeder is much practiced. Irrespective of the method used in planting, the farmer should sow about fifteen pounds of seed to the acre.

In some sections, corn or potato land is prepared by a thorough harrowing without previous plowing. In most sections, however, fall-plowing, spring-harrowing, and drill-sowing give the most satisfactory stands. Frequent irrigations pay on lands that have good drainage.

Heavy applications of farmyard manure to the stubble pay. Where commercial fertilizers are used, nitrogenous manures make most profitable returns. Clover mixtures serve this purpose.

Timothy ought to be cut as soon as the blossoms fall, but it does not deteriorate rapidly until the seed reaches the soft dough stage. This enables the farmer to utilize a later harvesting season than for any other forage crop. The hay cures readily, being in many cases hauled on the same day that it is cut. In humid sections, tedders, side-

[1] Piper, *Forage Plants*, p. 130.

delivery rakes, and loaders are widely used; in the West, it is handled largely as alfalfa. Derricks are used to build stacks and tracks to fill barns. The first crop bears most seed. Grain binders commonly harvest the seed crop, which is threshed in an ordinary separator with special sieves.

314. Use and value. — The most important use of timothy is for hay, since the pastures yield but little feed and the sod weakens under tramping. As a silage or a soiling crop it is little used. Though the standard hay crop of America, its intrinsic feed value is less than that of the clovers or alfalfa on account of its lacking the high

TABLE 3. ACREAGE AND YIELDS OF FORAGE CROPS IN THE UNITED STATES. (FROM PIPER.)

CROP	ACRE-YIELDS	ACRES	TONS	PER CENT
Timothy (alone)	1.22	14,675,000		
Red clover (alone)	1.29			
Timothy and clover (mixed) [1]		19,536,000		
Timothy (total)	1.22	24,457,584	30,359,698	31.2
Red clover (total)	1.29	12,274,454	15,532,602	15.9
Alfalfa	2.52	4,704,146	11,859,292	12.2
Cereals for hay	1.24	4,324,878	5,367,292	5.5
Other tame grasses	.99	4,218,957	4,166,772	4.3
Sorghums	1.05	2,078,242	3,118,863	3.2
Millet	1.38	1,117,769	1,546,533	1.6
Cowpeas	1.00	1,100,000	1,100,000	1.1
Canada peas	1.00	250,000	250,000	.3
Kentucky blue-grass	1.00	100,000	800,000	.8
Brome-grass	1.00	1,000,000	100,000	.1
All other tame grasses	1.00	600,000	600,000	.6
Wild grasses	1.07	17,186,522	18,383,574	18.9

[1] Taken as half clover and half timothy when grown in mixture.

protein content of legumes. Common grasses vary little in food value or digestibility. Palatability, ease of curing, prolific seed production, healthfulness, and yielding power determine what grass is most profitable to grow. Timothy excels other grasses in these qualities. Market demands influence price; the prejudice of farmers and stockmen also plays a part, often not an insignificant one. Timothy has an advantage also in that it is the standard market hay, and that many stockmen prefer it to clover and alfalfa, in spite of the fact that it surpasses them only for feeding driving horses.

315. Enemies. — Bill-bugs and joint-worms cause some insect injury; a rust and a smut infest the plant. The greatest harm, however, comes from leaving meadows sown too long without rotation. This causes the stand to be so thin as to reduce yields materially.

REDTOP (*Agrostis alba*)

316. Description. — Redtop is so called from the distinctly reddish appearance of a field of it in bloom. It is more long-lived than timothy, its stems are more slender but tougher, its leaves finer, its sod more compact but more shallow, and its panicle much more spreading. The seeds are small, light, triangular in shape, and generally grayish-brown in color. The compact sod is a result of numerous rootstocks, and of decumbent stems sending out roots from the nodes.

317. Adaptation. — As redtop withstands water-logging to a marked degree, it replaces timothy on very wet land, sometimes growing in sloughs or bottom-lands in which water stands part of the year. It resists as much cold as timothy and more heat. It grows in all parts of the United States and as far north as Alaska.

It has an extremely wide adaptability in regard to soils, provided they are wet. Strange to say, when once established it resists considerable drouth.

318. Culture. — Pastures nearly always contain red-top in mixtures, but seldom does it form fields grown by itself. Since seed varies much in viability, from two to fifty pounds are planted, from two to ten pounds being common in mixtures. Much of it on wet land is started by broadcasting the seed, often without any cultivation, whatever. For hay, it is handled as timothy. In irrigated pastures, it occupies the wettest places.

319. Value and use. — As feed, it is much less palatable than timothy or blue-grass, but because of being able to endure water-logging and tramping it is valuable. It grows well on soils too wet or too acid for blue-grass and timothy, and grows wild on many of the boggy range lands, where it supplements the native grasses. In lawns it forms a fairly smooth sod, but becomes coarse unless kept well cut.

On the market it is considered an adulterant of timothy, the price of which it lessens. As the yield is fair, no particular objection can be made to it.

KENTUCKY BLUE-GRASS (*Poa pratensis*)

320. Description. — Kentucky blue-grass is marked by its smooth, firm sod, fine stems, and blue-colored leaves, which end without a distinct point. The panicle is loose and turns whitish at maturity. There are several blue-grasses, but the only other common one is Canada blue-grass (*Poa compressa*), which may be told by its sparsity of leaves, tough stem, and compressed panicle. It yields less than Kentucky blue-grass, being considered a weed on that account.

321. Adaptation. — Apparently no degree of cold kills this grass, though it loses vigor in hot summers even when abundant water is supplied. Naturally adapted to temperate regions, it thrives in this zone wherever sufficient moisture falls on well-drained soils that are rich in lime. It can endure neither acidity nor water-logging. Nearly all of the seed grown in the United States is produced on a few hundred square miles near Lexington, Kentucky, which is in the heart of the Blue-grass Region.

322. Culture. — Because of the low vitality of the seed, heavy seeding is required for good stands. If sown alone, forty pounds may be needed. Usually the farmer sows smaller quantities in mixtures. In many cases blue-grass, due to persistent spreading by means of rootstocks, will drive out other crops, leaving nearly a straight stand. Fine, moist soils, well mixed with humus, are best. The seed is most often broadcasted and harrowed. Better stands may be had on lawns by covering them with straw, or by shading in another way. Nurse crops may or may not help in field culture. This depends on soil and climatic conditions.

323. Use and value. — Blue-grass yields little forage that may be gathered for hay. As a pasture plant, it is king in America, though meadow-foxtail is most popular in England. Mixed with white clover, Kentucky blue-grass forms the best pastures in this country and also the best lawns in the North and West. Bermuda-grass, however, supplants it in the South.

Its popularity for pasture is not without reason. Though yields are small, it is so aggressive that bare spots are soon filled. It gains rather than loses under heavy pasturing, if it gets sufficient moisture. All animals are fond of the grass when it is green. When dry it is much less desirable, however. In palatability, fresh blue-grass excels all others, with the possible exception of smooth brome-grass. On account of its aggressiveness, it is a bad weed in clover and alfalfa fields. The legumes yield much more heavily, and suffer when blue-grass creeps in, since it eventually crowds them out, unless frequent harrowings or occasional rotations follow.

ORCHARD-GRASS (*Dactylis glomerata*)

324. Description. — Orchard-grass is a deep-rooted, rather rank-growing, bunchy, yet leafy grass. The shape of the panicle suggests a cock's foot, by which name it is known in England. Bunching is due to vigorous roots devoid of stolons. Tufts sometimes two feet across cause decidedly rough surface, bare in many places. These tufts are strongly netted by means of many tough, fibrous roots. Undoubtedly, the plant roots three or four feet deep in favorable soil.

325. Adaptation. — Heat injures orchard-grass less than it does timothy or blue-grass, but cold hurts it much more seriously. The natural place for its cultivation is just south of the timothy belt. It is to be regretted that timothy has gained such a hold that other useful grasses, such as orchard-grass, oat-grass, and brome-grass, were not tried in regions too warm or too dry for the greatest development of timothy. Porous, well-drained, fertile soils permit orchard-grass to make best growth. The plant uses considerable moisture to advantage, though, when necessary, it can, with the help of deep roots, endure rather severe drouths. As shade does not injure the crop to a great extent, it does well in orchards.

326. Culture. — Similar care as to preparation of the land for sowing, and method of scattering the seed, should be observed in the case of orchard-grass as in that of the other grasses. Both spring and fall planting succeed. Fall planting should take place early enough to permit some growth before winter; spring planting gives best results when the ground has become warm but is still damp.

When sown alone for hay, from twenty-five to forty pounds of seed are used. More commonly, from four to ten pounds are planted in mixtures. Patches grown for seed require a stand only half as thick as hayfields.

Orchard-grass makes the best hay when cut in early bloom, as the stems become woody very rapidly, thus decreasing palatability. Because this grass matures several days before most other grasses, mixtures are usually unsatisfactory for hay on account of the variation in time of cutting. Harrowing and manuring help to keep up yields and to prevent the growth of excessively large bunches. Applications of irrigation water up to thirty or forty inches pay in the West, though smaller quantities yield more in proportion to the water used.

327. Value and use. — Orchard-grass yields about as much hay as timothy and more second growth, which consists largely of leaves, making it valuable for fall pasturage. Since it begins growth early, it also affords considerable spring pasturage. Where severe and continuous tramping injures the roots, bare spots appear at intervals. Other grasses are needed to keep a good sod in pastures.

Hay from over-ripe orchard-grass is coarse and woody; unless very carefully cured it lacks the palatability of timothy or blue-grass. The shortness of the period during which it may be cut and still make good hay is a decided drawback. Early maturity, on the other hand, aids in keeping down weeds in the crop and permits pasturing of the fields.

SMOOTH BROME-GRASS (*Bromus inermis*)

328. Description. — There is a large number of brome-grasses, most of which are hairy or have barbed seed. Chess, the wheat pest of the East, is *Bromus secalinus;* the June-grass or cheat-grass of the West, which has recently become a pest in alfalfa fields and on ranges, is *Bromus tectorum.* Among all these but one is really valuable. Smooth brome-grass is neither hairy nor barbed. On the other hand, an abundance of broad, smooth, succulent leaves marks its early growth. Round stems and broad leaves distinguish it from other common grasses before the culms head out.

When fully grown, *B. inermis* is likely to be three to four feet in height bearing a strikingly great number of leaves, many culms, and an open-panicled head often distinctly golden in color. This imparts considerable beauty to good stands. To support this growth a strongly stoloniferous root-system dives six or seven feet into porous soils.

329. Adaptation. — Deep rooting enables brome-grass to resist dry weather remarkably well. It seems to be one of the most successful grasses under low rainfall. Although frost injures the plant but little, too much heat prevents good growth in the South. Grown for ages in semi-arid Russia, this grass promises well in the northern part of the West, especially on the Great Plains. Arid soils are the best for root development, in that they are generally deep, porous, and fertile. The greatest growths are found on loams and clay loams.

330. Culture. — If practiced in arid regions, fall-plowing and the summer fallow will store moisture for spring planting of brome-grass. In many localities, fall seeding on well-prepared seed-beds, treated as if for fall wheat, is, however, probably more satisfactory. From ten to twenty pounds an acre are planted for hay and from four to ten for pasture. Because the seed clogs the drill holes, farmers usually broadcast and cross harrow it.

When it is once established, severe harrowing improves its growth by preventing the fields from becoming sod-bound. Applications of barnyard manure help to maintain yields on fields five or six years old. Moderate quantities of irrigation water are beneficial. By careful handling, the crop ought to succeed in some localities on the dry-farm.

331. Value and use. — For hay, the grass is cut just after full bloom and cured as is alfalfa. The abundance of green leaves makes curing more difficult than is the case with other grasses. The arid regions in which it is largely grown overcome this objection in part by offering bright haying weather. Brome-grass will cure where alfalfa does. The high percentage of leaves to stems gives the forage an inviting look and a desirable softness. The grass is probably more nutritious and a higher yielder than other common grasses. Its great palatability causes stock to relish it highly.

Pastures of brome-grass wear well, furnish much feed, and grow early as well as late. Some investigations suggest that it be mixed with alfalfa for pasture. Where alfalfa is used for hay and thrives, this should not be done, as grasses yield less and the value of alfalfa is lowered.

In spite of the many good qualities of brome-grass, it may prove undesirable. Not enough is known about it to make it advisable to plant great areas with impunity. However, it promises so well as to deserve a trial. Farmers should try the grass in small areas, or get advice from their Experiment Station, or from growers in their neighborhood before sowing extensive fields. Brome-grass varies widely. Keyser of Colorado found 121 variations. Wisdom in selecting the correct variety for hay or pasture on irrigated or dry-farms may lead to unqualified success with this new crop.

OTHER GRASSES

332. Tall meadow oat-grass (*Arrhenatherum elatius*) is an erect-growing perennial bunch grass that thrives under the same conditions as orchard-grass. It withstands more heat, more drouth, but less frost than timothy.

It does not count for much in American agriculture at present, but ranks high in France and other parts of Europe, where it is grown for hay. When heavily pastured, it weakens rapidly because of inability to fill unoccupied soil, due to its lack of rootstocks. Its long life increases its value to some extent. Perhaps, it may find some regions too warm for timothy and brome-grass, too gravelly and too dry for other common grasses where farmers need such a crop-plant.

Oat-grass is sown in either fall or spring without a nurse crop because it cannot endure shade to any marked degree. Heavy seeding is necessary on account of the low viability of seed. Eighty pounds are frequently used when the crop is grown alone. More often about twenty pounds are sown in mixtures with orchard-grass, with alsike clover, or with both.

A bitter taste lessens the palatability considerably. If cutting is delayed till after bloom, the culms get woody. A yield slightly higher than that of the ordinary grasses partly counterbalances its poor quality.

333. Bermuda-grass (*Cynodon Dactylon*) is valuable in lawn and pasture in the South. It is an exceedingly strong sod-former often serving effectively in preventing erosion on unprotected soils. Wherever moisture abounds and regular frosts do not occur, it resists tramping and grows continuously save in early spring. Lawns in the South are almost universally of this grass, which keeps green in hot summer but is brown in winter and early spring.

Little seed is produced ordinarily. New stands are started by planting small pieces of sod in furrows on a firm, moist seed-bed. These should be two to three feet apart each way for fields and one foot for lawns. Heavy disking opens up the sod causing a more vigorous growth when fields have become sod-bound.

When used for hay, each cutting is small, but with a fertile soil and a warm, moist climate, several growths make a high total yield. In many cases, however, successful hay crops are not produced. In feeding value, it is very similar to timothy. Because of its aggressive underground stems, it is a bad weed in many fields. To eradicate it, men who have studied the grass recommend shallow plowing just preceding dry, hot weather or frost. Smothering it with cowpeas or some other rank-growing crop is sometimes successful.

334. Johnson-grass (*Holcus halepensis*) is a coarse, broad-leaved grass closely related to sorghum. Producing both seed and large rootstocks abundantly, it spreads rapidly by means of irrigation ditches in warm sections such as the South, Arizona, and southern California. Johnson-grass succeeds anywhere in the cotton belt. In fact, it not only succeeds but usurps fields unless it is carefully guarded against. Difficulty of eradication has caused farmers to regard it as a noxious weed, in spite of the fact that it is probably the best hay grass in the South, frequently yielding as much as five tons a year. If cut young, the quality of hay is fair, but pastures are only medium because the succulent rootstocks weaken when it is grazed closely. Stock have occasionally been fatally poisoned as they are sometimes by sorghum.

Freezing of the soil below six inches in depth kills the plant. Where growth is vigorous, eradication is best accomplished by plowing before frost or drouth and then planting the soil to a crop that is to be intensely cultivated, such as cotton, or to a crop that will smother the pest, such as oats and vetch.

335. Miscellaneous grasses. — Two rye-grasses, several fescues, meadow-grass, and slender wheat-grass are cultivated in various small districts or throughout broad regions in scattered patches. Western wheat-grass and slender wheat-grass grow in bunches throughout the mountain region. Many sedges (*Carex sp.*) and rushes *Juncus sp.*) are erroneously regarded as grasses. In sloughs and wet bottom-lands, they furnish much low-grade hay and rough pasture. On salt lands, salt-grass (*Distichlis spicata*) makes a small growth of medium quality. These last are not cultivated, but are harvested from native meadows largely by ranchmen, who wish a coarse roughage to feed cattle over winter.

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CHAPTER XXIV

PASTURES, MEADOWS, AND SOILING SYSTEMS

THE pasturing of livestock on grassy plains and steppes was the most primeval form of agriculture. As civilization increased, man left off hunting and took to tending flocks and herds. Soon he found it profitable to have an understanding with his neighbor as to whose cattle were to graze on particular areas. Abraham and Lot divided their pasture-lands for this purpose. Later, when crops became important, livestock were still necessary. Thus to-day, wherever man lives, he has cattle and beasts of burden. These get a part of their feed from pastures or from unoccupied public lands, called ranges.

336. Definition. — By the term "pasture" is meant any land from which livestock gather feed for themselves, as opposed to soiling, which is cutting and feeding the green plants, or as opposed to hay-making, which consists of curing the crop by drying it before feeding. It makes no difference whether the areas are man-made or whether they are natural, nor does it matter what the nature of the plants grown may be, so long as they are used for feed.

337. Kinds of pasture. — If the area is naturally covered with pasture crops, or if the land is continuously used for the grazing of livestock, the pastures are said to be permanent. These permanent pastures are either range land, meadows, or sloughs. A part of the extensive prairies east of the Rockies is still a range pasture.

The meadows and fields renewed occasionally — regularly or irregularly — are temporary pastures. They consist either of fields left sown for a number of years or for one or two seasons. In many sections the stubble of grains and forage crops is pastured. These, strictly speaking, are not pastures, that is, the primary use is not for pasture but for crop harvests. Nevertheless, they are of economic importance.

338. A good pasture should be thoroughly and evenly covered with plants that will form sod of such a nature as not to be injured by the tramping of animals nor be checked in its growth through close cropping. These plants ought to be so palatable and fine as to encourage the animals to eat sufficient quantities, and so nutritious that the quantities eaten will nourish the body and supply energy for work, whether it be drawing loads, growing wool, or manufacturing milk. The pasture needs to be green a considerable part of the year, and to yield much feed.

339. Importance. — More than one-third of all the improved farm land in the United States is in pasture. In the West, the range land far exceeds the farm land in area. Part of the farm land — perhaps a third or more — is in temporary pasture. Much western land is so dry that it cannot be classed as grazing land, although sheep feed on it.

Immense droves of sheep and cattle formerly grazed throughout the West. The day of the cattle kings is passing rapidly where it is not now past, but forest reserves still furnish pasturage for numerous animals. The animals, taken from the range lands in the fall, are turned into the meadows and stubble fields to pick at the ungathered plant parts. In some sections they winter on meadows supplemented with a partial ration of hay. The convenience of a pasture in which to turn animals, especially during haying and harvesting, is of considerable value. Much làbor is also saved.

340. Native grass, together with rushes and sedges, largely comprises these meadows. The sedges (often called broad-leaf), with three-cornered stems and broad, bunched leaves, and the rushes (wire-grass and bulrushes), with round, hollow, stemlike leaves, grow abundantly in the wet valley bottoms and sloughs. These supply considerable second-class feed on the wet lands that are impregnated with alkali. Salt-grass and related species also grow in similar places making finer hay and better feed.

Wheat-grasses, lupines, wild vetch, and numerous other plants occur on the ranges. Sheep get considerable grazing from sagebrush and shadscale.

341. Crop-plants. — Kentucky and Canada blue-grasses, timothy, redtop, smooth brome-grass, orchard-grass, tall meadow fescue, Italian and perennial rye-grasses, tall meadow oat-grass, and red, white, and alsike clovers are all used in permanent and temporary pastures, and some of them for hay. In addition to these, alfalfa, the small-grains with and without a mixture of peas, rape, corn, and millets are used to varying extents in different localities. In general, these yield more palatable and more abundant feed than the native grasses. Except redtop, they thrive best on well-drained soils that are fairly rich in lime. Lime and drainage are especially necessary for Kentucky blue-grass, timothy, brome-grass, alfalfa, and red clover. Blue-grass and the rye-grasses need much moisture.

342. Mixtures help in many ways:

(1) They usually insure a continuous growth from early spring through summer to late fall.

(2) They render the feed more palatable because of variety, and more nutritious, when the grasses have legumes sown with them.

(3) They usually increase the yield, as they can be made to feed in different soil layers or during different seasons of the year. This is more likely to be true when deep-rooted and shallow-rooted crops are grown together.

(4) The legumes aid in keeping up the fertility.

(5) Deep rooting loosens the sub-soil thus promoting drainage and increasing available moisture.

(6) A plant that establishes itself in one season when mixed with one requiring two or more years, yields feed until the other can get well started.

Just what mixture to use is always a question, since no set of conditions is exactly like any other. There are all variations within a given mixture, according to the land, to the animals pastured, and to the fancy of the owner.

The Utah Experiment Station has found the following three mixtures well adapted to the irrigated West:

For bench lands under irrigation:

Kentucky blue-grass	12 pounds
Smooth brome-grass	8 pounds
Perennial rye-grass	6 pounds
Orchard-grass	3 pounds
White clover	2 pounds
Red clover	2 pounds
Alfalfa	2 pounds

For light sandy soils under irrigation:

Kentucky blue-grass	8 pounds
Meadow fescue	12 pounds
Tall meadow oat-grass	5 pounds
Smooth brome-grass	8 pounds
White clover	2 pounds

For low, wet lands such as sloughs:

Perennial rye-grass	8 pounds
Redtop	10 pounds
Rhode Island bent-grass	4 pounds
Meadow fescue	2 pounds
Alsike clover	5 pounds
White clover	2 pounds

A mixture used with success on the good soils of the East is as follows:

Timothy	10 pounds
Red clover	4 pounds
Alsike clover	3 pounds
White clover	2 pounds
Kentucky blue-grass	3 pounds
Tall meadow fescue	2 pounds
Orchard-grass	2 pounds

For poor land in the humid sections, the following is often used because it is cheap:

Timothy	3 pounds
Redtop	5 pounds
Alsike clover	5 pounds
White clover	2 pounds

Kentucky blue-grass is the most popular of all single pasture plants. The long dry periods encountered in dry-farm regions prevent the formation of good pastures. Various experiments on dry-farms show that smooth brome-grass and rye are successful. Timothy has done best on the mountain ranges, with brome-grass second. Brome-grass has a deep root-system and forms a sod resistant to tramping. This, except that it does not sod strongly, is likewise true of alfalfa, which is sometimes used for dry-farm pasture, particularly when either the first or second crop promises to be too small to pay for cutting. Many farmers turn the animals on stubble to gather remnants which would dry up and be lost by blowing away. Pastures on dry-farms seem to be more suitable for horses than for other animals.

343. For different animals. — One reason why horses do best on dry pastures is that they need rather large fields which promote exercise. They do not feed so close to the ground as to injure the root-crowns of alfalfa. They can get on with less water than some other animals, but need it regularly. They do not bloat as do cattle and sheep.

Cattle need a more succulent feed, and more water, than horses; therefore, green pastures are more valuable, particularly for milch cows. Since cattle eat rapidly, they sometimes bloat, especially on alfalfa wet with dew.

For sheep small pastures used in rotation are recommended in order to keep down parasites. Fine feed is desirable; resistant sod is preferable, as they eat close and injure the roots of such plants as alfalfa, timothy, and orchard-grass. They bloat easily on alfalfa and some grasses. If there are no willows in the field, there should be sheds to provide shade.

Hogs like coolness and water. They do as well on small pastures, since they require little food at one time. Shade and water in the feed lot compensate for small area; this, however, does not imply that food should be scarce. Hull-less barley and peas, corn and rape, corn, rape, barley and vetch, oats and vetch, oats and peas, and barley make good crops on which to turn hogs. They also dig out root-crops to advantage.

Poultry do better when they have access to green feed. Grains and alfalfa are used most.

344. Condition of pastures. — It is a common practice to utilize land not easily handled in the regular cropping system for grazing. This land may be too rocky to permit the use of plows and other machinery. It may be water-logged or covered with water; covered with willows; rough and uneven; cut up by sloughs and low ridges; or filled with some native growth such as rushes. Sometimes the very extensiveness of a man's ownings renders it impossible to farm the land with the equipment he has. His livestock may roam at will over whatever part of the public domain is unreserved. A number of serious faults are here suggested. In addition, too many farmers permit bunches to develop and weeds to get a hold in a part, or all of the field. Some parts may be too dry, even when other parts are covered with water. Finally, many pastures are not yielding to their full capacity on account of a poor stand of plants.

345. Improving pastures. — The rocky and very rough areas will, for a long time at least, be left in pastures, as not much else can be done with them. Removing many rocks is rather expensive.

Draining will much improve meadows that are too wet either in the spring or throughout the season. Land that is water-logged in the spring is likely to suffer for water later in the summer because the water-holding capacity is lowered by puddling, and because a shallow root-system is produced by excess water. A combination of drainage and irrigation will remedy this condition.

Brush-lands generally need partial or entire clearing before they become good pastures. Firing, grubbing, and sheep or goat pasturing help to clear brushy districts. Rushes and sedges tend to give way slowly to the more valuable grasses after lands are drained. Plowing and resowing may substitute this slow method. The farms that are yet unimproved will gradually disappear with the development of the country, and the permanent grazing lands will be made to yield grain and other crops.

The bunches are rejected forage close to a spiny weed, such as a thistle, but usually near a manure dropping which seems to taint the grass or drive off the animals by its odor. Harrowing two or three times a year with brush-drags or spike-tooth harrows, or disking, loosens the soil and scatters the manure, making good fertilizer from that which in heaps was repellent. The harrow, supplemented by a grubbing-hoe, removes the weeds that cause cattle to leave grassy bunches.

Thin stands may be made thicker by harrowing and by sowing extra seed. Overstocking causes too close grazing, which injures the pasture as well as the animals. The remedy is manifestly one of prevention.

Fertilizers, particularly farm manure, increase the yield if they are well scattered. Finally, constant use, even when unaccompanied by overstocking, is bad. Alternating on two or three pastures will prevent this injury.

346. Overstocking. — The pasture, which requires but little attention, is regarded by many as clear profit, though the yield is small. The sooner this idea is thrown aside, the sooner truly successful pastures will be developed. A number of points deserving attention have already been indicated.

Overstocking is putting on the land a greater number of animals than the feed can maintain. The animals soon go short of the best feed, and under stress of hunger eat the coarse, perennial plant parts. Sheep and hogs eat root-crowns and occasionally the roots themselves.

Deforesting and heavy sheep pasturing have practically ruined some of the best ranges. In parts of the West, cattlemen have come to realize this and they now compel the sheepmen to keep their flocks away from designated districts. Forest reserves handle the situation by limiting the number of animals that may be pastured on the reserve. In excessive hunger during a snowstorm, for example, a herd of range cattle ate at the oak brush, leaving no branches smaller than an inch in diameter.

Practically the same thing happens in over-grazed meadows. At first the stand gets poor; then bare spots make their appearance; and, finally, the surface becomes tramped, rooted-up, and barren except in spots. Of course the animals cannot keep in good condition. The greedy owner loses on both the animals and the pasture.

347. Management. — Manifestly, the remedy for overstocking is to prevent the injury. Proper discretion must determine the number of animals that may pasture a field, and the time they should feed continuously. Strong sod will bear close grazing longer than will weak. Timothy, orchard-grass, and clovers, except the white, suffer immediately. Blue-grass, redtop, sedges, and rushes are rather persistent and will withstand considerable close feeding. It is not profitable to pasture too closely, however, except in an emergency.

It is doubtful whether pastures of the less persistent grasses should remain longer than a few years without being plowed. The plants may weaken, the soil structure break down, and parasites accumulate until the old sod is a menace. Some of the most successful pastures are a part of the farm rotation. In its turn, say every four to ten years, the pasture may be moved with advantage to the plant, the soil, the animals, and the farmer.

Horses should not always be pastured in one meadow and cattle in another. Feeding habits differ enough to be a factor in pasture management. With a large field, it is usually better to use only part of it at a time and rotate the animals if they are not to be mingled. Dairy cows should not be worried by horses nor be in contact with the wallows of hogs.

A part of the pasture should be allowed to go unused; it needs a rest. This permits the plants to grow up. Legumes and other plants that grow at the end of the stem demand this more insistently than the grasses, the leaves of which have their growing point near the base of the leaf-blade. They grow without starting from the ground each time as must other plants. Parts of the grass will not be eaten down. To encourage a fresh start, the mower should be run over these spots at least twice a year. Then the coarse stems make better hay when cut. In many cases horses and cattle will pick up the clipped stems, although they avoid them while standing.

Sometimes, early in the spring, grass is not as palatable as it is a few weeks later. Waste is often prevented by waiting before turning the animals into the field. The yield and palatability of young grass increase with age.

348. Meadows. — In general, meadows for the production of hay demand about the same attention as pastures. Drainage of the wet land, irrigation of the dry, the use of superior crops, the removal of weeds, the reseeding of spots that are killed, and the renewal by rotation all deserve intelligent practice. Less attention is paid to harrowing and crop mixtures. For hay, plants should mature about the same time, while in pastures they should mature at different times, except when the meadows are used for pastures a part of the year as many are.

The natural meadows, as already indicated, are being gradually replaced by cultivated grasses or other hay-crops, because these yield more hay of better quality. In river- and lake-bottoms, much land is still bearing salt-grass, sedges, rushes, blue-grass, and redtop, all cut for small hay yields. Many of these areas cannot be reclaimed on account of the expense in labor and capital, and, therefore, will persist as pastures for a long time.

SOILING

349. Use. — In sections of the United States that have to feed cattle from high-priced land, and where labor is cheap, pastures are being partly replaced by soiling. Animals are not pastured but are fed on green forage hauled to them soon after it is cut and before it has lost its moisture. Succulence is especially valuable for dairy cows and for stock being raised for beef.

In Germany, soiling is practiced generally, while in Denmark, the animals are tethered in the fields instead of being allowed to pasture. In both of these countries land is high-priced and labor is cheap. Land must be made to produce as much as possible, because extensive tracts are not available to the farmers, consequently waste about the edges of the fields is decreased in every way. Fences are commonly omitted, permitting all the land to be cultivated. Since the United States still has unused areas that may be pastured, soiling and tethering are not practiced, except locally. Some of the soiling crops are shown in Figs. 79 to 82.

350. Value. — Disadvantages of soiling are:

1. Much more labor is required to mow and feed the crop in small quantities each day than to pasture or cut the entire field at once.

2. Haying each day is a hindrance to other farm work and is inconvenient on that account.

3. In stormy weather it is very disagreeable to handle crops.

4. It is difficult to provide a series of crops that will supply continuous green feed throughout the summer.

Among the advantages of soiling the chief ones are:

1. Greater crop returns are had from an acre than from pasture. This comes about by allowing the crops

Fig. 79. — A good hog pasture of cowpeas and corn.

to grow until near maturity, by preventing injury to plants from tramping, and by avoiding a puddled condition of the soil due to animals moving about on it in wet weather.

2. There is less expense for fences necessary to pastures, and less waste of land along fence lines that grow weeds.

3. The feed is more economically used, since there is no fouling from manure heaps.

4. The cattle can be kept more comfortable when fed green forage than when exposed to the hot sun or to wind and storms in open pastures.

Fig. 80. — Sorghums are adapted to hot, dry climates.

5. Manure can be preserved and applied to the right crop in rotation, thereby conserving fertility.

6. In consequence, about three times as many cattle may be kept on a given area of land. Their gain in flesh is greater or their milk flow is kept more even than under other systems of feeding.

The disadvantages off-set the advantages in such a way as to cause the utilization of crops for soiling to be an

Fig. 81. — Sorghum yields abundant grain and forage. Kansas.

economic question. It may not be profitable as a general practice in the United States, but it is in many dairy sections.

351. Soiling crops. — Any one crop is not ready for soiling for more than one or two weeks. A series of crops needs to be carefully arranged in order to keep green feed constantly on hand. In alfalfa districts, this one crop can be kept ready throughout the entire season except in early spring, when it is watery. An alfalfa field mowed part at a time until full bloom is reached can be mowed over in the same order, yielding nearly mature feed for the remainder of the summer and fall. Alfalfa is, moreover, the best soiling crop known, because of its high-yielding power, its palatability, and its high protein content. It cannot be surpassed in districts where it grows successfully.

Green cereals cut in the milk, corn fodder, grasses, peas, soybeans, millets, sorghums, vetches, rape, clover, and cowpeas are used separately and in combination. A variation in time of planting changes the time of maturity to considerable extent, thus lengthening out the period of usefulness. A series of small areas may be planted to various crops so selected, planted, and arranged as to give a constant supply of green forage. As soon as the early crops are used, they should be resown or others planted to prevent the land's lying idle. Roots may assist in autumn.

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361. Meadow Fescue.
502. Timothy Production on Irrigated Land in the Northwest.
509. Forage Crops for the Cotton Region.

CHAPTER XXV

SORGHUMS AND MILLETS

THE sorghums and millets, a comparatively new and rather distinct kind of crop, have recently come to notice in the semi-arid sections of the United States. The United States Department of Agriculture found them growing in similar regions of the Old World and introduced them here as worthy of trial. The millets spread rapidly for a time. The sorghums are now replacing them slowly but surely save in a few districts.

Both are by nature dry-weather crops, offering possibilities on the dry-farm and even under irrigation. Perennial forage crops are favored in the West largely because of alfalfa's being so extremely well-adapted. In spite of this, there seems to be a need for annual drouth-resistant crops.

SORGHUM (*Holcus*, or *Andropogon, Sorghum*)

352. Origin. — No one will ever know exactly just where the group of plants we know as sorghums originated. Some evidence suggests Africa as the starting point, but other facts likewise indicate an independent origin in India. Many wild grasses, closely allied to the domesticated members of the family, are found growing wild in Africa — more, in fact, than in any other part of the world. The sorghums are shown in Figs. 80, 81, and 82.

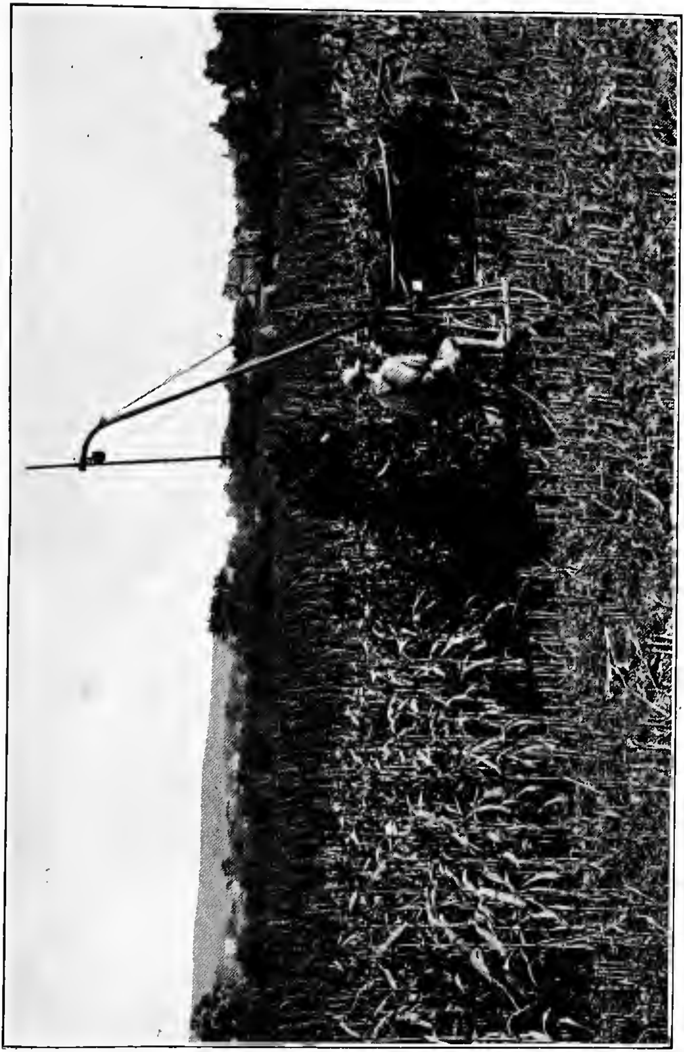

Fig. 82. — The corn harvester may be used for sorghums.

As crop-plants, sorghums are as old as any known. In Egypt they were grown when history was first recorded. They soon spread into Asia as far as Manchuria. Notwithstanding this, the Greeks grew no sorghum; neither did the Romans until shortly after the Christian era, when an importation from India took place.

As far as American experience is concerned, the history of the crop is brief. In 1853 Chinese sorgo (whence the word as we have it) was brought from France. In 1857, the United States Department of Agriculture introduced varieties from every part of the world where much was grown. The national government also encouraged the spread and trial of these varieties. Rather constant development has since followed in the regions adapted to the particular members of the family brought here, although the crop has not as yet become a major one. Its possibilities are potential rather than realized, that is, its promises are extensive, but its records narrow, on account of its having had but little chance to prove itself.

353. Relationships. — Sorghums belong to the grass family, being in many respects closely related to maize. Johnson-grass (*Holcus halepensis*) is a bad weed in the warmer parts of the United States. Vigorous rootstocks are largely responsible for the pestiferous habits of this plant. Not all Johnson-grass has rootstocks, since a few varieties of it are annuals, spreading only by seed. Then comes Sudan-grass and Tunis-grass, which resemble Johnson-grass and vary toward the sorghums. All of these are annuals, lacking rootstocks which cause perennial rooting habits. Sudan-grass seems to occupy a place of intermediate improvement between Tunis-grass and the cultivated sorghums.

354. Description. — Corn is so much like sorghum that by the ordinary person they would be mistaken for one another in early growth. Their root-systems are similar save that no brace roots are sent out by sorghum and that corn roots to a slightly greater depth. Three to four feet seems to be the commonly accepted depth for sorghums. An elaborate net-work of roots, however, occupies the first fifteen to twenty inches of soil.

Sorghum stems are jointed and filled with pith which in some varieties bears juice rich in sugar. The height varies from two to a dozen or more feet, but four to eight feet is common. Ordinary sorghum is usually not less than one inch or more than two inches in diameter. Stalks sucker readily, especially if cut before they are mature.

The leaves are not so abundant as on corn, but they are thicker and show a decided tendency to roll into upright cylinders in severe drouths. Rolling probably lessens transpiration materially by reducing the surface that is exposed to evaporation. Leaf sheaths, in some cases, clasp the stem well beyond the next node, presenting a more continuous covering than does corn.

After the tasseling period, sorghum differs widely from maize in appearance and growth habits. No ear develops. Its tassel flowers are perfect and the grain develops in the head, which may be a compact, spike-like aggregate or an open, broom-like panicle anywhere from three to thirty inches, — sometimes drooping, sometimes erect.

The main stem branches into a number of pedicels, which branch again. Seed, borne at the end of these, is rather globular and hard. In color, it varies from white through yellow, brown, and red to nearly black. Some kernels are flattened while others are almost spherical. Some varieties have seed less than one millimeter in diameter, others nearly a centimeter.

These variations are widest between the types used for different purposes. Just as corn varieties fall into six groups, or types, sorghum varieties naturally group themselves into three distinct types according to the purpose for which they developed.

355. Varieties. — Though other classifications are often made, the sorghums are commonly classified as (1) sweet sorghum, (2) grain sorghum, and (3) broom-corn. Particularly adapted for sirup, grain, or whisk production, each type is used for forage and grain. On account of the comparative infancy of the industry, sorghum production has not become nearly so specialized as corn- or fruit-growing in regard to selection of varieties for different purposes; yet, there is a general adaptation of varieties that cannot be ignored.

Sweet, or saccharine, sorghum is grown primarily for sirup and sugar. For that purpose, sorgo, as it is called, was brought to the United States. The sudden growth of the beet-sugar industry, however, offered a more economical means of procuring sugar. Shortly afterwards sweet sorghum proved the most valuable type for forage. The sweet sap seems to give it a palatability not found in other groups. The stalks are fine and leaves more abundant than in other kinds. The seed is small, with distinct red or dark brown color and borne in loose panicles. Amber, Orange, and Sumac are the most extensively-grown varieties; Red Amber, Planter's Friend, and Gooseneck are also worthy of mention.

Those varieties used for grain have little, if any, sweet juice in the pith, and they are coarser than the saccharine type. Shorter nodes, fewer leaves, larger kernels, and more clear-cut sheathing characterize grain sorghums. The heads are generally compact and white, yellow, or dark brown. Kafir, milo, feterita, durra, shallu, and kowliang are most common varieties. Milo and kowliang mature earlier than kafir — in about ninety to one hundred days. Not only are the kernels used for grain, but the fodder is used to some extent for forage.

Broom-corn is distinguished by the long brush on which small seed is borne sparsely. Since this type is grown for whisk, the length and evenness of the pedicels are primarily important. Standard broom-corn, which is generally about twelve feet tall, bears brush from eighteen to thirty inches long. A shorter brush from twelve to eighteen inches in length is produced on a smaller plant which is known as dwarf broom-corn because of being only four to six feet in height.

356. Distribution and adaptation. — As might be expected from a plant of tropical origin, sorghum is naturally adapted to a region of warmth and abundant sunshine. By choice of varieties or from having been grown for centuries in arid regions, it has come to prefer a dry atmosphere. Greatest yields are, of course, obtained where moderate moisture is available, but it can be successfully produced in comparatively dry districts. It is rather drouth-resistant in sections similar to South Africa and the Great Plains section of the United States. Piper [1] says, "No degree of summer heat seems too intense for the sorghums, but they are injured both in spring and in fall by light frosts."

Grain-sorghum varieties mature in such short growing-seasons that they are able to mature in South Dakota and southward. Some forage varieties do well in Minnesota and Ontario. Rapid growth coupled with drouth resistance enables this crop to produce more economical grain and forage than corn on the Great Plains where rainfall is less than twenty-five inches, though corn has not been replaced to any marked extent where the annual

[1] *Forage Plants*, p. 262.

precipitation exceeds this. The best area for sorghum in America begins in about the same longitude as does that of dry-farm wheat. The considerable resistance to alkali that is manifested by sorghums as a class should also hasten the spread of the crop in arid regions.

Nearly all arid regions of the Old World grow sorghum, with Egypt, South Africa, Australia, India, and northern China leading in total production. The order of importance cannot be ascertained, since statistics are unavailable partly because much of the crop which is used for forage is fed without being measured. In the United States, moreover, statistics are unreliable when it comes to details. Kansas is far in the lead, producing perhaps half the entire crop. Nebraska, Oklahoma, Texas, Colorado, and California grow small acreages. These states and Utah — perhaps some others — have large tracts of new land that could be made to produce sorghum economically. In some cultivated sections, other crops might be replaced profitably. Many trials by farmers and Experiment Stations must precede a definite statement as to where the crop will succeed or fail. Roughly, however, vast promise lies in the undeveloped possibilities of sorghums in dry regions west of the ninety-eighth meridian. This, of course, implies that selected varieties be tested as was suggested for corn. That some tropical sorghums have required more than seven months to mature when grown in Florida shows how essential the use of adapted varieties is to successful production.

Soils should be well-drained and porous to permit root penetration. Sorghums have a reputation for being "hard on the land" by causing the crop that follows to yield lightly. Some persons think this is due to the power of the plant to dry the soil considerably below the wilting point of other crops. Careful preparation of the seed-bed lessens the injury, which may be due to an exhaustion of readily-available plant-food. Poor soils, too, are often used to grow the sorghum crop, not that the plant prefers naturally the difficult soils and dry climates, but that it is hardy under adverse conditions.

357. Preparation of seed-bed and seeding. — In preparing the seed-bed, the same precautions are taken as for corn except that soil ought to be made finer. The best time for planting is after all danger of frost has passed and the soil is warm.

Grain crops are always drilled in rows from eighteen to forty-eight inches apart. More often corn-planters are used with special plates or with holes partly stopped to govern the rate of seeding. Seed is dropped from six to ten inches apart in the row. From three to five pounds will plant an acre at this rate.

Forage crops are planted either in rows or broadcasted at the rate of from fifteen to forty pounds an acre. Under most favorable conditions two bushels are planted. Dwarf broom-corn is planted three feet between rows and two inches apart in the row, while standard varieties do better in rows three feet six inches apart with seed at three-inch intervals in the row. Uniformity of stand gives uniformity of brush, which is highly desirable since both too coarse and too fine whisks are less valuable than the normal.

358. Treatment during growth. — Because seedlings are sensitive to soil or moisture, weeds injure them severely, and since they are tougher to mechanical contact than corn, more frequent and later cultivation may be given, and is, indeed, required. Intertillage with one-row cultivators keeps down weeds and mulches the soil until flowers appear. Listing is also practiced in some cases.

359. Harvesting. — When fully mature, the grain crop is cut either with a corn-binder, with a sled-cutter, or by hand. Thorough drying before threshing prevents heating of the grain. Curing is most easily accomplished in shocks which are built wide at the bottom to keep the heavy-headed grain from falling over. The bundles are either run through thresher or the heads run in and the stover withdrawn and shocked or stacked until used for rough feed. Occasionally the farmer heads the plants — particularly dwarf strains — by hand or machinery and threshes only the heads. The stalks are pastured or harvested separately.

Yields as high as seventy bushels an acre occur, though twenty is more common and forty is good. In years so dry that corn fails, sorghum has given twelve to twenty-bushel yields.

Forage is cut green, silage in the soft dough, and fodder just at bloom. Corn-binders cut large areas more cheaply than hand-labor. Hay is made sometimes by broadcasting thick stands, cutting with a mower, and curing as grass. In this case the stems ought not to exceed the thickness of a pencil and should be cut before blooming.

Acre-yields varying from ten to forty tons of green feed have been reported. Fifteen to twenty tons are taken off the land frequently. In cured hay or dried fodder, the returns net from two to eight tons in from one to six cuttings depending on the season and moisture available.

The whisk of dwarf broom-corn is pulled from the stem at the upper node and removed from the field at once. In standard varieties, the stems are cut partly through two feet or so above ground and two rows bent across each other making V-shaped platforms, or "tables," of crossed stalks. The "brush," as the whisk is called, is now cut off and placed on the "tables" to dry. After being cured in sheds, it is made into bales of 300 or 400 pounds. Sometimes seed is allowed to ripen, but this lessens the value of the whisk more than it increases the value of the grain. In both cases threshers remove the seed from the brush, which is thrust against the cylinder and then withdrawn. From two hundred to seven hundred pounds of cured brush represent ordinary returns from an acre.

When grown for sirup, sweet sorghum matures in the field. While still standing the leaves are stripped off; heavy rollers press the juice from the culms. Heat and settling clarify the juice of impurities. Warming in shallow pans concentrates the sirup to the desired consistency of 30 per cent moisture. About half or two-thirds of the juice presses out in a good mill, a ton yielding from 700 to 1200 pounds of juice which concentrates from ten to thirty gallons of sirup. From five to fifteen tons of stems grow on an acre.

360. Use. — Sorghum grain is used only for stock-feed in America, though in Asia and Africa it is an important human food. The grain is starchy and hard. Unless crushed, fed wet, or mixed with other feeds, a part of it escapes digestion. Eighty to ninety pounds of corn equal one hundred pounds of sorghum in feeding value. If fed alone, the grain has a constipating effect, which is relieved by the accompanying protein feed necessary to balance the ration. Colored seed is sharply bitter, due to tannin. Poultrymen prize the grain highly for their fowls.

The dry stems and leaves of the sorghum make fair roughage. As silage, sorghum nearly equals corn; as hay it ranks about the same as oats, wheat, or barley. It is cut for hay with mowers or binders. Stock may pasture considerable quantities of feed from green fields, since under favorable conditions it makes several growths and suckers freely. One serious danger, however, besets its use as pasture. After being stunted by excessive heat and drouth, prussic acid, a virulent poison, sometimes develops in the leaves or stems. This will kill stock in a few minutes. Exactly what conditions cause poisoning is not clear, but it seems that if the plant is kept growing, there is no danger. The dried fodder does not injure stock.

Sirup manufacturing is not widely practiced. The demand for whisk supplies for the manufacture of brooms encourages broom-corn production. Illinois, Kansas, Missouri, and New York produce 80 per cent of the whisk crop.

361. Enemies. — Kernel smut attacks individual seeds. Formalin seed treatment lessens the injury. Head smut covers the whole head and has not been successfully treated. Blight may kill the leaves. Selection of resistant varieties can probably control it.

In Texas, the sorghum midge does considerable damage to the heads. Corn ear-worms, fall army-worms, chinch-bugs, and sorghum aphids do some damage. Wise cultivation will largely control insects and plant diseases as well as weeds.

362. Storage and marketing. — The brush from broomcorn is marketed in a number of grades at one to six cents a pound depending on the length, uniformity, flexibility, and color of the whisk. Careful drying, sweating, and baling are essential in curing for quality, since the high moisture content renders molding and discoloration likely. Grain, fodder, and silage are handled as is corn, but very little gets to market. It is primarily a local crop. Not even the sirup, which is a farm delicacy and not a market product, gets far away.

SUDAN-GRASS

363. Description. — Sudan-grass, an annual sorghum, a native of Egypt, came to the United States in 1909, and does well on the Great Plains from South Dakota to Texas. Maturity is reached even in Canada. It stools abundantly, grows from four to ten feet in height, has the drouth-resistant qualities of the other sorghums, and has done well under irrigation in Colorado and California. It is grown only for hay or pasture. Sudan-grass resembles Johnson-grass save that it has no rootstocks. The stems are fine, leafy, and erect, producing from one to five tons of fair hay that any stock may eat safely, though the same troubles that occur with sorghum are possible when the second growth is pastured.

364. Culture. — Best results are attained from sowing after the ground is warm enough for corn or for grain sorghums. Planting may be done either in rows or by broadcasting. Three pounds will plant an acre in rows; fifteen to twenty-five pounds, an acre when drilled or broadcasted. Hay of the best quality is secured when grain is cut in full bloom. Mowers and binders are both used to cut the grass. Since seed yields up to 1500 pounds an acre, and since the seeds are small, the plant is extremely prolific but is not a bad weed because it is only an annual. Care should be taken to avoid planting seed in which Johnson-grass is found. To prevent this, the seed-plots must be clean.

MILLETS

The millets, like sorghum, are very important in India and China for human food, but they have found no use in America except for forage. Austria, Italy, and Balkan

Europe use them extensively for forage. They grow well in dry, hot districts with short seasons, sometimes maturing in forty to fifty days. They do well wherever sorghum pays, and will grow farther north, but they have several faults which confine them to districts where sorghums cannot mature sufficiently, and which cause them to be used only as catch-crops when it is too late to start more valuable plants. More than a million acres are grown, but cultivation is diminishing rather than increasing.

365. Relationship and description. — The millets include ten different species in five or more genera. The most common valuable type is the foxtail millet (*Setaria italica*). In this group are common, German, Italian, and Hungarian varieties. Other types are broom-corn millet, Japanese barnyard millet, and pearl millet. Foxtail millet is closely related to the common weed, green foxtail (*Setaria viridis*). It was cultivated in prehistoric times. Chinese records mention it about 2700 B.C.

The plants are annual grasses, very leafy, growing from one to four feet tall. The heads are from two to eight inches long in rather compact spikes which in some varieties are distinctly lobed. The seed is yellowish, about one millimeter in diameter, with the hull boxed around the grain. Numerous bristly hairs project outward from the spike.

366. Culture and value. — From two to four pecks of seed are sown to the acre, usually with drills. Row-planting is used occasionally for seed production. The slightest frosts kill millet; hence late planting pays. Any time in June seems favorable.

Quality in the hay deteriorates rapidly after full bloom, when the yield and quality are both greatest. For cattle, millet hay is about equal to grass, but is inferior to clover and alfalfa. Horses suffer in several ways from continuous feeding of millet hay. Action of the kidneys and bowels increases; joints swell and get lame; bony texture weakens. Wisdom suggests that cattle as well as horses be fed mixed roughage rather than straight millet.

Seed crops yield from fifteen to fifty fifty-pound bushels an acre. Just before maturity, binders cut the seed crop, which cures in the shock. Ripe heads shatter badly. Ordinary threshers are used to separate the seed from the straw.

A smut attacks the seed, but it can be destroyed by the formalin treatment that is used on seed wheat. Chinch-bugs are fond of millet, which, for that reason, is often used as a trap crop to be plowed under when the insects have collected on the plants.

367. Other types. — Japanese barnyard millet is coarser than foxtail millet, has branched heads, and is used for soiling, but does not cure readily for hay. It is grown widely for food in China, India, and other parts of Asia.

Broom-corn millet has a brush-like head and larger seed than the common type. It grows as a cereal crop in Russia and also to some extent for forage. The Dakotas and Manitoba produce considerable, which is also used mostly for forage.

Pearl millet, sometimes called penicillaria, is twice as large as other millets, has a rather woody stem filled with dry pith, and bears seed in a compact cylindrical head from which it has been called cat-tail millet. It is rather coarse and dry for hay. In the South, its immense yields of green forage make it and teosinte, another annual very similar to corn, popular for feed. As much as fifty tons to the acre of green fodder has been cut in one season from each of these crops.

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288. Kafir Corn.
322. Milo.
448. Better Grain-sorghum Crops.
458. The Best Two Sweet Sorghums for Forage.
552. Kafir as a Grain Crop.
605. Sudan Grass.

CHAPTER XXVI

FIBERS AND MISCELLANEOUS CROPS

THE world is so wide; soils are so different; climates vary in so many respects; there are so many kinds of plants with varying habits of growth that the plants grown for the use of man and beast are almost without number.

FIBERS

Both the plant and the animal kingdoms furnish fibers which are used largely for clothing, carpets, rugs, ropes, nets, cordage, and bags. Vegetable fibers consist almost entirely of cellulose, while animal fibers have sufficient nitrogen in them to give off, when burnt, an odor characteristic not only of wool and silk, but of hair and flesh. A white ash remains after the burning of vegetable fibers, but animal fiber burns to a crisp char that usually curls.

Vegetable fibers may be woody, bast, or floral. The wood and bast fibers are borne in the interior of the plant, bast in the inner bark, and wood in the deeper tissues of the fibro-vascular bundles. Bast fibers such as flax and hemp, and floral fibers such as cotton are by far more important for textiles than the wood fibers. Leaves also yield some fiber, as in the case of sisal and manila hemp.

COTTON (*Gossypium hirsutum*)

368. History. — Cotton cloth is cheap and practically all people wear some cotton. This has not always been the case. A century ago wool and silk were the common textiles.

Cotton had been grown for centuries in China and for a shorter period in India and Egypt, and being a native of the New World, for an unknown period of time in Peru and other parts of America. Not until the beginning of the nineteenth century, however, did it count for much as a world crop. Introduced into the Southern States, it thrived and was cultivated on a small scale before the Revolution. Washington and Jefferson grew it with the help of slaves who separated the lint from the seed by hand. When Eli Whitney's cotton-gin proved successful, cotton-growing spread rapidly. It has supported most of the people in the South, supplied a livelihood for millions in northern factories, and helped to build an immense foreign trade. On the other hand it was one of the big factors in intensifying the misunderstanding that led to the Civil War.

369. Relationships. — Hollyhock is the most common plant that is closely related to cotton; the mallows are also in the same family. In the same genus are five species of cotton: (1) Upland, (2) Sea-island, (3) Egyptian, (4) Peruvian, and (5) Bengal, or Indian. Of these long- and short-fibered upland or long- and short-staple cotton comprise most of the commercial fields in America. Some Sea-island is grown, however, in the tidewater regions, particularly in Georgia. The chief difference in the species is length of fiber, which varies from one-half inch in short-staple to two and one-half inches in Sea-island, long-staple producing a fiber of intermediate length.

Altogether there are several hundred varieties of cotton. These are grouped into eight types or variety groups: (1) Cluster, (2) Semi-cluster, (3) Rio Grande, (4) King, (5) Bigboll, (6) Long-limbed, (7) Intermediate, and (8) Long-staple Upland. These names, in general, indicate growth habits or growth regions. Jackson, Hawkins, Peterkin, Layton, Toole, King, and Allen Long-staple are standard varieties.

370. Description. — Cotton has a deep-rooting habit, but also sends numerous horizontal branches in the upper three inches of soil. The stem is solid, woody, considerably branched, and from three to six feet long. The leaves are broad, three-lobed, and palmately-veined, while the flowers are usually white or yellowish containing a pistil with a divided stigma and a compact group of stamens bearing waxy pollen. Though naturally cross-fertilized by insects, the flowers are capable of self-fertilization. Small stems arising from the main branches or sub-branches bear the flowers and later the boll, which is a heavy pod containing the lint and embedded seed. Under a microscope, mature lint shows a definite twisting, perhaps due to drying of the tubular fiber. This twist roughens the surface of the lint strengthening the grip one fiber gets on another when it is made into thread. Each fiber, a single cell, is a product of the flower. It surrounds the seed, which is about one-fourth inch in diameter. A coat of oil that covers the lint must be removed before cotton is dyed or before it is made into absorbent cotton.

371. Adaptation. — Cotton will grow in most soils; clays and loams, moderately dry and well-drained, are most favorable. Moderate moisture and frost-free seasons from six to seven months in duration encourage the best growth. Because these conditions exist in the Southern States as nowhere else, it is this section that produces most of the cotton of the world. Of twenty million 500-pound bales, the United States produces 12 million, India 4 million, Egypt 1.3 million. The other 7 million bales are the combined harvest of Brazil, Peru, Mexico, Turkey, and China. Texas, Georgia, Mississippi, Alabama, South Carolina, Arkansas, Oklahoma, North Carolina, and Louisiana produce 96 per cent of the American crop and rank in the order named. So exclusively does Texas grow cotton that 40 per cent of her improved land is devoted to this crop.

372. Culture. — It is a practice, common but unwise, to grow cotton on a field several years in succession. The stalks are broken and plowed under or burned. "Beds" are made by turning two furrows toward each other every three to five feet, the spaces often remaining unbroken until the first cultivation. Seed at the rate of one-half to one bushel an acre is drilled into these beds by a one-row planter after a shallow furrow is opened. When the plants are well started, dirt is thrown away from them and they are "chopped out" until the plants are left one or two feet apart in the row. From one to five cultivations are given, generally shallow, to avoid cutting the roots, which are abundant near the surface.

Much of the cultivation has been done with one-mule plows and poor machinery, but recently two-row cultivators, good harrows, and efficient plows have been introduced into many sections. Extensive cultivation without rotation and without barnyard fertilizer has resulted in the ruin of many fields in spite of the fact that lint and oil cause no drain on mineral fertility. Cottonseed meal and commercial fertilizers are used to some extent; diversified farming, rotation, and better culture are badly needed.

Boll-weevils and bollworms have caused much damage; cotton wilt and root rot, both plant diseases, injure the crop considerably. Better farming methods through education of the farmers — Negro and white — will bring success in pest control, progress in industrial activities, and better citizenship.

373. Harvesting and marketing. — As soon as the bolls open, men, women, and children begin picking by hand. Machines are used to some extent, but since the cotton bolls do not ripen at the same time, and since the machines injure the plants, they are not widely used. After picking comes ginning, which consists of separating the seed from the lint by means of revolving teeth.

The lint is bound in bales of approximately 500 pounds and covered with coarse bagging. Buyers take a large part of the crop at harvest, although some farmers, singly or in coöperation, hold their crop in warehouses for a more favorable selling time. Previous to long shipment, the bales are pressed into about half the volume of the original bales.

Variation in length of fiber causes a variation in price, usually from eight to fifteen cents a pound, though some years as little as 5 cents has been realized. In 1914, much of the crop could not be sold on account of a war in Europe cutting off a large part of our export trade of cotton, which ordinarily exceeds that of all other crops combined.

374. Use. — Cloth factories in the United States, England, Germany, France, Belgium, and Holland depend largely on American cotton for raw fiber. Oil is also taken from the seed, leaving oil-cake that is valuable for stock-feed; the bolls and coarser seed products mixed with the oil-cake and ground are used for nitrogenous fertilizer. A fine fuzz called linters, removed from the seed by special ginning, is used for making carpets and twine.

Some feed value is left in the stalks, which may be browsed. Burning the stalks is bad practice, unless necessary in insect or disease control, because they add organic matter to the soil when plowed under.

FLAX (*Linum usitatissimum*) (Fig. 83)

Flax has been grown from the earliest times as a fiber crop. Priests used it for their robes and for wrapping mummies, and the people made clothing from it in both Palestine and Egypt long before the time of Christ.

375. Description. — The plant consists of a slightly branched tap-root; a slender stem from one to three feet long, either simple or branched according to whether it is in thick or in thin patches; linear lanceolate leaves that are alternate and nearly sessile; beautiful, five-parted, delicate blue flowers; or a globular pod filled with ten flat-oval, russet seeds rich in oil. The bast fiber, or linen, is separated from the stem by "retting."

376. Adaptation. — Flax will grow on any kind of good soil in climates that permit the successful production of wheat. Russia produces two-thirds of the fiber flax of the world; Austria-Hungary, France, Belgium, and Holland grow most of the remaining third. The crop of the United States, grown largely for seed, is produced almost entirely in the three states: North Dakota, Minnesota, and South Dakota. Since many states in wheat areas have flax-growing possibilities, the crop will probably spread much. Like the United States, Argentina grows flax for seed, producing 34 per cent of the entire seed-crop. This exceeds the production of any other country. Russia is third and the United States second in importance.

377. Culture. — Most of the flax crop in the United States is produced on newly-broken ground before any other crop is sown. After plowing, the land is smoothed and two or three pecks to the acre planted one or two inches deep by means of grain drills. Little treatment

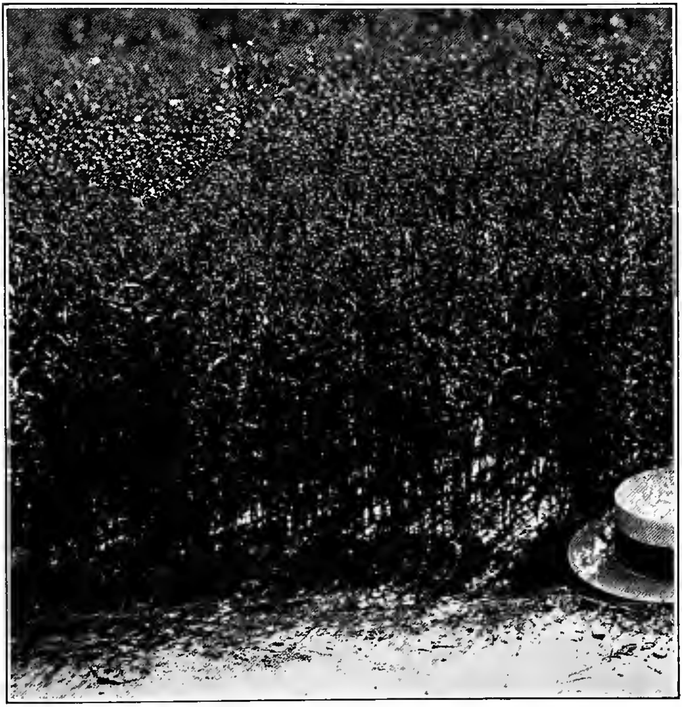

FIG. 83. — A good crop of flax seed. Wisconsin.

before harvest is given. The seed and fiber crops are harvested differently.

Seed flax is cut with a grain binder and threshed by an ordinary threshing machine. For fiber, the flax is pulled by hand, tied in bundles, and cured in shocks. The next process, retting, consists of spreading the stems thinly on the ground and exposing them to dew or water for three or four weeks. This loosens the fiber, which is removed by pounding with mallets or by bending in a machine. A thorough beating with wooden paddles completes the separation, after which combing separates the long fiber (flax line) from the short (tow).

378. Use and value. — Linseed oil, used in the manufacture of paints, varnishes, medicine, oilcloth, and linoleum, is extracted from the seed by crushing, heating, and pressing or by treating with naphtha. Residues, pressed into oil-cake or ground into linseed meal, are valuable for stock-feed. The straw contains some feeding value, and also a little brittle fiber that can be made into coarse bagging or used for packing in upholstery.

Well-cured fiber makes a cloth that is valuable because of its strength and uniform whiteness; because it does not fray in laundering as does cloth made from cotton or wool; and because it takes starch well. For these reasons, linen is used for collars, cuffs, other apparel, and for household articles that must be of spotless white.

OTHER FIBERS

379. Hemp (*Cannabis sativa*), which is related to the mulberry and the "mock," or osage orange, yields some coarse fiber for ropes, burlap bagging, and matting. The best crops are produced in corn-growing sections that have a moist, fertile soil rich in lime. Though other sections have favorable soil and climate, the blue-grass regions of Kentucky and Tennessee, and parts of New York and Nebraska as yet produce most of the crop.

The stamens and the pistils are borne on different hemp plants. Staminate plants branch less than the pistillate, and on that account yield a better fiber. Both kinds of plants vary from three to twelve feet in height. A tap root-system, a strong stem, and deeply-serrated leaves ending in a cluster are characteristic of the plant. Oval seed, about one-eighth of an inch in diameter and covered with a hull, are borne at the top.

From four to six pecks of seed are sown to the acre, just before corn-planting season. Little cultivation is necessary, as the plants usually smother weeds. When ready for harvesting, the crop is cut with mowers and binders, or by hand if it is too large for machinery. The separation of fiber from the stem is similar to that of flax.

380. Miscellaneous fibers. — Manila hemp, or abaca (*Musa textilis*), in the same genus as the banana, is much grown in the Philippine Islands for strong fiber out of which rope hawsers or cables, and high-grade binder twine are made. The plant requires abundant rainfall, considerable warmth, and well-drained soils. The leaf-sheaths of the plant furnish the fiber, which the natives get by scraping off the pulp.

Sisal (*Agave rigida*), in the same genus as the century plant, furnishes a fiber used for twine and for mixing with manila fiber in cordage. The leaves are crushed by machinery to loosen the hard strands. It is not very useful in marine service because salt water markedly decomposes it.

A number of other plants producing fibers are grown in various parts of the world: jute in India; maguey in Mexico and Central America; istle in Mexico, New Mexico, and Texas; and New Zealand hemp in New Zealand.

MISCELLANEOUS CROPS

Many other plants are grown wherever and for whatever purpose man desires them. He cares not what family they are in, nor what kind of plants they are, provided he can make some use of them. The use may in some cases be harmful, but this makes no difference; if he wants the plant, he grows it as a crop.

381. Cabbage (*Brassica oleracea*), **and kohlrabi** (*Brassica oleracea* var. *caulo-rapa*) are used to some extent for feeding in isolated districts. Kohlrabi, not widely grown

FIG. 84. — Cabbage as a field crop. Delaware.

in America, is an enlargement of the stem, while cabbage heads are massed leaves. Kohlrabi is sown, thinned, cultivated, harvested, stored, and fed in the same way as rutabagas; in yield and feeding value it is also very similar to the rutabaga. Cabbages are commonly sown in hot houses and transplanted in May or June two or three feet apart in hills with rows equally far apart. For feeding, the crops may be seeded thick in fields after the last frost and thinned later. Their chief use is for human food, though in some sections, they are grown for stock-feed, yielding occasionally as high as forty tons of forage to the acre. Cabbage is valuable for milch cows, but is rather difficult to cure; as pasturage it serves both cattle and sheep very well. A cabbage field is shown in Fig. 84.

382. Rape (*Brassica Napus*) grows from two to four feet tall sending out many broad, succulent leaves in early growth. Sown broadcast at the rate of three to five pounds an acre, it will keep down weeds; it yields most in rows two to three feet apart. It may be sown in late spring or during early summer either alone or with grain. Sometimes it is planted two or three weeks after grain, leafing out abundantly when the grain is cut. Sometimes it is sown between corn rows after cultivation has ceased. It is valuable for hog or sheep pasture, but is not cured for dry forage. Yields are rather heavy. Dwarf Essex is the usual variety.

383. Kale (*Brassica oleracea*), a headless cabbage, furnishes considerable winter soiling in the coast region of Washington and Oregon, being cut for green feed during the mild winter. The yields vary from ten to thirty tons of green forage an acre, with fifteen to twenty tons common under favorable conditions. This slightly exceeds the yield of rape. Since all the mustards feed heavily on mineral food of the soil, fertilizer is beneficial in considerable quantities. Farm manure in the West and commercial fertilizers in the East and in the Old World are used to supply these demands.

384. Enemies. — Although intensive culture should easily control the weeds, some insects and the disease club-root, common to the whole family, are by no means easily eradicated. The club-root (*Plasmodiorpha brassi-*

cæ) fungus develops inside the root, distorting it and causing the plants to die. The spores live in the soil awaiting a chance to attack other roots. Long rotation is the only method of control known for soil once infested.

The cabbage-root maggot (*Pegomyia brassicæ*) lays its eggs near the root, and the maggot riddles the root causing the plants to look sickly and then to die. One method of control is to place a spoonful of carbon bisulfide in the soil four to six inches from the plant, and to compress the soil tightly over hole. The liquid becomes gas and penetrates to the maggots.

Paris green or arsenate of lead, used as for potato bugs, that is, sprayed on young plants, aids greatly in controlling the green cabbage worm (*Pieris rapæ*). Plowing as soon as the crop is removed also helps considerably.

The cabbage aphis (*Aphis brassicæ*) feeds on the leaves and but for parasitic enemies would be decidedly injurious to all crucifers. It is best handled by thorough spraying with tobacco solution ("black-leaf 40") one part in four hundred of water.

Flea-beetles, cabbage loopers, cabbage webworms, cross-striped cabbage worms, diamond-back moths, and cabbage curculios do damage in various ways. The method of control is largely one of prevention by means of culture and rotation. Any good manual gives insecticide treatments.

TOBACCO (*Nicotiana Tabacum*)

Some plants have always supplied man with drugs which he has chosen to use for remedies, stimulants, or narcotics. Opium and cocaine were used for a long time to soothe, stimulate, or deaden nervous response. After the discovery of America, tobacco became the chief sedative plant, and it has gradually come into use the world over. People smoke or chew it, or use it for snuff. It finds some use as an insecticide and germicide, but this is of minor importance compared to its use in satisfying the "tobacco habit." The alkaloid poison nicotine is responsible for its narcotic effect on the nervous system.

385. Distribution. — Extreme sensitiveness to soil conditions limits the production of tobacco to small areas. Each of the several types thrives only on a certain kind of soil. Isolated districts from Connecticut to Texas produce tobacco, but more than half of the crop of the United States is grown in Kentucky, Virginia, and North Carolina.

386. Culture. — Virgin soil or sod land is most favorable for tobacco cultivation. Even on these, however, the plants are transplanted from seed-beds, which are necessary on account of the extreme smallness of the seed. The soil for the seed-bed is thoroughly fined and usually sterilized to a depth of three or four inches by burning brush or logs on it. Weed seeds are thus killed. In March or April, the seed is broadcasted crosswise and lengthwise of the seed plot to insure even distribution.

When the plants are nine or ten weeks old, they are transplanted from one to three feet apart in rows two to four feet apart. Frequent cultivation keeps down weeds and at the same time mulches the soil. During growth, the upright stem and upper leaves are cut off to stimulate growth of the remaining leaves. Both field and shade culture are practiced. Shading consists of a framework over which is placed thin cotton or laths short distances apart. These shut out a part of the light, thereby causing the leaves to be thin and soft.

387. Curing and marketing. The leaves are either pulled separately as they ripen or harvested all at once by cutting the whole plant. Curing requires steady drying that keeps the leaves pliable. Large barns are filled with the leaves hung over laths. Slow fires are often used to hasten curing in wet weather.

When well cured, the leaves are uniformly brown and not brittle. On a damp day, they are stripped off the stem and tied in bundles. These are later made into larger bundles and allowed to "sweat." If warehouses are near, the loose bundles are sold, but if shipping is necessary, the tobacco is packed in large hogsheads. Since carefully-graded leaves bring the best price, considerable care is exercised to separate leaves of different quality and to place only one grade in a package.

388. Sugar-cane. — About half the sugar of the world is made from sugar-cane (*Saccharum officinarum*), which is produced only in tropical and semi-tropical countries.

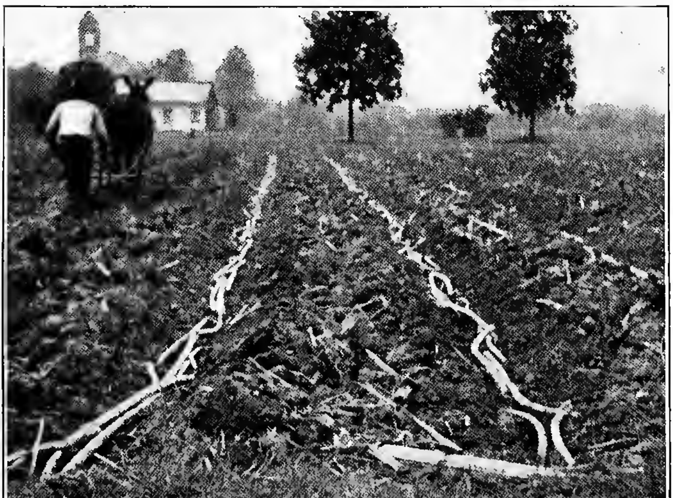

Fig. 85. — Planting sugar-cane. Louisiana.

British India, Cuba, Java, and Hawaii are the chief producers. Louisiana and Texas produce all that is grown in the United States. Alluvial soils along the lower Mississippi supply abundant moisture and, therefore, produce good yields.

Sugar-cane, which is a perennial, has plume-like tassels, bears no ears, has buds at the nodes, and resembles corn in size, nature of stem, leaves, and root-system. The buds grow when the stalks are covered with moist earth, as they are when a new crop is started (Fig 85). After planting, sufficient cultivation is given to control weeds.

Chemical analyses indicate the time for harvest by showing when the sugar content is highest. The cane is stripped of its leaves, topped in the field, and cut close to the ground with large knives. Since the sugar content lowers soon after cutting, the cane is taken at once to the factory, usually on cars. Heavy rolls crush the stalks, squeezing out the juice, which is made into sugar by much the same methods as beet juice.

389. Sweet potatoes. — Most of the sweet potato (*Ipomœa Batatas*) crop of the United States is grown in the South. Loose, friable soils favor best growth of the enlarged roots which are the edible plant parts. Cultivation is very similar to that given "Irish" potatoes. Shoots from the roots are transplanted for a new crop (Fig. 86). Since frost injures the crop readily, the plant is harvested before cold weather sets in.

Sweet potatoes are used almost entirely for human consumption, forming in the South a more important article of diet than the common potato (Fig. 87). They are fed to hogs to some extent and the fields are used for pasturing hogs, which are turned in to "root" out the potatoes.

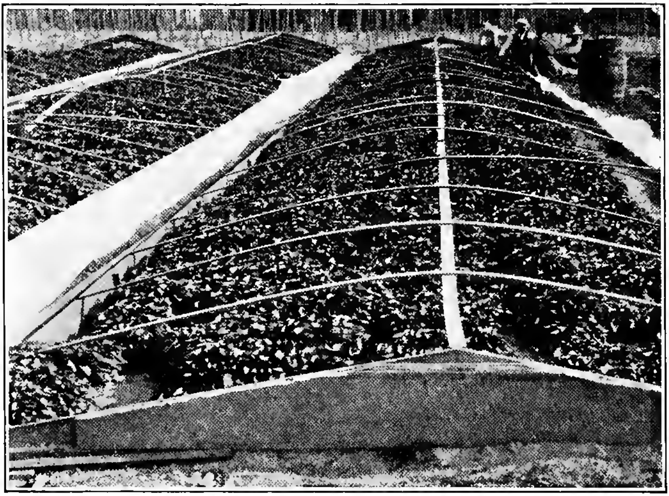

Fig. 86. — Sweet potato plants started in a plant-bed.

Fig. 87. — In the South sweet potatoes are an important crop.

390. Fruits. — Apples, peaches, pears, cherries, citrus-fruits, and small-fruits are all grown extensively in various parts of the country on such large areas that they might rank as field crops, though, of course, they are classed as horticultural products. Formerly, they were grown in small plots, but with more extensive culture their problems are akin in some respects to grain and forage, differing, however, in pruning, spraying, thinning, packing, and marketing.

Irrigation, cultivation, and fertility of orchard soils depend on the same principles that influence farm crops. Weeds must be kept down by plowing between the trees or by using cultivators (Fig. 89); the soil must be kept in good tilth by the addition of farm manure or the plowing under of cover crops. Clovers are probably best for this purpose. In some cases, at least, it seems advisable to have the rows in sod instead of bare.

391. Truck crops. — In the neighborhood of canneries, large acreages of tomatoes are grown under contract. This crop is usually transplanted from hot-beds and cultivated much as potatoes until harvest season, when the tomatoes are picked by hand and hauled to the factory.

Peas, beans, cucumbers, cauliflowers, and other garden crops are grown near factories for canning purposes, or near large cities that afford ready markets. Cantaloupes and melons are also grown under peculiarly favorable conditions and shipped or hauled to market.

Squash and pumpkins are grown on many farms for use in the house, or for cattle- and hog-feed. They are usually planted in hills five or six feet apart and cultivated as long as the vines permit. When the vines die from frost or from maturity, the squash and pumpkins are gathered and stored under cover.

FIG. 88. — Greenhouse crops are in demand near large cities.

FIG. 89. — A good implement with which to cultivate on a large scale.

392. Timber crop. — With the depletion of many forest lands, the price of lumber has risen to such an extent that it is profitable for farmers in many localities to grow small patches of timber. Hardwood for repair of various machines and tools ought to be at hand at all times. In some sections, a few trees may be grown for this purpose and kept free from low branches by pinching off branch buds and by pruning wisely.

393. Other crops. — Tea, coffee, nuts, tropical fruits, rubber trees, sugar maples, poppies for opium, hops, cacti, and dye and medicinal plants are grown to some extent in parts of the world. Besides these, countless plants are grown in small gardens for home use. Finally, the flower-growing industry has assumed importance (Fig. 88). Greenhouses and home-, roof-, and house-gardens abound with innumerable plants bearing beautiful flowers, leaves, or stems.

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CHAPTER XXVII

IMPROVEMENT OF CROPS

THOUGH our crops are far superior in many respects to those of our ancestors, there still remains room for undreamed-of improvement. Every farmer knows he will have some small and some knotty potatoes; that some of the wheat will shrink or lose color, become smutty or lodge and rust; that some ears of corn will be nearly bare, and that most ears will not be entirely filled with deep kernels. Regardless of its care, a farm returns lower yields some seasons than others; no matter how much caution is used in cultivation and selection of seed, poor stands in some parts of the field will be found. The farmer knows that his yield from each acre is never so large as it might have been had not the unexpected or the unavoidable happened, or had the field been handled a little differently. That much can be done to improve crops is apparent. A plant-breeding field is seen in Fig. 90 and a hand thresher in Fig. 91.

Experience has proved that careful cultivation, rotation, manuring, and irrigation may increase, and even double the yields in some cases. These gains last only for a short period of time, that is, until the effect of the extra care has passed. Next year it must be repeated to secure the extra yields. If plants could be found that would produce more, simply because they were higher yielders, whatever increase came might be expected year after year. Nor would this bar the opportunity for improvement by superior cultural methods; indeed, it often happens that the better the plant the more readily it responds to additional care.

Hunt[1] estimates that if grain plants could be obtained that would produce one additional kernel in each head or on each ear, the total yield of the United States would

Fig. 90. — Breeding nursery for timothy. (Pennsylvania Experiment Station.)

increase by 5,000,000 bushels of corn, 15,000,000 bushels of oats, and 1,500,000 bushels of barley. One additional potato in each hill would total 21,000,000 extra bushels of potatoes.

394. What is improvement? — Perhaps the most important thing in crop improvement is increase in yield. Better quality also deserves attention in that it increases the usefulness and market price of the product. Clean, uniform potatoes free from disease are much sought after, particularly for seed. Growers would pay extra for them.

[1] *Cereals in America*, pp. 14–15.

Plump wheat of uniform texture; soft, leafy hay; or apples alike in color, flavor, and size bring extra prices. Both yield and quality are resultants of several complex factors. They are ends — goals toward which improvement must be pushed. Not always can this be done directly, for it may be that one factor alone, such as disease in potatoes, is hindering. Improvement in yield or quality

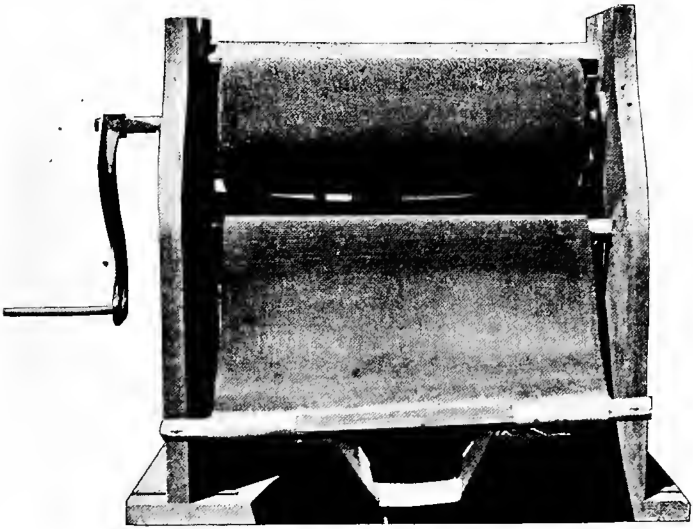

FIG. 91. — Hand thresher for work in plant-breeding.

is most often made by looking back to find the cause of the defect. One muddy tributary will discolor all the river below its entrance; if this is cleared, the whole stream is clear. If a crop lacks resistance to drouth, to heat, to frost, to insects, to disease, to alkali, or to water, it may be injured seriously any time by a single weakness, though it has strength in all other respects. "A chain is no stronger than its weakest link."

Should a variety of corn from a section with a long growing-season be brought into a district with a shorter one, it could not mature; and whatever its possibilities in other respects, not much will actually come from it. Though climatic adaptation is paramount, general suitability to soil and cultural methods is also essential. Potatoes succeed best on loose, fertile soils and under clean cultivation. A selection of adapted varieties is the first step toward better crops. Experiment stations are continually testing crops to find the strains best suited to their localities.

395. Ideal sought. — Improvement consists largely of advancement toward some desired quality in a given crop. The factors that determine best growth are tools of the plant-breeder who can wield them effectively. This he can do only when he knows where to strike and how. We have much to learn about plant-breeding, but even if we knew all, no great gains could be made unless the breeder had an ideal plant clearly in mind. Just as an architect sees and always works to build the house he has in mind, so must the plant-breeder know just what he desires. Nor must the ideal change. Imagine the kind of house a person would have if he changed his mind each week while he was building it. If his ideal is wrong, he will come out wrong; if he has a good plan, he will come out right, provided he does not change. So it is with the plant; the first ideal must be right, then all effort must bend toward it. But this ideal may be impossible or so nearly so that it is not feasible. We can hardly hope to grow grass that is all leaves, but we can accomplish much in reducing the percentage of stem. The ideal sought should be possible, valuable, distinct, and constantly striven for.

METHODS OF IMPROVEMENT

Crops may be improved by three general methods: (1) better culture, (2) attention to the purity and strength of seeds, and (3) plant-breeding, which consists of selection or of crossing and selection.

396. Cultivation. — Though farm methods have improved very materially since the Civil War and even in the last few years, many farms do not get cultivation that comes up to the best knowledge of the owners, much less up to the standard urged upon them by agricultural colleges and farmers' organizations. A more systematic practice of the care and use of farm manure, good plowing, early spring harrowing, wise rotation, moderate irrigation, clean farming, treatment for insects and plant diseases, harvesting in the proper way and at the proper time all deserve attention. A systematic practice of these well-known cultural methods will improve both the yield and the quality of farm crops. In any kind of farming the best results cannot come without proper attention to these principles.

397. Seed-testing. — Whether the farmer raises or buys his seed, it is almost sure to contain some impurities, such as broken kernels, seed of other crops, dirt, chaff, and weed seed. A mixture of varieties prevents marketing to best advantage where it does not hinder in other ways, while broken kernels, dirt, and chaff may cause poor crop stands, thereby lowering yields and affording opportunity for weeds to get started. Weed seeds introduce undesirable plants into the field. These usually cause a decrease in the desirability of the harvest as well as a decrease in yield, to say nothing of the extra labor entailed in controlling the pests. Noxious weeds new to the district or to the farm are frequently introduced into fields, causing endless difficulty and perhaps making impossible the profitable production of some crop. Russian thistle, bindweed, quack-grass, perennial sow-thistle, Canada thistle, and milkweed are a few weeds especially hard to eradicate that may be thoughtlessly introduced in impure seed.

In addition to impurities in the seed there may be some that lack the power to germinate or lack the necessary strength to send up vigorous plants. Since it is desirable to know what kind and how much impurity seed contains, and its relative power to grow, it is essential to test samples before sowing.

In order to do this, small quantities of seed from several parts of the sack or bin should be mixed thoroughly and divided into halves, one of which should be repeatedly mixed and divided until a representative sample small enough to test is secured. With the help of hand forceps, needles, and a hand lens a separation of the sample into five piles may be made: (1) good seed, (2) dirt and chaff, (3) other crop seed, (4) broken kernels, and (5) weed seed. By carefully weighing the separates, the tester can determine the percentage of purity, and by comparing the weed seed with samples in a collection, he can find out to what weeds they belong. The next step is to test the viability, or germinable power, of the pure seed. To do this a plate half full of moist sand is covered with a piece of white cloth or blotting paper, and 100 or 200 seeds are counted out on it. After placing another plate on top to prevent drying, the plates are set in a warm place. In a few days the seeds that have germinated may be counted and recorded. Repetition of the counting every day for a short period will show the percentage of germination. By referring to tables of purity and of germination standards, one may find out if the seed is worth planting.

398. Reproduction. — A seed is the mature, fertilized ovary of a plant and the connecting link between two generations of plants. The parent plant grew and developed partly in order to produce seed that it might leave another generation of similar plants. Flowers in plants seem to be primarily for this purpose. A perfect flower consists of calyx, corolla, stamens, and pistil, but many plants have only the last two parts, which are the important ones, since from them the seed develops. Pollen from the stamens alights on the stigma of the pistil and under favorable conditions sends a long tube down the style to the ovule. The union of the pollen and ovary causes a union of the male gamete in the pollen with the female gamete in the ovule. This process, known as fertilization, begins the life of the seed which, when mature, consists of (1) a miniature plant or embryo surrounded by (2) a quantity of stored-up food, both of which are in turn inclosed in (3) a membranous covering called the hull. Since each seed is capable of becoming a plant, the number of descendants a parent plant may have depends on the number of seeds it can produce. This varies from a few hundred in the case of some crops to a quarter of a million or more in the case of large Russian thistles or tumbling mustard.

399. Variation. — Mere chance would cause some of the many descendants to differ from others, but the law of variation causes each individual to differ from every other. Just as no two people are alike, no two plants are alike. They differ in color, size, shape, rooting, flowering, and in numerous other ways. Oats always bring forth oats, but there are no two oat plants that do not differ. One among several thousand will do best in particular surroundings. It is upon this principle that both natural and artificial selection depend.

400. Natural selection. — Because some one plant out of thousands is more fitted to survive in its particular surroundings, that one plant will grow most vigorously. Now, if all the seeds from any one kind of plant grew, this plant would soon fill the whole earth. Therefore, in the end, not many more individuals can live next year than do this year without crowding out others. Since only a few of all the descendants of a plant can possibly survive, those most fit live and the remaining ones die. Thus nature constantly improves the wild plants by unending, relentless selection. For countless ages, only the most fit of whole races have endured to rear descendants, which in turn are culled out by ever increasingly rigorous selection. The longer this weeding out of the weakest continues, the better adapted the survivors are to cope with their enemies. All our bad weeds originated in the Old World where, for thousands of years, they have been struggling for existence in cultivated fields. This long, incessant struggle to retain foothold has developed their means of survival.

401. Artificial selection. — Because man has put his crop-plants in unnatural surroundings, they have lost the fitness acquired before they were domesticated. The new struggle thus set up causes many variations which afford opportunities for selection. With an ideal in mind, man can improve these plants if he continues to select rigorously and unerringly from many generations of plants grown in the same environment. This is one reason why home-grown seed is better than imported. His ideal must not change nor must his grip weaken by unwise choosing. Only the best can be tolerated.

Although the method of procedure looks simple, considerable difficulty is encountered in deciding just which individual plant is best. For example, the hill of potatoes that yields most cannot always be taken as the best hill for parent stock because experiment may prove that it lacks the power to transmit its yielding qualities. Frequently this happens. The hill that maintains high average yields among its progeny is the one to be desired. Breeding plats are conducted according to this principle. A number of desirable hills are chosen as a starting point. When harvested the average size of hill and total yield are recorded. Next year each hill is planted separately and a record kept to show the pedigree of each mother plant. This is repeated year after year until sufficient data is on hand to enable the breeder to choose a strain that maintained the best average yields for a number of years. Since the poorest are constantly dropped out to make room for the best, the choice gradually narrows to a few. The same method of selection can likewise be followed with small-grains, corn, grasses, and other plants.

402. The best plants should be chosen. — In all cases it must be remembered that the whole plant is the unit of selection. One kernel of wheat is as good as any other kernel from the same plant, for each seed will tend to produce a plant like the one from which it came. Of course, if a stool of wheat or a stalk of corn has more room, better soil, or more favorable conditions in which to grow, it produces more than one not so favored. On this account, it is not fair to judge plants in different conditions against each other, because it is impossible to tell how much is due to greater food, moisture, or room and how much to superior qualities in the plant itself. Therefore, field selections ought to be made in such a way as to choose plants that produce exceptionally well in spite of the fact that they had no advantage whatever. This gives a starting point for a breeding plat at an experiment station or for a seed plat on the ordinary farm.

403. Variety tests. — Much is being accomplished on experimental farms by testing in rows or in plats the yielding power of the numerous varieties of crops in order to find out the one best adapted to climate, soil, and cultural methods of the district. Since out of twenty or more varieties some must be best, variety tests promise much.

The United States Department of Agriculture has broadened this work by keeping in the field a number of men to look for new crops or new varieties of common crops that promise to do well in some section of the United States with similar soil and climate. Turkey red and durum wheats exemplify such introductions. At experiment stations, new varieties are tested for a number of years before they are recommended to farmers. Many crop plants are found unsuited and are rejected; but a few have been valuable. In general, crops from southern Europe do well in California, from middle Europe in the Central States, and from the arid Steppes of Russia, in Great Plains areas.

404. Steps in breeding. — There are then three steps in breeding:

(1) Inducing variation.

(2) Selection of most promising variations.

(3) Testing the selections to find out their power of transmitting desirable qualities to progeny.

405. Crossing. — Besides changing the food, the moisture, the heat, or the cultural relations of a crop, a person may induce variation by artificially bringing the pollen of one plant in contact with the pistil of another. Some plants, such as corn, are naturally cross-fertilized, while others, such as oats, wheat, and barley, are naturally self-fertilized; but this makes no difference in the effect of crossing. In either case a widely-variant progeny will result in a few generations. This offers new starting points for selection.

406. Mendel's law. — If pollen from flint corn fertilizes dent, or if dent pollen fertilizes flint, the resulting kernels all look flinty. Let this corn be so planted next season as to be protected from further crossing, and about one-fourth of the corn will be dent and three-fourths flinty. The dent will always breed true but the flint will continue to produce some dent and some flint. A third part of the flint will breed true, but it is hard to tell which part, since all three-fourths appear to be flint, but only one part is pure flint. The corn that is harvested the fall after the cross is made has both characters in it but appears to be flint, that is, the flint character is dominant and the dent character recessive.

Let F represent the flint character, D the dent character, and x the nature of the cross-pollination. FxD gives FD. Next year $FDxFD$ gives 1 FF : 2 FD : 1 DD. One-fourth of the corn, FF, and one-fourth, DD, are pure and will breed true. Half is FD, or hybrid (contains two characters), and will "break up" next year into 1 FF : 2 FD : 1 DD. The union of the two characters is called combination and the later separation is known as segregation. Most characters of plants seem to go in pairs behaving as F and D in the example cited. They are then known as unit characters. This law of breeding may be stated thus: When two plants each having one of a pair of unit characters are crossed, the two characters form a combination in which both are present but in which the dominant character hides the recessive; and that in the next generation the dominant, the hybrid, and the recessive used will segregate out in the proportions of 1 : 2 : 1, respectively. It is called Mendel's law, after its discoverer, Gregor Mendel.

By the help of Mendel's law, breeders can tell something as to what the results of a cross are likely to be. Naturally, this has helped much in breeding work, but many things not yet understood stand in the way of rapid progress. One of these obstacles is that some plants like potatoes do not propagate by means of seed but by buds. In these cases, only straight selection can be used, since crossing is impossible under ordinary farm practice, though the true seed of potatoes is sometimes made to produce new variation by crossing.

407. Importance of large numbers. — Since plants do not cost much, thousands of them may be bred. Only a few animals can be discarded on account of their great value, but with plants, all save one or two out of thousands may be set aside. Because of this, greater rapidity in plant than in animal-breeding may be expected. Why then the poor development of plant-breeding? First, sexuality in plants was unknown until recently; secondly, animal-breeding began with the dawn of history and plant-breeding only two hundred years ago; thirdly, the male animal can be controlled, while pollen of plants, which blows everywhere, can be controlled only with the utmost difficulty. Much has been done, however, by selection and variety-adaptation tests.

408. Better seed. — Plant-breeding farms occasionally send out desirable strains of some crop. Frost-resistant fruits have introduced fruit-growing in districts where it was hitherto impossible; rust-resistant carnations, cantaloupes, and small-grains decrease losses in many sections; seedless oranges and grapes are boons to the fruit industry; corn that ripens in short seasons allows this crop to be grown northward; frost-resistant alfalfa is now widely grown in the northern Great Plains where this crop previously became winter-killed.

By the methods outlined in the treatise of each crop, farmers may get better seed. Assistance from the state and from the national government should help them. Careful attention to seed-testing, seed selection, and seed treatment will hasten the day of better seed and better crops.

"It is a time-worn but none-the-less true saying that good seed is essential to good agriculture. No matter how well the farmer prepares his land, no matter how much time, labor, and money he spends on it, if much or all of his seed fails to grow he will either have a poor crop or be obliged to reseed, thus losing time and labor."[1]

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[1] Coburn, *The Book of Alfalfa*, p. 27.

CHAPTER XXVIII

WEEDS

NATURAL selection has been operating so long that some plants are able to hold their ground against natural competitors. Weeds have survived not only against other plants but against man, who, by cultivation, has attacked them in new ways and in new places. They have survived in spite of man's effort to eradicate them. His effort to surround crops with conditions favorable to their growth has made the fight against weeds in cultivated ground still more relentless. On the other hand, crop-plants have been unfitted for competition by constant care and protection. Wheat, for example, would probably disappear in a few years, if it were left to take care of itself.

This ever-increasing keenness of competition makes weeds more and more fit to maintain themselves. Various, indeed, are the methods they have adopted. To overcome them, man first must learn their ways: to find a weak place in their armor is his hope. New tools, new methods of cultivation, and the application of sprays are only attempts to send against a weed an enemy whose methods of attack the weed is not prepared to face. The farmer must know the nature of the weed he is attempting to control; what it can and cannot withstand; and how best to strike into its weakest part.

409. Definition. — Weeds are simply plants growing where they are not wanted, — nuisances to the farmer in handling any particular crop or piece of land. Alfalfa in potatoes and volunteer wheat in beets are as distinctly weeds as are the common pigweeds or foxtail. Sometimes the crop-plants themselves stand so thickly upon the land that they crowd each other out by shading or by competition for moisture. Much damage comes to dry-farm wheat in this way, which causes larger losses than appear at first glance. Apples and peaches must be thinned to insure large fruit. When one apple limits the size or quality of another, it is a weed.

Some persons maintain that ugly plants are weeds, and only ugly ones. Morning-glories are not ugly but they are abominable nuisances. Sagebrush is ugly, but it is valuable in its natural home. Some persons regard as weeds only those plants that have flowers which do not attract attention. The flowers of the small-grains, for instance, are not at all noticeable, while morning-glories and Canada thistle, two of our worst weeds, have showy flowers. Others consider plants that spread rapidly to be weeds. This is usually the case. Below are two commonly-used definitions, but they probably make no clearer statements than the one given: (1) "A plant which interferes with the growth of the crop to which the field is temporarily devoted," (2) "Any injurious, troublesome, or unsightly plant that is at the same time useless or comparatively so."

410. Classification. — As regards length of life, weeds may be classified as annuals, winter annuals, biennials, and perennials according to whether they live one, two, or more years. This is, perhaps, the most useful as well as the most comprehensive classification made, for in it are all weeds, and upon it depends the method of eradication. Another useful grouping is to name the families, such as grasses, mustards, composites, and legumes. The objection to this system is that annuals and perennials often occur within a family, and hence demand different treatment. To tell whether a weed is an annual or a perennial suggests the general method of control. Both systems of naming are helpful and should, therefore, be used.

411. Occurrence. — No farmers are exempt from weed pests. They occur everywhere; they grew even in Eden. Ever since, they have been spreading far and wide by the numerous and ingenious methods that they have transmitted to the next generation, or that they have since acquired in the struggle for existence. So thoroughly has nature done the work that no spot has escaped.

At the doorstep, they creep out from the edge of the stone or out of a crack; along the pathway, they cover all ground not constantly trodden; in waste places, they mar the landscape; in crops, they crowd and struggle for supremacy; and even in the cemetery, they grow from the graves of the dead. It is only the living man with a hoe or a plow that they respect; only from him do they hide their heads, and then, not until he uses sharp edges. Nor do they lack persistency; let him leave a single root, and though they languish for a time, if he does not find the solitary root by which they cling to the soil and to life, they take a fresh hold and before he is aware, have tightened the grip until he realizes that he has lost his opportunity of easy conquest.

Not only do they persist in the soil, but they feed on other plants as parasites. The dodder twines about the alfalfa, sucking the sap; the mistletoe does the same on trees. Plant diseases are largely due to plant parasites.

The first year that virgin land produces a crop, some weeds creep in. Soon they trespass in large numbers. In a forest region devoid of common weeds, let a fire lay bare a section of land. The first year it will teem with plants not found in the neighborhood, the seed of which was either dormant in the ground, or was brought long distances by wind or water. The seed seems, like bacteria, to float in the air, though this is, of course, not the case.

412. Dissemination. — Weeds do, however, come from so many sources that it is impossible to tell the origin of every particular one. The sources of weed introduction may be summarized as follows:

(1) The seed of the crop itself often contains seed of noxious plants, such as cockle in wheat; wild oats in oats; trefoil, clover, and pigweeds in alfalfa; and Canada blue-grass in Kentucky blue-grass.

(2) Manure frequently carries hard-shelled seeds. Pig-weeds, mustard, cocklebur, and sunflower are frequently scattered in this way.

(3) Irrigation and run-off water carries the seeds of nearly any weed, for practically all will float.

(4) The wind wafts light, winged seed, like those of thistle, dandelion, and milkweed, for great distances, and rolls tumbleweeds, such as Russian thistle, over long stretches.

(5) Railroads have introduced many of our most serious pests, including Russian thistle. Steamships likewise carry them across ocean and river, which are naturally impassable barriers.

(6) Animals carry burs about in their hair or wool. Burdock is a notorious example of a hobo stealing a ride on a hair cushion; neither is cocklebur negligent of such opportunities. They travel first class.

(7) While eating the fleshy covering of wild berries, man scatters many plants by dropping the seed where he ate the delicious fruit.

(8) Man also mixes harmful seed with grain that he may

get more profit when the grain is sold. Often he does this innocently, but he has been known to do it willfully. Much sweet clover seed has been mixed with alfalfa because the clover was worth less on the market pound for pound. Canada blue-grass seed has been imported to adulterate that of Kentucky blue-grass.

(9) Settlers have introduced, for medicinal properties, new plants, which have later proved to be unmitigated nuisances. Burdock and hoarhound have been coaxed across the continent, coming perhaps as herbs from Europe.

(10) Finally, a few weeds scatter their own seed by means of miniature explosions generally caused by a pod bursting, as in some of the vetches. The squirting cucumber accomplishes the same purpose by the rind keeping rigid and forcing the seeds out.

413. Losses from weeds. — Exactly what are the losses due to weeds, is usually extremely hard to estimate. In some cases, they steal plant-food and in others moisture from the crop-plants. In addition large weeds shade or crowd out the smaller useful plants. One or all of these injuries may result at any time. In the West, however, the loss of water is the most serious, since, upon the moisture depends the quantity of crops produced, that is, water is the limiting factor. Badly-infested farms lose much in selling values on account of weeds. They can be cleansed only at great expense in cash, labor, crop loss, and time. Paint adds more to the price of a building than the cost of material and application; weeds detract more from the price of land than the cost of eradication. They are eye-sores. Some farms have suffered so much that they will not bring the owner any reasonable price; they are unsalable. Coe[1] cites an instance where land

[1] South Dakota Bulletin, No. 150.

valued at $150 to $200 could not be sold because it was infested with horse nettle.

Some weeds are poisonous, causing loss by the killing or the weakening of stock. Larkspur, loco, and water hemlock do this; other weeds taint milk, or render animals unclean; burs injure wool to a considerable extent.

Besides these direct injuries to the crop, the farmer suffers other losses no less important. Weeds may carry plant diseases or shelter insect pests. A troublesome disease of cotton also attacks numbers of common weeds which keep the fungus alive until it finds another opportunity to attack cotton. Alfalfa leaf-weevil is sheltered during the winter in dead weeds and rubbish of any sort.

Many weeds are a great hindrance in harvesting. They clog grain-binders, potato-diggers, and other machinery. Containing much moisture, they prevent crops from curing properly. In marketable products, extra labor is required to remove such foreign matter. Moreover, when the crop sells, the buyer docks in price or weight, or in both, far beyond the actual damage, on account of the presence of dry stems, seeds, odor, or taste due to impurities. Here is a direct money loss.

The most noticeable of all difficulties with weeds is that in their removal, incalculable labor is expended yearly. If cultivation had no other purpose and performed no other service than the killing of weeds, the loss would be enormous, but cultivation benefits the crops by loosening and mulching the soil, and perhaps in other ways. A crop that is one-third weeds increases the labor of handling it by one-half. Here is a loss seldom reckoned, but one deserving consideration.

Tumbleweeds, catching in wire fences, lodge there in numbers sufficient almost to hide the fence lines. Strong and even moderate winds exert immense pressure on this increased surface, tugging and straining on the wire, loosening posts in soft ground, and pulling staples. In addition to being unsightly, these weed accumulations when dry increase the possibility of disastrous fire.

Finally, some students maintain that weeds exert a moral stress on the farmer. From one viewpoint it does seem reasonable that the neglect of weeds may extend to other things. More reasonable, perhaps, is the idea that the weeds would not be allowed to over-run the farm, if the carelessness were not already present. If, however, there be a moral loss in addition to the one hundred million dollars due to damage of crops in the United States annually, the harm is, indeed, astounding.

414. Prevention. — Let us glance at the vital, practical phase — eradication. The sources of seed, the structure of the weed plant, and the nature of the injury are all factors in determining the method of control.

Here, as anywhere else, prevention is primary. Seed must be clean; let the farmer and seedsman look well to that. It is fundamental. Then the farmer should exercise wisdom in hauling manure from yards where contamination is likely. If ditch banks and fields are clean, water will carry but few weed seeds. Let roads and fence lines be cleared; horses and sheep cannot then carry "stickers." If man is careful, there is no need of seed scattering from cars, ships, or food products. These last, however, require the wisest kind of inspection and legislation, with the legislation cut to a minimum. Inspection and education are the most hopeful avenues from which aid is expected.

In a large measure, the problem of eradicating weeds must be handled by the community, that is, by the farmers as a group in a coöperative unit. Under the direction of the county farm demonstrator, the farmers that are not already organized should coöperate to combat weeds, especially new weeds which could be exterminated rather easily on account of their small number. Canada thistle is spreading through entire sections, where it might be held at bay. Then everybody must be alive to recognize new menaces. Here is a field for county "agents," agricultural teachers, students, and farmers who have some technical knowledge.

To assist the farmers who try to control weeds, a law compelling, at least, the mowing of weeds previous to seeding should be in force. The law must, of course, carry with it a penalty severe enough to make it effective. A law alone is of no avail. Unless a representative part of the community is living the law, offenders will not be punished. In such cases the law becomes dead, and worse than useless. Only the minority can be driven or deterred by a law; the majority must make and enforce it. Good farming comes first, coöperation, second; a general enlightenment, third; force and penalty have places only after these have served.

415. Eradication. — Meanwhile farmers must cultivate; especially while the weeds are young, since they are then killed much more easily than later. To exterminate annuals, which seed every year, only reasonable culture methods are necessary. To prevent their seeding is the crux of the whole matter. This eliminates them automatically, as soon as all the seed in the soil has germinated, which, however, may not be for years. To gain control of biennials, two years instead of one are required, for the plant forms seed two seasons. Plowing or cutting below the crown will kill them. Winter annuals, beginning growth in the fall, need attention during the autumn and early spring. Ordinary cultivation destroys these three kinds of weeds.

It is, however, with perennials that most difficulty is encountered. Some part of the plant lives a number of years. Leaves and seed-stems grow up from root-crowns or rootstocks each year. These parts are generally so deep in the ground that they are hard to reach. Dandelions and mallows are examples of plants propagated by root-crowns. Rootstocks are underground stems covered with buds, any one of which will grow. The leaves have dwindled into scales hiding buds which send out both stems and roots. This is the difficulty with morning-glories, salt-grass, Canada thistle, quack-grass, rushes, and sedges.

The roots will eventually starve if they are not fed. The leaves feed the roots; therefore, no green part is to be allowed above ground. It is necessary to rotate with crops that will smother them by shading, or that will permit constant cultivation. The rootstocks ought to be plowed in the fall, thus giving frost a chance to "get in a good lick." Constancy alone can prevent pests gaining strength; leaves above ground soon become green. The chlorophyll makes food for the storehouse that must be exhausted. A besieging fleet would not consider letting an occasional ship-load of supplies pass the blockade. When a strict blockade has weakened the enemy, then is the time to strike. In the control of weed pests, the course is identical. Weeds are most easily killed immediately after they germinate, before they can establish a root-system. This is the best time to attack them, since their lease on life is now weakest. Harrowing will both root out the plantlets and bring other seeds near the surface where they find conditions favorable to begin growth.

It is nearly as essential to germinate the seed that is in the soil as it is to kill the weeds. Though all seeds lose vitality in time, some live a number of years in the soil. Among these are mustard, cocklebur, and other hard-shelled seed.

If, for any reason, weeds are not attacked when only a few days old, cultivation should not be delayed longer than necessary. As some plants seem to be weaker during blooming, this may be a good time for attack. It is, in that seed has not yet formed. Delay beyond blooming period is likely to be fraught with serious consequences, for some weeds mature seed very shortly after the blossoms disappear. Some flowers of a plant may show at the same time that others contain mature seed. The blossom should serve as signal hung out to warn that seed will soon begin to ripen.

416. General principles. — Clark and Fletcher[1] give the following:

"1. There is no weed known which cannot be eradicated by constant attention, if the nature of its growth is understood.

"2. Never allow weeds to ripen seeds.

"3. Cultivate frequently, particularly early in the season, so as to destroy seedlings.

"4. Many weed seeds can be induced to germinate in autumn by cultivating stubble immediately after harvest. Most of these seedlings will be winter-killed or can be easily disposed of by plowing or cultivation in spring.

"5. All weeds bearing mature seeds should be burnt. Under no circumstances should they be plowed under.

"6. All weeds can be destroyed by the use of ordinary implements of the farm, the plow, the cultivator, the harrow, the spud, and the hoe.

"7. Be constantly on the alert to prevent new weeds from becoming established."

[1] *Farm Weeds*, pp. 15–17.

"The practice of summer-fallowing land, to the exclusion of all crops throughout the season, whatever may be said against it, affords the best opportunity to suppress noxious weeds. For lands foul with persistent growing perennials, a thorough summer-fallow will usually be the most effective, and in the end, the least expensive method of bringing the weeds under control.

"To keep farms free from weeds, few methods give such good results as a systematic short rotation of crops, with regular seeding down to grass or clover at short intervals."

417. Herbicides have been experimented with for a number of years in Europe, Canada, and the United States. Some interesting things have been discovered concerning the spraying of weeds to kill them. Copper sulfate (blue vitriol), iron sulfate, common salt, sulfuric acid, slaked lime, corrosive sublimate, and several other compounds have given some success in different experiments. Much care is necessary or the crop is injured along with the weeds. If a rainstorm follows soon after spraying, the chemicals run off and lose their effect. With more knowledge of the effect of chemicals on plants and more care in their application, considerable help should be derived from the use of herbicides.

Copper sulfate is mixed twelve pounds in fifty-two gallons of water; it kills burdock, prickly lettuce, common mustard, prostrate pig weeds, and goosefoot, according to experiments at the Iowa Station.

Common salt, applied both as spray and directly to the soil, kills some weeds but also injures the crop-plants. It is most valuable on an area in which a weed is just starting and where the crop can be sacrificed to eradicate the weed.

Carbolic acid, mixed one part to four of water, aids in the control of pig weed and smartweed, and also weakens Canada thistle when applied either to the root or to the leaves.

Corrosive sublimate, at the rate of two and one-half ounces to fifteen gallons of water, kills weeds, but is very dangerous on account of its toxicity to animals.

Iron sulfate is perhaps the most effective of chemicals when used one hundred pounds to fifty gallons of water. It is also used as a dust spray. Dandelions, large ragweed, sour dock, sorrel, hedge mustard, pepper grass, shepherd's purse, common mustard, bull thistle, and pig weed succumb to iron sulfate spray when it is properly applied.

These sprays are most effective on broad-leaved weeds mixed with grass crops, which have small exposed leaf areas. Grass weeds are not killed, while useful clovers and other broad-leaved crops are injured.

418. Summary. — Weeds are undesirable plants that are scattered in many ways, that cause various and insidious losses, and that must be controlled by methods varied to meet their habits of growth. Cultivation and rotation are the farmer's weapons; prevention is his unfailing ally. He must beware of imitations. There is none just as good.

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PART IV

FIELD MANAGEMENT

CHAPTER XXIX

PLANNING THE FARM

In order to make a well-balanced farm business capable of yielding the highest returns, considerable careful planning is necessary. Farmers are too prone to develop the farm enterprise along lines of least resistance, arranging the fields in the easiest way, rather than planning to save time and work during all the years that the farm will be operated. Planning is as important in farming as in business; and no good business man conducts his affairs without a definite scheme.

The fact that a farmer does not know exactly how he wants his farm to be arranged permanently should not prevent his making plans. He may have to change them somewhat in later years, but this should be no reason for not working on some kind of plan in the meantime. All planning should be done with the future in mind. It may be that sufficient capital is not available to place on the farm all the livestock that it is capable of supporting; but every farmer should plan to have some stock as soon as possible. Almost every farm should be planned to this end. Other enterprises, to be added from time to time, should be provided for in the plan. Some of the situations and appurtenances to a good farm establishment are shown in Figs. 92 to 97.

419. Plan should be stable. — Constant changing from one type of farming to another with every shift in prices is not consistent with good business methods. Every type of farming has its ups and downs, there being a more or less regular rise and fall in the price of all farm products, particularly those susceptible of rapid over-production. The farmer who succeeds is usually the one who stands by his colors until the time of adversity has passed; he is then ready to reap the reward which follows his persistence. It would, of course, be foolish to continue in a type of farming that could never be made to pay under the conditions in which the farmer finds himself; but he should not be induced to change on account of reverses that follow a temporary depression in prices.

A series of years with high prices for any farm product is almost sure to be followed by years of over-production. When the price of potatoes is high, everybody plants potatoes; this means that the price will fall. A good market for hogs can easily be overdone on account of the rapidity of their multiplication and the short time required for them to come to maturity. It takes a longer time to change the price of horses, cattle, and apples than that of hogs and potatoes; but they too are subject to changes. Staple crops like wheat and corn that can be stored from one year to another and transported great distances are much less affected by rapid fluctuations in price than the more perishable or bulky products.

As a rule, it is safer to go into the raising of potatoes when prices are low than when they are high, because only few farmers will plant potatoes during a depression. The farmer who plants about the same area of each crop every year gets the advantage of high prices as well as having to suffer from the low; he is usually better off than the farmer who changes his system every year. The unstable farmer is likely to make changes just at the wrong time.

420. Number of enterprises. — Each farmer should maintain enough enterprises to make sure that his income will not be shut off by the failure of one or two crops; and still he should not have so many enterprises that no specialization is possible. Each farm should have a number of major kinds of products from which the greater part of its income is derived. This enables the farmer to learn these branches especially well and makes him able to compete in them. There are only a few conditions, however, where high specialization in farming is desirable. If a farm is located near a special market, or if conditions are particularly favorable to some product, it may pay to specialize; but on the ordinary farm, diversification with a number of leading products is much safer.

421. The farmstead, including the farm home and other buildings connected with it, is the center of the farm activities. It should be so located that the operations of the farm can be carried on with the greatest economy; it should, at the same time, be a desirable place to live.

On many farms the farmstead is located on the corner nearest the town. This is usually a poor location, since it is necessary to make many more trips to the land than to town. For convenience in getting at the land, the best location is in the center of the farm; but so many advantages go with having the home located next to a public road that this is usually a better place to build. Something in the ease of getting at the land is sacrificed for the convenience of being on a regularly traveled road. Where land is owned on both sides of the road, it is a poor practice to put barns and stables on the side opposite the house, since the danger from passing vehicles is great, and the arrangement for convenience and beauty is not desirable.

The farmyard should be kept neat and the various buildings arranged for convenience, beauty, and healthfulness. As much care should be taken in planning the farm home as the city home, because the farmer is as much entitled to the conveniences of life as his cousin living in the city.

422. Arrangement and number of fields. — Some of the farms that have been handed down from generation to generation have been divided and sub-divided into fields of various sizes and shapes, seemingly without any plan, until it would be impossible to adopt any definite system without a complete rearrangement. Farms of this kind should be overhauled and entirely replanned to permit the use of modern machinery and modern methods. A great deal of time is wasted on irregular fields of undesirable sizes.

The fields should be so arranged that they will all be easily accessible from the farmstead. A desirable arrangement is to have one main road situated in such a way that it is connected with each field. This road if kept in good repair enables the farmer to haul large loads of manure to the fields as well as large loads of crops from them. A lane running to the pasture saves time and annoyance. Where one or two rotations are in operation on the farm, it is desirable to have all the fields the same size in each rotation. The number of fields should not be larger than necessary, since the land between fields is usually wasted, and encourages the growth of weeds.

423. Size and shape of fields. — The best size for fields will depend on the crop grown and a number of other factors. For garden crops, where most of the work is done by hand, the size of the field is not important; but for ordinary crops, where machinery is employed, fields should be so large that time is not lost in too frequent turning. The shape of the field is more important than most farmers realize. A small field can be worked to better advantage if it is longer than wide, because it can be plowed and cultivated with less turning than if it were square. A field with one side irregular or diagonal makes a great deal of extra work.

424. Fences and ditches. — Fences that are unnecessary are a great nuisance on the farm. (1) They occupy

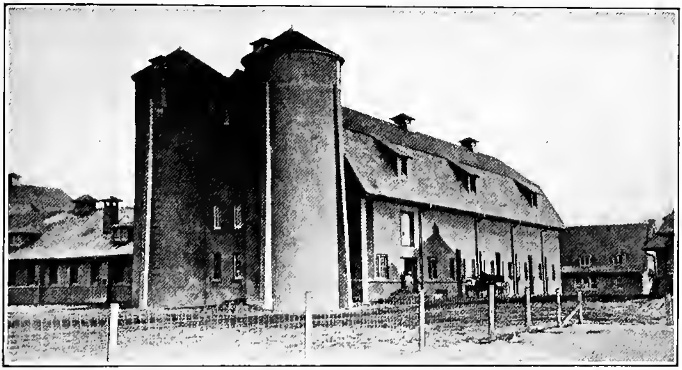

Fig. 92. — Adequate buildings add to the attractiveness of the farm.

land that might otherwise be producing crops; (2) they furnish protection to noxious weeds; and (3) if in poor repair, they are often sources of injury to livestock. In planning the farm, as few fences as possible should be included; and if the farmer wishes to rearrange his fields, he should not hesitate to remove old fences that are not needed. Neat fences, kept in good repair, add to the attractiveness of a farm; while fences in bad condition produce the opposite effect. In irrigated sections, the arrangement of ditches to supply various fields and still not to be in the way and not to cause too much waste of land, requires considerable planning. Economy of land, neatness, convenience in handling water, and a number of other factors must be kept in mind in planning ditches.

425. Use of waste places. — Many farms contain patches of land that are difficult to cultivate on account of their topography, arrangement, or the presence of rocks. It often costs more to till these patches each year than the returns justify. Where this is the case, it is advisable to use the land for a permanent pasture, for a wood lot, or for some other useful purpose that does not require cultivation.

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CHAPTER XXX

WHAT CROPS TO GROW

Crops form a considerable part of the income of practically every farm, whether the farmer is specializing in crops or in livestock. The income may be derived from the sale of crops or from the sale of milk and beef, which are crops transformed into more refined products. The keeping of any kind of stock is impossible without crops to feed them. True, feed may be purchased from the outside, but this greatly reduces profits. Warren, in New York State, found that the farmers who made most money always sold crops, even though they were in the livestock business. Men in the dairy business find it possible to raise a considerable amount of extra hay at very little additional expense. A farmer may have a hobby for livestock raising; but to make profits certain, he ought, in addition to stock products, to have some crops to sell.

426. Crop adaptation. — It is probable that as many losses in farming result each year from not raising the right crops as from poor culture methods. In deciding whether to raise a crop, it is not sufficient to know that it will grow; but its relative value in comparison with other crops should also be taken into consideration. Too many farmers are satisfied to produce the crops that have always been raised, without making a careful study to see if other crops would not be more profitable.

In deciding what crop to raise, the climate, the soil, and the market must be taken into consideration. Most crops can be made to grow under a number of climatic conditions, but they do best in a given zone; and it is working with a handicap to take them out of the zone in which they do best. Cotton might be made to grow in parts of New York State or Colorado, but in these places it could never compete with that produced in the Southern States.

Crops have preference regarding soils also. Peaches and cherries will grow in a heavy clay, but they do much better in a sandy soil. The small-grains, on the other hand, do best on a heavy soil, although they will grow in sand. It is well for the farmer to learn the kinds of soil to which each crop is adapted in planning his cropping systems.

A farm may be able to produce a given crop ever so well, but unless there is a profitable market, it should not be grown. Perishable crops must be raised near the place of consumption; bulky crops for market cannot be produced profitably at a great distance from the railroad.

427. Diversity of crops. — The value of crop rotations in keeping up fertility has been discussed. It is not advisable, however, to do as one man proposed after reading of the benefits of rotation: plant all his farm to alfalfa a few years, then plow it all up and plant to corn, and the next year to wheat, raising but one crop each year. While this procedure would give the soil the benefits of a rotation, it would lack the diversity demanded by good farm practice.

A number of crops should be raised at the same time on the farm in order (1) to lessen risk, (2) to distribute man- and horse-labor more evenly throughout the season, (3) to use equipment more effectively, and (4) to get a better-distributed farm income. It may be that all the crops raised will not give equal returns; but the one paying best can be raised in as large quantities as practical, and the others produced with labor that would otherwise be idle part of the time.

428. Crop specialties. — Under certain conditions crop specialties pay. For example, parts of California are so well adapted to the raising of oranges that no other crop can compete with them. Farmers under this condition are probably justified in raising but one crop, and in maintaining the fertility of the soil by the use of fertilizers. Under these special conditions, it is difficult to have a well-balanced agriculture; and it is doubtful if permanency of soil fertility can be secured with the intensive cultivation of these specialties.

429. Conditions for various crops. — Each type of farming, as well as each particular crop, requires a special set of conditions. Some of the factors that determine what crops can be raised successfully have been discussed already. A summary of the requirements of a number of the common crops may justify attention.

Corn requires a climate having a hot summer with nights not too cool. It needs a large amount of moisture during the period of most rapid growth, and it needs a soil well stocked with organic matter which cannot be entirely supplied through the application of mineral fertilizers.

Oats grow best in a cool, moist climate. They are not so particular about the fertility of the soil, but demand that it be well supplied with moisture. If the soil is too rich, there is a tendency for this crop to lodge and rust.

Barley is less particular about moisture than are oats, but it has many other requirements which are the same.

Wheat grows over a wide range of conditions, and can endure much more cold weather than corn. It is also able to adapt itself fairly well to moisture conditions.

Rye is adapted to cool climates. It will grow in a very poor soil, but does best in a soil that is fairly fertile. It never produces very heavy yields even under the best of conditions and is, therefore, not adapted to intensive farming.

All of these grain crops may be grown at great distances from large markets as they are sufficiently concentrated to be shipped. Most farms can, with profit, raise some kind of grain for home consumption even where it would not pay to raise it for shipment.

Potatoes require a rather cool climate, and do best in a mellow, deep soil. They need sufficient moisture to insure a uniform, even growth; but their quality is injured if too much water is present. Potatoes are perishable; hence the price is likely to be irregular.

Mangels, sugar-beets, and other root crops require conditions similar to those required by potatoes. Since they cannot be shipped any great distance, the market for sugar-beets is dependent on nearness to a sugar factory.

Alfalfa is one of the most profitable forage crops where conditions favor its growth. It requires a soil containing lime, and prefers an open sub-soil. The grass crops require cool, moist conditions for their best growth. Every farm should produce some forage. The kind of crop to raise for this purpose depends on a great many conditions, such as moisture, climate, soil, and the kind of livestock whose food it is to be.

Cotton, sugar-cane, and rice all require a warm climate and other special conditions which limit their growth to comparatively small areas.

The fruit-crops usually pay well if raised under the particular soil, climatic, and marketing conditions which they demand. Before planting an orchard, great care should be exercised to see that conditions are favorable, since many years may be wasted before a mistake is discovered.

From the numerous crops that are available, one should experience no difficulty in getting a diversity of profitable crops for almost any conditions.

430. Work in producing various crops. — In arranging a cropping system, crops should be selected which do not conflict with each other by requiring attention at the same time. As far as possible, the work should be evenly distributed during the year. After being planted, the small-grains require very little attention until harvest time. Corn and potatoes, on the other hand, need cultivation during the growing-season. The main work in raising sugar-beets comes at thinning and at digging time. Hay needs but little attention except at harvest. Much of the work in an orchard can be done during the winter. Thus, by proper planning, crops may be selected which use labor, machinery, and irrigation water at different times. This greatly increases the profits, by making returns more certain and larger, and by insuring constant work for men and horses.

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CHAPTER XXXI

EQUIPMENT OF THE FARM

FARMING is now an industry that is conducted largely by the use of machinery. There is hardly an operation from the planting of crops to the milking of cows that is not done with the aid of some kind of machine. In the early history of farming, practically everything was done by hand, and the few implements used on the farm were very simple. During the last century, however, there has been a complete revolution in this respect. With the invention of the grain harvester, the possibilities of agriculture were very greatly increased. Before this time the amount of grain that could be raised was limited to the quantity that could be harvested by the slow methods then in use. To-day no such limit exists, since every operation in grain-farming can be done with machinery. The size of a grain-farm is limited now only by the capital that is available. In the other branches of agriculture, the use of modern equipment has wrought similar transformations.

431. The farmer as a mechanic. — The farmer of a few generations ago could get along with but very little knowledge of machinery, since he had no machines, but now all this has changed. The modern farmer hardly does a thing without the aid of some complicated machine. The use of these various devices requires skill as well as considerable knowledge of mechanism. The farmer should also be able to repair his own machinery. He is probably working at some distance from a machine shop and if an implement gets out of order, considerable time is lost unless he is able to repair it. The expense of having some one else do the repairing is not so important an item as the time lost in waiting for the work to be

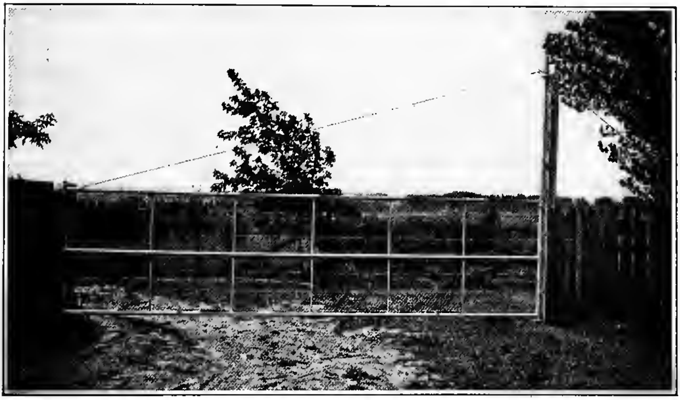

FIG. 93. — A neat and effective gate.

done. During the harvest season one day of waiting may cause a loss of many dollars.

432. Extremes in farm equipment. — Extremes in the use of farm equipment are often found. One farmer will not buy an implement unless he is absolutely compelled to. For lack of an extra plow, he will let a team lie idle most of the summer even though he has land that needs plowing. He considers the money spent for implements wasted, when in reality the plow might more than pay for itself in a single month. It is very poor economy not to buy the implements necessary to manage a farm in the most efficient manner.

Some farmers go to the other extreme and buy every new machine and device that is put on the market. As a result they have hundreds of dollars' worth of idle equipment. The wise farmer is conservative in purchasing equipment, and buys only standard implements. He is not, however, afraid to purchase a machine when he sees that it will earn money.

433. Machines that get out of date. — Every year many new kinds of machines are offered for sale. Some

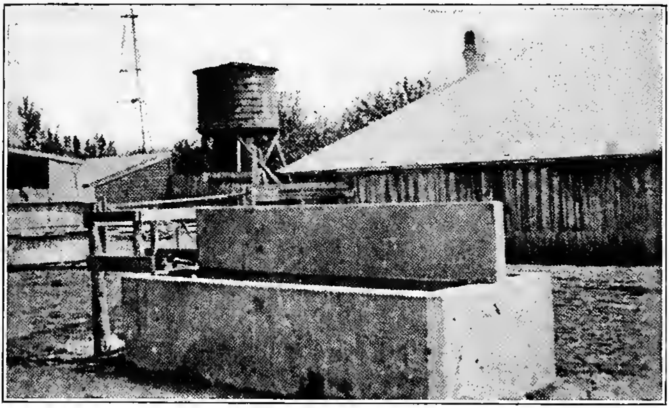

Fig. 94. — Cement finds many uses on the farm.

of these can safely be purchased at once, but the majority of new devices are only in the experimental stage when first put on the market. They may be good in principle, but probably many things about them will be perfected after a few years of trial. This means that there will be a rapid change, and that the first machine will be rendered out of date by more perfect models. It is usually a good thing, therefore, for the farmer to let new equipment have a year or two of trial before he ties up his money in it. Standard equipment such as wagons and plows seldom gets out of date.

434. Machines that are seldom used. — Some pieces of equipment that seem almost necessary on the farm are used but few times in a season. The farmer who has a few acres of grain needs a fanning mill to clean the seed, and yet it seems a waste to have this machine idle except for a few days during each year. This difficulty can be overcome in part by the coöperation of a number of farmers in the purchase and use of such machinery. Seed grain can be cleaned almost any time during the year. This makes it possible for a dozen or twenty farmers to use the same fanning mill, making the expense for each one very slight. The same rule can be applied to the ownership of grain drills, harvesters, threshing machines, and numerous other implements.

435. Size of machinery. — The size of machinery must be adapted to the needs of the farmer. On the very large farm, it is desirable to have all the machinery so large that it may be operated with as little man labor as possible. Where fields are small, on the other hand, large machines cannot be used to advantage on account of the constant turning that is necessary. The traction engine as a source of power in tillage operations may be used under certain conditions, but it finds no place on the ordinary farm. In trying equipment of all kinds, the farmer should consider well the sizes that will best meet his needs. The machines should be large enough to do his work, and not so large that capital is unnecessarily tied up in them.

436. The duty of machinery refers to the amount of work done, or the area of land served, by an implement during one season. The duty of a mowing machine would be very great if it could be working the year round, but it is used only during the comparatively brief period when hay is in the right stage to cut. The duty of a grain drill is low, because the season when grain can be planted is short and one implement can cover only a limited area of land. The duty of an implement is increased by keeping it in good working order and by running it double shifts during the busy season. By using lights and chang-

Fig. 95. — Gasoline engine used for stacking hay, Wisconsin.

ing men and teams, a potato digger may be run twenty-four hours in a day if necessary, thereby making its duty two or three times what it would ordinarily be. The same plan may be followed with many other implements.

437. Depreciation. — Every farm implement depreciates, partly through wearing out and partly through getting out of date. A gasoline engine built fifteen years ago would be worth very much less to-day, had it not been used at all, because many improvements have since been made. The Minnesota Experiment Station found that depreciation of equipment each year ranged from 12 per cent for threshing outfits to 3.47 per cent for grain tanks. Implements having complicated machinery like corn binders depreciate much more rapidly than simple ones like wagons. Depreciation is dependent less on actual use than on the care given. Machines soon rust away when left exposed to the sun and storms even if they are not used.

438. Caring for machinery. — The sure way to waste money on the farm is to buy expensive machinery and

Fig. 96. — Cheap but effective shelter.

leave it unprotected during all seasons of the year. Costly machine houses are not necessary, or even desirable. Some machine sheds, however, are so constructed that they depreciate about as rapidly as the machinery they were built to protect. A simple but neat shed that will keep out water and sun will suffice. This can be built at slight expense, and will pay for itself in one year if there are many expensive machines to shelter.

It is a good idea to clean and repair all machinery at the end of the season when it is put away. All parts likely to rust should be oiled. If this is done, the implement is always ready for use. The practice of repairing when the machine is taken out for use in the beginning of the season results in a great waste of valuable time. All machinery should be kept in a good state of repair, as this lessens the depreciation and increases the efficiency. Mower knives, plows, and other similar implements work much more efficiently if kept well sharpened.

439. Suitable farm buildings. — Farm buildings, although necessary, may be considered as the non-productive part of the farm. They are needed as protection for the farmer as well as for his stock, farm products, and machinery, yet they add nothing directly to the farm income. Buildings, therefore, should not be expensive, since they tie up capital that is needed in the more productive enterprises. People who know nothing about farming and the way its profits are obtained are likely to criticize the average farmer for his lack of expensive buildings. The farmer must be conservative in this respect, however, or his desire to make a showing in buildings will cripple him in his working capital.

There is no doubt that farm buildings could be improved in design, and that, with proper planning, the money now invested could have been better spent. The arrangement of farm buildings in many cases results in a great waste of time. The modern farmer, by the use of cement and other available building materials, can construct all necessary buildings at comparatively low expense. Care in planning enables him to do much more with his money than if he constructed a number of small buildings without regard to arrangement. The importance of convenience and sanitation have also been largely overlooked in the past.

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Farm Machinery and Farm Motors, Davidson and Chase.
Farm Development, W. M. Hays, pp. 355–384.
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U. S. D. A. Farmers' Bulletins:
No. 303. Corn-Harvesting Machinery.
347. Repair of Farm Equipment.
475. Ice Houses.
481. Concrete Construction on the Livestock Farm.
574. Poultry House Construction.
589. Home Made Silos.

CHAPTER XXXII

FACTORS OF SUCCESS IN CROP PRODUCTION

One of the most difficult things in any business is to maintain a proper balance between its parts. There is a constant tendency to develop hobbies, which means that other phases will be neglected. A merchant had a hobby of keeping his store neat and clean, claiming that an orderly establishment attracted trade. He was so particular about scrubbing and putting things in order, that when customers came in they were neglected; customers were secondary to cleanliness. He also neglected to give proper attention to buying and to other important parts of his business. As a result of his hobby and in spite of the fact that his store was a model of neatness, he lost most of his trade and became bankrupt.

The farmer, unless he is careful, will give most of his attention to one or two phases of his business and neglect the others. He must be constantly on the alert to keep the business well organized, to have the capital all working, to practice the right type of farming, to handle the crops and animals in the best way, and to market to the best advantage. He must recognize that successful farming is made up of a great many important factors.

440. Size of farm. — In order to make a success in the production of crops, the farm must be of the proper size. High yields may be obtained, but unless a considerable area is farmed it will be impossible to make a good living. A yield of fifty bushels of wheat to the acre would be considered excellent; but if the farmer only had five acres, the returns would furnish a scant living. The size of farm that is most profitable depends on a number of factors, one of which is the kind of crop grown. Ten acres of strawberries would be a large field, while a ten-acre field of wheat, oats, or barley would be considered

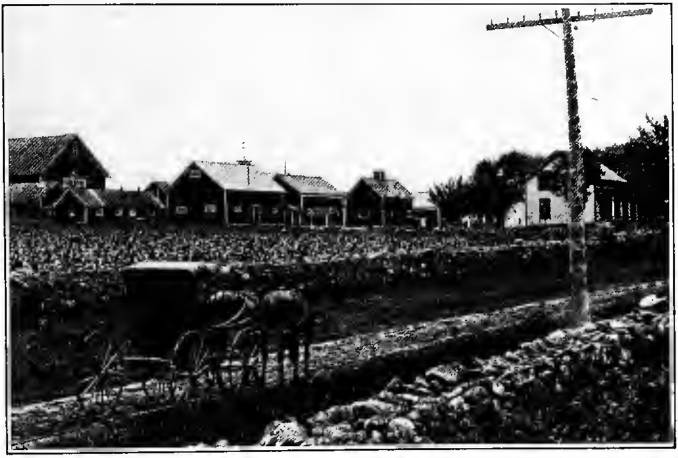

FIG. 97. — Scattered buildings increase farm labor.

very small. Whatever the crop, the area devoted to it should be sufficient to justify the attention of the farmer and to give him an income worth while. If the area is too large, it cannot be successfully handled, and returns will be decreased.

441. Capital. — Farming is a business requiring capital. This fact is often overlooked by those who wish to become farmers. They buy land on credit and then expect the farm not only to make a living for them but also to pay for itself in a very few years. If it does not do this, they say there is nothing in farming. Every one recognizes the fact that capital is required to enter the banking business; yet more capital is often invested in a farm than in a small bank.

The raising of field crops can probably be done with less capital than is required for any other branch of agriculture. Dairying and the pure-bred livestock business require a large initial outlay for stock; fruit-growing requires the investment of capital a number of years before returns are expected. Notwithstanding the relatively low capital required to raise field crops, they cannot be successfully produced without the investment of considerable money. The land must be purchased or rented and a suitable seed-bed prepared. Seed must be planted and the crop cared for during growth, then harvested and marketed before any returns are secured. Many failures occur in farming because sufficient capital is not available. The prospective farmer, therefore, to be most successful should have at his disposal sufficient funds to operate his farm in the most efficient manner.

442. Proper type of farming. — The type of farming followed is as important to success as are the methods used. In every section some types pay better than others, and the discovery of the paying type is one of the chief problems of the man on the land. This has been discussed more fully in Chapter XXX.

443. Good management. — Farming will not pay under the most favorable conditions without intelligent management. There are so many chances for losses that unless good judgment is exercised failure is sure to result. In farming, new conditions are constantly presenting themselves; hence it is impossible to lay down any set rules. The farmer must be constantly alert and ready to adapt the method to conditions as they exist. In many of the industries, the work is exactly the same year after year, and when once learned no difficulty is experienced. Farming, on the other hand, is never the same during any two years. Seasonal variations are so great that each day presents new problems.

The economical use of horses and machinery — plowing, planting, and harvesting at the right time and in the right way — and marketing products to the best advantage, both call for the highest type of executive ability. It is not enough to be able to raise good crops; they must be produced at a profit. This requires good management.

444. Keeping records. — The farmer cannot, without keeping some kind of records, tell which phases of his business are most profitable. The merchant keeps books primarily to tell whom he is owing and who owes him. The farmer can usually keep account of these things without a set of books; but in order to tell where his profits came from and where the losses occur a set of simple farm accounts is indispensable. By doing this, he is able to eliminate unprofitable crops and raise only those giving greatest returns. Few farmers will find it advisable to keep a complex set of accounts, but some simple bookkeeping will certainly pay.

445. Profits to a farmer vs. yields to the acre. — In discussing crop production, the idea is sometimes advanced that the chief aim of the farmer is to get high acre-yields. While high yields are desirable, they are by no means all that the farmer wants. His chief concern is to get a high total income for his year's work. A net earning of ten dollars an acre on a farm of 100 acres is more profitable than an earning of twenty-five dollars an acre on a farm of ten acres.

High yields do not always bring a high net profit for each acre. For example, potatoes usually bring actually less money to the farmer during a year when yields are high all over the country than during years of low yields. Methods should be adopted which give large yields; but of equal importance, is the organization of the business in such a way that the farmer will receive a high total income even though the yield of any individual crops is not high. In short, the function of the farmer is not primarily to make his land give big yields, but to use the land in helping himself to get a large yearly income. The farm is for the farmer, and not the farmer for the farm.

446. Profits from man and horse labor. — The farmer should not expect to make all his profits from the land; he should also make money from the men he hires and from the horses he uses. Some farmers seem to think that money paid out for hired help is lost, whereas in reality, a good profit should be made on every day's labor used on the farm. To do this requires careful management. The work must be so well planned that no time is spent doing unprofitable jobs. Employment must be arranged for rainy days and other times when it is impossible to do the regular farm work.

More attention is usually given to man than to horse labor. No farmer would think of keeping hired men if there was no work for them to do, but idle horses are kept on the place for months at a time. By providing work for all the horses on the farm, the cost of producing crops is greatly reduced.

447. Understanding each crop. — Each kind of crop has its own peculiar requirements, which must be catered to if they are to be profitable. The farmer should base his practices upon a knowledge of the needs of his crops. He must understand that alfalfa needs a soil containing lime, while corn needs a soil having considerable organic matter. He should also learn how fertilizers, irrigation water, and other factors affect the quality of the crops he raises so as to be able to produce crops which the market demands. To have the highest success, therefore, the farmer must be an observing naturalist.

448. Markets. — It is useless to raise crops unless they can be sold at a profit. The ordinary farmer is a much better producer than salesman. He is thinking continuously how to increase yields, but the question of markets attracts his attention only once or twice a year — just during the marketing season. The farmer may, however, at market-time lose more by a single unwise transaction than he has made during the entire season through extra attention to his crops.

A number of ways of marketing are available to the farmer. He may sell all his crop at wholesale to the dealer or consumer; he may dispose of it through a commission man who charges a percentage for making the sales; he may sell on a regular market through an auctioneer; or he may retail his products in small parcels to the individual consumer. No one of these methods of selling is best in all cases. Farmers are too prone to trust to local markets, instead of investigating every possible place of sale.

Considerable loss accompanies the storage of most farm products; hence, the common practice of holding for higher prices is not always to be recommended. Shrinkage and loss often amount to more than the increase in price received after holding for a number of months. If prices are particularly low at harvest and indications point to a rise later, it may pay to store. The farmer must watch markets closely from one year to the next, and investigate every opportunity to market his products profitably.

Success in crop production does not consist alone in doing one thing well; it calls for good judgment in many distinct kinds of work. The farmer who has a fad of marketing, or of raising crops in a particular way, often neglects other important factors, and as a result falls short of success. The successful farmer must keep his business well balanced, that is, he must give to each phase of his work the attention that its importance justifies.

SUPPLEMENTARY READING

Farm Management, G. F. Warren.
Rural Economics, T. N. Carver.
Cyclopedia of American Agriculture, Vol. I, pp. 162–202.
Cyclopedia of American Agriculture, Vol. II, pp. 81–109.
Cyclopedia of American Agriculture, Vol. IV, pp. 215–276.
Rural Wealth and Welfare, G. T. Fairchild.
Agricultural Economics, H. C. Taylor.
The Young Farmer, T. F. Hunt.
Coöperation in Agriculture, G. H. Powell.
The Farmers' Business Handbook, I. P. Roberts.
Farm Management, Andrew Boss.
U. S. D. A. Farmers' Bulletins:
No. 454. A Successful New York Farm.
621. Marketing Farm Products.

APPENDICES

APPENDIX A

ADDRESSES OF AGRICULTURAL COLLEGES AND EXPERIMENT STATIONS AND OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

When not otherwise indicated, the college and experiment station are at the same place. Any letter addressed to the "Agricultural College" or "Experiment Station," with proper post-office address, will reach the institution.

Alabama —
- College of Agriculture and Experiment Station — Auburn.
- Canebrake Station — Uniontown.
- Tuskegee Station — Tuskegee.

Alaska — Sitka.
Arizona — Tucson.
Arkansas — Fayetteville.
California — Berkeley.
Colorado — Fort Collins.
Connecticut —
- State Station, New Haven.
- Agricultural College and Storrs Experiment Station — Storrs.

Delaware — Newark.
Florida — Gainesville.
Georgia — Experiment.
Hawaii —
- Federal Station — Honolulu.
- Sugar Planters' Station — Honolulu.

Idaho — Moscow.
Illinois — Urbana.
Indiana — Lafayette.
Iowa — Ames.
Kansas — Manhattan.
Kentucky — Lexington.
Louisiana — Baton Rouge.
Maine — Orono.
Maryland — College Park.
Massachusetts — Amherst.
Michigan — East Lansing.
Minnesota — St. Anthony Park, St. Paul.
Mississippi — Agricultural College.
Missouri —
- College Station — Columbia.
- Fruit Station — Mountain Grove.

Montana — Bozeman.
Nebraska — Lincoln.

Nevada — Reno.
New Hampshire — Durham.
New Jersey — New Brunswick.
New Mexico — Agricultural College.
New York —
State Station — Geneva.
College of Agriculture and Cornell Experiment Station — Ithaca.
North Carolina —
College Station — West Raleigh.
State Station — Raleigh.
North Dakota — Agricultural College.
Ohio —
Experiment Station — Wooster.
College of Agriculture — Columbus.
Oklahoma — Stillwater.
Oregon — Corvallis.
Pennsylvania — State College.
Porto Rico — Mayaguez.
Rhode Island — Kingston.
South Carolina — Clemson College.
South Dakota — Brookings.
Tennessee — Knoxville.
Texas — College Station.
Utah — Logan.
Vermont — Burlington.
Virginia — Blacksburg.
Washington — Pullman.
West Virginia — Morgantown.
Wisconsin — Madison.
Wyoming — Laramie.

The United States Department of Agriculture is at Washington, D.C. One may address the Secretary of Agriculture, or write to one of the Divisions of the Department. The most important divisions are as follows:

Weather Bureau.
Bureau of Animal Industry.
Bureau of Plant Industry.
Forest Service.
Bureau of Chemistry.
Bureau of Soils.
Bureau of Entomology.
Bureau of Biological Survey.
Division of Publications.
Bureau of Statistics.
Office of Experiment Stations.
Office of Public Roads and Engineering.

Some of the most important addresses in Canada are:

Dominion Department of Agriculture, Ottawa, Ontario.
Experimental Farms, Ottawa.
Ontario Agricultural College, Guelph, Ontario.
Agricultural College, Winnipeg, Manitoba.

APPENDIX B

LABORATORY GUIDES

Manual of Agriculture — Soils and Crops, D. O. Barto.
A Laboratory Manual of Agriculture, L. E. Call and E. G. Schafer.
Lessons on Soil, E. J. Russell.
The Physical Properties of Soils, A. G. McCall.
Soil Physics Laboratory Manual, J. G. Mosier and A. F. Gustafson.
A Unit in Agriculture, J. D. Ellif.
Examining and Grading Grain, T. L. Lyon and E. G. Montgomery.
Laboratory Manual of Farm Management, G. F. Warren and K. C. Livermore.
Laboratory Manual of Cereals and Forage Crops, Geo. Livingston and Malon Yoder.

APPENDIX C

FERTILITY IN FARM PRODUCE

Approximate Maximum Amounts Removable to an Acre Annually

Produce		Pounds			Market Value			
Kind	Amount	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	Total Value
Corn, grain	100 bu.	100	17	19	$15.00	$0.51	$1.14	$16.65
Corn stover	3 T.	48	6	52	7.20	.18	3.12	10.50
Corn crop		148	23	71	22.20	.69	4.26	27.15
Oats, grain	100 bu.	66	11	16	9.90	.33	.96	11.19
Oat straw	2½ T.	31	5	52	4.65	.15	3.12	7.92
Oat crop		97	16	68	14.55	.48	4.08	19.11
Wheat, grain	50 bu.	71	12	13	10.65	.36	.78	11.79
Wheat straw	2½ T.	25	4	45	3.75	.12	2.70	6.57
Wheat crop		96	16	58	14.40	.48	3.48	18.36
Soybeans	25 bu.	80	13	24	12.00	.39	1.44	13.83
Soybean straw	2½ T.	79	8	49	11.85	.24	2.94	15.03
Soybean crop		159	21	73	23.85	.63	4.38	28.86
Timothy hay	3 T.	72	9	71	10.80	.27	4.26	15.33
Clover seed	4 bu.	7	2	3	1.05	.06	.18	1.29
Clover hay	4 T.	160	20	120	24.00	.60	7.20	31.80
Cowpea hay	3 T.	130	14	98	19.50	.42	5.88	25.80
Alfalfa hay	8 T.	400	36	192	60.00	1.08	11.52	72.60
Cotton, lint	1,000 lb	3	0.4	4	.45	.01	.24	.70
Cotton, seed	2,000 lb.	63	11	19	9.45	.33	1.14	10.92
Cotton stalks	4,000 lb.	102	18	59	15.30	.54	3.54	19.38
Cotton crop		168	29.4	82	25.20	.88	4.92	31.00
Potatoes	300 bu.	63	13	90	9.45	.39	5.40	15.23
Sugar-beets	20 T.	100	18	157	15.00	.54	9.42	24.96
Apples	600 bu.	47	5	57	7.05	.15	3.42	10.62
Leaves	20 T.	59	7	47	8.85	.21	2.82	11.88
Wood growth	1 tree	6	2	5	.90	.06	.30	1.26
Total crop		112	14	109	16.80	.42	6.54	23.76
Fat cattle	1,000 lb.	25	7	1	3.75	.21	.06	4.02
Fat hogs	1,000 lb.	18	3	1	2.70	.09	.06	2.85
Milk	10,000 lb.	57	7	12	8.55	.21	.72	9.48
Butter	400 lb.	0.8	0.2	0.1	.12	.01	.01	.14

[1] From Hopkins' Soil Fertility and Permanent Agriculture. (Ginn & Co.)

APPENDIX D

COMPOSITION, AMOUNT, AND VALUE OF MANURE PRODUCED BY DIFFERENT KINDS OF FARM ANIMALS

(Results of experiments conducted at Cornell University Experiment Station)

	Analysis and Value per Ton of Manure					Amount and Value per 1000 lb. Live Weight per Day		
	Water	Nitrogen	Phosphoric Acid	Potash	Value per Ton	Pounds per Day	Value per Day	Value Per Year
	Per ct.	Per ct.	Per ct.	Per ct.			Cents	
Sheep	59.52	.77	9.39	.59	$3.30	34.1	7.2	$26.09
Calves	77.73	.50	.17	.53	2.18	67.8	6.7	24.45
Pigs	74.13	.84	.39	.32	3.29	83.6	16.7	60.88
Cows	75.25	.43	.29	.44	2.02	74.1	8.0	29.27
Horses	48.69	.49	.26	.48	2.21	48.8	7.6	27.74

MINIMUM AMOUNT OF FARMYARD MANURE TO REPLACE THE ELEMENTS ABSTRACTED FROM THE SOIL BY A GOOD ACREAGE OF DIFFERENT CROPS

Wheat	5 tons
Barley	5 tons
Oats	5 tons
Corn	7 tons
Meadow hay	8 tons
Red clover	12 tons
Beans	10 tons
Turnips	15 tons
Potatoes	10 tons
Cabbage	25 tons
Carrots	10 tons

APPENDIX E

WEIGHTS AND MEASURES

Avoirdupois Weight

16 ounces (oz.)	= 1 pound (lb.)
100 pounds	= 1 hundredweight (cwt.)
20 hundredweight (cwt.) . .	= 1 ton (T.)
1 ton	= 20 cwt. = 2000 lb. = 32,000 oz.

Linear Measures

12 inches (in.)	= 1 foot (ft.)
3 feet	= 1 yard (yd.)
$5\frac{1}{2}$ yards, or $16\frac{1}{2}$ ft. . . .	= 1 rod (rd.)
320 rods	= 1 mile (mi.)
1 mi. = 320 rd. = 1760 yd.	= 5280 ft. = 63,360 in.

Square Measures

144 square inches (sq. in.)	= 1 square foot (sq. ft.)
9 square feet	= 1 square yard (sq. yd.)
$30\frac{1}{4}$ square yards	= 1 square rod (sq. rd.)
160 square rods	= 1 acre (A.)
640 acres	= 1 square mile (sq. mi.)
1 square mile	= 1 section
36 sections	= 1 township (twp.)
43,560 square feet	= 1 acre
160 acres	= $\frac{1}{4}$ section

Solid or Cubic Measures

1728 cubic inches (cu. in.) .	= 1 cubic foot (cu. ft.)
27 cubic feet	= 1 cubic yard (cu. yd.)
1 cubic yard	= 46,656 cu. in.
1 cubic yard	= 1 load
$24\frac{3}{4}$ cubic feet	= 1 perch
128 cubic feet	= 1 cord
1 ft. × 12 in. × 1 in. . . .	= 1 board foot

Liquid Measures

4 gills (gi.)	= 1 pint (pt.)
2 pints	= 1 quart (qt.)
4 quarts	= 1 gallon (gal.)
$31\frac{1}{2}$ gallons	= 1 barrel (bbl.)
$7\frac{1}{2}$ gallons water	= 1 cubic foot (approximately)
1 gallon water	= 8.3254 pounds
1 U. S. gallon	= 231 cubic inches

Dry Measures

2 pints	= 1 quart
8 quarts	= 1 peck (pk.)
4 pecks	= 1 bushel (bu.)
1 bushel	= 2150.42 cu. in.

APPENDIX F

QUANTITY OF SEED PLANTED TO THE ACRE

Wheat	1–2 bushels
Oats	2–4 bushels
Barley	1½–2½ bushels
Rye	1–2 bushels
Peas	2½–3½ bushels
Buckwheat	½ bushel
Mixed hay { oats	1 bushel
Mixed hay { peas	2 bushels
Flax	½–2 bushels
Corn	15–20 pounds
Potatoes	10–18 bushels
Red clover	8–12 pounds
Alsike clover	6–10 pounds
White clover	4–8 pounds
Timothy	10–15 pounds
Orchard-grass	15–20 pounds
Sugar-beets	12–16 pounds
Blue-grass	10–15 pounds
Alfalfa	10–20 pounds
Brome-grass	15–20 pounds
Bur clover	12 pounds
Sweet clover	10–25 pounds
Mangels	5–8 pounds
Redtop	6–8 pounds

APPENDIX G

MOST COMMON WEIGHTS OF SEEDS TO THE BUSHEL

	Lb.		Lb.
Alfalfa	60–80	Orchard-grass	10–18
Bermuda-grass	24–36	Pea	60
		Red-top (chaff)	10–14
Canada blue-grass	14–20	Red-top (fancy)	25–40
Kentucky blue-grass	14–30		
Clovers	60	Soybean	58–60
Cowpea	56–60	Timothy	45
		Vetch	60
Fescue, hard	12–16	Corn	56
Fescue, meadow	14–24	Barley	48
Flax	48–56	Oats	32
Hemp	40–60	Potatoes	60
Johnson-grass	14–28	Rye	56
Meadow-grass	11–16	Wheat	60
Millet	30–60	Beans	60–62
Oat-grass	7–14	Turnips	55

APPENDIX H

MEASURING RULES

Measuring grain. — A bushel of grain contains approximately $\frac{4}{5}$ cubic foot. To determine the capacity of a bin, find the number of cubic feet and multiply by $\frac{4}{5}$, or multiply by 8 and divide by 10.

Measuring ear corn. — It requires about two bushels of ear corn to make one bushel shelled. To find the capacity of a crib, find the number of cubic feet and multiply by $\frac{2}{5}$ or .4.

Measuring hay. — The quantity of hay in a mow is very hard to estimate accurately. The deeper the hay is, the harder it will be packed. Some kinds of hay are heavier than others; the longer it stands the more compact it becomes. Settled hay will usually weigh about five pounds per cubic foot, or 400 cubic feet will weigh one ton. (See Appendix I.)

Measuring land. — The easiest way to calculate land measurements is to figure 160 square rods as one acre. A strip one rod wide and 160 rods long, therefore, equals an acre, as does a strip four rods wide and 40 rods long, or eight rods wide and 20 rods long, etc.

A surveyor's chain is four rods long. It is divided into 100 links, so that all calculations are in decimals. Ten chains square equal one acre.

SQUARE MEASURE EQUIVALENTS

Sq. In.	Sq. Ft.	Sq. Yd.	Sq. Rod	Acre	Mile Sq.
144 =	1 =				
1,296 =	9 =	1 =			
39,204 =	$272\frac{1}{4}$ =	$30\frac{1}{4}$ =	1		
6,272,640 =	43,560 =	4,840 =	160 =	1	
4,014,489,600 =	27,878,400 =	3,097,600 =	102,400 =	640 =	1

APPENDIX I

RULES FOR MEASURING HAY IN THE STACK

A number of measurements are taken and the average obtained for: L = length, W = width, O = overthrow (a line is thrown over the stack to the ground on the other side and the overthrow is the distance over the stack from the bottom on one side to the bottom on the other). Then the number of cubic feet in the stack may be found from the following formulas:

$\frac{(O + W)}{4}$ multiplied by itself and this product by the length of stack = cu. ft.

$$\frac{(O \text{ times } W)}{4} \text{ times } L = \text{cu. ft.}$$

For small, low ricks use the formula $\frac{(O - W)}{2}W$ times L = cu. ft.

For round stacks, get the average circumference (C) at or above the base or " bulge," find the vertical height of the measured circumference from the ground and the slant height from the circumference to the top of the stack. Then use the formula $\frac{(C \text{ times } C)}{100}$ 8 times (height of the base + $\frac{1}{3}$ slant height of top) = cu. ft.

When the number of cubic feet is known, this number is divided by the number of cubic feet in a ton to find how many tons there are. There are about 343 cubic feet in prairie hay that has settled 30 days or more, but 422 cubic feet is often considered as closer. For alfalfa 422–512 cubic feet are used in different regions for hay that has settled 30 or more days. When the hay has settled 5 to 6 months 422 cubic feet and after a year 343 cubic feet are usually accepted as a ton. For round stacks a ton usually contains 512 or more cubic feet after 30 days. The number to be used varies with the depth of stack as well as with the time of settling.

APPENDIX J

WHEAT HARVEST CALENDAR

January. — Australia, New Zealand, Chile, and Argentine Republic.

February and March. — Upper Egypt, India.

April. — Lower Egypt, India, Syria, Cyprus, Persia, Asia Minor, Mexico, Cuba.

May. — Texas, Algeria, Central Asia, China, Japan, Morocco.

June. — California, Oregon, Mississippi, Alabama, Georgia, North Carolina, South Carolina, Tennessee, Virginia, Kentucky, Kansas, Arkansas, Utah, Colorado, Missouri, Turkey, Greece, Italy, Spain, Portugal, South of France.

July. — New England, New York, Pennsylvania, Ohio, Indiana, Michigan, Illinois, Iowa, Wisconsin, Southern Minnesota, Nebraska, Upper Canada, Roumania, Bulgaria, Austria-Hungary, South of Russia, Germany, Switzerland, South of England.

August. — Central and Northern Minnesota, Dakotas, Manitoba, Lower Canada, British Columbia, Belgium, Holland, Great Britain, Denmark, Poland, Central Russia.

September and October. — Scotland, Sweden, Norway, North of Russia.

November. — Peru, South Africa.

December. — Burmah, New South Wales.

APPENDIX K

PRICES OF WHEAT (CHICAGO MARKET) 1863–1910[1]

Years	Months of Lowest Prices	Yearly Range of Prices	Months of Highest Prices
1863	August	.80 @ 1.12½	December
1864	March	1.07 @ 2.26	June
1865	December	.85 @ 1.55	January
1866	February	.77 @ 2.03	November
1867	August	1.55 @ 2.85	May
1868	November	1.04½ @ 2.20	July
1869	December	.76½ @ 1.46	August
1870	April	.73¼ @ 1.31½	July
1871	August	.99½ @ 1.32	Feb., April, and Sept.
1872	November	1.01 @ 1.61	August
1873	September	.89 @ 1.46	July
1874	October	.81½ @ 1.28	April
1875	February	.83¼ @ 1.30½	August
1876	July	.83 @ 1.26¾	December
1877	August	1.01½ @ 1.76½	May
1878	October	.77 @ 1.14	April
1879	January	.81⅝ @ 1.33½	December
1880	August	.86½ @ 1.32	January
1881	January	.95⅜ @ 1.43¼	October
1882	December	.91⅛ @ 1.40	April and May
1883	October	.90 @ 1.13½	June
1884	December	.69½ @ .96	February
1885	March	.73⅜ @ .91¾	April
1886	October	.69⅜ @ .84¾	January
1887	August	.66⅝ @ .94¾	June
1888	April	.71⅛ @ 2.00	September[2]
1889	June	.75½ @ 1.08¾	February
1890	February	.74¼ @ 1.08¼	August
1891	July	.85 @ 1.16	April

[1] No. 2 cash wheat.
[2] The Hutchinson "corner" figures $1.04½ @ 1.05¼ the following day.

PRICES OF WHEAT (CHICAGO MARKET) 1863–1910
(*Continued*)

Years	Months of Lowest Prices	Yearly Range of Prices	Months of Highest Prices
1892	October	.69⅛ @ .91¾	February
1893	July	.54⅜ @ .88	April
1894	September . . .	.50 @ .65¼	April
1895	January	.48¾ @ .83⅜	May
1896	June	.53⅝ @ .94⅜	November
1897	April	.64⅛ @ 1.09	December
1898	October	.62 @ 1.85	May [1]
1899	December	.64 @ .79½	May
1900	January	.61½ @ .87½	June
1901	July	.63⅛ @ .79½	December
1902	October	.67½ @ .95	September
1903	March	.70¼ @ .93	September
1904	January	.81¼ @ 1.22	October
1905	August	.77⅞ @ 1.24	February
1906	Aug.-Sept.	.69⅛ @ .94¾	April
1907	January	.71 @ 1.05¼	October
1908	July	.84½ @ 1.11	May
1909	August	.99¼ @ 1.60	June
1910	November	.90½ @ 1.27½	February

[1] The Leiter "corner" figure. The above table was compiled by Charles B. Murray, editor of the Cincinnati Price Current.

APPENDIX L

CROP STATISTICS FOR CONTINENTAL UNITED STATES[1]

	CORN	WHEAT	OATS	BARLEY	RYE
Average Number of Acres					
1867–1876 .	38,688,449	21,690,478	10,195,566	1,323,839	1,338,763
1877–1886 .	63,408,900	35,062,189	17,826,840	2,153,883	1,936,360
1887–1896 .	74,290,879	36,583,809	26,919,954	3,164,889	2,077,653
1897–1906 .	87,971,235	45,540,593	27,689,458	4,158,986	1,799,512
Average Production					
1867–1876 .	1,011,535,800	258,407,900	278,267,071	29,735,169	18,217,420
1877–1886 .	1,575,626,651	436,726,976	491,482,427	48,137,782	24,880,175
1887–1896 .	1,800,271,093	464,093,443	686,859,971	72,117,116	26,784,385
1897–1906 .	2,240,363,473	631,181,626	835,644,006	108,684,958	28,341,965
Average Yield Per Acre	Bushels	Bushels	Bushels	Bushels	Bushels
1867–1876 .	26.2	12.0	27.5	22.8	13.6
1877–1886 .	25.1	12.5	27.8	22.4	13.0
1887–1896 .	24.0	12.7	25.5	22.7	12.9
1897–1906 .	25.4	13.8	30.1	25.5	15.7
Average Total Value					
1867–1876 .	$457,000,523	$202,245,463	$103,401,326	$23,030,837	$14,094,568
1877–1886 .	625,623,878	388,867,604	157,859,103	28,842,694	15,454,005
1887–1896 .	633,694,378	319,632,591	193,005,251	33,305,476	14,487,116
1897–1906 .	869,575,310	431,717,233	246,936,311	46,158,110	15,444,264
Average Value	Per Bushel Cents	Per Bushel Cents	Per Bushel Cents	Per Bushel Cents	Per Bushel Cents
1867–1876 .	46.5	103.0	37.5	78.3	76.0
1877–1886 .	40.3	89.8	32.5	60.9	62.8
1887–1896 .	36.6	68.7	28.7	46.6	53.6
1897–1906 .	39.0	68.8	29.4	42.1	54.3

[1] Calculated from Yearbook United States Department of Agriculture. The average yields per acre and value per bushel as here calculated are the averages of the ten yearly averages.

APPENDIX M

PLOWING AS AFFECTED BY SHAPE OF THE FIELD

(8 inch furrow)

Land	Length of Lands (Yards)	Breadth to give an Acre (Feet)	Number of Furrows in an Acre	Time Taken to Turn at Ends	Time Taken to Turn Soil
				H. M.	H. M.
1	78	186	279	4 39	3 21
2	149	98	147	2 27	5 33
3	200	73	109	1 49	6 11
4	212	69	103	1 43	6 17
5	274	53	79	1 19	6 41

APPENDIX N

AVERAGE DEPRECIATION A YEAR AND COST TO THE ACRE FOR FARM MACHINERY (Minnesota Bul. 117)

Machine	Depreciation per Year, on Original Cost	Cost per Acre
	Per Cent	
Threshing outfit	12.00	$0.335
Hay loaders	11.78	.151
Manure spreader	11.67	
Corn binders	10.03	.826
Harrows	8.72	.017
Reapers	8.13	.171
Grain binders	7.91	.181
Mowers	7.80	.206
Hay rakes	7.80	.085
Gasoline engines	7.35	
Corn cultivators	7.25	.155
Corn planters	7.15	.087
Grain drills and seeders	6.75	.075
Harness (heavy)	6.17	
Plows: Sulky	8.42	.087 (all plows)
Plows: Gang	7.40	
Plows: Walking	6.09	
Hay racks	7.76	.034 for grain; .158 for corn; .059 for hay (hay racks, sleds, wagons)
Sleds	5.81	
Wagons	4.89	
Horse weeders	5.71	
Disks	5.19	.089
Hay tedders	4.84	.113
Fanning mills	4.58	.010
Grain tanks	3.47	.011

APPENDIX O

GLOSSARY

Alkaloid. — Substances in plants that stimulate or deaden nervous action, such as strychnine, morphine, and caffein.

Ash. — Mineral matter left after burning; ashes.

Awns. — Beards on seed-coats or on chaff.

Bacteria. — Extremely small one-celled plants, — the smallest members of the plant kingdom. They depend on other plants or animals, either living or dead, for food.

Bast. — The fibrous part of the bark.

Bracts. — Leaflets near the base of true leaf, or on rootstocks; any leaves normally much reduced in size.

Calyx. — Outer envelope of the flower; if the parts are separate, they are called sepals; if not wholly separate, they are lobes.

Cambium. — Growing tissue usually between bark and wood. It lies between the phloëm and the xylem of the fibrovascular bundle, and as these bundles, when active, are on the outside of the woody cylinder, the cambium seems to lie between the wood and bark.

Capillary water. — All water that is held in films and that will evaporate without heating, if exposed to the air.

Carbohydrates. — Substances consisting wholly of carbon, hydrogen, and oxygen, such as sugar, starch, and cellulose. They constitute the greater part of the dry weight of plants.

Cell. — Smallest unit of living things, consisting of cell-wall inclosing jelly-like cytoplasm and heavier nucleus.

Cellulose. — Material composing cell-walls. Cotton, wood, walnut shell, bark, straw, and cabbage leaves are chiefly cellulose.

Chlorophyll. — Green coloring matter of plants, by the use of which plants manufacture their food.

Corolla. — The petals, or the inner floral envelope, in the flower (usually showy).

Cortex. — The bark. All of the tissues between the cambium and the epidermis; in woody plants, the whole exterior covering of the trunk or branches.

Cortical. — Pertaining to cortex; outer layers of the potato tuber, except epidermis, outside of the faint yellowish-green ring.

Cross-fertilization. — Fertilization is caused by the male element of pollen uniting with the female element of the ovule. The transfer of pollen from another plant is called cross-pollination.

Crude fiber. — Fibrous part of plants hard to digest; cellulose.

Current meter. — An apparatus lowered into a stream to find how fast the water flows.

Denitrification. — Changing of nitrates to a less usable form of nitrogen.

Dicotyledons. — Plants with two cotyledons or seed-leaves or with seeds in two parts. These plants grow from a cambium and lay down rings in the stem. They form two of three great divisions in higher plants. They are subdivided into gymnosperms such as pines, and angiosperms such as oak trees, peas, and all plants with split seeds. See *Monocotyledons.*

Elements. — Various chemical substances that cannot be separated by present means into two or more other substances.

Embryo. — The part of the seed that begins growth; the germ.

Endodermis. — Inner skin, usually rich in starch.

Endosperm. — The contents of a seed that lies outside the germ or embryo. It supplies food for the growing seedling. It is the white part of wheat.

Entomology. — The science that deals with insects.

Enzymes. — Chemical substances within plants or animals that aid in reactions or changes, such as the transformation of starch to sugar.

Epidermis. — An outer covering (from *epi,* outside, and *dermis,* skin); it is cast off by trees in early years of growth. The outer covering of trees is often cortex.

Fermentation. — The breaking down or changing of compounds by chemical reaction, such as the heating of manure and the formation of alcohol from sugar by yeast.

Fibro-vascular bundle. — Bundle or body consisting of fibers, and of ducts which transport water up the stems and elaborated foods down the stem. They show in corn pith as strands, and in wood and squash vines as V-shaped bundles.

Flocculation. — Grouping of the soil particles.

Formalin. — Solution of formaldehyde in water, usually 40 per cent.

Fungus, fungi. — A group of plants such as mildew, smut, mold, and mushrooms consisting mostly of thread-like tissues and devoid of chlorophyll. They propagate by means of spores (detached cells) instead of seeds.

Genus. — A group of closely-related species of plants, all bearing one general name, as *Trifolium,* the clovers; *Populus,* the poplars.

Gravitational water. — Water in excess of film water. It passes downward through soil due to pull of gravity.

Hygroscopic water. — Water held closely by soil particles as a thin film. It cannot be evaporated without heating.

Lenticels. — Pores in plants. The epidermis is often torn by the growth beneath. These openings may penetrate into deep tissue.

Lint. — Cotton fiber.

Linters. — Short fiber on cotton seed.

Medullary. — The inner layers of the potato, inside the faint yellowish-green ring.

Medullary rays. — Ducts or pithy areas extending radially from bark to center of stem.

Microörganisms. — Plants or animals so small that they cannot be seen without a microscope.

Monocotyledons. — Plants having only one cotyledon or seed-leaf, or seed in one part. They usually have parallel-veined leaves, and since they have no cambium, do not lay down rings in growth. They constitute one of three great divisions of higher plants. All grasses and cereal grains, palms, lilies, and orchids are examples. See *Dicotyledons.*

Natural selection. — Selection or persistence in nature of those individuals most fit to survive, out of the many that begin life.

Nitrification. — Changing less available nitrogen to nitrates which are readily used by plants. Bacteria change ammonia, free nitrogen, and nitrites to nitrates by oxidizing them.

Nitrogen-fixation. — Making free nitrogen into compounds of nitrogen that are solids or can be made into solids readily.

Nodules. — Enlargements on roots of legumes containing colonies of bacteria which live on food made by the plant, but which take nitrogen from the air. Legumes are the only agricultural plants known to bear nodules.

Nucleus. — The center of cell activity, usually darker than the other cell contents.

Organism. — Any living thing or body, as a plant, an animal, a microbe.

Osmosis. — Passage of water or dissolved material through a membrane to equalize the concentration of the solution on both sides of the membrane.

Ovary. — The part of the pistil containing the ovule or ovules; the seed-case.

Ovule. — The body which, after fertilization, becomes the seed.

Palisade cells. — Elongated cells under the epidermis of some leaves.

Panicle. — Branching flower-cluster or seed-cluster, as in oats.

Parasites. — Plants or animals that subsist or feed on living plants or animals.

Pathology. — The science concerned with the nature, cause, and control of disease.

Pericycle. — Region of the stem just outside the phloëm; inner bark.

Phloëm. — Fibrous tissue on the inner part of the bark just outside the cambium through which elaborated plant-food passes downward.

Photosynthesis. — Manufacture of sugar and starchy foods by chlorophyll in the presence of sunlight from water and carbon dioxide. (From *photo*, light, and *synthesis*, to put together.)

Pistil. — Ovule-bearing organ of flowers, consisting of ovary, style, and stigma; when ripe or mature, the seed-case.

Plasma membrane. — A thin, colorless membrane covering the protoplasm.

Plastids. — Small distinct bodies of protoplasm, which store starch and which contain chlorophyll or the yellow color of flowers.

Pollen. — Contents of the anthers, usually in the form of small grains. Pollen carries within it the male element. When this unites with the female element in the ovule, fertilization results and seed growth begins. Pollen is usually fine powder, such as the yellowish dust that comes from corn tassels.

Protein. — Plant or animal compounds comprising protoplasm, containing nitrogen and sulfur, in addition to carbon, hydrogen, and oxygen.

Protoplasm. — The living contents of a cell, rich in nitrogen.

Reproduction. — Process of starting the next generation.

Respiration. — Breathing; a process that proceeds in all living organisms. Oxygen is used up, carbon dioxide liberated, and heat given off.

Saprophytes. — Organisms that secure a part of their food for energy from foods already combined. These foods are often dead tissue.

Self-fertilization. — Fertilization results from a union of pollen and ovule. When pollen fertilizes the ovule of the same plant, the process is called self-fertilization. See *Cross-fertilization.*

Sieve-tubes. — Vertical row of cells in the phloëm through which elaborated food passes downward, so-called because of sieve-like end walls.

Species. — One kind of plant, as alfalfa, red clover, white clover, sugar maple, oat. Any group or assemblage of individuals that are so much alike as to seem to be the progeny of one similar ancestor, or which are not sufficiently unlike to warrant the giving of more than one botanical name to them.

Spermatophytes. — Plants that produce seeds, as all the so-called higher plants.

Spike. — Cluster when seeds or flowers are borne on short pedicels or branches bringing the spikelets close together, as in wheat.

Sponge tissue. — Loose tissue in leaf, so-called because of large spaces between cells.

Stamens. — The pollen-bearing organs of flowers; the essential part is the anther or pollen-case, and this is usually borne on a stalk or filament.

Stigma. — The part of the pistil that receives the pollen; it is usually at the top of a style or stalk.

Stoloniferous. — Spreading by means of rooting branches, or stolons which appear at or near the surface; in grasses, sod-forming by rootstocks.

Stomata. — Mouth-like openings in leaves of plants. They permit the intake of carbon dioxide and allow water and oxygen to pass out. When plants wilt, two small cells fall together, partly closing the opening.

Style. — The neck-like or stalk-like part of the pistil that holds the stigma well out toward the opening of the flower.

Tissue. — Groups of cells that do the same kind of work; specialized parts of plants or animals.

Tracheal tubes. — Channels or tubes in woody part of plant, for carrying water from roots to leaves. They are found in the xylem and have thick and thin places in their walls.

Translocation. — Movement of stored food from one part of the plant to another.

Transpiration. — The giving off of water from the leaves and other parts of plants. This water has been used in carrying dissolved material to the leaves. Evaporation also cools the leaves in hot weather.

Vacuoles. — Bodies of cell-sap inclosed in the cyptoplasm.

Weir. — A device to measure flowing water.

Xylem. — That part of the fibro-vascular bundle, through which sap passes upward. It lies within the cambium. Wood in trees is almost entirely xylem.

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