The Rural Text-Book Series

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THE SMALL GRAINS

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Swedish Select Oat

Frontispiece

THE SMALL GRAINS

BY

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AGRICULTURE

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To

MY FATHER

LEWIS D. CARLETON

THIS BOOK

IS AFFECTIONATELY DEDICATED IN APPRECIATION

OF THE FACT THAT ITS PRODUCTION IS MADE

POSSIBLE THROUGH HIS MATERIAL

AID AND ENCOURAGEMENT

RENDERED YEARS AGO

PREFACE

In the preparation of this volume the author has kept in mind the manifest need of giving more attention to the fundamental facts underlying agronomy, in the present-day training of students in agriculture. Such need has been felt directly by the author in his organization of young men for agronomic and pathologic research. It is the occasional student who finds himself prepared by sufficient training in those applied sciences related to the study of field crops to meet the awaiting problems of investigation. As the stream cannot rise higher than its source, so the agriculture of the future cannot be greatly improved unless the leaders themselves are placed on a firmer scientific footing.

From the above, it will be correctly inferred that this book is intended primarily for instruction in colleges and universities. It will be a disappointment, however, if it shall not be found adapted for use in agricultural short-courses, academies, and high schools, and by many farmers and general readers.

The manner of presenting some of the subjects is very different from that usually followed, but the changes are considered well justified, and it is hoped will commend themselves. After discussing briefly the fundamental principles of plant structure and nutrition, as related to cereals, — which subjects may be omitted by those students who have had good training in plant physiology, — the four principal cereals are treated separately and from the individual plant standpoint, as to their origin, characters, classification, varieties, selection, and hybridization. Thereafter these cereals are treated together in respect to the further subjects of soil and climatic relations, acclimatization, cultivation, irrigation, weeds, insect and fungus pests, and uses. By this method there is avoided much duplication of topics under each cereal that would otherwise be necessary. For example, smut diseases are discussed for all the cereals at the same time, and not duplicated under each cereal. Buckwheat, being botanically different from the four cereals referred to, is treated separately as to all topics; and the same is true of rice.

Scientific names, references to literature, and the matter in small print, are included for scientific accuracy and completeness, and may be omitted to such an extent as may seem desirable to the instructor. Citations of literature are made in the body of the text, and refer to a bibliographic list in the appendix, arranged (1) according to chapters, (2) alphabetically as to authors under the chapters, and (3) chronologically under each author. It should be noted that the classification under each cereal is tentative, and is presented as a temporary working basis for the student. The subject is an open field of investigation in which little has been done.

As this is the author's first book, and it is attempted to present our knowledge of the cereals up to date, there may naturally be errors therein. Any information as to such shortcomings will be gratefully received.

Acknowledgment is hereby made of much assistance received from many persons in the preparation of the book, particularly from members of the Office of Cereal Investigations and others in the Federal Department

of Agriculture and at the experiment stations and agricultural colleges. Special acknowledgment is due to C. E. Leighty and H. B. Humphrey for help in preparing certain chapters, and to C. W. Warburton for excellent criticism of manuscripts. Drawings for many of the illustrations have been made by A. B. Boettcher, J. H. Stevenson, W. E. Chambers, J. Marion Schull, and F. H. Hillman. The greater part of the mechanical construction of the text has been performed by Amanda Faught Carleton, who also helped much with criticisms and suggestions. Credit is given for each illustration, not original, in the list of illustrations.

M. A. CARLETON.

WASHINGTON, D.C.,
January, 1916.

CONTENTS

PART I. CEREAL PLANTS

CHAPTER I

CHAPTER II

CHAPTER III

CHAPTER IV

CHAPTER XI

CHAPTER XII

PART III. CEREAL CROPS

CHAPTER XIII

CHAPTER XIV

CHAPTER XXIII

LIST OF ILLUSTRATIONS

TABLES

PART I

CEREAL PLANTS

THE SMALL GRAINS

CHAPTER I

FORM AND STRUCTURE

CEREALS belong botanically to the very large family of flowering plants called grasses (Poaceæ or Gramineæ). In this volume is a discussion of all the cereals except maize, proso, and the grain-sorghums,[1] with the addition of buckwheat, a member of the smartweed family (Polygonaceæ), but commonly classed with cereals. These are known collectively as the small grains. Wheat, oats, barley, and rye, requiring similar treatment, are handled simultaneously under a number of heads. Rice and buckwheat are discussed independently as to all phases.

1. Roots. — There are two sets of roots in cereals. The first or seminal roots, 3 to 8 in number, arise directly from the hypocotyl; the second or coronal roots, which are permanent, arise from the point just a little below the surface of the ground called the crown. The permanent roots of cereals are wholly fibrous, extending outward and downward in all directions from the crown. There is an entire absence of a tap root such as exists in alfalfa, cotton, and other field crop plants. The most essential character in the roots is the existence of myriads of minute

[1] For maize and sorghum-like plants, see Montgomery, "The Corn Crops."

rootlets or root-hairs which absorb water and liquid food for the nourishment of the plant. There is little or no growth of cereal roots after the beginning of flowering, in which fact cereals differ from dicotyledonous plants. The product of the root penetration in depth by the diameter of the lateral spread of the roots is called the root coefficient (Fig. 1).

FIG. 1. — Cereal seedlings, showing the origin of coronal or permanent roots, in one case some distance above the seed.

2. Culms. — In cereals the culms or stems are round and usually hollow (48, 50, 53, 58), with solid joints or nodes. There are both sheath nodes and culm nodes, the former being those usually observed, showing externally as swellings at the base of the leaf sheath. These nodes aid the plant in recovering an erect position and therefore may be important characters in relation to lodging. From buds at the basal nodes of the culm additional culms may branch off, and from these culms still others in the same way. Thus the process of "tillering" is explained, which is carried to so great a degree in certain cereal varieties or in all varieties under favorable conditions.

In minute structure the culm is characterized by the presence of a large amount of hard tissue (sclerenchyma), which gives it great firmness. This tissue often takes the form of rings lying just beneath the epidermis and is closely associated with fibrovascular bundles (Fig. 2).

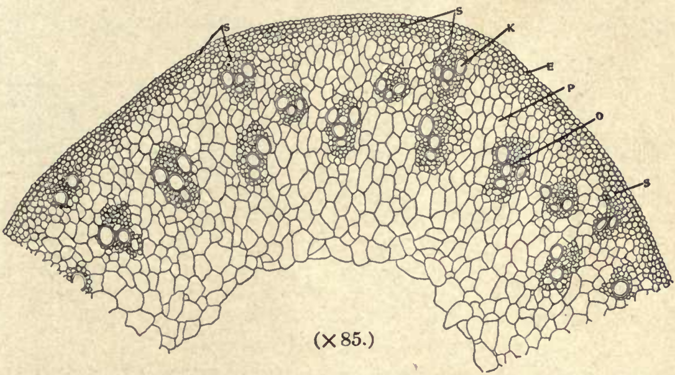


FIG. 2. — Part of cross-section of a culm of wheat: *E*, epidermis; *P*, parenchyma; *O*, fibrovascular bundle; *K*, vessel; *S*, sclerenchyma.

3. Leaves. — All cereals have alternate two-ranked leaves. Tufts or bunches of leaves are often formed near the ground. A cereal leaf consists of two parts, the sheath and the blade. The sheath incloses the culm as in a tube, but is split down the side opposite the blade, and its two edges overlap, the outer edge being raised slightly. There is an appendage extending upward at the line of union of the sheath and blade, called the ligule. The glume of the flowers corresponds to a sheath, the blade being absent or reduced to the form of an awn. Near the ligule there are also two ear-shaped appendages (auricles), one from each edge of the leaf, which partially or entirely clasp the culm. They are well developed on barley, but are lacking on oats. On young wheat plants they often bear a number of hairs.

The leaf-blade is usually narrow-linear or linear-lanceolate and often is twisted. In rye and wheat it is twisted to the right. In oats it is twisted in both directions, in one direction above and in the other below. Fibrovascular bundles ("nerves") parallel each other throughout the

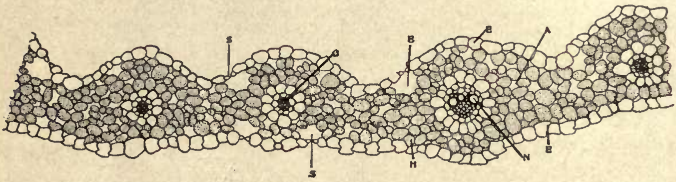


FIG. 3. — Part of cross-section of a wheat leaf: *A*, mesophyll; *B*, intercellular space; *E*, epidermis; *H*, chlorophyll grains; *O*, fibrovascular bundle; *N*, vessel; *S*, stoma and guard cell. (×71.)

blade, ending at the edge, and give firmness to the leaf. The primary bundles are accompanied on one or both sides by bundles of hard tissue (sclerenchyma).

The epidermis of the leaf in many cases contains much silica in its cell-walls, which stiffens the blades. Wedge-shaped bulliform cells, arranged in fan formation, between the nerves, expand and force the blade to open. The stomata or "breathing-pores" are in longitudinal rows and each surrounded by four cells, two of these being long, narrow guard cells. In the cases of wheat and oats, at least, these stomata are more abundant in the upper epidermis (Fig. 3).

4. Inflorescence. — By the branching of the upper portion of the stem, inflorescence originates; it may occur in different ways: if the branches form single spikelets and the lowest glumes appear sessile upon the main axis, the inflorescence is a spike; if the spikelets are formed only upon further divided or secondary branches, it is a panicle.

5. Spikelets. — The unit of inflorescence is the spikelet, and, as above stated, its form is dependent upon the arrangement of the latter. It consists of a much shortened, close-jointed axis, having two-ranked, modified leaves or bracts. The lower two of these are known as glumes proper, which are followed by a flowering glume recently called lemma, which partly incloses a branch bearing sexual organs, protected also on the other side by a bractlet called a palea having its back toward the axis of the spikelet. Occasionally, as in barley and rice, the spikelet is one-flowered. Often the flowers that are present are not all fertile. Either glumes or sexual organs are sometimes rudimentary. Lemmas are frequently awned, and usually have a middle nerve. They frequently extend downward on the axis from their point of insertion. This portion grown to the axis is separated from the free part by a furrow called the callus. The palea is generally more delicate in texture than the lemma, has its edges usually turned in, and has usually a furrow instead of a midrib.

There are sometimes opposite the palea and above the lemma two small scales called lodicules, standing with their edges touching and grown together at their bases. These are usually considered to be two parts of a rudimentary perianth, a third part of which (the posterior lodicule) is found in certain other grasses, although Hackel regards the two anterior lodicules taken together as a second palea and the posterior as a third. When these lodicules are present, the swelling of their bases causes the separation of the lemma and palea, and thus aids in the opening of the flower. As to the succession of flowering of the spikelets, in panicles the terminal spikelets of the panicle and its branches flower first, and from there downward. In spikes the middle spikelets or those just above the middle are first to flower. Within the spikelet flowering progresses from below upward.

6. Reproductive organs. — Flowers of the cereals contain usually three stamens, but in rice there are six arranged often in two whorls of three each. One stamen, the earlier and better developed of the three, always stands above the lemma, while the other two stand in front of the keels of the palea. The stamens have slender, distinct filaments, which in the closed flower are very short, but at the time of flowering elongate rapidly. They soon tip over in such a way that the main mass of the pollen is emptied. The narrow-linear anthers have a fine connective and are versatile; that is, the filament is attached below the middle by a tapering end, which condition assists in the scattering of the pollen by the wind. The pollen is finely granular, spherical and smooth, and discharged in abundance.

The pistil includes an ovary with one ovule and two usually sessile stigmas. The stigmas, distinguished by their papillate cells, are much branched, the branches being usually arranged in a spiral. These branches bear smaller papillæ, and the entire system, possessing a large surface, is well adapted to catch pollen carried by the wind.

7. Fertilization. — Cereals, so far as known, are anemophilous; that is, fertilized through the medium of the wind. Usually both self- and cross-fertilization are at least possible, and both probably occur. In all barleys, however, cross-fertilization is rare, and in many two-row varieties apparently impossible. On the other hand, cross-fertilization is the rule in rye. Wheat and oat varieties are usually self-fertilized, but there are adaptations for cross-fertilization, and no doubt the latter occurs much more frequently than is generally supposed. It is certain that there are numerous natural crosses among durum wheats and emmers. Also common wheats no doubt cross with these groups naturally, thus reducing these striking intermediate forms sometimes seen in the field which are otherwise unexplained.

8. The ovule. — Without a funiculus, the ovule grows to the ventral suture of the carpel, and is hemitropous, having the micropyle facing downward and outward. There is an outer and inner integument, and along the anterior side of the former, the pollen tube passes to the micropyle. The embryo sac makes rapid growth at once after fertilization, and in the meantime there is stored up within it an abundant supply of food material, especially a large amount of starch. The ovule increases in size until it completely fills the cavity of the ovary and finally merges with its walls. The embryo, at first club-shaped, develops its upper portion into a cotyledon, which becomes shield-shaped. From the epicotyl arises externally a collar-like projection upward, the beginning of the coleoptile. The foundation of the radicle at first lies deep in the lower portion of the embryo and grows with it, but later becomes separated from the surrounding tissue, which latter forms the coleorhiza or root-sheath, corresponding to the coleoptile. Other radicles soon arise at the base of the main radicle, while the beginnings of foliage leaves in the upper embryo increase to 3 or 4 (Fig. 6).

There is, therefore, already considerable development of the embryo plant at maturity of the seed.

9. Seed. — The fruit of a cereal is a caryopsis or kernel, of which the seed and the pericarp are grown together (Fig. 4). In milling, this thin pericarp, together with the adjacent layer of aleurone, is removed as bran (592). In many cases, as in the barleys, the pericarp unites with the

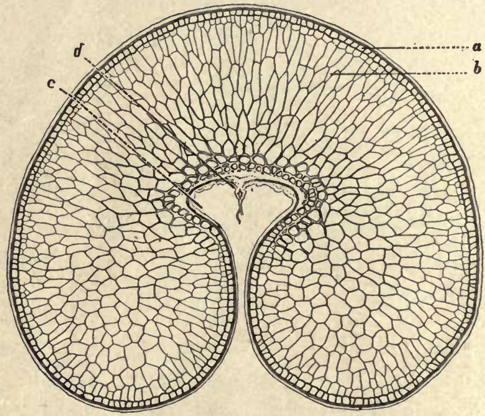


FIG. 4. — Cross-section of a wheat kernel: *a*, aleurone layer; *b*, parenchyma; filled with starch grains; *cd*, a portion further enlarged in Fig. 5, showing there the starch grains.

lemma and palea (84, 113). In other cases (55, 58), the latter are simply close around the kernel and not adherent to it, as in the spelt and emmer.

Near the base of the grain, on the posterior side, there is a mark called the hilum, showing the place of original attachment of the seed to the wall of the ovary. On the opposite side, facing the lemma, is the embryo, showing plainly through the pericarp. An important part of the embryo is the scutellum, a rather thick, flat body, roundish, elongated oval, lying close to the endosperm. The plumule and radicle arise in its shallow exterior. On the inside of the scutellum occurs a so-called epithelium of palisade-formed cylindrical cells, with delicate walls. Its purpose, apparently, is to absorb the amylaceous material of the endosperm. Opposite the scutellum and in front of the embryo is a small scale-like appendage, the epiblast, present only in wheat and oats and apparently of no functional importance (Fig. 9).

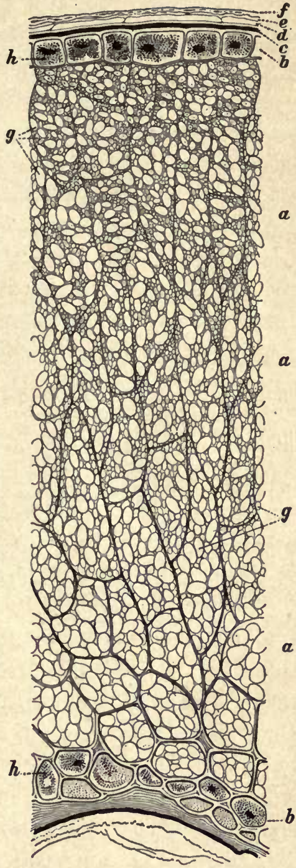


FIG. 5. — A part of the section in Fig. 4, taken at *cd*, further enlarged: *a*, starch endosperm; *b*, aleurone layer; *cdef*, investing membranes, representing the original integuments of the ovule and the wall of the ovary; *g*, starch grains; *h*, aleurone grains. (× 108.)

10. Reserve food-materials. — In the seeds of cereals, the reserve food is stored within the endosperm, while in those of legumes, it is stored in the seed leaves or cotyledons. There are two main groups of reserve materials, the non-nitrogenous, including carbohydrates, fats, and oils; and the nitrogenous, composed of various proteins, and commonly referred to under the general term of aleurone. The embryo itself contains oils, proteins, and carbohydrates. The endosperm, consisting of large parenchyma cells, has an abundance of starch grains, except in the outer layer. Very small protein bodies are distributed throughout the seed, but especially in the outer portion of the endosperm. In the starchy portion, these bodies occur between the starch grains. If they fill the intervals more or less completely, the endosperm becomes translucent or corneous and the kernel is said to be flinty. If the intervals are not closely filled, air spaces remain, the endosperm becomes opaque, and the kernel is called mealy (Fig. 5). Both conditions (in the case of wheat) often occur in the same variety and even in the same season's crop. There are corresponding differences in color of the kernel, and the mealy kernels are commonly referred to commercially as "yellow berries." The whole phenomenon is one of environment, in which heredity has little or no part, and in which climatic changes have apparently the chief influence, as shown by recent experiments (316–317).

11. Starch grains. — In different cereals, the starch grains vary greatly in size and shape. They are often spherical. In wheat starch they are either lenticular and rather large, or comparatively small and many-sided, or compound, composed of 2 to 25 partial grains. Those of barley are similar to those of wheat but a little smaller, while those of rye kernels are larger. In rice they are either single or in compound oval form, containing 2 to 100 parts. Commercial rice starch, however, contains no compound grains. In oat starch, which is otherwise similar to the latter, such compound grains are present. The exact mode of starch grain formation in seeds is not well understood, but it occurs within plastids, called amyloplasts — specialized portions of the protoplasm. In structure starch grains appear stratified in all cases, the layers being deposited concentrically around a point called the hilum. Chemically, a starch grain is composed of carbohydrates of which there are two forms; (1) the starch-cellulose or outer layer similar to ordinary cellulose, and (2) an inner portion, termed granulose, which readily dissolves with dilute sulphuric or hydrochloric acid. It is this part which gives the characteristic test for starch, the blue color in presence of iodine. The

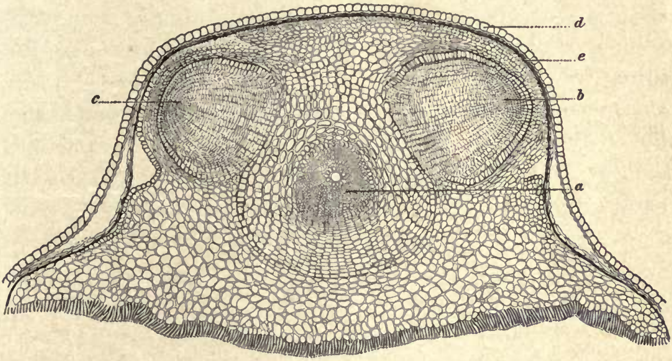


Fig. 6. — Cross-section through the embryonic portion only of the wheat kernel: *a*, first seminal root; *b*, second seminal root; *c*, third seminal root; *d*, epithelial cells; *e*, testa. (× 42.)

starch grains of glutinous rices and proso millet (*Panicum miliaceum*) turn red or reddish brown, instead of blue, under the same test, probably because of some modification in their composition.

12. Aleurone grains. — The reserve-proteins of the seed are contained in the aleurone grains, which are smaller and less developed in the starchy seeds of cereals than in oily seeds. They are rather complex bodies, containing a mineral portion composed usually of a double phosphate of lime and magnesia, and sometimes one or more calcium oxalate crystals; while frequently crystalline proteins are also present. The latter give the property of swelling up quickly on the addition of water. Chemically, the aleurone grains consist chiefly of three proteins: (1) *peptones,* insoluble in water (not even precipitated by boiling); (2) *globulins,* insoluble in water, but soluble in 10 per cent or saturated solution of sodium chloride; and (3) *albuminates,* insoluble in water or the sodium chloride solution, but soluble in alkali. The crystalline proteins consist either of globulins or albuminates.

Gluten of wheat does not exist as such in the dry kernel, but is formed by the addition of water to the proteins, gliadin and glutenin, found in the outer part of the endosperm.

CHAPTER II

GROWTH AND NUTRITION

THE well ripened seed, if kept dry, will remain dormant, resistant to various injurious influences for several years and still retain its vitality. After the second year, however, there is a steady decrease in viability, and after eight or ten years few or no seeds will germinate.[1]

13. Germination. — On the addition of water, and with the proper temperature, the aleurone and starch grains swell, the seed increases greatly in size and becomes softer, and germination begins. As before stated (8), the foundations of the first or seminal roots are laid before germination in the hypocotyl. Each of these seminal roots breaks through the coleorhiza independently and becomes surrounded by a portion of it as a sheath. Previously root-hairs from the coleorhiza itself fasten the seed to the soil. The upward extension of the embryo axis or mesocotyl is virtually the first internode of the new plant, and is well developed in oats. In wheat it is little developed, and not at all in barley. The coleoptile, inclosing the plumule pushes to the surface, and then opens to allow the 2 to 4 leaves of the latter (the plumule) to emerge.

[1] Of course, all stories about the growth of wheat, emmer, and barley seeds that have lain with mummies in Egyptian pyramids during many centuries have no basis in fact.

In ordinary soil, fairly moist, the time required after seeding for the young plant to emerge above ground averages about 5 to 8 days, but may be as short as three days. Among wheats the soft-kerneled varieties will come up quicker than the hard.

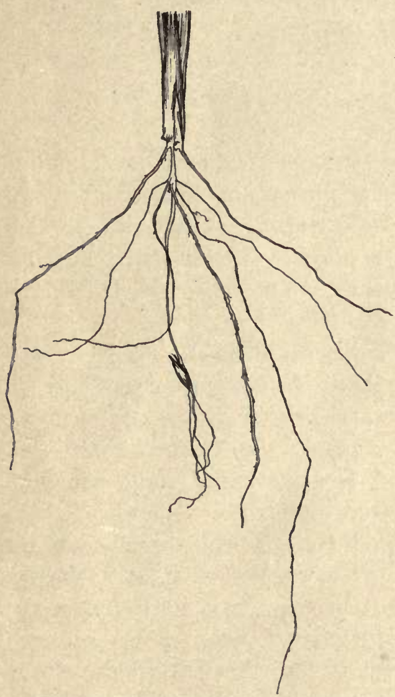


FIG. 7. — Seedling of Kherson oat, showing roots from two different crowns at $2\frac{1}{4}$ and 3 inches above the seed. ($\frac{1}{2}$ natural size.)

14. The seedling. — The life of the plant after germination may be conveniently divided into four stages; (1) the seedling stage, (2) the jointing stage, (3) the heading stage, and (4) the ripening stage. The seedling, as it appears two or three weeks after emergence above ground, bears usually four green leaves, in addition to the coleoptile above mentioned, which quickly withers. The crown, which is the place of separation of stem and root, is formed just beneath the ground, without regard to the depth of planting. If, therefore, the seed is planted deep, the plumule will push upward, before branching, near to the surface, where the crown will be formed some distance above the seed.

Sometimes a plantlet is formed at the point of attachment of the seed by budding from the main axis, while the latter proceeds upward and forms a new or secondary crown nearer the surface. In fact, the entire cereal plant axis, from the seed upward, is practically equivalent to an underground stem, which will branch and root from any portion bearing a node just beneath the ground. It is by taking advantage of this fact that experimenters have increased the product from a single seed almost indefinitely, through covering with earth successive portions of a plant as it progresses upward, thus constantly producing new crowns and new stems (Figs. 7 and 8).

FIG. 8. — Wheat seedling, showing two different crowns

15. Leaves and branching. — New branches soon start from the crown, which is virtually the first node of the plant. This is the process known agronomically as tillering, and the branches or tillers, in the case of winter varieties, are practically all started before the beginning of the winter resting period.

There is much variation in the characters of the seedling even between varieties. The leaves of most wheat seedlings, for example, are glabrous or nearly so, but in emmers and einkorn they are very pubescent, which imparts to them a gray green color. Seedling barley plants are readily distinguished from those of other cereals by their broad leaves and their well developed auricles. Rye seedlings have narrow leaves, and the first leaves usually have a purplish tinge of color. Winter varieties of any cereal usually have narrower leaves than spring varieties. This character, together with the spreading habit, will at once indicate a winter variety in spring seeding that may have been planted by mistake. Seedling leaves vary in color from very light green or yellow green through dark green to purple. Color of seedling leaves is of distinct value in classification. The character of spreading or growing erect is also of importance, also the amount of growth and the time of emergence of successive leaves through a certain period.[1]

16. Jointing. — After reaching a height of 8 to 12 inches the first visible node or joint of the plant appears. The height of jointing as well as heading varies greatly, however, according to the variety and season. The first one or more joints above the crown have already formed, of course, some time before, but were invisible. Winter cereals pass the entire winter resting period before jointing, while spring varieties joint without such a resting period. The upper part of the plant grows in length much more rapidly than the lower, and the upper internodes are longer than the lower. The upper nodes also usually show above the leaf sheath, while the lower ones are hidden.

17. Heading. — As before stated, there is great variation in the height of the plant at which jointing or heading takes place in different cereals and varieties, depending on the season. It may be 8 inches or 4 feet. It may be

[1] In this country it is a remarkable fact that the seedling stage and the root systems of our most common crop plants are pretty nearly unknown subjects.

observed that cereal plants increase their height $\frac{1}{2}$ to $\frac{3}{4}$ after beginning to head, thus showing the rapid growth of the culm during the heading period, and the greater length of the upper internodes, particularly the one bearing the spike called the peduncle. The head or spike usually stands at time of full growth of the plant far above the last leaf sheath. In many two-row barleys, however, the spike remains inclosed in the leaf sheath, till after fertilization, and never does entirely emerge.

18. Ripening. — Cereals ripen, on an average, about one month after heading, but sometimes considerably sooner. Ordinarily, for the plant to be ripe, the spikes (or panicles) should be yellow or golden in color, and the straw also yellowish. If the spikes are black when ripe, or any darker color than yellow, the color of the straw will be the chief indication, and the date of ripening may occur sooner than expected.

Nutrition

19. Digestion of reserve food. — The growth of the seedling plant proceeds at first entirely at the expense of the reserve food materials in the endosperm (10). These materials are complex, the starch and oils having come to the seed in the simpler form of sugar, and the proteins in the forms probably of sugar and amides. In feeding the embryo there is an interesting reverse process, these complex materials now being re-converted into their previous simpler forms, through the action of unorganized ferments or enzymes. The scutellum, already described (9), is the chief absorbing and converting organ during germination, and furnishes from its epithelial layer (Fig. 9) two enzymes, cytase for the breaking down of cellulose and diastase [1] for the conversion of starch into maltose (malt sugar).[2] The oils are probably first split into

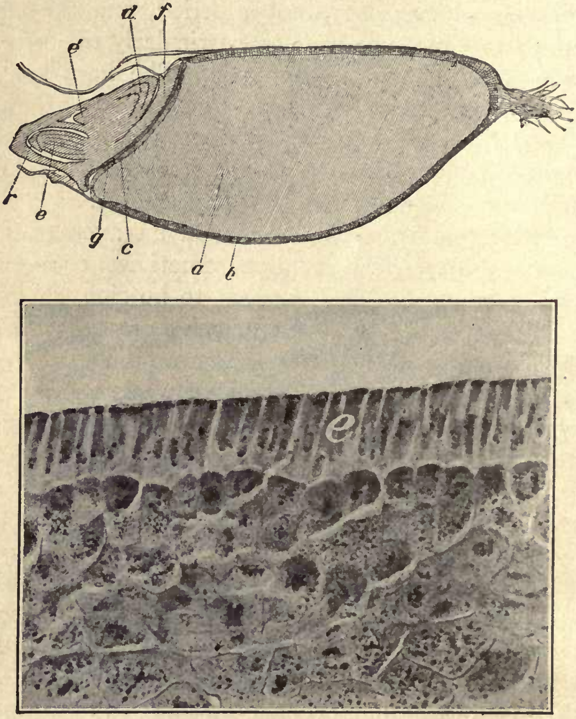


FIG. 9. — Top, longitudinal section of barley grain. Bottom, photomicrograph of the scutellum of a germinating barley kernel, showing the epithelial layer at *e*.

[1] There are also diastases concerned with the process of translocation, occurring in the chlorenchyma of leaves. A particular form, of interest to cerealists, is the takadiastase, produced during the action of *Aspergillus Oryzæ* upon wheat or rice starch (Duggar, 1911, p. 270).

[2] It is this diastatic ferment which is chiefly concerned in the rather extensive business of barley malting.

glycerine and fatty acids (by a group of enzymes called lipases or steapsins) and these, in turn, finally converted into carbohydrates (Vines, p. 173). The proteins are converted back to the amide forms by proteolytic enzymes similar to the pepsin and trypsin of the digestive organs of animals.

20. Photosynthesis, or starch formation. — On the exhaustion of the reserve materials of the endosperm, new food must be manufactured for the growing plant from similar constituents of the air and soil. The first and principal foods produced are carbohydrates, chiefly starch, which are formed only in green portions of the plant, especially in the leaves. They are made in the chloroplasts, which bodies are abundant in the palisade cells of the leaf and numerous in the spongy parenchyma. The process is effected by the chlorophyll in the chloroplasts,[1] employing the energy of the sunlight. In the apparently intricate process of formation of carbohydrates, water and carbon dioxide of the air are primarily concerned, the latter obtained through the stomata of the leaf and the intercellular spaces. There is much more starch in the leaf cells in the evening than in the morning, because it is formed only in the daylight, and during darkness is translocated in other portions of the plant. Moisture and heat are essential in photosynthesis. Water not only takes direct part in starch formation, but its presence keeps the stomata open and the tissue turgid, thus favoring photosynthetic action. The extreme range of tem-

[1] Plastids are relatively small distinct bodies, originating in the protoplast (the original and simplest form of the cell) which perform special functions, and are known as leucoplasts (from which the others are derived), and chromoplasts (Stevens, 1907, p. 9).

perature within which photosynthesis may occur in the small cereals is from just below freezing to 75° C., while the optimum temperature is about 62° C.

21. Protein production. — The synthesis of nitrogenous foods can apparently take place in any living portion of the plant, but appears to be most common in the leaf; and intermediate compounds or amides, such as asparagin, are found there also in large amounts. Some of these proteins contain carbohydrate groupings only, besides nitrogen, while others contain sulfur also, and others phosphorus. There is a great lack of definite information on this subject, however, but it is known that protein food construction goes on independently of the presence of chlorophyll.

22. Essential food elements. — It is seen from the foregoing that the primary elements entering into the actual structure of the plant are carbon, hydrogen, oxygen, nitrogen, and often sulfur and phosphorus. Analyses have shown, however, that potassium, calcium, magnesium, iron, sodium, silicon, and chlorine occur in cereal plants. All of these, except the last three, are said to be essential elements. It is maintained that the presence of potassium is essential in carbohydrate production. Iron is necessary for the normal development of chlorophyll. Though silicon is very abundant in the ash of cereals, it is not considered essential, because not required in the growth of the plant. As it occurs in the cell wall, it seems that it may, by giving support to the plant, be of importance in plant adaptation.

23. Provisions for food circulation. — The seedling at first has its food near at hand, which diffuses to the growing parts where needed through the rapidly forming parenchyma cells. After exhaustion of the reserve foods, the further food supply, as previously stated, must be constructed from the water and mineral salts of the soil, coming through the roots, and the carbon dioxide of the air, obtained through the leaves. These are combined into more complex carbon compounds and nitrogenous foods in the green portions of the plant, chiefly in the leaves, of which there are now several, located at some distance from the roots and from each other, and the plant is of considerable size. There is need, therefore, of some means of passage or translocation of materials to the places where needed. Such means is soon provided in the form of the fibrovascular bundles, which pass the entire length of the stem and roots, and, by branching, into the leaves (mid-ribs, nerves, veins). These are readily seen in a crude form, as threads through the pith, when a dry stalk of maize is broken through an internode.

24. Fibrovascular bundles and leaf structure. — There are two distinct portions of a bundle in cereal plants, the phloëm or outer portion, and the xylem or inner portion. In each of these portions tubes, running lengthwise of the bundle, and therefore of the stem or leaf, are formed by rows of elongated cells placed end to end. In the xylem these tubes or vessels, called tracheids, are very large and have lost their adjacent end walls and protoplasm and carry chiefly water. In the phloëm they are called sieve tubes and carry soluble or finely divided (emulsified) foods (Pfeffer I, p. 577). These vessels are differently formed, having their adjacent cell walls developed into perforated plates, through which their retained protoplasm is continuous.

A cereal leaf in cross-section is shown to be made up of three main portions, the upper epidermis, a middle portion or parenchyma called mesophyll, and the lower epidermis. The mesophyll is made up chiefly of spongy parenchyma and is abundantly supplied with chloroplasts. The border parenchyma is a sheath surrounding each extension into the leaf of a fibrovascular bundle. There are many large intercellular spaces in the spongy parenchyma that intercommunicate freely and connect with the stomata (Fig. 3).

25. Translocation and assimilation. — It will now be easy to understand the entire elaboration and translocation of food materials: from the soil, water and soluble salts are absorbed into the roots through the root-hairs and are thence conducted through the fibrovascular bundles into the leaves. Here there is a constant supply of carbon dioxide from the air, through the stomata and intercellular spaces, which, with the water in the parenchyma cells (delivered thereto through the border parenchyma from the nearest bundle) enter into the formation of sugar, starch, or other carbon compounds, by the energy of the sunlight, in the presence of the chlorophyll existing in these cells. It should be stated that this action may also take place in the border parenchyma itself.

The mineral salts from the soil combine with nitrogen and carbon compounds to form amides or other nitrogenous materials.

After making use of a portion of these foods in actual assimilation, or leaf construction, and retaining other portions as cell contents (oils, mineral crystals), the remaining soluble or diffusible portions, such as sugars, oils, and amides, are translocated to other portions of the plant, being delivered through the border parenchyma into the bundle, the tracheids of which carry the water and small portions of food materials, and the sieve tubes carry the bulk of the soluble foods. On reaching their destination the materials in solution are formed into complex proteins, starch, and cellulose, as above stated, and become a part of the plant structure.

26. Course of the foods. — The water and salts from the soil pass simply upward into the stem and to all branches. The elaborated foods in the leaf must pass both downward and upward to reach all portions of the plant. Evidently, in order to supply other sides of the culm not in line with leaf bearing branches, the food must also be able to pass across to other bundles. It is especially necessary in cereal plants where the leaves are two-ranked; that is, occur only on two sides of the culm. However, in these plants, which usually have hollow internodes, there is nevertheless pith present in all nodes, through which the fibrovascular bundles from all sides cross and anastomose with each other, so that food in any one bundle may pass into many others, and thus to other sides of the stem.

27. Transpiration. — Water not only carries food in solution, but may itself become an important constituent of foods. Its escape from the plant, therefore, by simple surface evaporation or through the stomata, called in either case transpiration, often proves to be a serious loss. There is evidence, also, that transpiration is often beneficial. By means of the transpiration current dissolved foods are largely enabled to pass quickly and over comparatively long distances in the plant. It appears to aid in the translocation of ash constituents, which are of much importance in certain cereals. It may aid in gaseous exchanges within the plant and may have a cooling effect upon plants that would otherwise be much injured by exposure to great heat. As suggested by Pfeffer (1900, p. 235), there must be an optimum rate of transpiration for each plant, varying in accordance with different external conditions.

28. Protection against transpiration. — There are various protective characters possessed by the more drought-resistant plants, which serve to check transpiration, such as a thickened epidermis, preventing cuticular transpiration, and reduction of the transpiring surface, by the absence or narrowness of leaves, or rolling of leaves. A covering of small hairs overlapping each other will obstruct transpiration. Many cereal varieties, native in desert or semi-arid districts, possess one or more of these protective characters. At the same time, as above hinted, these varieties appear to be improved by a certain amount of enforced transpiration, as they usually bear more vigorous kernels and possess greater winter-hardiness and resistance to attacks of fungi and insect pests than the ordinary varieties of humid districts (48, 50, 53). The same varieties also lose these qualities to a considerable degree on transference to humid areas.

CHAPTER III

WHEAT

WHEAT, rye, and barley are included in that tribe of the grass order called Hordeæ, in which the 1- to ∞-flowered spikelets are sessile and alternate on the rachis, thus forming a true spike. Wheat and rye are still more definitely located in the sub-tribe Triticeæ, whose genera have the spikelets situated transversely to the rachis and not in the median line. The glumes are opposite.

29. Description. — In the genus Triticum, including common wheat, the spikes have a terminal spikelet, and the lowest 1–4 spikelets are smaller than the others. The spikelets are closely imbricated; glumes broad, with one to many awns or a blunt or toothed apex; lemmas rounded on the back, often boat shaped, many nerved, ending in one to several teeth or an awn; kernels very slightly compressed laterally, deeply sulcate, hairy at the apex, free; embryo with epiblast.

There are two sections of the genus, one including the old genus Ægilops, in which the glumes are flat or rounded on the back, and the other, in which the glumes are sharply keeled, including the cultivated varieties. There are twelve species of Ægilops, distributed in southern Europe and western Asia. Common wheat has long ago been successfully crossed with *A. ovata* (Hackel, 1890, pp. 170–180), and more recently with *A. triticoides*.

30. Roots. — On germination, the wheat kernel throws out three seminal roots in the same plane, with occasionally a fourth odd one. Still other branches put forth near the bases of these, so that there are sometimes apparently as many as 8 seminal roots, as in the variety Fultz. Later the coronal or crown roots begin forming from nodes just below the surface of the ground. The depth of the seminal roots, therefore, depends upon the depth of planting, but the depth where the plant finally roots and feeds is independent of the depth of planting. The coronal roots rapidly divide into myriads of branches. There are about eight branches to the inch, on each main root, to a depth of 18 to 20 inches. Below this few branches are found. It seems probable, therefore, that those roots which go to such depths as 4 to 7 feet, as in semi-arid districts, do so in search of water (Hays and Boss, 1899) (Fig. 10). The roots start from the main axis apparently in whorls of four each. The bulk of the plant-food is obtained within a comparatively shallow depth, but through an enormous root surface of divided and subdivided roots, covered with root-hairs. Winter wheat roots will reach a depth of 116 cm. and spread laterally 126 cm., the root coefficient being 14616. Spring wheat roots run 103 cm. deep and spread 104 cm., root coefficient 10712 (Rotmistrov, 1913, p. 25).

31. Culms. — In wheat the culms are hollow, but sometimes may be pithy within. They vary in height from two to five feet, but in the driest seasons on the plains may be even shorter. The same variety will vary in height in different districts, on different soils, and with different amounts of water. There is particularly great variation in the length of the peduncle or uppermost internode, supporting the head. Wheat is generally taller than barley and often taller than oats, but usually not so tall as rye. The taller the plant, the greater the tendency toward "lodging," which in turn interferes with the harvest and makes the crop more subject to rust attacks. A natural corrective of lodging is the ability of the plant to arise by bending upward at the node next above the break or "crinkle," producing a swollen "elbow joint."[1] Weakness of the stem is sometimes a varietal characteristic to be avoided by the grower.

32. Leaves. — Wheat and rye leaves are similar, but are usually narrower than the leaves of oats and barley. They vary greatly in their dimensions and even in the shade of color, and in texture, in different varieties, and are of considerable importance in classification. The leaves of the seedling present especially interesting characteristics, which in many instances distinguish subspecies and other smaller divisions. Wheat and other cereals may be partially distinguished from each other in the seedling stage by the auricle (see 3), or clasp, as follows: —

1. Auricle present.
   a. auricle very small, Rye.
   b. auricle large, Barley.
   c. auricle intermediate and sometimes with hairs on outer margin, Wheat.
2. Auricle absent, Oats.

In hardy winter seedlings, the leaves are narrow and usually dark green or at first purplish near the roots. They soon spread out flat on the ground in preparation for the snow and cold winter. Spring varieties, and most durum and poulard wheats, grow erect quickly and have coarse light green leaves. Ligules short, truncate, with extremely short triangular teeth or only very

[1] "Crinkle-joint" or "break-over" disease is a special case of crinkling caused by the presence of one of the imperfect fungi (Bolley, 1913, pp. 22–23).

weakly undulating, glabrous, with very short scarcely perceptible hairs on the margin.

33. The spike. — The entire assemblage of floral organs on one culm is called the spike. Each separate cluster of these floral organs is known as a spikelet. In wheat there is only one spikelet at each node or joint. The spikelets are arranged alternately on the zigzag rachis, and transversely to its median line. At the base of each spikelet short bristly hairs occur. These vary in color and length or may be lacking. The spikes vary in length from 2 to 5 inches, but are usually 3 to 4 inches. Spikes differ greatly in form and degree of compactness. Some are clubbed at the upper end while others taper toward the apex or from the middle toward both base and apex. The spike may be square, or flattened in the same plane with the spikelets or transversely to the spikelets. Density, or the length of internodes of the spike, is an important character, and apparently a varietal characteristic. The number of internodes to a decimeter is a good basis of calculation. Taking 10 internodes at a time, a good formula is $D = 1000 \div L$, in

Fig. 10. — Turkey wheat plant, showing roots 7 feet long, grown at Nephi, Utah.

which L is the total length of 10 internodes in millimeters.

34. The spikelet. — There are two or more flowers in a spikelet, inclosed by two chaffy glumes. Usually two or three kernels are matured, but there may be five or more, as sometimes in club wheats. The glumes in wheat are oval, instead of awl shaped as in rye. They vary greatly in different varieties, and are therefore important in classification. The color varies from light yellow to black. They are glabrous or pubescent (velvet). They may be firm and strongly keeled or membranous, and the keel may end in a beak of varying length and sharpness. The glumes of the terminal spikelet differ from the other glumes (see Fig. 13).

35. Flowers. — The wheat flower has three stamens. The anthers are versatile, that is, attached below the middle to the tapering end of thread-like filaments in such a way that they easily upset, each one thereby throwing out the pollen masses through slits in its two portions. There are two plume-like stigmas, which spread apart as the flower opens, and one ovule. The sexual organs are inclosed by two chaffy parts, an outer and lower one or lemma, and an inner one or palea. The awn when present is borne on the lemma; lodicules 2, obliquely ovate, short, the lower portions fleshy, the upper membranous, hairy on the margin.

Wheat is usually self fertilized, but many natural hybrids are known. Artificial pollination is readily accomplished by removing the anthers before bursting and applying to the stigmas pollen from a plant, the anthers of which have just freed the pollen. A good time for artificial pollination is in the early morning.

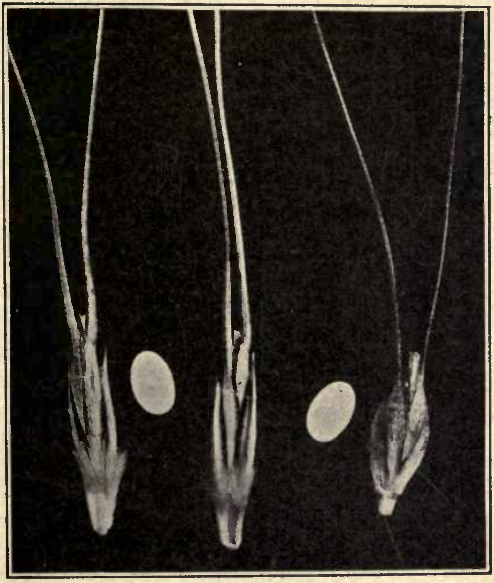
36. The kernel. — The wheat kernel is a dry indehiscent fruit called a caryopsis, such as previously described (9). In thrashing, the kernel is freed from the chaffy portions (except in emmer, spelt, and einkorn). There is great variation in the size and shape of the kernel, but there is always a deep crease extending nearly its entire length, on the side opposite the embryo. The wheat kernel differs from the rye kernel, in being shorter (usually), and plumper, and having a deeper crease. The kernel varies in color from a yellowish white, through amber, to dark red. In a few cases it is violet. There are degrees of hardness, usually known as soft, semi-hard, and hard. As a rule, the total nitrogen and protein content increases in proportion to hardness.

37. The origin of wheat. — There has been considerable discussion of the origin of wheat, but about the only common conclusion reached from it all is that this cereal, at the dawn of history, was indigenous in Western Asia. De Candolle (1892, pp. 358–359) says: "The area may have extended toward Syria, as the climate is very similar, but to the east and west of Western Asia, wheat has probably never existed but as a cultivated plant, anterior, it is true, to all known civilization."

Some of the most ancient names for wheat are Sanskrit *sumana* and *godhuma,* Chinese *mai,* Hebrew *chittah,* and Egyptian *br.* These names, so very different, and yet so old, indicate a great antiquity in wheat cultivation.

Artificial crossing having been effected between cultivated wheat and *Ægilops ovata,* some writers have considered this species to be the ancestor of wheat. A particular difficulty of this subject results from the considerable diversity in the subspecies of wheat, making it quite possible that some of them have originated from separate ancestors.

38. Origin of emmer and einkorn. — Emmer and einkorn are peculiar forms, having even yet so primitive an appearance that it would seem their ancestors would be readily found. Aaronsohn has, in fact, discovered a species near Mt. Hermon, in Palestine, which is thought



a *b*

FIG. 11. — Comparison of wild emmer (*a*) and black winter emmer (*b*).

to be the wild prototype of emmer (Aaronsohn and Schweinfurth, 1906). There is little doubt that it is at least a wild wheat, as it crosses readily with all forms of wheat except einkorn. The ancestor of the more common wheats, however, remains undiscovered (Fig. 11).

The one kerneled wheat or einkorn appears so different from other wheat groups that it is most likely a distinct botanical species, this idea being supported by the fact that it will cross with other wheats only with great difficulty, though all other subspecies intercross readily. This wheat is native in Servia, Crimea, Caucasus, and Asia Minor. It is at least a very ancient cultivated form. In 1909 Larionov (1910, pp. 7–13) found three wild forms of einkorn — white chaff, black chaff, and black-bearded red chaff — near Balaklava in southern Crimea.

39. Antiquity of wheat in China. — According to Julien, every year, about the vernal equinox, it has been the custom for the Chinese Emperor, princes, and presidents of boards, to conduct a public ceremony of plowing and sowing five kinds of seed. These are wheat, rice, common millet, proso millet, and soja beans. This ceremony was instituted in the twenty-eighth century B.C. by Emperor Chin-nung, who, according to the Itung Chi or Great Geography of China, is still worshiped in a temple on top of the mountain Po ku Shan, near Lu an Fu, in southern Shansi province. Chinese scholars claim that all these plants, whose seed are used in the ceremony, are native in China. There is not sufficient evidence to establish this claim, but it does appear that wheat cultivation in China is very ancient.

40. Present range. — The subspecies of wheat have a range of cultivation throughout the world, both as to elevation and latitude, greater than that of any other cereal, and probably greater than that of any other crop, except that barley is grown at slightly higher latitudes and in some instances at a higher elevation. Wheat is now grown successfully in practically the hottest and coldest of civilized countries, — in the tropics of the

Philippines, Equatorial Africa, Brazil, and Costa Rica, and near to the Arctic Circle in Europe and North America. Four years ago British East Africa began supplying wheat almost sufficient for its own needs, and the crop also did well in Uganda and Nigeria. The Scoptsi people have succeeded with wheat and other cereals north of Yakutsk in Siberia. In Finland and Scandinavia even winter wheat reaches over sixty degrees north, and in Canada, spring wheat has succeeded well at Ft. Simpson 818 miles north of Winnipeg. At Ft. Vermilion, almost 600 miles north of Winnipeg, a flour mill has been in operation many years. Onega wheat thrives near Archangel; while Romanov and Fife mature grain in 100 days at Fairbanks, Alaska, two degrees from the Arctic Circle. (Georgeson, 1914, p. 28.)

41. Classification. — There are in cultivation, eight groups of wheat varieties, generally recognized, with botanical names and relative rank, according to Hackel (1896, pp. 180–187), as follows: —

- Triticum
  - monococcum, Linn., einkorn or one-kerneled wheat.
  - sativum, Lam.
    - dicoccum, Schr., emmer.
    - spelta, Linn., spelt.
    - tenax
      - vulgare, Vill., common wheat.
      - compactum, Host., club wheat.
      - turgidum, Linn., poulard wheat.
      - durum, Desf., durum wheat.
  - polonicum, Linn., polish wheat.

It will be seen that only three of these groups are considered by Hackel to be distinct species. The least deserving of specific rank is *T. compactum*, which can hardly be called even a subspecies. In this volume each will be discussed as a separate agronomic group, without regard to specific rank.

42. Common wheats (*Triticum vulgare,* Vill.). — This is the best known and most widely distributed of all the subspecies of wheat, and includes probably a greater number of varieties than all other subspecies together.

FIG. 12. — Spikes and kernels of two varieties of common wheat. (More than ½ natural size.)

The characters of this subspecies, both botanical and agricultural, are in large part well known. The spikes are long in proportion to thickness, as compared with those of some other subspecies. They are broader in the plane of the rows of spikelets, as a rule, and narrower on the sides of the furrow between the rows; taper toward the apex, but may be very blunt or even thicker above; are usually loosely formed comparatively, awned or awnless, and possess glabrous chaff, but may be pubescent. The spikelets generally contain 2 or 3 kernels, but sometimes 4 or more. The glumes or outer chaff of the spikelets are slightly keeled. The culm of the plant is usually hollow, but occasionally somewhat pithy within and varies greatly in strength and height in different varieties. The leaves also vary in character, but are rarely as wide as those of the durum and poulard wheats, and are pubescent in only a few varieties (Figs. 12 and 13).

FIG. 13. — Spikelet and kernel of common wheat. (× 1½.)

The varieties of this subspecies naturally possess the most diverse characteristics, because of their very wide adaptation and cultivation under such diverse conditions. Their greatest characteristic as a whole is their well-known and long-established quality for flour production, for which reason the term "bread wheat" is sometimes inaccurately applied to them. The hard red-kerneled varieties have the highest protein content. On the other hand the white wheats and other soft winter wheats are the best for cracker manufacture. A few of the most popular breakfast foods are made from common white wheats.

43. Subdivisions. — The subspecies is usually divided into a number of botanical varieties based upon the presence or absence of awns, nature and color of the chaff, and color and form of the kernel. Supplementary to these are certain other characteristics of agronomic and commercial importance, which assist in more accurate identification of an agronomic variety, such as hardness of kernel and the fact that the variety is spring or fall sown. Eight botanical characteristics are commonly employed; — awned or awnless spikes, red or white chaff, glabrous or pubescent chaff, and red or white kernels, with which 16 combinations may be arranged. The number may be increased by the occasional use of additional characteristics. Leighty (1914, pp. 13–14) has, in fact, made 13 subdivisions to include only the wheat varieties of the humid area of the United States or that portion of this country east of about the 96th meridian. The color of chaff and kernel is usually red or white or some shade of these colors, approaching brown or yellow, though there are instances of a definite chestnut brown chaff, a few cases of violet kernel, and a few black chaff varieties.

44. Subdivisions of common wheats in the United States and Canada. — The principal varieties of common wheat now in cultivation in the United States and Canada, arranged in their subdivisions, are about as follows: —

1. *Awnless, glabrous white or yellow chaff, white or amber kernels.*
   Australian White, Defiance, Dicklow, Early Ontario, Palouse Bluestem.
2. *Awnless, glabrous white or yellow chaff, red kernels.*
   Hard Spring — Fife, Marquis, Minn. No. 163.
   Soft Winter — Extra Early Oakley, Fultz, Fultzo-Mediterranean, Hickman, Leap Prolific, Lofthouse, Ontario Wonder, Prosperity, Purple Straw, Southern Bluestem, Zimmerman.
3. *Awnless, glabrous red or brown chaff, white or amber kernels.*
   Soft Winter — American Banner, Early Windsor, Dawson Golden Chaff, Gold Coin, Koffoid.
4. *Awnless, glabrous red or brown chaff, red kernels.*
   Soft or Semi-hard Winter — Beechwood Hybrid, China, Currell Prolific, Early Red Clawson, Early Ripe, Harvest King, Michigan Amber, Poole, Red Wave, Rochester Red.
5. *Awnless, pubescent white or yellow chaff, red kernels.*
   Hard Spring — Minn. No. 169, Velvet Bluestem.
   Soft Winter — Crail Fife, Jones Winter Fife, Mealy.
6. *Awnless, pubescent red chaff, white or yellow kernels.*
   Sonora.

7. *Awnless, pubescent red or brown chaff, red kernels.*
   Soft Winter — St. Louis Grand Prize.
8. *Awned, glabrous white or yellow chaff, white or yellow kernels.*
   Early Baart.
9. *Awned, glabrous white or yellow chaff, white or amber kernels.*
   Soft Winter — Seneca Chief.
10. *Awned, glabrous white or yellow chaff, red kernels.*
    Hard Spring — Chul, Early Java, Fretes, Preston.
    Hard Winter — Kharkov, Malakov, Turkey.
    Soft or Semi-hard Winter — Budapest, Deitz Longberry, Fulcaster, Gypsy, Ironclad, Kansas Mortgage Lifter, Lebanon, Mammoth Red, Nigger, Red Wonder, Reliable, Rudy, Valley, Winter King.
11. *Awned, glabrous red or brown chaff, white or amber kernels.*
    Soft Winter — Early Gennesee Giant, Jones Longberry No. 1.
12. *Awned, glabrous red or brown chaff, red kernels.*
    Soft or Semi-hard Winter — Blue Ridge, Farmers Trust, Lancaster, Mediterranean, Sibley New Golden.
    Hard Spring — Huron, Ladoga.
13. *Awned, pubescent white or yellow chaff, white or amber kernels.*
    Soft Winter — Bearded Winter Fife.
14. *Awned, pubescent white or yellow chaff, red kernels.*
    Soft or Semi-hard Winter — Rural New Yorker No. 57, Virginia.
15. *Awned, pubescent red or brown chaff, red kernels.*
    Soft or Semi-hard Winter — Velvet Chaff.

As all wheat varieties in North America have been introduced, the total number now in cultivation is comparatively small, and the preceding list comprises nearly all that are of much importance.

45. Subdivisions and varieties in other countries. — Because of the great antiquity, wide adaptation, and usefulness of wheat, there are more varieties of that cereal than of any other in the world except rice. The number in foreign countries, in the common subspecies alone, is very great. The following list, classified into subdivisions as above, must therefore include only some of the most important, and even these are here mentioned simply to give, in connection with the preceding list, a general view of the world's wheats and their relationships, and not from an encyclopedic standpoint.

(TRITICUM VULGARE ALBIDUM, AL.)

1. *Awnless, glabrous white or yellow chaff, white or yellow kernels.*
   Soft or Semi-hard Winter — Australian Purple Straw,[1] Bellevue Talavera, Broad-leaf Cape,[2] Chiddam White Winter, Flanders White, Ghoni Safed, Hungarian White, Hunter White, Hopetoun, Kostroma, Lammas White, Mundi Pissi, Naples White, Roseau, Tuscan, Talavera, Touzelle White, Urtoba, Victoria White, Vyssoko-Litovsk, Zeeland.
   Soft or Semi-hard Spring — Chiddam White Spring, Tesoro.
   Hard Winter — Mudia.

(TRITICUM VULGARE LUTESCENS, AL.)

2. *Awnless, glabrous white or yellow chaff, red kernels.*
   Soft or Semi-hard Winter — Chili Squarehead, Crepi, Golden Drop, Hallet Pedigree, Hickling Winter, Juli, Lammas, Noe, Poltava, Probsteier, Saumur Winter, Shirreff, Victoria Winter.
   Soft or Semi-hard Spring — Altai, Hickling, Jena, Kustovka, Saumur Spring.

(TRITICUM VULGARE ALBORUBRUM, KCKE.)

3. *Awnless, glabrous red chaff, white or yellow kernels.*
   Soft or Semi-hard Winter — Buxar White, Danzig Red Chaff, Fenton, Khiva, Mundi Red Chaff, Rousselin, Sandomir.

[1] This may be equivalent to Australian White of California. The reader must allow for possible synonyms in many instances until the wheats are more carefully studied and sorted.

[2] This variety is both spring and winter.

(Triticum vulgare miltura, Al.)

4. *Awnless, glabrous red chaff, red kernels.*
   Soft or Semi-hard Winter — Bordeaux, Browick, Buxar Red, Dessau, Haigh Prolific, Hallet Red Nursery, Old Lammas Red, Talavera Red, Touzelle Red, Scotch Red, Squarehead Master.
   Soft or Semi-hard Spring — Noe Red Spring, Palermo, St. Laud Red.
   Hard Winter — Swiss Red Winter, Berdiansk Winter, Caucasian Winter, Ghirka Winter, Roumanian Winter.
   Hard Spring — Altai Red, Ghirka Red Spring, Kupyansk Red Spring, Servian Spring.

(Triticum vulgare leucospermum, Kcke.)

5. *Awnless, pubescent white chaff, white or yellow kernels.*
   Soft or Semi-hard Winter — Essex Velvet Chaff, Pearl, Tunstall Thick Chaff, Talavera Velvet, Touzelle velvet, Lammas White.

(Triticum vulgare villosum, Al.)

6. *Awnless, pubescent white chaff, red kernels.*
   Soft or Semi-hard Winter — Bohemian Velvet Chaff, Dorking Glory, Goldene Aue, Richmond Giant, Svartlo.

(Triticum vulgare delfii, Kcke.)

7. *Awnless, pubescent red chaff, white or yellow kernels.*
   Soft or Semi-hard Winter — Afghanistan, Attock Rodi, Amritsar Ghoni, Batala Khoni, Galgalos, Ghoni Red, Karnal Mundli, Mainstay, Portici.

(Triticum vulgare pyrothrix, Al.)

8. *Awnless, pubescent red chaff, red kernels.*
   Soft or Semi-hard Winter. — Bristol Red, Golden Rough Chaff, Rye Wheat.

(TRITICUM VULGARE CYANOTHRIX, KCKE.)

9. *Awnless, pubescent gray blue chaff, white or yellow kernels.*
   Soft or Semi-hard Winter — Gray Blue Winter.

(TRITICUM VULGARE GRÆCUM, KCKE.)

10. *Awnless, glabrous white chaff, white or yellow kernels.*
   Soft or Semi-hard Winter — Cape Bearded, Caucasian Bearded, Deshi Pissi, Dudhia, Kheri, Meerut, Muzaffarnagar White, Samarkand White Bearded, Saldome, Servian Winter, Shirreff Bearded, Tamra, Zaracos.
   Soft or Semi-hard Spring — Atalanti, Calcutta White Spring, Juldus, Persian White Bearded, Vernoe White Spring, Madrid.
   Hard Winter — Ak, Talimka, Khabra, Sari-Magiz.

(TRITICUM VULGARE ERYTHROSPERMUM, KCKE.)

11. *Awned, glabrous white chaff, red kernels.*
   Soft or Semi-hard Winter — Delhi Red, Fretes, Gold Yellow Winter, Haffkani, Karnal Red, Kastamuni, Pissi Red, Rawalpindi, Rieti, Rab, Sirsa, Zira Red, Zborow.
   Soft or Semi-hard Spring — Apulia, Geja, Marzolano, Petali, Puglia, Valencia Red, Victoria Spring.
   Hard Winter — Bigha, Buivola, Crimean, Kharkov, Nepal, Raipuri Red Pissi, Theiss, Wallachian.
   Hard Spring — Chul, Ghirka Bearded, Turkestan Red, Saxonka.

(TRITICUM VULGARE ERYTHROLEUCON, KCKE.)

12. *Awned, smooth red chaff, white or yellow kernels.*
   Soft or Semi-hard — Hansi Pissi, Persian White Bearded, Samarkand White Bearded, Sultanpur White, Turkestan White Bearded, Unao.

(TRITICUM VULGARE FERRUGINEUM, AL.)

13. *Awned, glabrous red chaff, red kernels.*
   Soft or Semi-hard Winter — Andros, Barletta, Clever Hochland, Fern, Fox, Walderdorff Regenerated, Jassy,

Kathi Pissi, Kubb, Odessa Red Chaff, Red Russian, Tosetto.
Soft or Semi-hard Spring — Umea.
Hard Winter — Indian Red Winter, Kathia Red, Mandla Pissi, Taganrog Red Winter.
Hard Spring — Cartagena, Irkutsk, Piche, Vernoe Red Bearded.

(Triticum vulgare cæsium, Al.)

14. *Awned, glabrous gray blue chaff, red kernels.*
Soft or Semi-hard — Baukura Jamali, Blue Chaff, Malda Jamali, Sabour Dudhia, Semaria Ghat.

(Triticum vulgare meridionale, Kcke.)

15. *Awned, pubescent white chaff, white or yellow kernels.*
Semi-hard Winter — Karystos Velvet.

(Triticum vulgare velutinum, Al.)

16. *Awned, pubescent white chaff, red kernels.*
Soft or Semi-hard Winter — Nimar, Velvet White Chaff.

(Triticum vulgare turcicum, Kcke.)

17. *Awned, pubescent red chaff, white or yellow kernels.*
Semi-hard Spring — Turkestan Velvet Red Chaff.

(Triticum vulgare barbarossa, Al.)

18. *Awned, pubescent red chaff, red kernels.*
Soft or Semi-hard Winter — Kastamuni Velvet Chaff, Shorthead Velvet Chaff.
Hard Spring — Juldus Velvet Chaff.

(Triticum vulgare cœruleo-velutinum, Kcke.)

19. *Awned, pubescent gray blue chaff, red kernels.*
Semi-hard Winter — Blue Velvet Chaff.
Hard Spring — Vernoe Blue Chaff.

(Triticum vulgare fuliginosum, Al.)

20. *Awned, pubescent black chaff, red kernels.*
Soft or Semi-hard Winter — Batala Red, Black Velvet Chaff, Kunjhari, Muzaffargarh, Multan Dagar, Desi Red, Persian Black.

46. Club or dwarf wheats (*Triticum compactum*, Host). — Though this group of wheats cannot properly be given even the rank of a subspecies botanically, yet the different varieties in the field appear quite as distinct from the common wheats as do many of those of the distinct subspecies. There is also considerable variation within the group. In the names of almost all varieties in this country, the word "club" appears, but in foreign countries they are often called dwarf wheats. In this group the plant is very erect, with a stiff, usually rather short, culm, attaining an average height of probably little more than 2 feet. These wheats are awned or awnless, the awned varieties usually being native in hot countries. The spikes are extremely short as a rule, thicker at the apex than at the base, often squarely formed and in some varieties much broader and flattened on the furrow side, kernels commonly white but sometimes red. The spikelets are set extremely close together, often standing almost at right angles to the rachis, three- to five-kerneled, sometimes with four kernels nearly throughout the spike. The outer and inner chaff are much the same as in the common wheats. The kernels are usually short and rather small, sometimes round, white or red, often boat-shaped, and occasionally appear much like those of hulless barley. The peculiar structure of the spike in these wheats allows them to be comparatively large yielders, which is naturally an important characteristic. They are very deceptive in this respect, the shortness of the spike leading one to suppose at first that it does not contain so many kernels as are really present. The kernel is persistent in the chaff, and therefore club wheats may be, and usually are, harvested long after ripening, without loss from shattering. Because of their short, stiff straw, club wheats stand up well. Besides furnishing the kind of flour desired in some localities, these wheats are good for making crackers, and for the more starchy breakfast foods. They are rather drought-resistant, and therefore adapted in dry, hot regions. There are both spring and winter varieties, but more of the former (see Fig. 14).

FIG. 14.— Club wheat: on left, spike and kernel, ½ natural size; on right, spikelet and kernel, × 1½.

47. Subdivisions and varieties of club wheats. — The club wheats may be subdivided on about the same basis as the common wheats, but there are not so many subdivisions. The principal subdivisions and their representative varieties in all countries are about as follows: —

(TRITICUM COMPACTUM HUMBOLDTII, KCKE.)

1. *Awnless, glabrous white chaff, white or yellow kernels.*
   Soft Winter — California Club, Chili Club, Daudi, Malorca, Multan Makini, Mocho.
   Hard Winter — Chinori, Jondhri.
   Soft Spring — Blanquillo, Little Club.

(TRITICUM COMPACTUM WERNERIANUM, KCKE.)

2. *Awnless, glabrous white chaff, red kernels.*
   Soft Spring — Sicilian.

(TRITICUM COMPACTUM RUFULUM, KCKE.)

3. *Awnless, glabrous red chaff, white or yellow kernels.*
Soft Spring — Red Chaff Club.

(TRITICUM COMPACTUM CRETICUM, AL.)

4. *Awnless, glabrous red chaff, red kernels.*
Soft or Semi-hard Winter — Sicilian Red Squarehead.
Soft Spring — Herisson.

(TRITICUM COMPACTUM LINAZA, KCKE.)

5. *Awnless, pubescent pale yellow chaff, white or yellow kernels.*
Soft or Semi-hard Winter — Chili Velvet, Linaza.

(TRITICUM COMPACTUM WITTMACKIANUM, KCKE.)

6. *Awnless, pale yellow chaff, red kernels.*
Soft or Semi-hard Winter — White Velvet Club.

(TRITICUM COMPACTUM CLAVATUM, AL.)

7. *Awnless, pubescent red chaff, white or yellow kernels.*
Semi-hard Winter — Blue Red Velvet Club.

(TRITICUM COMPACTUM SPLENDENS, AL.)

8. *Awned, glabrous white chaff, white or yellow kernels.*
Soft Winter — Carbillo, Yellow Bearded Club.
Soft or Semi-hard Spring — Canada Club, Chinese Club.

(TRITICUM COMPACTUM ICTERINUM, AL.)

9. *Awned, glabrous white chaff, red kernels.*
Semi-hard Winter — Herisson Bearded, Yellow Chaff.
Semi-hard Spring — Kupyansk, Sennær.

(TRITICUM COMPACTUM HYSTRIX, KCKE.)

10. *Awned, glabrous gray-blue chaff, red kernels.*
Spring — Long Kernel.

(TRITICUM COMPACTUM FETISOVII, KCKE.)

11. *Awned, glabrous red chaff, kernels white or yellow.*
Hard Winter — Vernoe Winter.

(TRITICUM COMPACTUM ERINACEUM, KCKE.)

12. *Awned, glabrous red chaff, red kernels.*
Hard Spring — El Hamra, Vernoe Red Club.
Semi-hard Winter — Brown Herisson, Chiniot Makkhi, Michigan Bronze, Red Kubb.

(TRITICUM COMPACTUM SERICEUM, AL.)

13. *Awned, pubescent white chaff, white or yellow kernels.*
Semi-hard Winter — Bearded Velvet Winter.

(TRITICUM COMPACTUM ALBICEPS, KCKE.)

14. *Awned, pubescent white chaff, red kernels.*
Semi-hard Winter — White Chaff Winter.

(TRITICUM COMPACTUM ECHINODES, KCKE.)

15. *Awned, pubescent red chaff, red kernels.*
Semi-hard Winter — Velvet Winter.
Semi-hard Spring — Palermo Velvet.

48. Poulard wheats (*Triticum turgidum,* Linn.). — The subspecies of poulard or rivet wheats is very closely related to the durum wheats. In many instances the varieties of the two subspecies so intergrade with each other that it is difficult for an expert to distinguish them. Some poulard varieties also greatly resemble the club wheats, and some the common wheats. Probably many of the very diverse forms at present existing are recent natural hybrids of two or more subspecies.

The poulard wheats are usually rather tall, with broad leaves, which in most varieties are pubescent or often glaucous. The culms are thick and stiff, and sometimes pithy within. Spikes long, often squarely shaped, with long awns, that are white, red, or bluish red in color, or sometimes black. Spikelets two to four, and arranged on the spike rather compactly. Glumes strongly and sharply keeled. Kernels large, proportionally short and boat-shaped, or sometimes almost semi-circular in middle cross section, rather hard, light yellowish red in color, sometimes nearly white, and becoming vitreous in varieties allied to the durum group, or on growing in certain localities (Fig. 15).

FIG. 15. — Poulard wheat: on left, spike and kernel, $\frac{1}{2}$ natural size; on right, spikelet and kernel, $\times 1\frac{1}{2}$.

The name poulard is most commonly applied to these wheats. In Europe they are sometimes called English wheats, a very misleading name, as they are little grown in England. On the other hand the few varieties that have been grown in that country are known there as rivet wheats. In Germany they are called *bauchiger weizen*, and the corresponding French name is *ble petanielle.*

The wheats of this group are used sometimes in the manufacture of macaroni and other pastes. They are also occasionally used alone in bread making, but are more often employed, as in France, for mixing with common wheats in grinding in order to give the quality of bread flour that is desired.

To a small section of this subspecies, having compound or branched heads, some have given the separate name of composite wheats (*T. compositum*). Some common names applied to varieties of this section, all of which may be synonymous, are Seven-headed, Wonder Wheat, Hundred Fold, Miracle, Alaska, and Egyptian. It should be noted, however, that the group of emmers (*T. dicoccum*) includes several varieties with compound heads similar to these. Such compound forms often occur also in hybrids and even in greenhouse cultures of pure lines.

The poulard wheats are native usually in hot, dry regions, and therefore often rather drought-resistant, but not so much so probably as the durums. Many of the varieties are also very resistant to orange leaf-rust. One variety, Seven-headed or Alaska, is resistant to smut.

49. Subdivisions and varieties of the poulard subspecies. — Poulard wheats are of no commercial importance in North America. The few representatives here mentioned, except Seven-headed wheat, occur only in foreign countries, chiefly in southern Europe.

A. Simple Spikes

(Triticum turgidum lusitanicum, Kcke.)

1. *Glabrous, white chaff, pale awns, white or yellow kernels.*
   Semi-hard Winter — Gallands Hybrid.

(Triticum turgidum melantherum, Kcke.)

2. *Glabrous, white chaff, black awns, white or yellow kernels.*
Soft or Semi-hard Winter — Nice Black Bearded, Baluchistan Black Bearded.

(Triticum turgidum gentile, Al.)

3. *Glabrous, white chaff, pale awns, red kernels.*
Semi-hard Winter — Nice, Normandy, Taganrog.
Semi-hard Spring — Pisana.

(Triticum turgidum nigrobarbatum, Desv.)

4. *Glabrous, white chaff, black awns, red kernels.*
Semi-hard Spring — White Chaff Black Bearded, Saisette Black Bearded, Buisson.

(Triticum turgidum speciosum, Al.)

5. *Glabrous, red chaff, red kernels.*
Soft or Semi-hard Winter — Auvergne Giant Red, Mariol, Mazzochio, Pole Rivet, Marseilles Red.

(Triticum turgidum megalopolitanum, Kcke.)

6. *Pubescent white chaff, pale awns, white or yellow kernels.*
Semi-hard Spring — Touraine White Velvet.

(Triticum turgidum Salomonis, Kcke.)

7. *Pubescent white chaff, black awns, white kernels.*
Soft Winter — Baluchistan Velvet Chaff.

(Triticum turgidum buccale, Al.)

8. *Pubescent white chaff, pale awns, red kernels.*
Soft or Semi-hard Winter — Cone Rivet.

(Triticum turgidum dinura, Al.)

9. *Pubescent red chaff, pale awns, red kernels.*
Soft or Semi-hard Winter — Montauban, Nonette de Lausanne, Turquet, Tunisian.

(Triticum turgidum jodura, Al.)

10. *Pubescent blue chaff, red kernels.*
Soft or Semi-hard Winter — English Rivet, Heidelberg Blue Velvet, Paines Defiance, Veneto.

B. Composite Spikes

(Triticum turgidum pseudocervinum, Kcke.)

11. *Glabrous, reddish chaff and awns, pale yellow kernels.*
Soft or Semi-hard Spring — Castillian Red, Liban, Composite, Miracle White Chaff.

(Triticum turgidum Plinianum, Kcke.)

12. *Glabrous red chaff, black beards.*
Hard Spring — Semikoloska.

(Triticum turgidum mirabile, Kcke.)

13. *Pubescent red chaff, white or yellow kernels.*
Soft or Semi-hard — Miracle.

(Triticum turgidum Linnæanum, Al.)

14. *Pubescent red chaff, red kernels.*
Soft or Semi-hard — Miracle Red Chaff, Wonderwheat.

50. Durum wheats (*Triticum durum*, Desf.). — The durum wheats, as before stated, are, many of them, very similar to certain poulard varieties. As a rule, however, the heads are not so thick and the kernels are longer and usually much harder. The plants are taller than those of common wheats, with stems either pithy within, or hollow with an inner wall of pith, or in a few varieties, simply hollow as in the common wheats. The leaves are usually glabrous, but have a hard cuticle, and are almost always resistant to orange leaf-rust. The spikes are compact, often rather slender, but may be very short, flattened on the furrow side, and are always awned; spikelets with 2 to 4 kernels. The glumes are prominently and sharply keeled, and the lemma somewhat compressed and narrowly arched in the back. The kernels are usually rather long, very hard, sometimes translucent and vitreous in fracture, amber colored, occasionally inclining to reddish (Fig. 16).

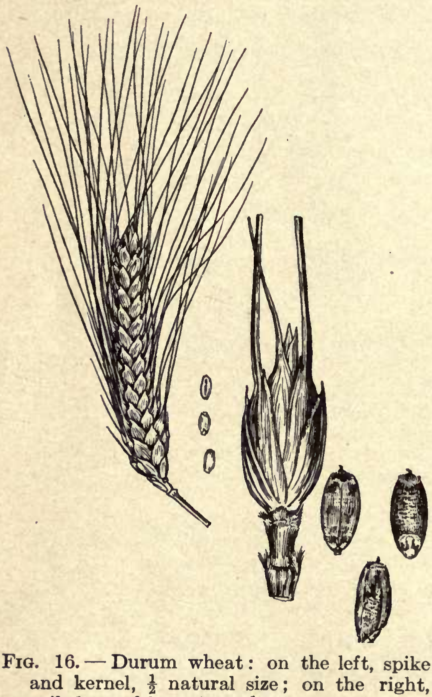


FIG. 16. — Durum wheat: on the left, spike and kernel, ½ natural size; on the right, spikelet and kernel, × 1½.

The varieties of this subspecies are most widely known as durum wheats. In Europe they are called simply hard wheats, and correctly so, as they are the hardest kerneled wheats that are known. The Fife, Bluestem, and Turkey, called hard wheats in this country, are not nearly so hard as these. On account of the resemblance of the spikes of durum wheat to those of barley the former is sometimes called Gerstenweizen or barley wheat.

51. Adaptation and uses. — Durum wheats are adapted to soils rich in nitrogenous matter and slightly alkaline, and give the best results in a very hot dry climate. Almost all varieties are adapted only for spring sowing, except in districts having mild winters. The young plants of this subspecies and the poulard wheats are light green in color at first, and grow erect rapidly. Durum wheats are very sensitive to changes of environment, and quickly deteriorate when grown in a soil or climate to which they are not adapted, as in a humid district. About the best durum wheat, for all purposes, is found east of the Volga River on the border of the Khirghiz Steppes.

The durum subspecies furnishes the great bulk of the world's supply of wheat for macaroni, though a considerable quantity of these pastes is yet made from poulard, polish, and common wheats. On the other hand, durum wheats are used for bread much more than is generally supposed. In east Russia they are the most popular for that purpose, and are employed largely for bread in France and in northern Europe. In this country much durum wheat is used in flour blends. Only in recent years has durum wheat come to form a considerable percentage of the wheat production of this country. The principal variety of North American durum is Kubanka. Many varieties are grown on the dry lands of India that are not yet well known elsewhere.

52. Subdivisions and varieties of durum wheats. — The representative varieties of durum wheats, with their approximate classification into groups, are about as follows: —

A. Glabrous Chaff

(Triticum durum leucura, Al.)

1. *White chaff, pale awns, white kernels.*
   Hard Winter — Daudkhani, El Medeba, Jalalia White Chaff, Soria, Ekdania White.
   Hard Spring — Berberisco, Candeal, Saragolla, Xeres.

(Triticum durum affine, Kcke.)

2. *White chaff, pale awns, red kernels.*
   Hard Spring — Obispado, Trimenia.
   Hard Winter — Banda Kathia, Chawal Kathia, Kathia Red, Kathia White Chaff, Ekdania Red.

(Triticum durum leucomelan, Al.)

3. *White chaff, dark awns, white or yellow kernels.*
   Hard Winter — Tunis.

(Triticum durum hordeiforme, Host.)

4. *Yellow chaff, pale awns, white or yellow kernels.*
   Hard Spring — Aidurka, Arnautka, Gerstenweizen, Gharnovka Yellow, Kubanka, Volo.
   Hard Winter — Jalalia Red Chaff.

(Triticum durum murciense, Kcke.)

5. *Red chaff, pale awns, red kernels.*
   Hard Spring — Murcia, Persian Red.
   Hard Winter — Dalalia, Kathia Red, Kempu, Lal Potia.

(Triticum durum alexandrinum, Kcke.)

6. *Red chaff, dark awns, white kernels.*
   Hard Winter — Kara Bidai, Marouani, Medeah.

(Triticum durum provinciale, Al.)

7. *Blue-black chaff, dark awns, white kernels.*
   Hard Spring — Black Don, Nero, Seville.

(TRITICUM DURUM OBSCURUM, KCKE.)

8. *Blue-black chaff, dark awns, red kernels.*
Hard Spring — Azulejo.

B. PUBESCENT CHAFF

(TRITICUM DURUM VALENCIÆ, KCKE.)

9. *White chaff, pale awns, white kernels.*
Hard Spring — Ismaël, Valencia.

(TRITICUM DURUM FASTUOSUM, LAG.)

10. *White chaff, pale awns, red kernels.*
Hard Spring — Fanfarron blanco.

(TRITICUM DURUM MELANOPUS, AL.)

11. *White chaff, dark awns, white kernels.*
Hard Spring — Alonso, Syerouska.
Hard Winter — Adjini, Bakshi, Dagar, Kala Kushal, Mahmoudi, Wadanak.

(TRITICUM DURUM AFRICANUM, KCKE.)

12. *White chaff, dark awns, red kernels.*
Hard Spring — Bigha, Fanfarron velloso raspinegro.
Hard Winter — Athani, Bangasia, Katha, Velvet Don.

(TRITICUM DURUM ITALICUM, AL.)

13. *Red chaff, pale or red awns, white kernels.*
Hard Spring — Fanfarron velloso rubion.

(TRITICUM DURUM APULICUM, KCKE.)

14. *Red chaff, dark awns, white kernels.*
Hard Spring — Apulia, Chapado velloso, Claro de Raspa Negra.
Hard Winter — Bansi, Gangajali, Sindhi.

(Triticum durum ægyptiacum, Kcke.)

15. *Red chaff, red awns, red kernels.*
Hard Winter — Kathia Velvet Chaff.

(Triticum durum niloticum, Kcke.)

16. *Red chaff, black awns, red kernels.*
Hard Winter — Bangasia, Red Chaff.

(Triticum durum taganrogense, Desv.)

17. *Blue-black chaff, white kernels.*
Hard Spring — Carmen Candeal, Mazzochio, Sicilian Black.

53. Polish wheat (*Triticum polonicum*, Linn.). — Polish wheat is considered by many writers to be a distinct species. Though there are several varieties, apparently only one variety, White Polish, is very widely known. The plant is usually rather tall, with culms glabrous and more or less pithy within. It does not stool extensively. The spikes are extremely large and loosely formed, and before ripening are bluish green in color. A special peculiarity of this species is the rather long, narrow glumes, papery in structure, and standing out slightly from the spike, instead of being rigid and closely applied to the spikelets, as in other wheats. All varieties are awned. The kernels are of great size when normal, proportionally quite long, yellowish white in color, and very hard (Fig. 17). The name Polish wheat is universally applied to this species, though for what reason is not clear. There is no evidence at all that it originated in Poland, and in fact it has been very little grown in that region. It is more probable that its native home is some portion of the

Mediterranean region. Other names have been given to this species but they are quite local in their use; such are Giant rye, Astrakhan wheat, Jerusalem rye, and Montana rye.

FIG. 17. — Polish wheat: on left, spike and kernel, $\frac{1}{2}$ natural size; on right, spikelet and kernel, $\times \frac{1}{2}$.

In almost all of the few cases where Polish wheat has been tried in this country it has done well from both the standpoint of yield and quality of the grain. It seems never to have occurred to any one to make use of the wheat for the production of American macaroni, though it should be good for that purpose, and a great demand for its increased production might thus be created. As it is, there is not sufficient incentive to the farmer for growing this wheat, since it is not well adapted for bread making if used alone.

Though requiring considerable moisture at seed time, Polish wheat is well adapted for cultivation in arid districts; in fact, it produces the best quality of grain when grown under arid conditions. It is also somewhat resistant to orange leaf-rust, but not so valuable in this respect as the durum wheats.

54. Subdivisions and varieties of Polish wheat. — There are few varieties so far known that are strictly of the Polish subspecies. They are as follows, classified according to our present knowledge: —

(Triticum polonicum rufescens, Kcke.)

1. *Spikes rather long, glabrous red chaff, red kernels.*
   Hard Spring — Long Kernel Red Chaff.

(Triticum polonicum levissimum, Haller.)

2. *Glabrous white chaff, white kernels.*
   Hard Spring — Common Polish.

(Triticum polonicum villosum, Desv.)

3. *Pubescent white chaff, white kernels.*
   Hard Spring — Velvet White Chaff, Libau.

(Triticum polonicum chrysospermum, Kcke.)

4. *Pubescent white chaff, red kernels.*
   Hard Spring — Red Polish.

(Triticum polonicum compactum, Krause)

5. *Glabrous white chaff, short awns.*
   Hard Spring — Thick Chaff Polish.

(Triticum polonicum attenuatum, Kcke.)

6. *Spikes thick, narrowing toward the apex, glabrous chaff, long awns.*
   Hard Spring — Long Bearded Polish.

55. Spelt wheat (*Triticum spelta*, Linn.). — This and the two following species are in several respects very different from any of the preceding. They are also not widely cultivated, although more commonly grown than

Polish wheat, and are used only to a limited extent for human food. Nevertheless, in the intercrossing of different species for the improvement of our bread wheats some very valuable qualities may be obtained from the varieties of these species.

This subspecies is called spelt in English, *Spelz* in German, and *épeautre* in French. In Germany the old name *Dinkel* is also sometimes applied. The varieties often called spelt in this country and Russia are not spelt, but emmer (*T. dicoccum*).

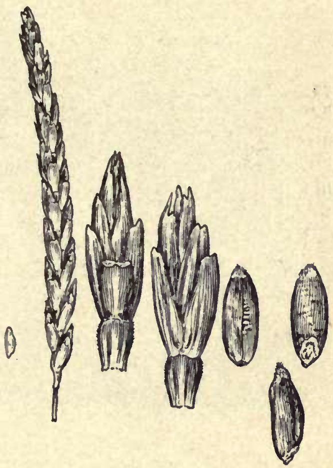
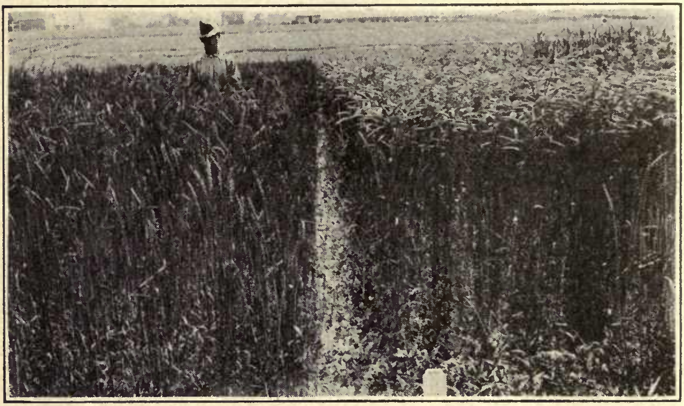


FIG. 18. — Spelt: on the left, spike and kernel, $\frac{1}{2}$ natural size; on the right, spikelet and kernel, $\times 1\frac{1}{2}$.

The spelt plant grows to the average height of wheat, or perhaps a little higher, and possesses a hollow stem. The leaves are of ordinary size, usually glabrous, but sometimes with scattering hairs; spikes loose, narrow, and rather long, awned or awnless, especially characterized by a very brittle rachis, allowing them to be easily broken in pieces in thrashing. The spikelets are usually far apart on the spike, arched on the inner side, and contain usually two kernels; outer chaff oval, four-angled, boat-shaped, and only slightly keeled; kernels light red in color, somewhat compressed at the sides, with a narrow furrow, the walls of the furrow flattened, and with sharp edges. The kernel is always held tightly within the chaff, and cannot be separated in thrashing (Figs. 18 and 19).

56. Uses of spelt. — Spelt is used very little for human food, but is generally fed to stock. It is very important, however, for certain portions of our country, at least, to obtain for the common wheats the particular quality of this group of holding the kernel tenaciously. This can readily be done, as the Garton Brothers have amply demonstrated in England, by intercrossing varieties of



a *b*

FIG. 19. — Two varieties of spelt: *a*, Red Awnless; *b*, White Awnless.

the two subspecies. In certain varieties that would otherwise be of great value in the Pacific Coast and Rocky Mountain States the prevention of shattering at harvest is one of the most important improvements that can be made. The few varieties possessing this quality that are now grown in these districts are sometimes not desirable in other respects. At the same time complaint is often made that certain introduced varieties which are most excellent from the standpoint of yielding capacity and hardiness are rendered worthless because of the great loss from shattering. It has also been observed by certain experimenters that the quality of constant fertility, or of producing "well filled" spikes, is greatly increased by the introduction of the spelt element. We probably little realize the loss in yield that is simply the result of inability of the variety to fill its spikes. There are both winter and spring varieties of spelt, and some of the former are very hardy. Certain varieties are also rather drought-resistant, but with some exceptions they are more or less subject to damage from rust.

57. Subdivisions and varieties of spelt. — The spelts should be better known in this country, and therefore the following classified list of varieties may be of use to the student.

A. Awnless

(Triticum spelta album, Al.)

1. *Glabrous white chaff.*
   Winter — White Winter, Schlegel, Vögeles.
   Spring — White Spring.

(Triticum spelta rufum, Al.)

2. *Glabrous red chaff.*
   Red Spring, Red Winter, Epeautre brun ordinaire.

(Triticum spelta Alefeldii, Kcke.)

3. *Pubescent, gray-blue chaff.*
   Blue Winter.

B. Awned

(Triticum spelta Arduinii, Al.)

4. *Glabrous, white chaff.*
   Epeautre blanc barbu, White Winter Bearded, White Spring Bearded.

(Triticum spelta vulpinum, Al.)

5. *Glabrous, red chaff.*
Winter — Fox, Red Winter Bearded.

(Triticum spelta albovelutinum, Kcke.)

6. *Pubescent white chaff.*
Velvet White Chaff Winter.

(Triticum spelta rubrovelutinum, Kcke.)

7. *Pubescent red chaff.*
Velvet Winter Bearded, Velvet Spring Bearded, Velvet Red Chaff Winter.

(Triticum spelta cœruleum, Al.)

8. *Pubescent blue chaff.*
Winter — Blue Velvet Bearded, Epeautre bleu barbu.

58. Emmer wheats (*Triticum dicoccum*, Schr.). — This group has no English name, but is often incorrectly called Spelt in this country. The German name is *emmer* and the French *amidonnier*. As the German name is now well known and easily pronounced it should be generally adopted, and the name spelt applied where it belongs. In Russia, where the group is well represented, it is called *polba*, which name has been invariably but incorrectly translated spelt heretofore. As a matter of fact, very little, if any, true spelt is grown as a field crop in Russia, but a large quantity of emmer is produced annually.

The culms of emmer are pithy or hollow with an inner wall of pith; leaves sometimes rather broad, and usually pubescent; spikes almost always awned, very compact, and much flattened on the two-rowed sides. The spikelets (hulled kernels as they come from the thrasher) look much like spelt, but differ chiefly in the presence of a short pointed pedicel (see Fig. 20). In the case of spelt, this pedicel, which is really a portion of the rachis of the spike, if attached at all to the spikelet, is always very blunt and much thicker. Usually, however, its pedicel does not remain attached to the base of the spelt spikelet after thrashing; instead, each spikelet carries on its inner face the pedicel belonging to the next spikelet above. Besides, the emmer spikelets are flattened on the inner side and not arched as in spelt, so that they do not stand out from the rachis as the spelt spikelets do, but lie close to it and to one another, forming a solidly compact spike. The spikelets of spelt, on the other hand, are placed far apart and, being arched on the inner side, stand out from the rachis, forming a very loose spike. The spikelets of emmer are usually two-kerneled, one kernel being located a little higher than the other. The glumes are boat-shaped, keeled, and toothed at the apex. The kernel is somewhat similar to that of spelt, but is usually harder, more compressed at the sides, and redder. There are both spring and winter varieties. All varieties so far known are awned. Emmer is considerably resistant to drought, and certain varieties are very resistant to rust. It is also

FIG. 20. — Emmer: on the left, spike and kernel, $\frac{1}{2}$ natural size; on the right, spikelet and kernel, $\times 1\frac{1}{2}$.

adapted to general conditions, more so than other cereals, and will withstand to a considerable degree the effects of wet weather in humid climates. Emmer will produce a fair crop under almost any condition of soil and climate, but thrives best in a dry prairie region with hot summers, where it gives excellent yields. In this country, emmer, like spelt, is used for stock feed, in the same manner as oats (Fig. 20).

59. Subdivisions and varieties of emmer. — As in the poulard subspecies, the emmers include varieties with composite spikes, and the first subdivision is made upon that basis. The further classification and the chief varieties are here given.

A. SPIKES SIMPLE

(TRITICUM DIOCOCCUM FARRUM, BAYLE.)

1. *Glabrous white chaff.*
   Winter — Khapli, Paputia, Reisdinkel, White Chaff Winter.
   Spring — Broadhead Reisdinkel, Krupnic (Servian Emmer), Common Emmer (North America and Russia).

(TRITICUM DICOCCUM TRICOCCUM, SCHÜBL.)

2. *Glabrous white chaff, spikelets often three-kerneled.*
   Winter — Egyptian Emmer.

(TRITICUM DICOCCUM PYCNURA, AL.)

3. *Spikes thick, glabrous reddish chaff.*
   Spring — Red Broadhead, Thickhead Red Chaff.

(TRITICUM DICOCCUM BRUNNEUM, AL.)

4. *Glabrous red chaff.*
   Spring — Red Chaff Spring, Servian Red Chaff.

(TRITICUM DICOCCUM MAJUS, KCKE.)

5. *Pubescent white chaff.*
Winter — White Velvet Winter.

(TRITICUM DICOCCUM FLEXUOSUM, KCKE.)

6. *Pubescent white chaff, crooked awns.*
Winter — Bent Bearded Velvet Chaff.

(TRITICUM DICOCCUM BAUHINII, AL.)

7. *Pubescent Red Chaff.*
Winter — Red Velvet Winter.

(TRITICUM DIOCOCCUM ATRATUM, AL.)

8. *Pubescent blue-black chaff.*
Winter — Black Velvet Winter.

B. SPIKES COMPOSITE

(TRITICUM DICOCCUM CLADURA, AL.)

9. *Glabrous red chaff.*
Winter — Red Composite.

(TRITICUM DICOCCUM KRAUSEI, KCKE.)

10. *Pubescent red chaff.*
Winter — Red Velvet Composite.

(TRITICUM DICOCCUM MELANURA, AL.)

11. *Pubescent blue-black chaff.*
Winter — Black Velvet Composite.

60. Einkorn (*Triticum monococcum*, Linn.). — This species of wheat is quite distinct from any other, though the spikes resemble those of emmer somewhat. It has no English name, but is called *Einkorn* in German, and *engrain* in French. The German name has been adopted in this country and is already fairly well known in American literature.

The plant of einkorn is short, with thin narrow leaves, and presents a peculiar appearance in the field. It seldom reaches a height of more than three feet. The stem is hollow, slender, and very stiff. The leaves of the growing plant are usually yellowish green, sometimes blue-green. Portions of the culm may be brown. The spikes are slender, narrow, very compact, awned, and much flattened on the two-rowed sides, and always stand erect, even when ripe, but easily break in pieces. The spikelets are flat on the inner side, or form a concave surface with the projecting edges of the glumes. They are arranged very compactly in the spike and are one-kerneled, except in the variety Engrain double, where they possess two kernels. The glumes are deeply boat-shaped and rather sharply keeled, the keel terminating in a stiff tooth. The kernels, which are tightly inclosed in the spikelet, are light red and extremely flattened, becoming thus bluntly two-edged and possessing an exceedingly narrow furrow (Fig. 21).

Fig. 21. — Einkorn: on left, spike and kernel, $\frac{1}{2}$ natural size; on right, spikelet and kernel, $\times 1\frac{1}{2}$.

This species is at present but little improved over the original wild form, and only a few varieties have been developed. Nevertheless some of the most valuable qualities may be expected from these varieties if they can be successfully employed in hybridization experiments.

They are among the hardiest of all cereals and seem to be constant in fertility, and in the author's experience, are proof against orange leaf-rust. Einkorn is entirely unknown in this country, except among a few experimenters, but is grown to a limited extent in Spain, France, Germany, Switzerland, and Italy.

61. Subdivisions and varieties of einkorn. — There are apparently only four cultivated varieties of einkorn yet known, classified as follows: —

(TRITICUM MONOCOCCUM HORNEMANNI, CLEM.)

1. *Chaff red, with short hairs.*
   Winter — Red Chaff.

(TRITICUM MONOCOCCUM LÆTISSIMUM, KCKE.)

2. *Chaff glabrous, yellow.*
   Yellow Chaff.

(TRITICUM MONOCOCCUM VULGARE, KCKE.)

3. *Glabrous red chaff.*
   Spring or Winter — Common Einkorn.

(TRITICUM MONOCOCCUM FLAVESCENS, KCKE.)

4. *Chaff glabrous, faint yellow.*
   Spring — Double Einkorn.

62. Distribution of wheat in the United States and Canada. — Upon the basis of our knowledge to date of the conditions of wheat environment and adaptation of varieties, the United States and the grain-growing portion of Canada may be considered as divided roughly into ten wheat districts, each possessing characteristics more or less different from those of the others. In fact, in some instances, they are as different from each other as though they lay in different continents. They are as follows: (1) The Northeastern Spring wheat district, (2) the Semi-

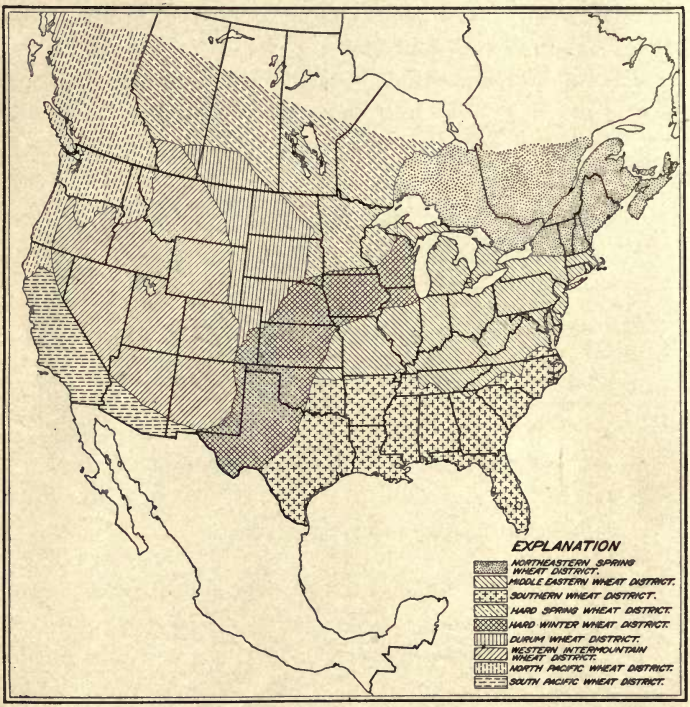


FIG. 22. — Map showing natural wheat districts in the United States and Canada.

hard Winter wheat district, (3) the Southern wheat district, (4) the Hard Spring wheat district, (5) the Hard Winter wheat district, (6) the Durum wheat district, (7) the Southern Plains wheat district, (8) the Western

Intermountain wheat district, (9) the North Pacific wheat district, and (10) the South Pacific wheat district. In the Canadian portion, especially, the boundary lines must be regarded as simply arbitrary or very approximate, because of the large areas included and the very recent development of its central and western districts. The characteristics of each of these districts, varieties now grown, and improvements needed are next discussed (Fig. 22).

63. Northeastern Spring wheat district. — In this district are included approximately all of Quebec, Prince Edward Island, New Brunswick, Nova Scotia, the eastern portion of Ontario to the Albany River, Maine, New Hampshire, Vermont, northern New York, and the northern peninsula of Michigan. The winter wheats are rather soft and starchy and the spring wheats semi-hard. The color of the grain is yellowish white, amber, or red. The soil, especially if not heavily fertilized, does not possess the necessary amount of alkali, phosphate, and humified organic matter required for the production of hard, glutinous wheats. Moreover, the climate is against their production, being too moist and cool in summer. Nevertheless in New York and Ontario, by means of the plentiful application of fertilizers and the unusual attention paid to seed selection in this district, a large amount of good wheat is annually grown in proportion to the entire area. Forty or forty-five years ago, when the area given to wheat culture in this country was much more limited than at present, and when the hard red wheats were not so popular, New York had a deservedly great reputation both for her wheat production and flour industry. The fact that so high a standard is maintained in the wheats of this district in the face of adverse natural conditions, is strong proof of the importance of intelligent wheat culture, particularly in respect to seed selection and the proper treatment of the soil. In some localities of this district the standard is considerably above what one would expect, while in some other districts it is far below what it should be.

Except in the extreme southern portions of this district spring sowing is practiced, and there is a need for hardy winter sorts which will be able to extend the winter-wheat area farther northward. In some localities rust is occasionally very injurious, the black stem-rust sometimes completely destroying the crop. Early maturing and rust-resistant sorts are therefore desirable for escaping or overcoming the attacks of this parasite.

1. Principal varieties now grown: —

Dawson Golden Chaff	Huron
Early Red Clawson	White Russian
Fife	White Fife
Preston	

2. Needs of the district: —

Hardier winter varieties	Rust-resistance
Early-maturing varieties	

64. Semi-hard Winter wheat district. — In this district are included the lower New England States, southern New York, Pennsylvania, New Jersey, Delaware, Maryland, West Virginia, the western portion of Virginia, Ohio, the southern peninsula of Michigan, Indiana, Illinois, and southern Wisconsin. It is one of the important cereal districts of North America. The wheats now grown are usually semi-hard, but are in places rather soft. There is a constant decided tendency toward the use of harder red wheats in recent years, and the proportion of such wheats now grown is much larger than 20 years ago.

Nevertheless there is still a demand for harder kerneled wheats and varieties hardier in winter. Black stem-rust is sometimes very destructive in these states, particularly in the lower moist and timbered portions.

1. Principal varieties now grown: —

Currell Prolific	Lancaster
Dawson Golden Chaff	Martin Amber
Deitz Longberry	Mediterranean
Early Red Clawson	Nigger
Farmer Friend	Perfection
Fultz	Poole
Fulcaster	Red Wave
Fultzo-Mediterranean	Red Wonder
Gypsy	Ruby
Harvest King	

2. Needs of the district: —

Winter-hardy varieties	Early maturity
Rust-resistance	Stiffness of straw

65. Southern wheat district. — This area includes eastern Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Alabama, Mississippi, the southern portions of Illinois and Missouri, Arkansas, the eastern portions of Oklahoma and Texas, and any portions of Louisiana and Florida where wheat may be grown. The annual wheat production is comparatively small. In the greater portion of the district the combination of great rainfall with mild temperature is not conducive to great success in wheat growing. The soil is also generally not of the best for such purpose. Rust is always very bad, because of the constantly damp, warm climate. In spite of these difficulties there is no doubt that with sufficient effort the wheat industry might be very materially improved. Recently there has been much interest awakened in the possibilities of successful wheat culture. Probably one of the greatest obstacles in the way of profitable wheat raising in portions of the South is the lack of good flour mills, much of the grinding being at present performed by the most primitive grist mills. With a continued increase in wheat acreage there will perhaps be a corresponding increase in the number of first class mills constructed. The great popularity of cotton also prevents extensive cultivation of small cereals.

On account of the severe rust attacks which occur in this district it is highly desirable to grow early-ripening and rust-resistant sorts. But there are really not many early-maturing wheats grown in this country, and of the early foreign varieties already tested none has yet proved to be sufficiently hardy. Much investigation is yet needed.

Occasionally wheat is much injured in the northern portion of this district by late spring frosts. It is on such occasions that late-maturing wheats and late-sown crops may have the advantage, since those ripening early are likely to be caught by the frost just at blooming time and be prevented from "filling," while the later-ripening crops, blooming after the frost, escape such injury. It seems possible, however, to grow varieties that will resist the action of these frosts, and therefore varieties hardy in this respect are desirable.

The wheats at present grown in the Southern wheat district are either soft or semi-hard, and usually have amber or reddish kernels. They are either awned, as in the case of Fulcaster, or awnless, of which the Fultz and May wheats are examples. Wheat in the southern states is always more likely to be infested with weevil than in any other district, and much annoyance as well as injury results from this cause (see 533).

1. Principal varieties now grown: —

Currell Prolific	Leap Prolific
Early May	Mediterranean
Fultz	Purple Straw
Fulcaster	Red May
Georgia Red	Red Prolific
Harvest King	Southern Bluestem

2. Needs of the district: —

Rust-resistance	Stiffness of straw
Early maturity	Weevil-resistance
Resistance to late spring frosts	

66. Hard Spring wheat district. — The hard spring wheat area includes Minnesota, the eastern portions of North Dakota and South Dakota, northern Wisconsin, western Ontario, eastward about to the Albany River, Manitoba, all but the extreme southwestern corner of Saskatchewan, and northern and eastern Alberta. In this district, because of the deep black soil and dry hot summers, there is grown the highest grade of common spring wheat in the world, excepting the spring wheats of the middle Volga district of Russia, which are very similar. Two general types of wheat prevail, Fife and Velvet Bluestem. Of each one there are several strains. In late years a third type has appeared in considerable quantity, called Preston in Canada, and S. D. Climax, Velvet Chaff, and Minn. No. 188 south of the Canadian border. Still more recently a new early-ripening hybrid, called Marquis, has become well established in the northern portion of the district. In the Canadian portion of the district Marquis wheat appears adapted in general, in the north and east, and Fife in the south and west. Another Canadian hybrid, Prelude, is still earlier than Marquis, and therefore adapted to the most northern localities.

The average annual production of this district is larger than that of any other similar area in the world, but the average acre yield is low. The large size of the farms is one of the worst features connected with wheat growing in the Northwest. From this cause not enough attention is given to details of the work. The tillage is not thoroughly accomplished, weeds are not kept down, there is more or less waste of land, and the grain is allowed to degenerate in quality.

The needs of the grower in this district are not so great as in some others, but there is much to be desired. In the northern portion earliness of maturity is needed to enable the wheat to escape the early autumn frosts which sometimes catch the crop before harvest, while in the southern portion chinch bug depredations and rust attacks might often be avoided through possession of the same quality. A combination of earliness and rust-resistance in the same variety would be especially desirable. The average yield could be made very much larger, as already stated, but it is a matter depending fully as much on methods of culture as on the improvement of varieties. Proper seed selection should be more rigidly practiced. There is a possibility of still further substitution of hard winter wheat in South Dakota and southern Minnesota, which if accomplished would be a great advantage.

1. Principal varieties now grown: —

Bolton Bluestem	Prelude
Fife	Preston
Haynes Bluestem	Turkey (winter)
Huron	Velvet Bluestem
Marquis	Wellman Fife
Minnesota No. 163	White Fife
Minnesota No. 169	

2. Needs of the district: —

Early maturity	Drought-resistance
Rust-resistance	Hardy winter varieties in southern portion

67. Hard Winter wheat district. — In this district is comprised roughly the middle Great Plains, that is, Kansas, eastern Colorado, and the larger portions of Nebraska and Oklahoma, but including also Iowa and northern Missouri. As the name implies, it is characterized by the production of hard winter wheats, of the very best quality. The only other wheat district in all the world that is exactly comparable to this one, so far as known, is that including the Crimea and the country directly between the Sea of Azov and the Caspian Sea. The latter districts at present produce wheats a little better than are produced in this district, and therefore should be drawn upon for any improvements that are attempted through introduced sorts.

The wheats of this district have slender, stiff culms, narrow spikes, usually awned, and medium or small, hard, red kernels. In this district there is the most interesting example of the changes that may take place for the better in the development of the wheat industry. Forty years ago the softer wheats (often white kerneled) were chiefly grown over a large portion of the district, and a large proportion of spring wheat was sown. Now the hard winter varieties are used almost entirely. The introduction of these hard-kerneled winter sorts has added remarkably to the certainty and value of the wheat crop, and has greatly decreased the ravages from rust and chinch bugs. Because of the great overlapping of districts, many varieties listed below are not hard winter wheats, and some not winter wheats at all.

Such improvements are after all but fairly begun, and there is yet great demand for hard-kerneled sorts and varieties that will resist the winters of northern Iowa and Nebraska, and southern South Dakota. As the wheat area extends farther westward, there is also still need for drought-resistant sorts. In fact, in this and the district next described, there is the most exacting demand of the entire country for hardy winter varieties. The extreme severity of the drought and winter cold combined forms a greater obstacle to winter wheat culture than exists in any other district.

Early maturity is of importance in this district in order to allow an escape from the worst effects of the drought in the western portion and from rust in the eastern portion.

1. Principal varieties now grown: —
   - Currell Prolific
   - Early Java
   - Fultz
   - Haynes Bluestem
   - Harvest Queen
   - Kharkov
   - Malakov
   - Turkey
   - Velvet Bluestem
   - Zimmerman
2. Needs of the district: —
   - Early maturity
   - Drought-resistance
   - Hardier winter varieties

68. Southern Plains wheat district. — Chiefly central and west Texas is included in this district, but also a small portion of Oklahoma and southeastern New Mexico. The climatic conditions are much more severe than would be expected from the geographic position. Much of the area is beyond the 98th meridian, where there is much drought, but which is made all the more severe by the great evaporation. In the north central portion the well known "black waxy" soil is so heavy and stiff that it cracks and heaves greatly in the late winter, thus exposing the wheat roots to the weather. The chief variety of wheat is the Mediterranean, which is quite hardy, but not sufficiently so every season for the higher portions of the Panhandle. A very large undeveloped western portion of the district can be used for wheat by the establishment of hardier varieties. The Hessian fly and green bug are sometimes serious pests in this district.

1. Varieties now grown: —

Fultz	Mediterranean
Fulcaster	

2. Needs of the district: —

Drought-resistance	Rust-resistance
Winter-hardiness	Resistance to Hessian Fly and Green Bug

69. Durum wheat district. — By the year 1905 the durum wheat became well established in this country. The crop is now so large, and the territory so large in which no other wheat can take its place, that it is quite proper to regard this area now as a separate wheat district. The district adapted includes western Nebraska, eastern Wyoming, the western portions of South Dakota and North Dakota, eastern Montana, the extreme southwestern portion of Saskatchewan, and southeastern Alberta. Drought and the winters are extremely severe in the greater part of this district, and only the hardiest spring wheats, such as the durum wheats, can succeed. Also as the area lies far westward near the mountains the soil is lighter, not so deep, and has less humus than in the eastern Great Plains, and therefore retains less water from the same amount of rainfall. The constant need is for drought-resistant varieties.

The great rust-resistance of durum wheats has caused them to be grown too far east, much out of their proper area. The range should be extended westward, beyond the 100th meridian. The center of durum wheat production at present appears to be about Lamoure County, North Dakota. It should be beyond the Missouri River. Kubanka is the chief variety grown. During two or three

Fig. 23. — Field of durum wheat at Broadview, Montana.

seasons there has been some complaint of "blighted" spikes in durum wheat. The matter has been investigated, and appears to be caused by extreme heat at a critical date in the flowering stage. (Salmon, 1914.) (Fig. 23.)

1. Varieties now grown: —

Arnautka	Ghirka Spring	Preston
Defiance (irrigated)	Kubanka	Turkey
Fife	Marquis	Velvet Bluestem

2. Needs of the district: —

Early maturity	Heat-resistance in flowering stage.
Drought-resistance	

70. Western Intermountain wheat district. — Between the Sierra Nevada and the Rocky Mountains proper, and stretching north and south entirely across the United States into Canada, is a very large area, in which wheat is grown either in very small scattered patches by irrigation or in a few special localities where, because of the nature of the soil, "dry-farming" is possible, even with the very low rainfall. Where irrigation is practiced, the wheat is

Fig. 24. — Field of Alberta Red (Turkey) winter wheat at Raymond, Alberta.

very soft, usually white, and starchy. Where Turkey or Kharkov wheat is employed under so called "dry-farming" in the central and northern portions, the wheat is much harder and more glutinous, but not so much so as when grown on the Great Plains. The influence of the Chinook winds permits the growing of these winter wheats as far north as Montana, and even in southern Alberta (Fig. 24).

There are three characteristics of this district: (1) extreme aridity often necessitating irrigation, (2) the low humus content of the soil, and (3) the abundance of alkali usually present. These conditions are closely interrelated and mutually dependent upon one another. The absence of humus is a natural result of the reduction of the rainfall, upon which depends the existence of plant life. Rainfall also tends to equalize the distribution of the alkaline substances of the soil, which

Fig. 25. — Field of Koffoid wheat near Nephi, Utah.

in this district, however, are concentrated, in places, in high percentages. The practice of over irrigation is often allowed to make conditions worse by a deposit of alkali largely above that which was already present. Wheat does better in soil that is alkaline rather than acid in reaction, but an excess of alkali becomes very injurious. Rust on wheat is rare and in some localities entirely unknown. Smut, however, is present to a great extent. Stiffness of the straw and absence of rain prevent the grain from lodging, so that harvesting may be delayed for weeks with little or no injury. At high elevations in the mountains of this district frost may occur any month in the year, and wheat is often seriously damaged by early autumn frosts. Early maturity is therefore important (Fig. 25).

1. Principal varieties grown or adapted: —

Alberta Red	Gold Coin (Forty Fold)
Buffum No. 17	Koffoid
Club Wheats	Kharkov
Dicklow	Lofthouse
Defiance	Russian Red
	Turkey

2. Needs of the district: —

Early maturity	Increase of gluten content

71. North Pacific wheat district. — There is included in this district the grain-growing portions of British Columbia, Washington, extreme northern Idaho, and western Montana, and northern and western Oregon. All wheat varieties that have become acclimatized have characteristically soft kernels, white, amber, or at most light red in color. The usual lack of humus in the soil and, in some localities, the generally cool summers probably are responsible for the production of kernels of this kind, as in the Western Intermountain district (Fig. 26). Much of the wheat commonly grown in this district is of the club type, which is usually very prolific and rather drought-resistant, which qualities probably partially account for the large yields per acre. Spikes of club wheat are sometimes found that contain 160 kernels.

A very valuable characteristic of the club wheats is their ability to hold the grain in the chaff so that there is little danger of shattering, even during the driest season, if there should be much delay in the harvest (see Fig. 14). In some localities the grain is sometimes left standing several weeks before harvesting, a habit which, however, has no good excuse for its practice.

In southern Washington and adjacent portions of Idaho and Oregon is the Columbia River Basin, which

FIG. 26. — Little Club and Palouse Bluestem wheats.

possesses peculiarities of soil and climate considerably different from those of the Pacific Coast. The soil is very finely divided volcanic ash, and when dry is simply dust, but absorbs and retains moisture remarkably. After rains it is sticky and hard to manage. The most serious obstacle to successful wheat culture is the annual drought beginning about two weeks before ripening, particularly in the western and southern portions. From this cause the wheat is often badly shriveled. In order to escape the severe effects of drought early-maturing sorts are desirable. Toward the north and east winter-hardiness is needed. Almost everywhere non-shattering varieties are required. The combined harvester is commonly employed, but the self-binder is used in very hilly localities.

In British Columbia and the eastern portions of the district, the summer climate is very cool and early maturity is desirable. The gluten content of the kernel is usually small.

1. Principal varieties grown: —

Dawson Golden Chaff	Kharkov	Red Russian
Forty Fold (Gold Coin)	Little Club	Palouse Bluestem
Jones Winter Fife	Turkey	

2. Needs of the district: —

Early maturity	Winter-hardiness in the colder portions
Non-shattering	

72. South Pacific wheat district. — This district includes practically all of California and southern Arizona. All varieties have soft and white or light colored kernels. The chief varieties in California are Australian White and California Club grown in the middle and northern portions, and Sonora in the southern portion. Early Baart, Galgalos, and Chul have recently come into use. All varieties are both winter and spring wheats. Non-shattering varieties are always demanded. Increase of the gluten content is probably the greatest need. There is a great lack of soil humus. Recent experiments show that green manuring will greatly increase the acre yield, even much beyond that of fallow land. On the other hand, remarkable yields of wheat and barley are obtained on the reclaimed black soils of the "Tule" lands near Stockton. In southern Arizona practically all wheat is irrigated.

1. Varieties now grown or adapted: —

Algerian	Galgalos
Bobs	Palouse Bluestem
California Club	Seven-headed
Chul	Sonora
Early Baart	Australian White

2. Needs of the district: —

Increase of gluten content	Early maturity
Non-shattering	

73. Geographic groups of wheat. — Our knowledge of wheat distribution in other countries is limited, and besides a full discussion of that subject here is not desirable. It will be of use, however, to mention the nativity of groups of wheats having particular qualities. This will, in certain instances, show the sources of varieties which might supply the needs stated under the description of each wheat district, and at the same time give some idea of geographic distribution. Some of the most important of such groupings that may be made are here given.

74. Glutinous and starchy wheats. — (1) White, soft starchy kernels are found in the wheats of the Pacific and Western Intermountain districts of North America, examples Little Club, Gold Coin, and Australian White; in the club wheats of Chile; in the white wheats of Australia, as Talavera and Purple Straw; in the white Pissi wheats, Ghoni Safed, Karnal Mundhi, and similar sorts of India, and in some Turkestan varieties. (2) Amber or reddish kernels also starchy occur in the wheats of eastern United States, such as Fultz, Early Red Clawson, and Jones Winter Fife; in western and northern Europe, in Lammas, Golden Drop, Hallett Pedigree, Bordeaux, and others; in Australia and Japan, and in the red Pissi wheats, Rawalpindi, Sirsa, and others of India. (3) Glutinous qualities in the common wheat group are to be found generally in the hard red wheats. Examples are Turkey, Kharkov, and Fife in our Great Plains and central Canada, and Krimka, Ghirka Winter, and Russian in southern and eastern Russia. (4) The very highest gluten content is possessed by light amber wheats of the durum group. Examples are Kubanka in our northern Great Plains; Beloturka, Gharnovka, and others in eastern and southern Russia; Medeah, Berberisco, and others in the Mediterranean region; Sari in Turkestan, and Kathia White, Jalalia, and Bansi in India. (5) There is also a group of red-kerneled durum wheats, many if not all of which are highly glutinous. Examples are Velvet Don in the Great Plains and southern Russia; Kathia Red, Ekdania Red, Bangasia and Lal Potia in India, and Bigha in Asiatic Turkey. (6) Macaroni-making qualities exist particularly in such varieties as Saragolla and Trimenia of Italy, Pelissier and Medeah in Algeria, the durum wheats of the Azov Sea district, and the Poulard and Polish wheats of southern Europe.

75. Resisting wheats. — (7) Stiffness of straw, preventing lodging, exists in einkorn, and in the spelts and emmers of the Balkan district, east Russia, and this country; in the dwarf wheats of Japan and China; in the round-kerneled dwarf wheats of the Punjab in India, and in the club wheats of Turkestan and the Pacific and Western Intermountain districts of this country. (8) Rust-resistance is found in certain durum varieties, especially Iumillo of Italy; in the poulards, emmers, and einkorns of the districts bordering the Mediterranean and Black Seas, and the emmers of India, particularly the variety Khapli; in the hard winter wheats of southern Russia; and in certain blue black-chaff wheats of western Asia and India, such as Persian Black. (9) Resistance to shattering exists of course to perfection in all spelts, emmers, and einkorns. This character also exists to a great degree in almost all wheats in western Asia, particularly in Turkestan. In that region it is a character, in some instances, no doubt, developed through unconscious selection by the people, as harvesting is always long delayed because of lack of machinery. The Chul wheat, now introduced from Turkestan into this country, is a good example. Non-shattering is a character, generally of club wheats, and therefore is found in the club varieties of our own Pacific and Western Intermountain districts, and in Chile. (10) Resistance to drought may be found in the durum wheats of east Russia, Algeria, and India; in the round-kerneled dwarf wheats of northern India, such as Chiniot Makkhi, Daudi, and Multan Makini; in the common red wheats of east Russia, and probably most of all in the wheats of all groups in Turkestan. Good examples of the last are Chul, Ak, Kara, and Sari. (11) Resistance to both drought and cold are found to the greatest degree in the hard winter wheats of east Russia.

76. Earliness, yield, and fertility. — (12) Earliness is a characteristic of almost all Indian wheats, and is found to a marked degree in the dwarf wheats of Japan and China. It also exists in California in Sonora, and Early Baart; in Australia; in the violet-kerneled Abyssinian wheats, and in many western Asian varieties. (13) Constancy in fertility appears to be a quality of all spelts, emmers, and einkorns, and generally of close-chaffed wheats. (14) Yielding power is largely a matter of resistance, and therefore a relative characteristic. The length and number of spikes being equal, it is naturally greatest in club wheats, but is also great in some hybrids.

CHAPTER IV

OATS

The oat plant belongs in the tribe of grasses called Aveneæ. In this tribe the spikelets are usually 2- to ∞-flowered, usually in panicles; all flowers perfect or one staminate; glumes often persistent or remaining after the lemma and palea have fallen, usually longer than the lemma, the latter usually awned on the back, sometimes near the point; awn geniculate, rarely nearly straight; palea two-keeled; style short or none; stigmas feathery, protruding above the base or middle of the spikelet; kernel usually furrowed, embryo small, starch grains compound.

77. Description. — Avena, Linn., the genus including cultivated oats, has usually 2- to 6-flowered spikelets in panicles; glumes membranous, unequal; lemmas rounded on the back, 5- to 9-nerved, often 2-toothed; awn dorsal, geniculate, twisted below (sometimes straight or wanting in cultivated varieties); callus of lemmas and the rachilla often hairy; ovary hairy all over or only at the point; caryopsis fusiform, deeply sulcate. Hackel (1896, p. 121) says there are over fifty species of oats in the temperate zones of the Old World, besides a few in the New World. There are two sections of the genus, annuals and perennials, to the former of which cultivated oats belongs. The spikelets of this section are nodding and the glumes many nerved. The common cultivated oat, *Avena sativa*, Linn., which has awns of the persistent lemmas straight, bent, or none, is thought to have originated from the wild oat, *A. fatua*, Linn., which has geniculate awns and deciduous lemmas, or from some other similar wild species.

78. Roots. — In oats there are three seminal roots. The crown from which the coronal or permanent roots and main culms originate is about one inch below the surface of the ground. The permanent roots are fibrous, as in other cereals, and there is no tap root. The roots of oats are larger and more numerous than those of wheat, and therefore loosen and mellow the upper part of the soil a little more. They attain a length of 110 cm. and spread 94 cm., giving a root coefficient of 10340. The roots of winter oats, or of any winter cereal, are usually longer than those of spring varieties.

79. Culms of oats are larger in diameter and more succulent than those of wheat. As in wheat, at each underground node of every culm, a bud may develop which will produce another culm. The lower nodes of this culm may in turn produce other culms, and so on. The number of culms from one original kernel, or the degree of tillering, varies greatly in different varieties with the thickness of seeding and with other conditions. Winter varieties tiller more than spring varieties, as in other cereals. The culms are hollow. The height of the plant varies from 2 to 5 feet. Love and Leighty (1914, pp. 20–34) determined that " there are high, positive, and fairly stable correlations between average height of plant and (*a*) total average yield, (*b*) total and average number of kernels produced, and (*c*) average number of spikelets per culm."

80. Leaves. — Compared with wheat, the oat plant is rather leafy. The leaves are $\frac{1}{2}$ to $1\frac{1}{2}$ inches wide, and are wider on an average than in the common wheat varieties. In the seedling stage, the leaves of winter oats

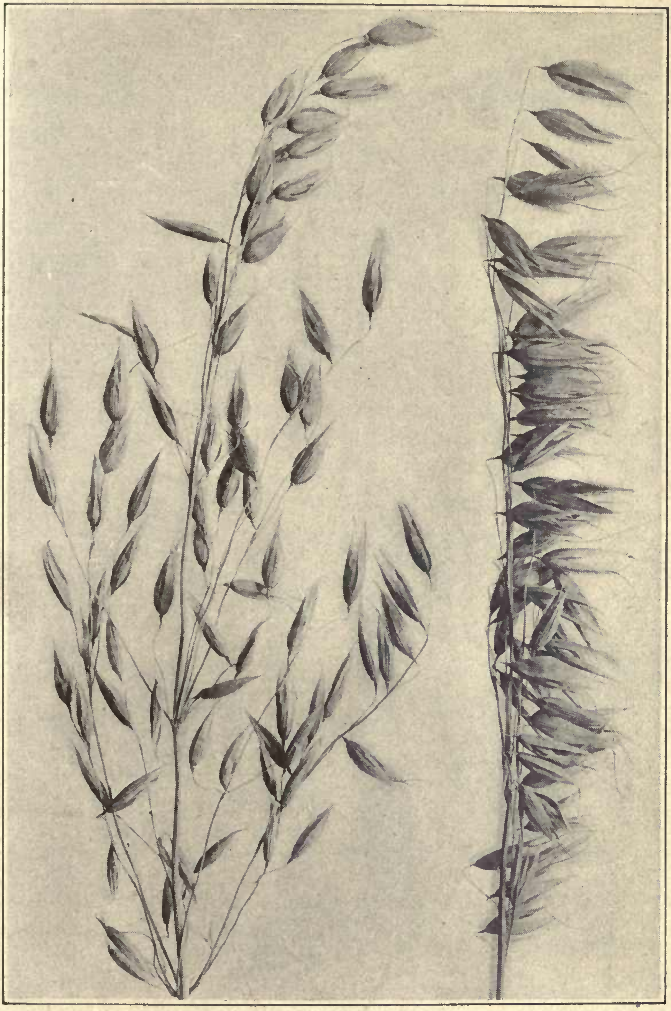
FIG. 27. — Plant of Winter oats in early fall condition.

are narrower and usually darker green than in the spring varieties, and in the former they at once spread out on the ground instead of assuming an erect habit. There are no auricles at the junction of blade and sheath, which fact serves to distinguish young oat plants from those of other cereals. The under leaf margins bear scattering hairs. The ligules are short, oval, with very distinct 3-angled, lance-shaped, pointed teeth (Fig. 27).

81. The panicle is usually 9 to 12 inches long. It is made up of several half whorls of branches, which arise from alternate sides of the rachis. The panicle is either spreading or compacted and turned to one side; the rachis and rachilla round and glabrous; the former rough above and sleek below; the lowest or two lowest half whorls usually with a light seam or edge of cuticle running around them. The branches bear 1 to ∞ spikelets (Fig. 28).

82. Spikelets. — Each spikelet contains 2 or more flowers, of which usually only the two lowest are fertile, the lower one of these being the larger and producing the larger kernel. The axis is glabrous or has scattered or crowded bristles in one or both flowers. The glumes are thin membranous, broadly lanceolate, pointed, glabrous, broadly arched, 7- to 11-nerved; the upper a little larger than the lower, and having commonly two more nerves. Glumes exceeding the flowers except in the hulless group. The two kernels which develop lie close together and may or may not separate in thrashing.

83. Flowers. — The lemma is much firmer in texture than the glumes, is broadly arched, usually oval and pointed; the apex toothed, emarginate, cut slightly, 2-cleft or entire; color white through yellow and brown to black; lemma glabrous or rarely with bristles, rough toward the apex. In the lower flower, it usually possesses an awn arising from its dorsal portion; awn brown or black, varying much in length, bent at ripening, twisted to the right below the bend, the thinner and usually longer portion above the bend not twisted, when small neither bent nor twisted; palea shorter than the



a *b*

Fig. 28. — Forms of oat panicle: *a*, spreading panicle; *b*, side panicle.

lemma, glabrous, rough toward the apex, thin membranous 2-keeled, the keels bearing many short cilia; stamens 3, anthers 4 mm. long, somewhat narrow, yellow, emarginate at base and apex, attached to filament in the middle; reproductive organs similar to those of wheat (35) (Fig. 29).

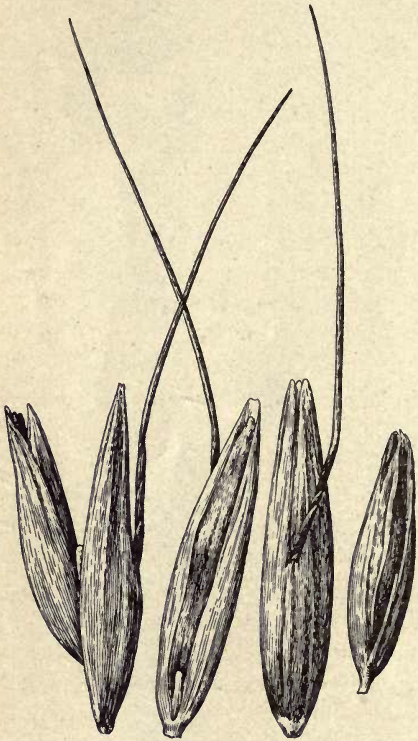


Fig. 29. — Spikelet of Swedish Select oats, showing both kernels, and twisted awns, and the absence of basal bristles.

84. Kernels. — Except in the hulless group, the kernel at the time of ripening is tightly inclosed by the lemma and palea, the first forming what is commonly called the hull, but which is very different from the thin hull or bran of the wheat kernel. The kernel proper is usually almost cylindrical, but varies in length and shape, and is very hairy; light yellow, in the hulless group yellowish brown; bran thin and tender.

The proportion of caryopsis or kernel proper to hull, and the hardness and length of the latter are of commercial importance. The percentage of caryopsis does not, however, decrease directly with the decrease in size of combined caryopsis and hull, for the hull is much thinner in some varieties having smaller sized kernels. To give a good example, it was found in the results of an extensive test that the large-kerneled heavy Swedish Select variety usually weighed more per bushel and much more per 100 kernels than the thin, long-kerneled Sixty Day, but the latter possessed 1 per cent to 5 per cent more of the caryopsis than the former. The usual proportion for American varieties is about 70 per cent (Warburton, 1910, pp. 9–12; Carleton, 1910, pp. 32–34).

85. The origin of the common oats appears to be as little known as that of wheat, though the latter is without doubt more ancient. The difficulty in case of this cereal is increased by a considerable confusion of wild and cultivated forms. There is a prevailing opinion at present that two species, *Avena fatua*, Linn., and *A. sterilis*, Linn., have given rise to practically all cultivated oats. The sterilis species is of more recent origin, and is definitely located in the Mediterranean region, having arisen in North Africa. The sativa species, which probably is derived from *A. fatua* and includes nearly all the cultivated varieties, appears from the general trend of all evidence to have originated in eastern temperate Europe or western Asia.

86. Present range. — The extremes of latitude and altitude for possible oat cultivation are not great. Spring varieties are grown at considerable heights and rather far north, but their range does not exceed that of wheat in these respects and falls short of that of barley. Excepting the sterilis species, oats is somewhat inclined to be a cold climate cereal, but only with respect to spring varieties, for it is only slightly winter hardy. It is grown as a winter crop in such areas as the Mediterranean region and the southern states of this country. On the other hand, it has obtained no footing in any strictly tropical climate.

In Finland, oats is regularly cultivated beyond the Arctic Circle, and extreme points of its cultivation reach almost to the 68th parallel. It is the most common cereal in Norway, where it reaches its highest latitude, 69° 28′. In Alaska, oats has matured for several years at Rampart, latitude 65° 30′. Certain varieties matured there in less than 90 days. Bonanza oats has matured at Ft. Providence on the Mackenzie River, latitude 60° 17′. In various descriptions of crops of oriental countries, wheat and barley are mentioned much more often than oats. Going westward in China from Kwei Yang, it is said that oats and buckwheat do not appear until the Yunnan boundary is reached, but oats is common in Yunnan and Szechuen. No doubt there are many forms of the hulless and side oats, at high elevations, and on the plateaus, in western China, Tibet, and Turkestan that are not yet well known. The same thing may be true of forms of the sterilis and other species in northern Africa and in Abyssinia. Hulless oats grow at high altitudes near Issyk Kul, in Turkestan, and both hulless and side oats seem to be common in Transbaikal. *Avena chinensis*, Fisch., a hulless oat, occurs in the Peking mountains and in Mongolia. Rockhill found oats at Gartok on the eastern border of Tibet, but supposed it was wild. It is said to be unknown in the greater part of Africa, but is grown sparingly in extreme North Africa and South Africa and Abyssinia. On the other hand, wild forms are common in Abyssinia.

87. Classification. — The cultivated oats are derived chiefly from the species *Avena fatua*, Linn. and *A. sterilis*, Linn. For present purposes, the former will be considered as roughly separable into three botanical subspecies, *A. sativa*, Linn., *A. orientalis*, Schreber, and *A. nuda*, Linn., having as common names (1) the spreading oats, (2) the side oats, and (3) the hulless oats, respectively. According to Trabut (1911) the species of red or Algerian oats is removed from the original *A. sterilis* by several intermediate forms. He has designated the former by the name *A. sterilis algeriensis*. He also concludes that *A. strigosa*, Schreber, sand oats, and *A. brevis*, Roth., short oats, each containing but one poor variety, are derived from *A. barbata*, Pott., a species adapted to dry climates. *A. abyssinica*, including Abyssinian cultivated varieties, is derived from *A. Wiestii*. The outline of the classification which at present appears to be nearest correct is as follows: —

Avena	fatua, Linn.	sativa, Linn., common or spreading oats.
		orientalis, Schreber, side oats.
		nuda, Linn., Hulless oats.
	sterilis, Linn.	algeriensis, Trab., red or Algerian oats.
	barbata, Pott.	strigosa, Schreber, rough or sand oats.
		brevis, Roth., short oats.
	Wiestii, Steudel	abyssinica, Hochst, Abyssinian oats.

88. Common or spreading oats (*Avena sativa*, Linn.). — By far the greatest number of cultivated varieties are included in this subspecies. The panicle is open and spreading, which fact distinguishes the species from the side oats (see Fig. 28), while the attachment of lemma and palea to the caryopsis chiefly distinguishes it from the hulless forms. For a very long time, this appears to have been the only subspecies of cultivated oats known in

Europe or America. It is probable that the oldest cultivated forms were of this subspecies. The numerous present varieties differ from each other in the formation of the awn, presence or absence of the same, the number of ker-

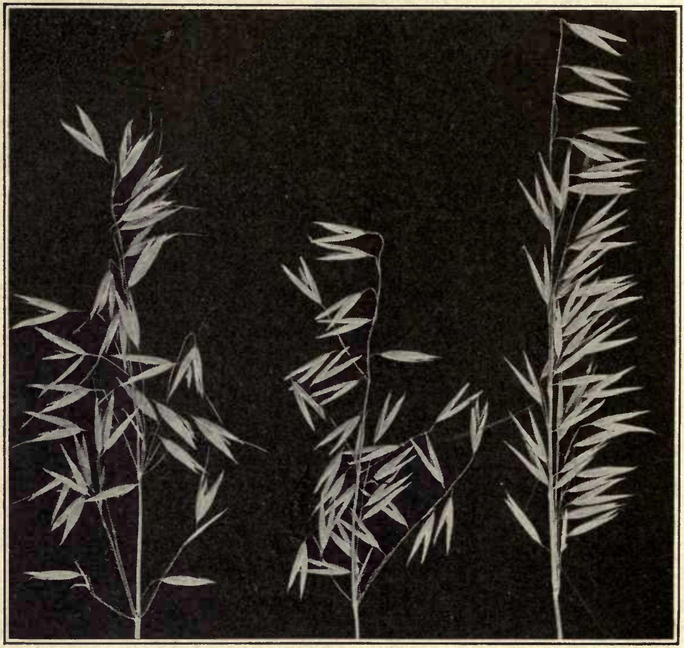


FIG. 30. — Oat panicles: *a*, Victory; *b*, Kherson; *c*, Russian White.

nels in the spikelet, the form, size, and color of the kernel, and the time of maturity. The representative varieties of this subspecies are here given, classified, as in the case of the wheats, according to Koernicke and Werner (Fig. 30).

(Avena sativa mutica, Al.)

1. *Awnless,*[1] *hull white or light yellow.*
Spring — American Beauty, American Triumph, Amur, Big Four, Civada Blanca, Daubeney, Early Pearl, Early Champion, Early Gothland, Gentile prima verite, Granja de Barcelona, Irish Victor, Ligovo, Orkney, Perm, Probsteier, Providence, Pringle Progress, National, Siberian, Shatilovski, Silvermine, Tobolsk, Sensation, Umea, Victory, Wideawake, Waterloo, Welcome, White Schönen.
Winter — Culberson.[2]

(Avena sativa prægravis, Langethal)

2. *Awnless, hull white or light yellow, kernels oval, distended.*
Spring — Berlie, Canadian, Clydesdale, Nagpur, Surprise.
Winter — Provence Winter.

(Avena sativa aristata, Krause)

3. *Awned, hull white or light yellow.*
Spring — Abundance, Banner, Belyak, Burt, Cluster, Danish, Lincoln, Newmarket, President, Swedish Select.

(Avena sativa trisperma, Schubler and Mort.)

4. *Awned, hull light yellow, 3-kerneled.*
Spring — Palermo, Three Kernel Lappland.

(Avena sativa aurea, Kcke.)

5. *Awnless, hull golden yellow.*
Spring — Danish Island, Flemish Yellow, Golden Rain, Kherson, Sixty Day, Drummond.

[1] In the same variety of oats there is extreme variation as to the presence and size of awns, so that different writers will place the same variety in different groups, depending upon the material at hand. In these pages, awnless means that most of the specimens studied have either very small awns or usually none.

[2] There is no agreement as to the identity of this variety. The name is often applied to a strain of Rustproof.

(AVENA SATIVA GRISEA, KCKE.)

6. *Awnless, hull gray.*
   Winter — Gray Winter, Russian Gray Winter, Virginia Gray Winter, Winter Turf.

(AVENA SATIVA BRUNNEA, KCKE.)

7. *Awnless, hull brown.*
   Spring — Houdan, Rousse Couronné, Dun.

(AVENA SATIVA NIGRA, KRAUSE)

8. *Awnless, hull black.*
   Spring — Black Brie, Chernii, Etampes, Joanette, North Finnish Black, Old Island Black.

(AVENA SATIVA MONTANA, AL.)

9. *Awned, hull dark.*
   Spring — Berg, Victor.
   Winter — Black Russian, Boswell, Webb Black Winter.

89. Oriental or side oats (*Avena orientalis*, Linn.). — This subspecies of oats, as its name implies, appears to be a definite product of the Orient. It seems not to have been known in Europe until comparatively recent times. It is chiefly characterized by the fact that the panicle is compacted and turned to one side (see Fig. 28). Side oats seem, on the whole, a little more restricted in adaptation to northern latitudes than the spreading oats. They are somewhat deceptive as to probable yield, the compactness of panicle causing a tendency for one to overestimate their yields. All side oats are spring varieties. The classification and representative varieties are about as follows: —

(AVENA ORIENTALIS OBTUSATA, AL.)

1. *Awnless, hull white.*
New Zealand, Odnogrivii Byelii, Senator, Sparrowbill, Storm King, Tatar King, Tatarian White.

(AVENA ORIENTALIS TATARICA, ARAUINO)

2. *Awned, hull white.*
Hungarian White, Russian White.

(AVENA ORIENTALIS FLAVA, KCKE.)

3. *Awned, hull golden yellow.*
Golden Giant, Seizure.

(AVENA ORIENTALIS TRISTIS, AL.)

4. *Awnless, hull black or brown.*
Hungarian Black, Neffly, Odnogrivii Chernii.

(AVENA ORIENTALIS PUGNAX, AL.)

5. *Awned, hull black or brown.*
Italian Black, Tatarian Black, Tatarian Brown.

90. Hulless or naked oats (*Avena nuda*, Linn.). — The hulless oats appear to have come from central and eastern Asia, where they are at present more abundant than in any other area, though it is written that a variety was grown in England in the middle of the sixteenth century. They are found particularly in the Tibetan-Himalaya highlands, in Russian and Chinese Turkestan, and in northern and western China. In this country there is occasionally found both a large-kerneled and a small-kerneled variety, but neither is of much importance in general cultivation. The place of hulless oats in classification is uncertain. The forms of panicle of both the sativa and orientalis subspecies occur in hulless varieties, and from that standpoint, the latter would appear to belong to those subspecies. They are, however, quite different in respect to the spikelet axis, which is so far prolonged that the number of flowers is increased, the uppermost of which exceed the glumes. The lemma, like the glumes, is thin, membranous. In the lowest spikelets the flowers are less numerous and may not exceed the glumes. The caryopsis is proportionally large. The hulless oats and Polish wheats are called by one authority "fixed monstrosities." The few varieties are as follows:

(AVENA NUDA INERMIS, KCKE.)

1. *Panicle spreading, awnless, chaff pale yellow.*
   Large Hulless, Mongolian, Small Hulless.

(AVENA NUDA CHINENSIS, FISCH.)

2. *Panicle spreading, awned.*
   Chinese Hulless.

(AVENA NUDA GYMNOCARPA, KCKE.)

3. *Panicle one-sided, awnless, chaff pale yellow.*
   Large Side Hulless.

(AVENA NUDA VAR.)

4. *Panicle one-sided, awned, chaff pale yellow.*
   Tatarian Hulless.

91. Red or Mediterranean oats (*Avena algeriensis*, Trab.). — The red oats, also called sterile, Mediterranean, Algerian, Italian, Turkish, and Rustproof oats, are, as above stated, derived from *Avena sterilis*, but form at present a cultivated subspecies considerably modified from the original species. Trabut (1911) has given it the name *Avena sterilis algeriensis*. It is considered here as a subspecies, like *Avena sativa*.

The cultivated red oats show still the important characteristic of *A. sterilis*, the basilar articulation. That is, the second kernel does not articulate at its point of union with the spikelet axis, as in *A. fatua*, but, on separation from the spikelet, carries with it the axis itself, differing in this way from those of other species as the emmer spikelet differs from the spelt spikelet. The second kernel remains attached for some time. The caryopsis is a little longer than in the sativa and orientalis groups. The lemma is rather long, bristled at the base, and is often awned. There is great variation in these characters even in the intermediate wild forms, while in the cultivated varieties both bristles and awns are much reduced and may be wanting. The awns, when present, are not geniculate as in the wild forms, and are only slightly twisted. The color of the

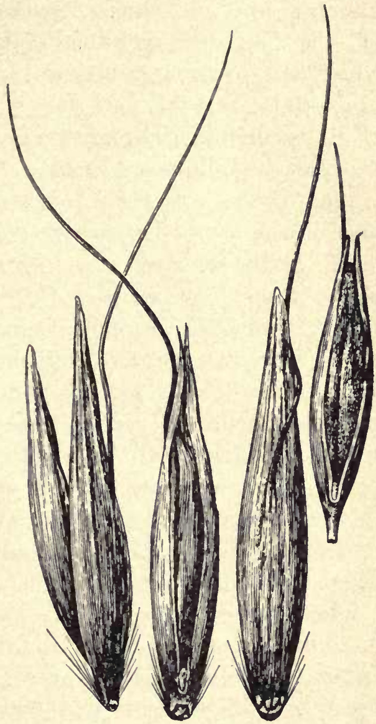


Fig. 31. — Spikelet of Rustproof oats, showing both kernels, and the basal bristles.

hull varies from pale red through brown to black. In this country about three groups may be recognized; (1) the Italian Rustproof, rather strongly awned and quite bristly, (2) the common Rustproof, not so strongly awned and bristled, and earlier-ripening than the Italian, and (3) the Fulghum, which is still earlier-ripening, and in which the awns and bristles are usually wanting (Fig. 31, see also Fig. 34).

The principal cultivated varieties of this subspecies are about as follows: Abrantes, Appler, Apulia, Cataluna, Italian Rustproof, Red Algerian, Ruvo di Puglia, Rustproof, Asia Minor Rustproof, Fulghum.

92. Hairy or sand oats (*Avena strigosa*, Schreber). — Both this subspecies and the short oats, according to recent researches, are derived from *A. barbata*, which has a very extensive range. Both subspecies are distinguished from common oats by the pedicellate lower flower and the presence usually of 2 awns in each spikelet. The spikelet axis in both groups is tufted hairy under the upper flower or under both flowers or may be glabrous. In this subspecies the lemma is divided at the apex into two fine awn-like points in addition to the awn itself. The color of the kernel (hull)is grayish to dark gray.

The hairy oats occurs as a weed in Europe, especially in common oats. It is of slight economic value, and is cultivated only in sandy or otherwise poor soils or unfavorable climates as in the Orkney and Shetland islands, where other oats fail. The straw has been found good for cattle. Practically only one cultivated variety appears to be known, — the Sand or Hairy or Bristle-pointed or Meager oat, in French, "avoine strigeuse."

93. Short oats (*Avena brevis*, Roth.). — The short oats differs from the hairy oats by the presence of two short coarse teeth at the apex of the lemma, instead of the fine awn-like points. The awn is also shorter and tooth-like, and the kernel (hull) thicker and a little shorter. The kernel is grayish to dark gray in color.

This subspecies is also of slight economic importance, and when cultivated at all, is grown in Spain, Portugal, in portions of France and Germany, and in Belgium. In Portugal it is grown under the name *Avea môcha*. Practically the one cultivated variety, Short oat, in French "avoine courte," is recognized. It should be noted that, because of their adaptation to unfavorable conditions, both the short and hairy oats may be of much value in breeding work.

94. Abyssinian oats (*Avena abyssinica,* Hochst.). — The Abyssinian oats are, according to Trabut, derived from *A. Wiestii,* which latter is only slightly different morphologically from *A. barbata,* but is more strictly a desert species. Trabut found, under cultivation, all the transition stages between *A. Wiestii* and *A. abyssinica,* the cultivated form. The Abyssinian oats differs from *A. Wiestii* in its spikelet axis, being much less hairy or entirely glabrous, and having much firmer articulations, thus retaining the kernel. There is great variation in the color of the kernel in different forms. Apparently no distinct cultivated varieties have yet been developed, but there are a number of partially developed or wild forms, roughly segregated by the Abyssinians, by whom they appear to be used as forage. This oats is also reported to be in cultivation in southern Arabia, chiefly for forage but also as food for man. Even there, however, it is more generally a weed in cultivated fields. Here again there is opportunity for much good breeding work in the use of these various half wild forms of the Abyssinian group, particularly in the production of drought-resistant varieties, which, among the oats, are much needed.

95. Distribution in North America. — With respect to the adaptation and distribution of oat varieties, the United States and Canada may be considered as divided into districts, corresponding rather closely with the wheat districts, except that there is no definite parallel area to the durum wheat district in oat distribution. There are, therefore, nine oat districts as follows: (1) the Northeastern oat district, (2) the Middle Eastern or Yellow oat district, (3) the Southern or Winter oat district, (4) the Northern Plains or Side oat district, (5) the Middle Plains or Transition oat district, (6) the Southern Plains or Red oat district, (7) the Western Intermountain oat district, (8) the North Pacific oat district, and (9) the South Pacific oat district. As the characteristics of these districts in relation to oat adaptation are much like those described under wheat, only a brief discussion of each seems necessary.

96. Northeastern oat district. — In this district is included roughly all of New England, New York, Pennsylvania, northern New Jersey, West Virginia, northern Ohio, Michigan, the eastern maritime provinces of Canada, Quebec, and Ontario westward to the Albany River and the 90th meridian. White oats are generally grown in this district, and usually those having a spreading panicle. As a rule the midseason or late oats with large white kernels seem to do better than early varieties. In the extreme north, however, earliness is of importance. Early varieties would also have the advantage sometimes in escaping periods of rust or dry weather. Much oat straw is used for stock feed, and therefore the yield of straw is of more importance than in some other districts.

In a four-years test at the Maine Experiment Station the variety Lincoln made the most straw, and Kherson the least. The climate is generally well adapted for the oat crop, but outside of Ontario very little experimental work has been done for oat improvement until very recently.

Fig. 32. — Swedish Select oats at Shortsville, New York.

The states and provinces of chief production are Ontario, New York, Quebec, and Pennsylvania (Fig. 32).

Principal varieties now grown or adapted: —

Abundance	Lincoln	Swedish Select
Banner	Long White Tatar	Siberian
Big Four	Ligovo	Tatar King
Cluster	O. A. C. No. 72	Victory
Clydesdale	Old Island Black	Welcome
Daubeney	Silvermine	

Needs of the district: —

Strength of straw	Means of preventing rust
Earliness in northern localities	

97. Middle Eastern or Yellow oat district. — There are included in this district Delaware, portions of New Jersey, Maryland, Virginia, North Carolina, Tennessee, and

Kentucky, and nearly all of Ohio, Indiana, and most of Illinois. The area is partly what is known as the "corn belt." A large oat production is furnished by a few states in this district. Dry periods in certain seasons and periods of severe rust attacks in others near harvest time make it of great importance to grow early varieties, which will escape the effects of these periods. Such varieties have already become well established, including particularly the Kherson, Sixty Day, and Early Champion. The first two named varieties, commonly grown, have a yellow hull, which is commercially undesirable.

Varieties now grown or adapted: —

Big Four	Improved American	Silvermine
Early Champion	Kherson	Swedish Select
Great Dakota	Sixty Day	

Needs of the district: —

Resistance to lodging	Whiteness of kernel
Rust prevention	Earliness

98. Southern or Winter oat district. — The Winter oat district comprises portions of Maryland, Virginia, and North Carolina, South Carolina, Georgia, northern Florida, Alabama, Mississippi, western Kentucky and Tennessee, southern Missouri, Arkansas, Louisiana, and eastern Oklahoma and Texas. As the name implies, winter oats is adapted in all portions of this district. It is practically the "cotton belt," except the extreme northern portions. While the Burt and spring Rustproof oats are often sown, the winter varieties will nearly always give better results. It is a common practice to sow the Rustproof at different dates during the winter, but always, beyond an optimum date in late fall, the earlier the seeding the better. Trials at the Arkansas Experiment Station indicated that the first week of October is the best time for seeding. Rustproof oats ordinarily is both a winter and spring variety. Strictly winter strains have been developed, however, that are very hardy some distance north. The Winter Turf or Gray Winter is always strictly a winter variety. The Culberson, though quite different from the Turf, is also a rather hardy winter

FIG. 33. — Field of Appler oats, near Columbia, South Carolina.

oat. The total oat production of the district is small, but is increasing considerably recently (Figs. 33 and 34).

The frequent injury from late spring frosts makes it requisite that winter cereals in the South shall possess a particular kind of hardiness, that must show itself after growth starts in the spring.

Principal varieties now grown: —

Appler	Culberson	Rustproof
Bancroft	Fulghum	Winter Turf
Burt	Virginia Gray Winter	
Cook	Hundred Bushel	

Needs of the district: —

Resistance to late spring frosts	Earliness
Rust prevention	Winter hardiness
White-kerneled varieties	

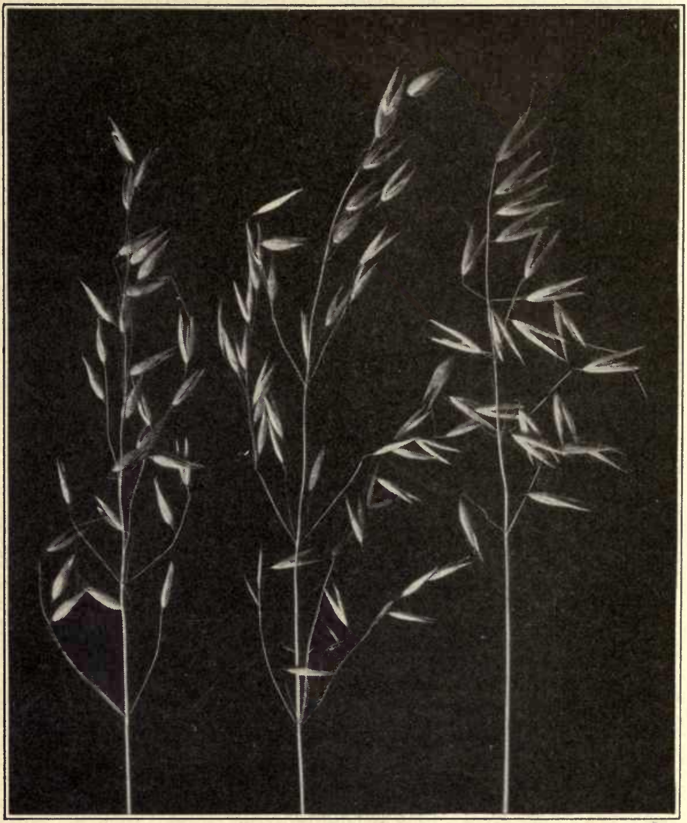


FIG. 34. — Panicles of winter oats: *a*, Winter Turf; *b*, Culberson; *c*, Rustproof.

99. Northern Plains or Side oat district. — In this district are included North Dakota, eastern Montana, the larger portions of Minnesota and Wisconsin, and a very large area in Canada, including western Ontario and all of Manitoba, Saskatchewan, and Alberta where there is cultivation. As conditions are here more favorable for oat production than in other districts, there is a wider range of varieties employed. The side oats, however, seem to be especially adapted, though they usually do not yield as much as the spreading oats, and are really in the minority in cultivation. As a rule, late, large-kerneled varieties are best. The principal side oat varieties are Russian White, Tatarian White, and Tatarian Black. Of the spreading oats, Swedish Select has been a popular variety in the United States portion of the district. In the Canadian portion, Banner, Abundance, and Victory appear to be the popular oats. Kherson and Sixty-Day of the Yellow oat district give good results in some localities. At some extreme northern points Daubeney has been of value because of its earliness.

Principal varieties now grown or adapted: —

Abundance	Ligovo	Sixty-Day
Banner	Lincoln	Silvermine
Tatarian Black	Newmarket	Siberian
Daubeney	Orlov	Twentieth Century
Danish Island	O. A. C. No. 72	Russian White
Golden Rain	Probsteier	Tatarian White
Irish Victor	Swedish Select	Wisconsin Wonder
Kherson	Victory	

Needs of the district: —
Earliness in certain localities.
Drought-resistance in the western part.

100. Middle Plains or Transition oat district. — In this district are included all of Iowa and Nebraska, very small portions of Illinois and Wisconsin, half of Minnesota, nearly all of South Dakota and eastern Wyoming, and a small corner of Colorado. Various northern and southern oat varieties compete for establishment, including the southern Rustproof and northern Swedish Select, also Silvermine of the east and Kherson of the west, making it truly a transition district. The conditions in a large part of the district are very severe for oat-growing, and the varieties that finally prevail must be of the hardiest. The two varieties gradually predominating are Kherson and Sixty-Day. In Iowa, Early Champion is also extensively grown. Silvermine, Swedish Select, and Rustproof have done well in portions of the district. The usually recurring drought of early summer makes drought-resistance an important characteristic. Earliness also is very desirable that the crop may ripen if possible before the drought occurs.

Varieties now grown: —

Early Champion	Rustproof	Sixty-Day
Kherson	Russian Green	Swedish Select
Newmarket	Silvermine	

Needs of the district: —

Drought-resistance	Earliness

101. Southern Plains or Red oat district. — This district includes a large portion of Missouri, Kansas, eastern Colorado, western Oklahoma, western Texas, and eastern and southern New Mexico. As Texas Red or Rustproof is the variety most generally grown, it may well be called the Red oat district. However, Kherson and Sixty-Day have in recent years been found well adapted in Kansas. Rustproof and Kherson have proved to be the best at the Oklahoma Experiment Station. In Texas the fall-sown Rustproof oats of the Southern district is gradually succeeded by the spring-sown strain to the northward and westward as the climate becomes too severe for fall seeding. Roberts (1908, p. 147) ascertained that "Red Texas oats tends to 'run out' after two years' growing in Kansas, giving way to a black variety, the seed of which always appears in seed of the red sort imported from Texas. In the latter state the black-seeded plants are present, but do not supplant the red sort as in Kansas."

Varieties now grown or adapted: —

Kherson	Rustproof	Sixty-Day
Silvermine	Burt	

Needs of the district: —

Earliness	Drought-resistance
Rust prevention	

102. Western Intermountain oat district. — The intermountain district includes scattered areas, largely irrigated, between the Sierra Nevada and the Rocky Mountain ranges. The percentage of cultivation under dry farming is rapidly increasing. The district is not so well adapted for oats as for wheat and certain kinds of barley. Late large-kerneled varieties, such as Swedish Select, Banner, and Siberian, do best generally where there is irrigation. Side oats are fairly well adapted, and occasionally hulless oats are found. Very high yields are obtained, particularly in the northern portion, and the bushel weight is usually high. The Swedish Select is especially well adapted for irrigation, but also does well under dry farming, and is widely distributed. Kherson and Sixty-Day do well on the dry farms. The total oat production of the district is small. Winter oats is grown to a small extent, particularly in Utah.

Principal varieties grown or adapted: —

Abundance	Clydesdale	Progress
American Wonder	Danish	Roosevelt
Banner	Improved American	Siberian
Big Four	Kherson	Swedish Select
Boswell Winter	Lincoln	White Russian
Colo. No. 37		

Needs of the district: —

Resistance to frosts	Winter hardiness in places
Earliness at high altitudes	Drought-resistance on dry lands

103. North Pacific oat district. — This district includes the Pacific Coast cultivated area from the head of the Sacramento Valley to and including British Columbia and northern Idaho. Conditions in western Washington, Oregon, and British Columbia are favorable to large yields of oats. Large-kerneled, late white varieties, such as Big Four and Improved American, are the best adapted. Side oats are popular in places. For the dry land sections Sixty-Day is well adapted. Winter oats are grown in some localities. British Columbia is yet little developed agriculturally, but Banner, Abundance, Ligovo, and Daubeney appear to do well there.

Varieties now grown or adapted: —

Abundance	Kherson
Banner	Ligovo
Big Four	Russian Black (winter)
Daubeney	Sixty-Day
Gray Winter	Swedish Select
Improved American	

Needs of the district: —

Strength of straw	Winter hardiness

104. South Pacific oat district. — California, from the head of the Sacramento Valley southward, and southern

Arizona are included in this district. As in the case of wheats, the conditions and varietal adaptation are similar to those of Australia, the Mediterranean region, and Turkestan. Semi-winter oats do better than spring oats or true winter oats. Rustproof, Algerian, and other varieties of the red oats are admirably adapted, and improve in appearance greatly on transfer to this district. No good Australian or Turkestan varieties have been introduced, but such would no doubt give good results. Varieties from Abyssinia also should be well adapted.

Varieties now grown or adapted: —

Asia Minor Rustproof	Burt
Algerian Red	Rustproof

Needs of the district: —

Semi-winter varieties
Further introductions of Mediterranean and Oriental varieties

105. Distribution in other countries. — (1) Side oats are grown in Siberia and other northern and highland regions of Asia, and in Russia and Hungary. (2) Large white-kerneled oats occur in northern and central Europe. (3) Black spreading oats are found in Finland, France, Germany, and the British Islands. (4) Gray and brown-kerneled oats, many of them winter varieties, are grown in southern Europe and Scotland (one variety Dun). (5) Yellow oats are scattered indefinitely through central Europe, one variety (Danish Island) in Denmark. (6) Red oats belong preëminently and originally in the Mediterranean region. (7) Hulless oats come from the highlands of Tibet, northern India, Turkestan, and Mongolia, and from northern and western China. (8) Hairy or sand oats occur in the region from Spain and Portugal to Great Britain in the Orkney and Shetland Islands, and in Belgium and west Germany. (9) The short oats are found cultivated and as weeds in Portugal and Spain, in certain portions of France and Belgium, and in a few places in northwestern Germany. (10) The half wild Abyssinian varieties (forms of *A. abyssinica*) are developed in Abyssinia, but are reported to exist also in southern Arabia, as weeds and also are cultivated there sparingly for forage and as food for man.

CHAPTER V

BARLEY

Barley belongs, with wheat and rye, in the same tribe of grasses, Hordeæ, which was described under wheat. It differs from the other two cereals in having 3 spikelets at each joint of the rachis, 2 of which are sterile in many forms. The subtribe Elymeæ, in which it is more definitely located, is further described as follows: terminal spikelet, when present, has both glumes, together with the lemmas, in its median line. In the lateral spikelets the glumes are thrown out of this line because of the crowding together of the spikelets, and stand close together in twos in front of each spikelet; stamens three.

106. Description. — In the genus Hordeum, including cultivated barley, the glumes are narrow, usually subulate, all together forming a kind of involucre around the spikelets; lemmas in the median line of the rachis, five-nerved, extending into a strong awn; caryopsis usually adherent to the lemma, hairy at the apex or glabrous in the cultivated varieties, usually sulcate, without epiblast.

Hackel groups the sixteen species into three subgenera, placing cultivated barley, *Hordeum sativum*, Jessen, in the subgenus Zeocrithum, Beauv., which includes twelve species, all the wild forms of which have the rachis articulate, each joint falling off with the group of spikelets attached above it. In cultivated barley the articulation is lost. The middle spikelet is fertile and sessile, the lateral ones sessile or very short pedicellate, fertile or sterile; terminal spikelet aborted; glumes obtuse. *Hordeum murinum,* Linn., a common weed, which has pedicellate lateral spikelets, belongs here.

107. Roots. — As in other small cereals, the roots of barley are fibrous. The seminal roots are 5–8 in number. Often there are 6 in two parallel rows of 3 each. The crown, from which the permanent roots arise, is formed near the surface of the ground, and may be one or more inches above the seed, depending upon the depth of planting. Barley is generally believed to be more shallow rooted than the other cereals. Barley and oat roots appear to be coarser and more numerous than those of wheat, and form a more matted growth near the soil surface. In other words, these cereals are closer and stronger feeders. The roots of barley apparently grow even less than those of other cereals after the beginning of flowering. In winter barley, according to Rotmistrov (1913, p. 25), the root length is about 120 cm. and the root coefficient 13200; in spring six-row varieties root length 110 cm., root coefficient 7920; in two-row varieties root length, 120 cm. root coefficient 10800.

108. Culms. — The barley plant is shorter, as an average, than that of any other cereal, though some two-row varieties attain a good height. With the exception of portions of the spike, the entire plant is glabrous or occasionally has scattering hairs on the leaves. The culms are round, and hollow except at the nodes. The length of culm is affected greatly by environment. Odessa and Oderbrucker vary in height just the reverse of each other in Minnesota and Montana, the former being taller in Montana and the latter in Minnesota. The number of culms in a single plant averages 3 to 6 but may reach 15 to 30, and varies in different varieties, but still more following different rates of seeding. A change of environment also has great effect. It has been observed that Manchuria and Smyrna White barleys, when spaced 4 × 8 inches, average 2.9 and 6.1 culms to the plant respectively, when spaced 4 × 4 inches, average 2.7 and 4.5, and when spaced 4 × 2 inches, average 1.3 and 2.3. The six-row varieties average a greater number of culms to the plant in Minnesota than in California, the two-row varieties the reverse (Harlan, 1914, pp. 12–13). The leaves are rolled in the bud, and in young plants are usually twisted to the right. The leaf sheath is round and split to the base.

109. The leaves of barley are as a rule slightly broader than those of the other small cereals, and are generally gray-green in color. The leaf blade is lanceolate-linear, gradually acuminate; surface harsh above, with a prominent middle nerve below and about twelve strong side nerves; the base of blade not ciliated, pale or sometimes reddish brown; auricles larger than those of any other cereal. The ligule is short, truncate, or somewhat advanced in the middle but quite obtuse and sloping away to the ends; not toothed, only having the margins weakly uneven; sometimes with separate blunt projections; in other cases with very short fine teeth; glabrous, except extremely short scattering hairs on the margin [1] (Fig. 35).

110. Spikes or heads. — Barley in head resembles very much certain awned wheat varieties. The spikes are without a terminal spikelet, and are generally simple,

[1] The nature of the leaf and date of formation of first leaves and tillers in the young plant have not been given sufficient attention, even less the progressive behavior of winter varieties during winter.

rarely composite. The rachis is strongly compressed, flattened, hairy at the margins, with hollows present alternately on the two flat sides, in which the spikelets stand. Opposite and below each hollow the rachis segment

Fig. 35. — Young plant of winter barley.

springs out abruptly. This character permits an easy distinction of a barley head from that of wheat or rye, even with the rachis quite glabrous, as such peculiarity is lacking in those cereals. It is further characteristic of the barley rachis that its margins on the flat side next to the spikelet have a narrow longitudinal prominence. In wheat the divisions of the rachis are directly arched or bent, the entire rachis appearing therefore bent to and fro or zig-zag. Rye resembles barley more in this respect. In sixteen selections from Manchuria barley grown at the Minnesota Experiment Station, the density of the spike varied greatly. In this case only it was also found to correlate well with the date of emergence of the awn or earliness. Always the tendency to greater density occurred to the westward (Harlan, 1914, pp. 20–22).

111. Spikelets. — In barley there are three spikelets at each joint of the rachis, only one of which in the two-row varieties is fertile; usually sessile but sometimes the lateral ones very short pedicellate. The inner glume of the six-row varieties is apparently forced out of place by the crowded spikelets, both glumes occurring near each other on the outside of the spikelet;[1] glumes usually linear, flat, awned, with three nerves; those of the middle spikelet widely separated at the base, those of the fertile lateral, spikelets touching each other at the base, those of the sterile lateral spikelets merged into one and grown fast to the spikelet axis. In a few groups the glumes of the middle spikelet are broad lanceolate, 3–5-nerved. The axis of the spikelet is continued beyond the base of the kernel in the form of a basal bristle, upon the nature of which a number of the more recent subdivisions in classification of barley depend. This bristle is lodged within the furrow of the kernel, and carried away with it in thrashing. In some cases it is covered with long stiff hairs, in other cases with short curly hairs (Fig. 36).

[1] This is Hackel's view. Körnicke maintains that the inner glume is lacking entirely and the outer is divided. There is some confirmation of this idea in the fact that in certain groups there is only the one simple outer glume (Hackel, 1896, p. 187, Körnicke, 1885, pp. 129–130).

112. The flower in the fertile spikelet usually is sessile, in the sterile spikelets pedicellate. The lemma is ovate, broad arched, 5-nerved, somewhat angled at the nerves, glabrous, sometimes having purple or brownish purple stripes, especially in two-row varieties, which disappear in ripening, drawn out into a long, stiff, straight awn. The inner pair of side nerves has, in some cases, numerous small translucent teeth; in other cases smooth. This is a distinguishing character, and has been used in separating groups. Another group character is the nature of the base of the lemma. Just above the line of attachment of the lemma to the rachis, on the dorsal side, there is, in the two-row nutans group, a slight horseshoe-shaped depression. In the two-row erectum group the dorsal side of base is not depressed, but there may be a transverse crease. The same differences are found in six-row barley. The awns are longer in the middle spikelet than in the lateral spikelets, flat on the inner side, flat, angled, or arched on the outer side, usually smooth on the surface, but much roughened on the margins by rigid, pointed teeth. They include a continuation of the middle nerve and the two nearest side nerves of the lemma. In rare varieties the lemma is without awns, and merely pointed. Such forms occur sometimes in hybrids. In the hooded barleys there is a trifurcate appendage in place of the awn, one of the segments being hood-shaped. The palea is obtuse, glabrous, two-keeled or two-nerved, arched inward between the keels and turned in at the margins.

FIG. 36. — Barley kernels showing the two kinds of basal bristles: on left, the curly bristle; on right, the straight-haired bristle, $\times 2\frac{1}{2}$.

The two lodicules are usually long, but vary much in form in different varieties. In the lower portion they are thick, fleshy, and glabrous, in the upper portion membranous and hairy. In some varieties they are entirely membranous, and in certain varieties the surface is entirely hairy: filaments three, anthers long, yellow, opening in the upper portion; pollen grains globular.

Barley is rather strictly self-fertilized, particularly in the two-row varieties, so much so that it is very difficult in certain cases to perform artificial pollinations successfully.[1]

113. Kernels. — The caryopsis is usually grown fast with the lemma and palea, and all together referred to as the kernel, as in oats. In some varieties the former is naked, as in hulless oats. The longitudinal furrow is a little narrowed from the back, and rather deep, so that the lateral diameter of the kernel is greater than the dorso-ventral diameter, while the latter is greater in einkorn, and the two about equal in other wheats, rye, and oats. The caryopsis is rather vitreous in fracture; aleurone cells in many rows, in other cereals in single rows; starch grains simple. The colors of the barley kernel, hulled and hulless, are various, and the causes interesting. Composition of the kernel is in some degree a varietal characteristic, but varies much more through changes of environment. All varieties in California have a lower nitrogen content than in the Northern Plains states, though the California Feed or Coast barley is

[1] The exsertion of the head occurs imperfectly in some varieties, and after flowering in others. The pollen ripens while yet in the leaf sheath. The awns emerge at about heading time; hence in variety studies it is proposed to substitute the date of emergence of the awn for the date of heading, which is also about the date of flowering (see Harlan, 1914, p. 7).

always lower in nitrogen than other six-row varieties wherever grown.

"There are two coloring materials in barley: One, anthocyanin is red in its acid and blue in its alkaline condition; the other, a melanin-like compound, is black. The pigments may occur in the hulls, the pericarp, the aleurone layer, and occasionally in the starch endosperm. The resulting colors of kernel are quite complicated. White denotes the absence of all pigment. A heavy deposit of the melanin-like compound in the hulls results in black; a light deposit results in brown. Anthocyanin in the hulls results in a light violet red. In hulless forms the melanin-like compound in the pericarp results in a black kernel; anthocyanin produces a violet one; anthocyanin in the aleurone cells alone produces a blue kernel." (Harlan, 1914, pp. 35–36.)

114. Origin of barley. — Barley is one of the most ancient cultivated plants. As in the other cereals, the most common and most diversified groups appear to have the oldest history. Though much is yet to be learned of the details of development of different groups, *Hordeum spontaneum*, C. Koch., is generally conceded to be the oldest barley ancestor now known to be growing wild. It occurs in all the region between the Red Sea and Caucasus mountains and Caspian Sea. It most nearly resembles the two-row barley, but differs from the latter in having an articulate axis, a longer and stiffer beard, and more hairiness, the characters usually emphasized in a cereal ancestor. Though the two-row barley is most nearly related to the present wild form, six-row barley, it seems, is the species most anciently cultivated. The latter has been found in the earliest Egyptian monuments and in the remains of the Lake Dwellers. It is said that this barley was the only one existing in India at the close of the eighteenth century. No form of hulless barley has been found wild[1] (Fig. 37).

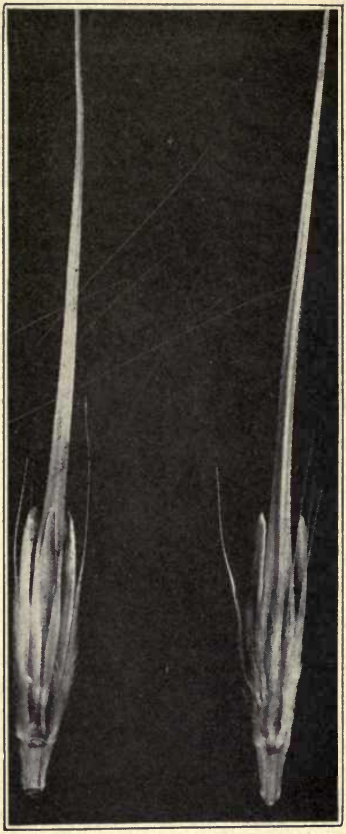


FIG. 37. — Spikelets of wild barley (*Hordeum spontaneum*).

As research goes on, one principle appears to be gradually working out, strikingly common to all the cereals, — that the most common and most diverse groups are the oldest, and also the fact that each cereal except rye, includes more than one species, each of which is probably of different origin. Some of the detail facts supporting these principles may here be stated; for example, those cultivated groups having the greatest tendency toward articulation of the rachis, the greatest degree of hairiness, and the longest and stiffest beards are the least separated from their wild forms, and their ancestry should therefore be most easily traced.

115. Present range. — Spring barleys attain the highest latitude and altitude of all cereals. Winter

[1] As recent as 1895 Bornmüller discovered in Kurdistan, Persia, a primitive form, closely related to H. spontaneum, which Körnicke (1908) has identified as the var. ischnatherum of Boissier's H. ithaburense, and from which Schulz (1913, pp. 90–93) believes H. polystichum, Döll. to be derived, the latter including the six-row barleys.

varieties, on the other hand, are not particularly hardy. Barley is grown beyond the parallel of 68° in Finland, up to 70° in Norway, as far as 65° in Sweden, up to the Arctic Circle in Russia, where the Lapland variety is grown; to 62° in Yakutsk government, Siberia, and at $65\frac{1}{2}$° at Rampart, Alaska, where it ripens in 80 to 95 days after seeding. Barley of other very different varieties thrives also in the tropical plains of the Ganges and in the hot districts of northern Africa, and is grown at Timbuctu, $17\frac{1}{2}$° from the equator. In the highlands of Abyssinia it is found still farther south. It grows at an elevation of 9400 feet in Afghanistan, up to 11,800 feet in the Himalaya region, as high as 11,000 feet in Abyssinia, 13,000 feet in Peru and Bolivia, and reaches 15,200 feet in Tibet. At the place last mentioned a considerable quantity is grown each year in a basin surrounding Dangra Yum Lake in Hor Province. Barley is most frequently mentioned among the cereals of the Old World. It is more adapted to alkaline soils than other cereals. Winter varieties are few and less hardy than winter wheats, but a little hardier than winter oats.

116. Classification. — It is rather generally accepted at present that two-row barley is derived from *H. spontaneum.* The six-row pyramidal and common six-row barleys are usually included under *H. polystichum,* while *H. intermedium* includes forms considered to be of hybrid origin. The classification most generally accepted is here shown: —

Hordeum
- spontaneum, K. Koch, distichum, Linn., two-row barley.
- polystichum, Döll
  - vulgare, Linn., common or nodding six-row barley.
  - hexastichum, Linn., club or erect six-row barley.
- intermedium, Kcke., hybrid barley.

117. Atterberg's group classification. — In recent years a system of classification of barleys in detail within the subspecies has been devised by Atterberg (1889), and afterwards improved upon by Neergaard (1889, pp. 54–61), and perfected by Bolin (1893), which is very useful in the identification of varieties. It permits a division of each subspecies into four types based upon certain botanical characters as follows: —

I. Kernels with long-haired rachillæ (basal bristles) and lodicules and without teeth on the lateral nerves.

II. Kernels with long-haired rachillæ and lodicules and with teeth on the lateral nerves.

III. Kernels with short-haired more or less woolly rachillæ, and lodicules and without teeth on the lateral nerves.

IV. Kernels with short-haired more or less woolly rachillæ and lodicules, and with teeth on the lateral nerves (see Newman, 1912, pp. 133–136).

As this system was worked out and is used extensively at the plant breeding station of Svalöf, Sweden, it is known as the "Svalöf System."

118. Erect six-row barley (*Hordeum hexasticlum,* Linn.). — All spikelets in this subspecies are fertile and awned. They are arranged in six distinct rows standing out from the rachis, as easily seen by viewing the spike endwise. Because of shortness of the internodes the spikelets stand erect, and are much compacted. From many actual measurements it is found that common nodding six-row barley averages from 25 to 30 internodes to the decimeter, while in the erect six-row barley the average is over 40. In the erect six-row barleys the side spikelets are separated from the middle spikelets by an angle of over 60 degrees, while in the common nodding six-row,

a *b*

FIG. 38. — Spikes of six-row barleys: *a*, erect six-row; *b*, common or nodding six-row.

the angle is less than 60 degrees. It is usually stated that all barley spikelets are sessile. There are apparently some exceptions in the side spikelets of six-row barley, in which cases they are either pedicellate or their bases are much elongated [1] (Figs. 38 and 39).

FIG. 39. — Spike and kernels of hooded hulless (Nepal) barley.

119. Distinguishing characters. — The kernels are distinguished from those of two-row barley by a distinct twist in the lemma (hull) in two-thirds of them, that is, the side kernels. In those of the right side the twist is toward the right, and toward the left in those of the left side. This twist brings the awns of the side kernels into such position that their flat surfaces are opposite each other and not in the same plane as those of the awn of the middle kernel. The kernels of the middle row also differ in being broadest nearer the apex, the

[1] Harlan (1914, p. 17) mentions a Greek form in which the side spikelets have a pedicel over half as long as the adjacent internode.

basal portion being somewhat elongated, while those of two-rowed varieties are broadest in the middle and symmetrical in contour (Fig. 40).

120. Distribution. — Erect six-row barley was apparently cultivated in the most ancient times. The spike is accurately shown on some of the oldest European coins. At present it is grown in southern Europe, particularly in the higher Alpine districts, sometimes with two-row barley at the upper limit of cereal cultivation, also in mixtures with common barley in the Mediterranean region. In Germany it is little grown. A small quantity is produced in upper Bavaria, and in Westphalia. There is much uncertainty about its distribution because of confusion with common barley. A number of varieties are grown in eastern Asia. In Great Britain it is known as winter barley.

FIG. 40. — Spikelet of six-row barley, $\times 2\frac{1}{2}$.

121. Subdivisions of erect six-row barley. — The most common, widely distributed and representative group is the pyramidal barley. It corresponds in form to the fan barley of the two-row subspecies. It has pale yellow pyramidal spikes, and long spreading awns. It is the group illustrated on ancient coins. It is the winter barley of Great Britain and grown considerably in southern Europe and Japan. The group of parallel barleys has, on the other hand, long parallel spikes, with close lying awns. It is grown in Japan and Abyssinia. Two other groups of black barleys and one similar to parallel barley, except for its broad glumes, are found only in Abyssinia. There is one hulless group with short pyramidal spikes, found only in Abyssinia and China. The principal varieties of erect six-row barley are here given, classified:

A. KERNELS HULLED

(HORDEUM HEXASTICHUM BRACHYATHERUM, KCKE.)

1. *Spikes pale yellow, awns short.*
   Winter — Chinese Winter, Japan Six-row.

(HORDEUM HEXASTICHUM PYRAMIDATUM, KCKE.)

2. *Spikes pyramidal, white to dull yellow, awns long.*
   Spring — Cataluna, Long Six-row.
   Winter — English Winter, Long Six-row, Winter Club.

(HORDEUM HEXASTICHUM PARALLELUM, KCKE.)

3. *Spikes parallel, white, awns long.*
   Spring — Reed Triumph, Mariout.
   Winter — Japan Winter.

B. KERNELS HULLESS

(HORDEUM HEXASTICHUM REVELATUM, KCKE.)

4. *Spikes short, compact, white, awns stiff, short.*

122. Common barley (*Hordeum vulgare*, Linn.). — In the common nodding six-row barley, called inaccurately four-row barley, the flowers of all three spikelets are fertile. The spikes are therefore six-rowed as in erect six-row barley, but differ from the latter in the greater length of internode, whereby the spike is much looser, and the spikelets do not overlap those immediately above, but lie closer to the rachis. Because of this condition, the adjoining rows of side spikelets of two opposite sets lean toward each other, those of one row coming alternately over and under those of the other in such a way as to produce the illusion of one row of spikelets. In certain Abyssinian forms the illusion is most complete, only four very distinct rows appearing to be present. All gradations of length of internode exist, so that this distinction between the groups is not a good one.

Common barley is a very old group, and the many varieties are widely distributed. It is at present the chief source of brewing varieties in North America, though two-row varieties are extending their area. It predominates in Russia, Syria, and Turkestan and in South America. The only very hardy winter barleys are in this group. Such varieties occur particularly in southern Russia and western Asia.

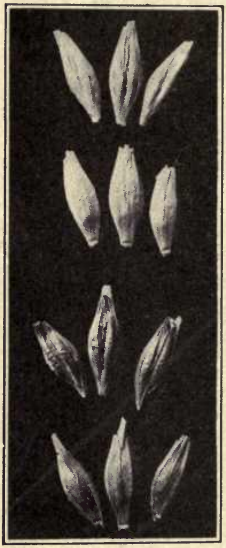
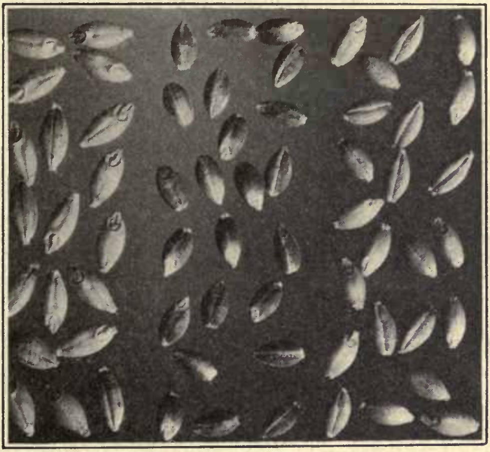


FIG. 41. — Kernels of common or nodding six-row barley.

123. Groups of common barley. — The most important group is that of the pale yellow barleys with straight beards. It includes winter varieties in southern latitudes. Such varieties differ none in form from the spring varieties, but if sown in the spring, produce few or no culms that season. Some representatives of the group are very sensitive to wet cold. Curious forms occur having a trifurcate appendage in place of the awn, one of the segments of which is hood-shaped, these forms being known as hooded barleys.

One of these, the Nepal, is hulless; another, called Success, belonging to the Horseford group, is hulled. The former came from the Himalaya Mountain region, while the latter originated in this country. These are the only hooded barleys commonly cultivated. Other hooded forms, both hulled and hulless, are found in Abyssinia



a *b* *c*

FIG. 42. — Kernels of six-row hulless barleys; *a*, White Hulless; *b*, Black Hulless; *c*, Himalaya Hulless.

and South Africa, in one of which only the middle row of spikelets bears hoods. Other forms of common barley with varying colors of the lemma, or hulless kernel and awns crooked or wanting, occur in central Asia and in Africa. Hulless forms have in recent years come into Siberia from central Asia and China. The black barley group (No. 3 below) is very interesting and widely distributed. These barleys often lose a portion of their color and become semi-black. In Russia they are frequently found in mixtures with other varieties. There are a considerable number of winter varieties of black barley native in southern Russia and western Asia. The principal varieties of common barley and their places in classification are as follows (Figs. 41 and 42): —

A. Kernels Hulled

(Hordeum vulgare pallidum, Ser.)

1. *Spikes pale yellow, awns straight.*
   Spring — Altai, Barbarossa, Beldi, Bessarabian, Giant Four-row, Lapland, Yarensk, Lulea, Manchuria, Nugent, Oderbrucker, Odessa, Yerli, O. A. C. No. 21, Pearl, Svartlo, Turkestan, Telli, Umea.
   Winter — Baku Winter, Caucasian Winter, Kursk Winter, Tennessee Winter.

(Hordeum vulgare cœrulescens, Ser.)

2. *Spikes blue gray.*
   Spring — Ægina, Basse, Bigha, Coast, Florence, Leonforte.
   Winter — Russian Gray Winter.

(Hordeum vulgare nigrum, Willd.)

3. *Spikes black, awns rough.*
   Spring — Don Black, Erivan, Gatamai, Persian Black, Taganrog.
   Winter — Common Black Winter, Tiflis Black, Daghestan Black.

(Hordeum vulgare leiorrynchum, Kcke.)

4. *Spikes black, awns smooth.*
   Spring — Julia, Nekludov.

(Hordeum vulgare rikotense, R. Regel)

5. *Spikes white, awns smooth.*
   Spring — Stassevich, Kyarkhana.

(HORDEUM VULGARE HORSFORDIANUM, WITTM.)

6. *Spikes awnless, lemmas trifurcate.*
   Spring — Success, Tarassevich, Horsford.

B. KERNELS HULLESS

(HORDEUM VULGARE CŒLESTE, LINN.)

7. *Spikes pale yellow, long, narrow, kernels slim, yellow.*
   Spring — Baku, Heaven barley or Jerusalem barley or Davids Korn.

(HORDEUM VULGARE HIMALAYENSE, PITTIG.)

8. *Spikes pale yellow, short, kernels thick, gray blue.*
   Spring — Himalaya Hulless, Walper Hulless.

(HORDEUM VULGARE VIOLACEUM, KCKE.)

9. *Spikes gray violet, awns violet.*
   Spring — Black Hulless.

(HORDEUM VULGARE TRIFURCATUM, SCHL.)

10. *Spikes awnless, lemmas trifurcate.*
    Spring — Nepal.

124. Intermediate or hybrid barley (*Hordeum intermedium*, Kcke.).— In this subspecies the spikelets are all fertile, but bearded only in the two middle rows. As the name implies, it is intermediate between the two-row and six-row subspecies. In fact, it is considered by some to be composed of natural hybrids of these groups. There are two subdivisions, in one of which the spike is wide and erect, while in the other it is narrow and nodding. In all forms the side spikelets are awnless and have smaller kernels than the middle spikelets, showing a partial resemblance to two-row barley. The two groups are: —

a *b*

Fig. 43. — Spikes of two-row barleys: *a*, erect two-row barley; *b*, nodding two-row barley.

(HORDEUM INTERMEDIUM TRANSIENS, KCKE.)

1. *Spikes compact, erect.*

(HORDEUM INTERMEDIUM HAXTONI, KCKE.)

2. *Spikes loose, nodding.*

FIG. 44. — Spikelet of two-row barley, × 2½.

125. Two-row barley (*Hordeum distichum*, Linn.). — The two-row barleys differ from the other subspecies in the structure and fertility of the flowers. In this subspecies, the flower of the middle spikelet is normally perfect and fertile, but that of the side spikelets is only staminate or still further reduced. As each spikelet is one flowered, there is therefore but two rows of kernels, one on each side of the rachis. Only the lemma of the middle spikelet is awned. The side spikelets lie close to the axis. In normal forms of these side spikelets the lemma is long, rounded, obtuse, and without awn; filaments, either stunted or three well developed; all kernels broadest in middle, and symmetrical (Figs. 43–46).

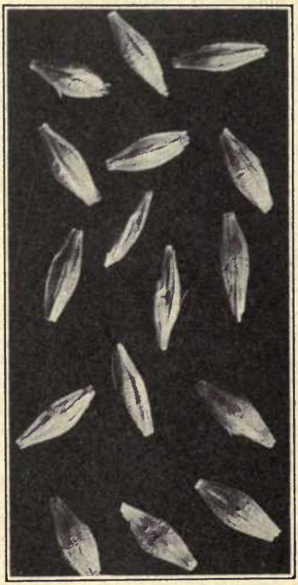


FIG. 45. — Kernels of two-row barley.

126. Grouping and distribution. — In agricultural practice the most important groups are the nutans and erectum, each of which includes many varieties. The spike of the nutans varieties is long, slender, and loose, while that of the erectum varieties is shorter and compact. Atterberg has shown that in the nutans group, the dorsal side of the kernel has at the base a horseshoe-like depression, while in the erectum group there is no such depression, but that portion of the kernel is often pinched with a transverse crease or furrow. The two-row barleys are the chief brewing barleys of Europe. They are especially dominant in Germany, Austria, Scandinavia, and England, and have been much improved in recent years. They are less widely distributed however than common barleys, and there are fewer varieties. The important varieties and their classification within the subspecies are about as follows (Fig. 43) : —

Fig. 46. — Kernels of two-row hulless barley.

(Hordeum distichum nutans, Schubl.)

1. *Spikes pale yellow, awns appressed, rough.*
   Spring — Annat, Cape, Chevalier, Erfurt, Gold, Old Irish, Gute, Hanna, Hannchen, Kitzing, Lerchenborg, Smyrna White, Popplesdorf, Porter, Probsteier, Persian, Princess.

(Hordeum distichum medicum, Kcke.)

2. *Spikes pale yellow, awns appressed, smooth.*
   Spring — Persian Smooth-awn, Werner.

(Hordeum distichum nigricans, Ser.)

3. *Spikes black, awns rough.*
Spring — Abyssinian Black, Roumanian Black, Smyrna Black, Vilmorin, Egyptian Black, Arabian Black.

(Hordeum distichum persicum, Kcke.)

4. *Spikes black, awns smooth.*
Spring — Erivan, Persian Black.

(Hordeum distichum erectum, Schübl.)

5. *Spikes pale yellow, thick, broad.*
Spring — Archer, Brewers Favorite, Diamond, Goldthorpe, Imperial, Plumage, Primus, Standwell, Swan Neck.

(Hordeum distichum zeocrithum, Linn.)

6. *Spikes pale yellow, narrowed toward the apex, awns spreading, fan-shaped.*
Spring — Fan barley or Peacock barley.

(Hordeum distichum nudum, Linn.)

7. *Spikes pale yellow, kernels hulless.*
Spring — McEwan or Tibetan or Two-row Hulless or Coffee barley.

127. Deficient barley (*Hordeum distichum deficiens*, Steud.). — The groups of barley just described come well within the limits of definition of the subspecies, and are therefore groups of normal two-row barley. There are certain groups, however, that are lacking still further in parts of the floral organs of the side spikelets, these flowers either lacking both sexual organs, or being entirely wanting. To this section, deficiens, belong two groups of forms cultivated in Abyssinia, one having pale yellow spikes and both having undivided glumes which are largely grown to the spikelet axis (111). There are three other groups, with pale yellow, brown, and black spikes respectively, in all of which the glumes of the side spikelets are divided and not grown to the spikelet axis. Of these the first group is cultivated in Arabia and Abyssinia and the other two in Abyssinia only.

128. Distribution in North America. — Barley is a comparatively small crop in the United States and Canada, although third in rank of the small cereals. It is also much more irregular in its distribution than wheat and oats. While California and Minnesota each produce over 30 million bushels annually, three-fourths of the states produce each less than two million bushels. All of Canada produces 48 million bushels, or about 21 per cent of the North American crop. It seems sufficient for the present purpose to designate only about six North American barley districts: (1) The Northeastern or Six-row barley district, (2) the Southern or Winter barley district, (3) the Northwestern Plains or Two-row barley district, (4) the Southern barley district, (5) the Western Intermountain barley district, and (6) the Pacific Coast barley district. These correspond in a general way to the wheat and oat districts.

129. Northeastern or six-row barley district. — In this district are included all of New England, the middle states to the southern boundary of Pennsylvania, and the northern states southward almost to the Ohio River, and middle Missouri, and westward to about the meridian of 96° in Kansas and nearly to the Missouri River in North and South Dakota; the Maritime Provinces, Quebec, Ontario, Manitoba, and Saskatchewan to a line through Regina and Saskatoon.

This district may be called the six-row barley district, as that kind of barley seems generally best adapted, with some apparent exceptions in the Canadian provinces. It might also be called the Manchuria barley district, as the Manchuria variety is very generally and commonly grown. Nearly or quite half the total barley production of North America is in this district. The states and provinces of largest production are Minnesota, Wisconsin, Ontario, and Manitoba. At the Wisconsin Experiment Station, the average yields of different six-row barleys in a five-year period ran from 32 to 51 bushels an acre. The Oderbrucker, equivalent to Manchuria, was found to be the best in yield, and has become the dominant barley of the state and is now commonly grown in adjacent territory. At the Minnesota station Manchuria yielded 45 to 50 bushels an acre, while two-row varieties made 37 to 41 bushels. In Ontario similar results have been obtained. At Brandon, Manitoba, in a five-year test six-row barley yielded 60 to 67 bushels and two-row barley 50 to 67 bushels an acre. In eastern South Dakota, the Odessa six-row has given better results for a long time than any other six-row variety, even including selections. A little farther westward, both in the United States and Canada, the two-row varieties soon equal the six-row, and finally exceed them in yield.

Varieties now grown or adapted: —

Beaver	Invincible	Oderbrucker
Japan Black	Manchuria	Old Island Two-row
Canadian Thorpe	Nugent	Silver King
Chevalier	O. A. C. No. 21	Success
Duckbill	Odessa	Stella
Gold		Swan Neck

Needs of the district: —

Earliness, particularly in northern localities
Hardy winter varieties in southern portion
Proper rotations

130. Southern or Winter barley district. — The barley crop in the southern states is exceedingly small, and from the standpoint of production alone the area would not be included as a barley district. There are two facts, however, that make it an area of some importance in this connection: (1) The barley acreage is rapidly in-

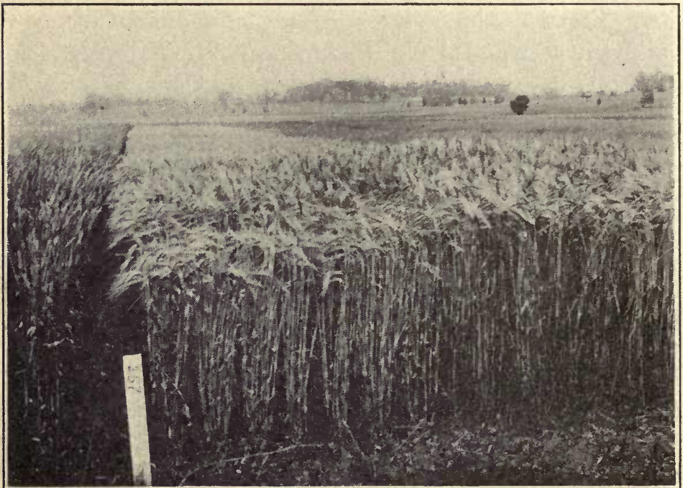


FIG. 47. — Tennessee winter barley at the Maryland Agricultural Experiment Station, College Park.

creasing very recently, and properly so, because of the use of barley in feeding live-stock, to which increased attention is also being given. (2) The adaptation is wholly for winter varieties, a condition making it considerably different from the Northeastern district. The district includes Delaware, Maryland, Virginia, Kentucky, the Ohio River Valley, southern Missouri, and all the remaining southern states southward to and including eastern Oklahoma and Texas. The total barley production is less than a million bushels. As the use of barley for hay is likely to continue or even increase, a hardy winter strain of hooded or awnless barley is desirable, to avoid injury to stock from swallowing the awns.[1] Rust is sometimes very damaging to barley in this district (Fig. 47).

Varieties now grown or adapted: —

Arlington Awnless	Success
Union Winter	Tennessee Winter

Needs of the district: —

Earliness in spring varieties	Rust prevention
Hardiness in winter varieties	Winter hooded or awnless varieties

131. Northwestern Plains or two-row barley district. — There are included in this district western Saskatchewan, Alberta, eastern Montana, the western two-thirds of North and South Dakota, northwestern Nebraska and eastern Wyoming. Generally the two-row barleys give best results in this district, but much is yet to be learned as to varieties in detail in all of the districts. As the two-row varieties are tall and often nodding, they tend to lodge worse than the six-row varieties in humid areas, and are therefore adapted to the drier plains. The larger part of the total North American production of two-row barley is in this district. Tests at the Northern Plains experiment stations and in Alberta and western Saskatchewan, Canada, have resulted in considerably better yields for two-row barley than for six-row. In

[1] The Arlington Awnless, developed by Derr (1910, pp. 473–474), does not yet appear to be sufficiently hardy for fall seeding in the northern border of the winter barley area, though it appears to be a good variety.

Montana, Smyrna White, a two-row variety, is now found to be much the best. At Lethbridge, Alberta, the behavior of the two subspecies under irrigation is reversed, the six-row being then the better. For best results with barley as well as other small cereals in this district, a good intertilled crop is much needed to precede the cereal crop.

Varieties now grown or adapted: —

Canadian Thorpe	Invincible	Odessa
Claude	Mansfield	Swedish Chevalier
Hanna	Manchuria	Smyrna White
Hannchen	O. A. C. No. 21	Swan Neck
Gatami		

Needs of the district: —

Earliness to escape frost in the northern portion, and to escape drought in the southern portion
A proper alternating intertilled crop
Drought resistance

132. Southern Plains barley district. — In this district are included the eastern two-thirds of Nebraska, eastern Colorado, Kansas, western Oklahoma and Texas, and eastern New Mexico. While in dryness of climate this district is much like the preceding, conditions in other respects are quite different, and the barley adaptation is entirely different. Varieties that will escape the early summer heat better than the slow two-row sorts are required. The evaporation being extreme, greater drought resistance is needed, also winter hardiness that will permit a wider extension of winter barley cultivation. The total barley production of the district is at present small. The present winter varieties may be grown in the southern portion. Farther north, Success or Horsford barley is somewhat common. Coast barley has done the best at the Akron, Colorado, experiment farm. At the Kansas State experiment station, Manhattan, Tennessee Winter gave a much better average yield in a six-years test than the spring barleys. At the McPherson, Kansas, experiment farm, in a four-years test, six-row spring barleys did better than either winter or two-row varieties.

Varieties now grown or adapted: —

Coast	Oderbrucker	Success
Manchuria	Odessa	Tennessee Winter

Needs of the district: —

- Drought resistance
- Earliness in spring varieties
- Hardier winter varieties

133. Western Intermountain barley district. — This district includes both irrigated and dry land areas between the western mountain ranges as given under oat distribution. A fair quantity of barley, comparatively, is produced in this district, composed of various varieties.

FIG. 48. — Manchuria (Minn. 105) barley at Montana Agricultural Experiment Station, Bozeman.

Both two-row and six-row barleys are grown, including hulless and hooded varieties. In general, the two-row barleys do better in the northern portions of the district and the six-row in the southern portions. On a weight basis, the hulless varieties often yield best. In Utah and southern Idaho, a winter variety, the Winter Club, is grown considerably. At the Nephi, Utah station, however, Coast barley yielded better than any winter variety. Throughout the district an established crop rotation is needed, including a suitable intertilled crop to precede barley and other small cereals (Fig. 48).

Varieties now grown or adapted: —

Chevalier	New Zealand	Tennessee Winter
Coast	Nepal	Winter Club or Utah Winter
Hanna	Oderbrucker	
Manchuria	Success	

Needs of the district: —

Crop rotation	Hardier winter varieties in southern localities
More soil humus	

134. Pacific Coast barley district. — Included in this district is all the Pacific Coast territory from British Columbia to California and southern Arizona. The conditions amply justify a separation into a North Pacific and a South Pacific section, divided at about the head of the Sacramento Valley. In the northern section, however, there is a very small barley production, and the varietal adaptation is so uncertain that it is not worthy at present of a discussion as a separate barley district. The rainfall is very great generally, and the temperature lower than in the southern section, and probably in future a distinct varietal adaptation will be determined. Coast barley seems to be the variety now most commonly grown.

In the southern or California section, as before stated, the conditions are similar to those of India and Australia and in some respects to those of the Mediterranean region, Turkestan and Abyssinia. Barleys, therefore, from these regions are adapted, and some, in fact, have already been tested in California, with good results. Barley production in California has rapidly increased in recent years, while wheat production has just as rapidly decreased. Coast barley is the variety chiefly grown, but two-row varieties are also in use. What varieties are best is really a problem by no means yet solved for this district. In a four-years trial at Modesto, Smyrna White and Tennessee Winter gave very good results. At the Plant Introduction garden at Chico, several varieties have done much better than Coast. Fully as important improvements can be made in field management and seed selection. A good crop rotation is needed, especially such a one as will add humus to the soil through green manuring.

Varieties now grown or adapted: —

Abyssinian	Hannchen	Smyrna White
Coast	Peruvian	Tennessee Winter
Beldi		

Needs of the district: —

Crop rotation	Seed selection
Green manuring	Weed eradication (crop rotation)

135. Distribution in other countries. — (1) Pyramidal six-row barleys are grown apparently in scattering localities in Spain, Portugal, Greece, and Italy, and in Westphalia in Germany, also as a winter barley in the British Islands. (2) The parallelum varieties come from Japan, China, and Abyssinia. (3) Common or nodding six-row varieties of the pallidum group are grown in northern

Europe, Russia, and western and northern Asia. In Russia, the Lapland and Yarensk varieties occur far north. (4) Common white winter barleys are found in the Caucasus and Turkestan. (5) Large-kerneled or gray blue barleys are grown in warm countries, often as winter varieties, in the Caucasus, in the Mediterranean region, and in Chile. (6) Black spring and winter barleys are found in southern Russia, central Asia, Persia, and Abyssinia. (7) Hooded hulled barleys in addition to the Success or Horsford variety occur in Abyssinia. (8) Smooth-awned barleys are grown in southern Russia. (9) Hulless barleys of the common six-row subspecies come from central and western Asia, the Caucasus, and Abyssinia. The hooded hulless barley comes from the Tibetan-Himalaya region. (10) Two-row barleys of the highest class, often pure bred, are grown chiefly in Sweden, Germany, Austria, Denmark, and the British Islands. These are of the nutans and erectum groups. (11) Smooth-awned two-row varieties come from the Caucasus and Persia. (12) Black two-row varieties are grown in southern Russia, western and central Asia, and Abyssinia. (13) Fan or Peacock barley is generally but sparingly distributed in Europe. (14) Two-row hulless varieties are found in central and western Asia and in Abyssinia. (15) The deficient barleys are found chiefly in Abyssinia and Arabia. (16) Erect six-row hulless varieties are found only in Abyssinia and China.

CHAPTER VI

RYE

LIKE wheat, rye belongs in the tribe Hordeæ, subtribe Triticeæ, in the latter of which the spikelets are solitary at each notch of the rachis, and not three as in barley. In the genus Secale, which includes rye, the glumes are one-nerved and the spikelets 2- (rarely 3-) flowered, while in Triticum the glumes are many nerved and spikelets 2- to 8-flowered. Rye and wheat are crossed only with much difficulty, and always with wheat as the female parent. The hybrids are usually sterile.

136. Description. — Spikes without terminal spikelets, somewhat loose, rachis articulate in the wild forms; spikelets not inflated, 2- (rarely 3-) flowered, the lower flowers approximate; glumes subulate-pointed; lemmas long awned from the apex, sharply keeled to the base; keel fringed; kernel slightly compressed laterally, deeply sulcate, hairy at the apex, free, without epiblast; embryonic rootlets 4, of which 3 are in the same plane.

According to Hackel there are two species of rye: (1) *Secale fragile*, Bieberst., which has long awns on the glumes extending far beyond the lemmas, and (2) *Secale cereale*, Linn., which has subulate-pointed glumes not exceeding the lemmas. The former is found on the sandy plains of Hungary and southern Russia, and appears to be of no commercial importance. The latter is descended from *Secale montanum*, Gus., and includes all cultivated rye. The ancestral species is perennial and has an articulated rachis which breaks apart at ripening, both of which characters have disappeared. However, cultivated rye left standing a long time in the field will shoot up again.

137. Roots. — Germination of rye is more rapid, and may take place at a somewhat lower temperature, than in the other cereals, and therefore rye usually comes up quickly after being sown. The coronal root system is composed of a number of so-called adventitious roots which are sent out at the base of the culm or crown, which is usually less than one inch under the surface of the ground. No tap root is formed. The adventitious roots are slender, fibrous, and grow downward more or less directly into the soil, the system being vertical rather than lateral. By branching they form a network which occupies the soil more or less completely. Rotmistrov (1913, p. 24) found that the roots of winter rye, at the milk stage of the kernel, extended downward 130 cm., and the lateral spread was 92 cm., making the root coefficient 7080.

138. Culms. — The height of the rye plant depends upon the circumstances of the environment. Under the best conditions it may sometimes attain a height of 10 feet, and frequently a height of 7 feet. The average, however, is not over 5 feet, it being usually 6 to 12 inches higher than wheat grown under the same conditions. The culm is cylindrical and the surface smooth, except near the top, where it is rough and thickly covered with short hairs. The diameter of the culm is less than that of the other small grains, and this with its greater height makes the rye culm appear rather delicate and weak, but in reality it is tough and rigid and does not lodge on adapted soils to a greater extent than wheat. The internodes are hollow, but nearly inclosed with pith just below the spike. Mature rye straw is not so suitable for feeding purposes as straw from other cereals, it being tougher and less digestible and containing a smaller amount of nutritive matter. It is valued highly for bedding and manufacturing purposes, and special means are often employed in thrashing to preserve the straw straight and unbroken.

Koernicke and Werner (1885—**2** : 570) report the 7-year average number of culms to a plant produced in a rich, friable loam soil, when seeded in drill rows 8 inches apart, as follows: —

Winter rye, minimum 4 culms, maximum 6.6, average 5
Spring rye, minimum 1.2 culms, maximum 3.4, average 2.1

Johannis rye seeded in July produced an average of 12 culms to the plant; when sown in November, 5 culms; in February, 3.4 culms.

The number of culms produced to a plant when different spaces are allowed is reported as follows: —

25 square centimeters,	3.2 culms
100 square centimeters,	6.4 culms
225 square centimeters,	12.1 culms
400 square centimeters,	8.8 culms

139. Leaves. — The first foliage in the bud and in early growth is reddish brown in color. The later leaves are linear-lanceolate in shape and either glabrous or more or less hairy on the upper surface or on both upper and lower surfaces. The middle nerve stands out sharply on the lower side and on each side of this and parallel to it are five or more other nerves which stand out less sharply.

The ligule is short, membranous, somewhat rounded and glabrous, with usually extremely short sparse hairs at the exterior edge, on the blade. The auricles are narrow white, membranous; withering and falling away before maturity or wanting; sometimes ciliated.

Koernicke and Werner (1885—**2**:571) report the average number of leaves to a culm for winter rye to be 4.3; for spring rye 3.5; and the average leaf surfaces to a culm as 312 and 181 square centimeters respectively. The blade is usually from 5 to 8 inches long and .25 to .4 inch wide.

FIG. 49. — Spikelet and kernel of rye.

140. The spikes are usually from 4 to 6 inches long and are rather slender. When ripe they are almost square, because there are almost always but two kernels to the spikelet. The spikes are awned in all varieties, the awns being flexible and usually from 1.5 to 2.5 inches long. On account of the weight of grain and the smallness of the upper culm, the spike nods or droops decidedly, often causing the plant to lean. The rachis is strongly flattened and is alternately notched on the flattened sides. The edges formed by the flattening are very hairy and there are bunches of hairs at the notches. There is no terminal spikelet.

141. Spikelets. — There is a single spikelet in each notch of the rachis, its broad side facing the rachis. First above the articulation with the rachis, and apparently sessile upon it, are the two glumes, which are small, linear, tapering to a point, keeled, one-nerved and shorter than the lemmas. The lemmas are next above on the axis. These are lanceolate and armed with a round, tapering awn, on which are sharp teeth, pointing upward; lemmas keeled to their base and with stiff hairs on the keel except at the base; on each side of the keel two other nerves.

The palea is about the same length as the lemma but is blunt and two-keeled. It is smooth throughout and flat, while midway between the keels is a small linear groove. Next above and opposite the palea are the two small delicate scales or lodicules. These are oblique ovate, membranous, and ciliated above, fleshy below with a membranous outer margin (Fig. 49).

142. The flower is placed above and between the lemma and palea. It consists of 3 stamens placed above the ovary which is surmounted by two sessile, feathery stigmas. The anthers are yellow to dull, greenish brown, narrow-linear, notched at tip and base, about 10 to 12 mm. long, being three or four times as long as the anthers of wheat. Each is attached below the middle to the slender, distinct, upward-tapering filament. At the time of blooming the thin-walled cells of the filaments elongate rapidly and the anthers are elevated. On becoming free the anthers reverse their position or tip over and the pollen escapes to the wind from slits in the upper and outer edges, a process provided for by the peculiar attachment of anther and filament.

The ovary is smooth, with a thick, hairy terminal cushion. The two feathery stigmas are about twice as long as the ovary on the apex of which they are borne.

143. The kernel when ripe extends more or less beyond the glumes, owing to the rather small size of the glumes and their spreading position. It is long in proportion to its width when compared with wheat and barley. The width decreases from the middle and is reduced to a point at the germ end. The apical end is blunt and covered with short, hollow hairs, these being shorter than those in wheat. The hollows in the hairs have a greater diameter than the cell wall, which is not true of the hairs of the wheat kernel. There is a deep longitudinal groove or suture on the side of the kernel next the palea. The sides of the groove are pressed together more or less tightly so that the depth of the suture is not apparent except in cross section. The opposite side of the kernel is rather definitely rigid, the sides appearing somewhat pinched. The outside covering of the kernel is more or less wrinkled and dull in appearance. In color the kernel may be of varying shades of blue green, gray, yellow, grayish brown, the color being in the aleurone layer. Endosperm vitreous in section; aleurone cells in one row; starch grains simple.

144. Origin of rye. — Apparently this cereal has not been comparatively long in cultivation. According to De Candolle (1892, pp. 370–382) it has not been found in Egyptian monuments. It has no name in Semitic languages nor Sanscrit nor in the modern languages directly derived from these. It has no mention, it seems, in old Chinese or Japanese literature, but is now much cultivated in Siberia. Unlike the cases of other cereals, no trace of rye has been found in the remains of the Lake Dwellings. Its earliest cultivation appears to have been in western Asia and southern Russia. It is interesting in this connection to remember that Russia has for a long time grown much more rye than any other country, and also to note that all the known species of Secale inhabit western Asia and southeastern Europe. It is also pertinent that in Shugnan and near Tashkent, *Secale montanum* has been observed growing so thickly that it appeared to have been sown.

145. Present range. — Rye is by nature a plant of high latitudes, and is of rare occurrence in very warm regions. Nevertheless, it is not grown so far north nor at such extreme elevations as barley. Only spring varieties are planted near the northern limits of cultivation. In Finland rye is grown north of the Arctic Circle but not generally so, while barley is generally grown north of 68°. In the Himalayan region rye is grown up to 14,000 feet altitude. From Germany eastward to the Ural Mountains is the region of far the greatest production. In Norway its cultivation extends to latitude 69°. In southern Europe rye is grown almost only at high altitudes. Spring rye, under the special name "yaritsa," is a common crop in central and eastern Siberia. In South America rye is grown little, if at all, outside of southern Chile. At Rampart, Alaska, latitude 65° 30′, rye has matured for several years.

146. Classification. — The species *Secale montanum*, from which cultivated rye is considered to have sprung, includes, in the broad sense, two other species, *Secale anatolicum*, Boissier, and *Secale dalmaticum*, Visiani. Schulz (1913, pp. 71–72) gives very plausible reasons for believing that the descent of common rye has been through the former of these two species. It is found in Syria, Armenia, Persia, Afghanistan, Turkestan, Sungari, and the Kirghiz Steppe. The different forms of it vary greatly, some of these being more nearly like common rye than the other species. It has a long vegetative life period, and in southern Russia it is reported that cultivated winter rye will furnish three or more crops from the same roots. From present knowledge the relationships of the species of rye appear to be as follows: —

Secale	fragile, Bieberst.	
	montanum, Guss.	dalmaticum, Visiani.
		anatolicum, Boissier.
		cereale, Linn., cultivated rye.

There is only the one species of any importance in cultivation.

147. Cultivated rye (*Secale cereale,* Linn.). — Four groups of varieties of cultivated rye are recognized by Körnicke, — Common, Red, Dark Brown, and Monstrous. The monstrous rye is similar to common rye, but has more than one spikelet to each internode of the rachis. It is said to have originated in Turkey.

The further classification and representative varieties of rye here follow : —

(Secale cereale vulgare, Kcke.)

1. *Spikes simple, white or yellowish.*
   Spring — Cataluna, Centeo barazzo, Irkutsk, Minho, Magellan, Nerchinsk, Palermo, Saxon Spring.
   Winter — Abruzzes, Aland, Azov, Abyssinian, Alt Paleshkin, Bestehorn Giant, Champagne, Dean, Excelsior, Erzerum, Garde du Corps, Heinrich, Hanna, Ivanov, Johannis, Kusthof, Mammoth, Mountain or Alpine, Nyland Winter, Probsteier, Pirna, Petkus, Russian Giant, Spanish Double, Schlanstedt, Swedish, Schiff, Tyrolese, Thousandfold, Una, Vasa Winter, Westerwald, Welkenhaus, Zeeland, Zermott, Göttingen.

(Secale cereale vulpinum, Kcke.)

2. *Spikes simple, fox-red.*
   Winter — Erzerum Red.

(Secale cereale fuscum, Kcke.)

3. *Spiles simple, brown.*
   Winter — Erzerum Brown.

(Secale cereale duplofuscum, Kcke.)

4. *Spikes simple, dark brown.*
Winter — Erzerum Dark Brown.

(Secale cereale monstrosum, Kcke.)

5. *Spikes composite.*
Winter — Turkey Composite, Monster.

148. Distribution in North America. — The production of rye in North America is the smallest of all cereals except buckwheat and rice. From about the close of the civil war the rye crop in the United States decreased up to 1874, then began increasing again, but did not reach 30 million bushels until 1891, and not until 1913 did it attain to 40 million bushels. The bulk of the present rye production falls approximately into one continuous district, including the following states and province: New York, Ontario, Pennsylvania, New Jersey, Ohio, Indiana, Michigan, a part of Illinois, Wisconsin, Iowa, Minnesota, Nebraska, North Dakota, and portions of Kansas and South Dakota. Much the largest production of any state or province is in Wisconsin, while this state with Michigan, Minnesota, and Pennsylvania produce about half of all the rye of the United States. Ontario produces about twice as much as all other Canadian provinces together. In the southern states and New England, rye is grown chiefly for hay, pasture, and soil improvement.

149. Varieties. — The crop being comparatively unimportant, not much investigation of rye has been done in this country, but much study of this cereal has been conducted in Europe, particularly in Germany and Austria. In Minnesota a test of 8 years at the State

FIG. 50. — Spike of Henry rye.

FIG. 51. — Spike of Arlington rye.

Experiment Station indicated that Dean, St. Johns, Petkus, and Schlanstedt were the best of ordinary varieties. Nevertheless Minn. No. 2, a selection from Swedish, bred at the station, continually exceeded these varieties in yield, and made twice the yield an acre of rye throughout the state, in a trial of 10 years (Boss, 1910, pp. 6–7). In Wisconsin the varieties Ivanov and Petkus have given good results. At the Ottawa, Canada, Experiment Farm, spring rye, Ottawa Select, and the winter varieties, Dominion, Thousandfold, and Mammoth White, have done well. In the southern states, Abruzzes, grown as a winter rye, has done best (Figs. 50–54).

Rye being cross-fertilized, the varieties are not numerous. In this country there are commonly in use just the two designations spring and winter. Rye makes a hardier winter crop than wheat, so that spring rye is rather rare.

Varieties now grown in North America: —

Abruzzes	Giant Rimpau	Minn. No. 2	Schlanstedt
Dean	Heinrich	Ottawa Select	Swedish
Dominion	Ivanov	Petkus	Thousandfold
Excelsior	Mammoth	St. Johns (Johannis)	

Needs: —

Much sorting and selection	Greater proportion of straw in places
Earliness	

150. Requirements of rye. — While rye does best on clay or sandy loam, it is better adapted to a poor soil and an unfavorable climate than either wheat or barley. The soil should be well drained. Rye will stand considerable acid in the soil, and is a good crop for heather and marsh lands being reclaimed. Rye requires a smaller total quantity of heat for full development than wheat, and therefore matures sooner. This advantage of rye

Fig. 52. — Spike of Abruzzes rye.

Fig. 53. — Spike of Giant. Winter rye.

Fig. 54. — Spike of Ivanov rye.

increases as the climate becomes cooler. Winter rye requires a total of 1700° to 2400° C., and spring rye a total of 1400° to 1800° C. Rye has a greater water requirement than any other cereal except oats.

151. Distribution in other countries. — (1) The common white chaff varieties of rye, usually winter varieties, are grown chiefly throughout Russia, Germany, and Austria-Hungary. (2) Spring rye, usually with small kernels ("yaritsa"), is very common in Siberia, particularly in Irkutsk government and the Transbaikal territory. Spring rye is also grown in northern Russia, including Finland, and in the Scandinavian peninsula. (3) In a general way the dark small-kerneled varieties are adapted in the northern and drier regions, and the varieties with colored kernels in southern and more humid regions. Examples are the Ivanov from Russia and the Abruzzes from Italy. (4) The red-chaff and dark brown-chaff varieties of rye come from Transcaucasia. (5) Monstrous rye with composite spikes comes from Turkey.

CHAPTER VII

CEREAL IMPROVEMENT — INTRODUCTIONS

SINCE none of the small cereals is native in this country, all varieties now grown have been at some time introduced from foreign lands. It is natural, therefore, that our greatest source of improvement of these cereals must now, and for some time in the future, lie in occasional introductions of varieties or strains superior to those we already have, but which are well known in their native country and have become segregated and adapted to conditions similar to ours through a long period of development. The field of research in this line and its possible results still appear to be unlimited. The groups of varieties in which certain needed qualities may be obtained, have been mentioned, as well as their native homes. In the following pages an account will be given of the progress already made, with descriptions of particular introductions.

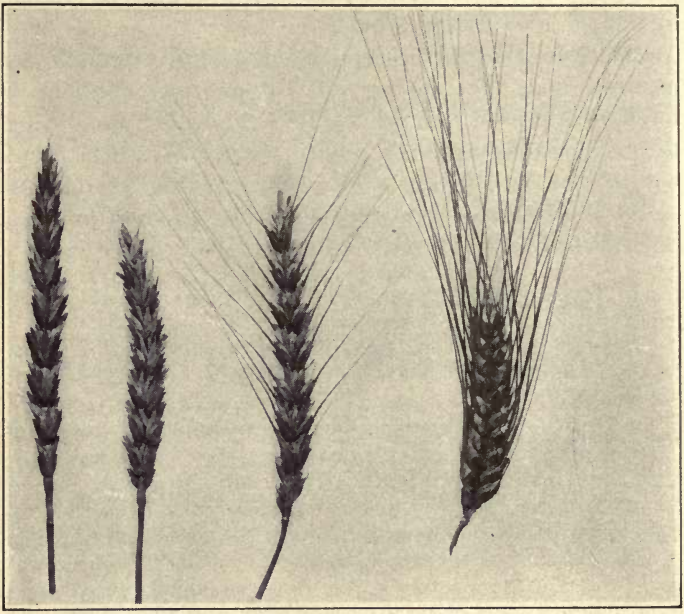
152. Mediterranean wheat. — This wheat is said to have been obtained first from the islands of the Mediterranean sea in 1819, by John Garden of Wilmington, Delaware, and is apparently the oldest introduced wheat that has remained in cultivation. At various times the United States Department of Agriculture secured seed and distributed it to all parts of the country. The wheat soon met with favor everywhere. It is a hardy red-chaffed, awned, prolific winter wheat, producing a large red kernel of good milling quality. It is fairly resistant to rust, and was supposed to resist the attacks of the Hessian fly, but appears not to be so effective in the latter respect as was expected. The wheat has continued to be popular in certain districts, particularly in Texas. It is one parent of several good hybrid wheats.

153. Fife wheat. — A most interesting example of improvements that are possible through introductions of foreign varieties is found in the Fife wheat of Canada and the northern states of the plains. This wheat, which has become the basis of the large wheat and flour production of the Northwest, originated, according to the Canadian Agriculturist of 1891, in the following way: —

> Mr. David Fife, of the township of Otonabee, Canada West, now Ontario, procured through a friend in Glasgow, Scotland, a quantity of wheat which had been obtained from a cargo direct from Dantzic. As it came to hand just before spring seed time, and not knowing whether it was a fall or spring variety, Mr. Fife concluded to sow a part of it that spring and wait for the result. It proved to be a fall wheat, as it never ripened, except three ears, which grew apparently from a single grain. These were preserved, and although sown the next year under very unfavorable circumstances, being quite late and in a shady place, it proved at harvest to be entirely free from rust when all the wheat in the neighborhood was badly rusted. The produce of this was carefully preserved, and from it sprang the variety of wheat known over Canada and the Northern States by the different names of Fife, Scotch, and Glasgow.

If the above is an accurate statement of the introduction of Fife wheat, indications are rather strong that it is of Russian origin, judging from the description of the grain and source of the cargo, in connection with the present similarity of this wheat to Russian varieties. Various strains have been developed till there are now a half-dozen or more so-called varieties in use. They are red, hard-kerneled wheats, yield fairly well, and produce flour of excellent quality (Fig. 55).

154. Hard winter wheats. — A remarkable development in wheat culture in this country has been made in



a *b* *c* *d*

Fig. 55. — Spikes of hard wheats: *a*, Fife and *b*, Velvet Bluestem hard spring wheats; *c*, Turkey or Kharkov hard winter wheat; *d*, Kubanka durum wheat.

the middle states of the plains, in what we now call the Hard winter wheat district, all brought about through the introduction of the hardy, red-grained, winter wheats. Forty years ago very little hard wheat was grown in this region, all seed being brought by the early settlers from states farther east, where soft wheats are chiefly cultivated. Spring varieties formed the basis of a large proportion of the wheat production. But the spring wheats were rusted, injured by drought because of late maturity, and in some seasons almost wholly destroyed by chinch bugs, while the soft winter sorts, such as White Michigan and Poole, also rusted badly, and were not able always to stand the winters. For some time these defects were overcome in great measure by the use of the variety Odessa, popularly called " grass " wheat in some localities, which is probably equivalent to the variety Ulka of southern Russia. It is hardy, red-grained, rather rust-resistant, and has the additional advantage of being adapted for either autumn or spring sowing. A little later, the well-known variety Fultz also became quite popular in the West, as it is still in the greater part of the United States.

155. Turkey or Crimean wheat. — But the variety which more than all others finally completely changed the status of wheat culture in this district, is that which is commonly but unfortunately known as Turkey. It is an awned, hard red wheat of the highest class, coming originally from the Crimea in southern Russia, and not from Turkey, as the name would imply. The wheat was introduced by the Menonites into Harvey and McPherson counties, Kansas, about the year 1873. Each settler brought one bushel of seed from the Molochna district in northern Taurida, to which locality it came from the Crimea in 1860. Within a very small area in Kansas, Turkey wheat has been grown about forty years, but its merits did not become generally known until about 1890. It then soon became the popular wheat and made fall seeding practicable much beyond the previous northern limit of winter wheat-growing. The flour has obtained a reputation for quality distinctly its own and of the best in foreign markets. At the same time there is no longer so much damage from the attacks of rust and chinch bugs. As it is very drought-resistant, its introduction has extended the winter wheat area farther westward.

In more recent years a slightly different strain of this wheat, named Kharkov, was introduced by the United

Fig. 56. — Turkey wheat at the Judith Basin Substation, Montana, yielding 63 bushels an acre.

States Department of Agriculture, through the author, from the eastern part of Kharkov government, a locality much colder and some drier than Taurida. The Kharkov wheat is now grown in about half the entire hard winter wheat area and has served to greatly extend the area (Fig. 56).

156. Kubanka wheat. — With the advance of settlement westward, it became desirable to obtain a wheat variety adapted to the northwestern plains where the winters are too cold for even the Turkey or Kharkov wheat, and the summers too dry for Fife spring wheat. Such a wheat, Kubanka, was found by the author for the United States Department of Agriculture, in the Kirghiz Steppe of western Siberia, at two places, near Uralsk and Orenburg, in 1899 (Fig. 57). From the 800 bushels of seed, obtained that year and the next, there is now produced each year in this country an average of about

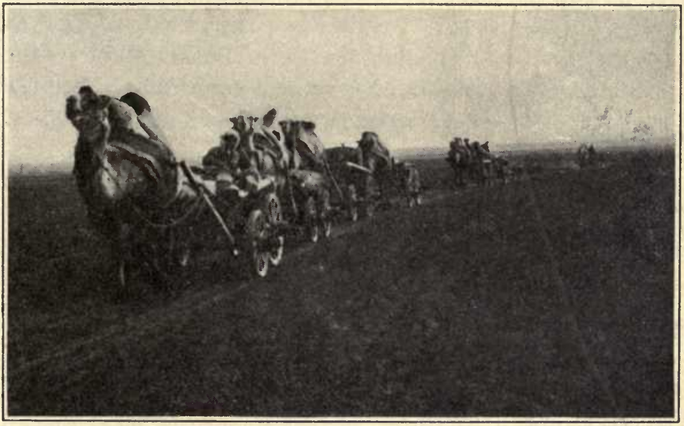


Fig. 57. — Hauling Kubanka wheat to market in the Kirghiz Steppe.

40 million bushels. Kubanka is a durum wheat with golden yellow chaff, and large, light amber colored kernels that are vitreous in fracture (see Fig. 16). Other durum varieties, such as Arnautka and Nicaragua, had been grown for years in the United States and Canada in a small way, but had not been utilized, commercially, and therefore had no market. The introduction of Kubanka was followed with trials of it for both macaroni and bread. Favorable results of these trials, together with a foreign demand, created a market. For some time

durum wheat still sold at a great discount, but the acre yield was so much greater than that of ordinary spring wheat that its cultivation was nevertheless profitable. Since 1910 Kubanka, a large part of the time, has sold at a premium, as great as its previous discount, and appears now to be as well established commercially as agriculturally.

Fig. 58. — Dawson Golden Chaff wheat.

157. Previous opposition to hard wheats. — The hard wheats stand to-day in the highest class, in most countries. Both the wheat and the flour sell at the highest prices. About or nearly half the total wheat production of North America is of these wheats. Nevertheless each of the three previously discussed hard wheats in its introduction met with intense opposition commercially. The causes of the opposition were chiefly the difficulty of grinding and the large proportion of oil and ash accompanied by a darker color of the flour, and in some cases a lack of expansion in baking. In the case of each wheat these objections have either become less serious or have been gradually overcome by changes in milling and baking machinery and methods of manufacture.

158. Introductions into Michigan. — In Michigan there was an energetic movement for a decade or longer to obtain hardy winter sorts, which resulted in a great improvement not only for that state but for adjoining territory. The millers of the state were especially active in this movement and the matter was frequently a prominent topic of discussion at the meetings of the State Millers' Association. The variety Budapest from Hungary, and Dawson Golden Chaff from Canada (Fig. 58), were introduced and became favorite varieties. Another variety, Theiss, introduced from Hungary, obtained a well-merited reputation as a hardy, red-winter sort in the north central states and as far west as Kansas. It has, however, not even yet received the attention that it should have.

159. Introductions into the Pacific coast region. — In a large part of the Pacific coast region, and the Columbia River Basin, the improvements which resulted in such large yields were made through the introduction of club wheats, which are very prolific, hold the kernels in the spike, and in other respects are well adapted to the conditions of this region. One or more of these wheats came from Chile, but the origin of some of them is not known. Two varieties not club wheats, Australian and Palouse Bluestem, but which are among the best on the Pacific coast, probably belong to the Purple Straw group of Australia. In southern California and some other localities, the variety Sonora had great part in the early development of wheat cultivation. It is a white-kerneled wheat with reddish pubescent chaff. The kernels are a little harder than those of the club type. It is reported that it came originally from the state of Sonora in Mexico.

160. Ladoga wheat. — In Canada, where Fife wheat began its interesting history, this variety has continued to be very satisfactory, with the one exception that, in certain districts, it has not been sufficiently early. Government officials therefore endeavored to secure "a hard wheat of good quality which would ripen early enough to escape the autumn frosts which sometimes injure the crops in some parts of the Northwest of Canada." A variety was finally obtained that appeared to be suitable, through a seed dealer in Riga who had made a special study of the cereals of northern Russia. It was grown in latitude 60° near Lake Ladoga, north of Petrograd, and is known by the name of Ladoga. The first consignment to Canada was received in the spring of 1887, when 667 sample bags were distributed for trial, "from which 275 returns were received, and from these reports the average time of ripening was estimated at ten to fifteen days earlier than that of Fife, a gain which would, if maintained, materially lessen the risk of injury from frost." In 1888 a second distribution of 1529 sample bags of 3 pounds each was made, from which 301 reports were received. These, taking in the entire Dominion, placed the time of ripening 10 days earlier than that of Fife (Saunders, 1889, pp. 5–6). The average yields, the two years, were respectively 58 pounds and 50 pounds for each 3 pounds sown. The better samples of Ladoga were found to be fully as rich in gluten as the best Fife. Though apparently a good wheat, it appears not yet to be widely cultivated, but is said to be the only variety now grown in the Peace River country. It is otherwise important, however, in being a parent of several good hybrid wheats.

161. Chul wheat. — Chul-bidai or Chul wheat is common throughout Turkestan, both because of its drought resistance and because it is non-shattering. The latter quality is very important in that country, as all harvesting is done by hand and therefore must be much delayed. It is hence adapted for the Pacific coast and apparently for the Columbia River Basin. This wheat was first obtained by N. E. Hansen in 1898, at Tashkent, for the United States Department of Agriculture. Its full value was not realized for some time. In 1902 a second larger introduction was made by E. A. Bessey from Dzhizak, 100 miles north of Samarkand. The California Experiment Station secured some of the seed, and distributed it to farmers for seeding in the fall of 1903. The yields from these plantings averaged about 20 bushels an acre. In its native home Chul is grown on the steppes, without irrigation, and is a common wheat, but has hard kernels. It is sown either in the spring or fall, but preferably just after the snow melts in the spring.

Chul is an early, erect, and vigorous variety, which grows to a height of 2½ to 4 feet. The wheat stools freely and produces spikes which are medium long, tapering, and awned. It will stand the strong winds of the Sacramento Valley without shattering. The kernels are large, long, tapering, translucent, and much harder than those of Australian White (Blanchard, 1910, pp. 24–25). As originally introduced, Chul was a mixture, having two colors of chaff and two colors of kernel. It has given excellent results in trials in California and at Moro, Oregon, but is not yet extensively grown.

162. Fretes wheat. — The Fretes was obtained for the United States Department of Agriculture by D. G. Fairchild and C. S. Scofield at El-Outaya, in Constantine Province, Algeria, in 1901. In Algeria it is one of the few common wheats grown, and is noted for its early maturity. It is said to have originated from a shipment of Russian wheat which was made into Algeria, at the time of a famine, many years ago. Because of its nativity it should be resistant both to drought and alkali.

Fretes is an early, vigorous variety, which in California should be sown not later than December 15. It reaches a height of 3 to 4½ feet. The spikes are of medium length, tapering, and have awned white chaff. It shatters little, but is not so good in this respect as Chul (Blanchard, 1910, pp. 28–29). Fretes has also given good results in trials in California and at Moro, Oregon, and yields better than Australian White or California Club.

163. Black winter emmer. — For a long time, winter emmers have been grown in southern European coun-

Fig. 59. — Field of Black Winter emmer at Channing, Texas, yielding 52 bushels an acre.

tries from Spain eastward to Servia. One variety in particular, the Black Winter, has been advertised for many years by European seed firms and small samples received from these firms at different times were planted in this country by the United States Department of Agriculture, in experiment plats, in the fall, and gave good results. It was decided, therefore, to obtain sufficient seed to give this variety a thorough trial. In August, 1904, 36 kilos of seed were obtained by the Department from France and planted in the fall of that year. Through the resulting crop and following crops the seed was increased from year to year, and finally distributed to experiment stations and private farms. The results of these trials were generally good.

Several varieties of winter emmer are grown in southern Europe. Aside from minor characters, these differ from the spring emmers in having a considerably larger, especially broader spike and a larger, stiffer culm. The leaves and chaff of Black Winter emmer are pubescent throughout. It is resistant to drought, and on the other hand stands the bad effects of wet seasons in humid districts. It is winter hardy, but not so good in that respect as Kharkov wheat (Fig. 59).

164. Swedish select oat. — The Swedish select oat was introduced into the United States by the author in the spring of 1899. It was obtained, along with other cereals, while making an exploration of the cold and semi-arid regions of Russia and western Siberia in 1898–99, in search of cereals adapted to corresponding conditions in this country. This oat apparently originated at Svalöf, Sweden, as a pedigree variety developed by selection many years ago, and was afterward grown in Finland and in Petrograd province, Russia. Under the severe weather conditions of these localities it became acclimatized for a cold and dry climate.

The Swedish select is a large-kerneled white oat, with a spreading top or panicle. The distinguishing marks are a blunt, plump kernel, with usually dark, slightly twisted awns and a heavy weight a bushel (see frontispiece and Fig. 29). It is a very prolific variety, which quality, together with the size and weight of the kernel, is no doubt the result of previous selection. The usual weight a bushel is 34 to 36 pounds, while in Montana a weight of

44 to 46 pounds is not rare. Comparisons of yields with other varieties should therefore be made on the basis of bushels by weight instead of measured bushels. Swedish select also grows to a considerable height and produces much straw, its chief fault being a tendency toward overproduction of straw when grown on rich or low land. The roots are large and vigorous, giving the plants hardiness in cold or dry seasons. In the northern United States, between the Great lakes and the Rocky mountains, the average annual production of this variety is at least 50,000,000 bushels, and in 1910 it was estimated that the annual farm value of the oat crop in Wisconsin alone was increased over $2,000,000 by virtue of the presence of this variety (see Fig. 32).

165. Kherson oat. — The Kherson oat came from the Kherson Government, Russia. F. W. Taylor obtained the seed for the Nebraska Agricultural Experiment Station, while traveling in that country in 1896, but it was not planted until the spring of 1898. It was widely distributed in Nebraska, but for several years was little known outside that state.

The plant of Kherson oat is a vigorous but not rank grower. The straw is comparatively very short. The leaves are broad; the panicles spreading; the kernels light yellow in color, long and tapering, and having a very thin hull. It ripens very early. The bushel weight and acre yield are very good (Lyon, 1904, pp. 3–4) (see Fig. 30).

The climate of Kherson Government is similar to that of Nebraska and Kansas, but drier. The Kherson variety therefore should be well adapted to the Middle Plains, which on trial was found to be true.

166. Sixty-Day oat. — In March, 1901, the Sixty-Day oat was obtained by the United States Department of

Agriculture from C. I. Mrozinski of Proskurov, in Podolia Government, Russia. Podolia lies just west of Kherson and the conditions of soil and climate are very similar, though it is not quite so dry as in Kherson. It also happens that the Sixty-Day oat closely resembles the Kherson oat, in fact appears practically identical with it, although under the same conditions there is sometimes considerable variation in yield. Though both are adapted to middle latitudes, it appears that the adaptation of Kherson tends slightly more to the west and north, and Sixty-Day more to the east and south. It was soon evident that the Kherson and Sixty-Day oats filled a "long-felt want" in the central and middle eastern oat districts of the United States, and the oat industry has been greatly stimulated by their introduction. They are very early, yield heavily, and do not lodge. The name Sixty-Day, however, is misleading, the time to maturity being from 90 to 100 days.

There is some discrimination against these oat varieties, because of the yellow color and small size of the kernel, which has sometimes resulted in a price difference, in favor of white oats, of 1 or 2 cents a bushel. There is a great variation in color in different localities. To the north and west the color becomes whiter. Because of the thin hull, there is a greater proportion of caryopsis to hull than the appearance indicates, and the feeding value of these oats is higher than that of most other varieties (Warburton, 1910, pp. 9–12).

167. Other oat introductions. — The North Finnish Black oat was obtained by the United States Department of Agriculture, through Barbour Lathrop and D. G. Fairchild, in 1900, also in April, 1901, from Tornea, Finland, where it is a standard variety. The kernels of this oat are black with whitened tips, and often glabrous, geniculate, with much twisted awns on the back. The panicles are spreading. The straw is stiff and resists lodging. The variety is not yet much grown in this country, but it has thus far been found the best in all oat variety trials in Alaska.

The Algerian Red oat was also obtained by the United States Department of Agriculture in 1903, from Algeria, through L. Trabut. It has been found well adapted in the southwestern United States, and does fairly well in the middle and southern Great Plains. It closely resembles the Rustproof. This oat is early and drought-resistant. The panicles are spreading. The kernels are reddish brown and bristly at the base, and occasionally are awned at the back. The variety is not yet commonly grown.

The Clydesdale oat was introduced from Scotland by Peter Henderson in 1885. It is a large-kerneled, white oat, having an unusually heavy bushel weight, and is now grown to a considerable extent in the eastern United States.

168. Manchuria barley. — What appears to be the first importation of the seed of Manchuria barley was made by Hermann Grunow of Miffin, Wisconsin.[1] While in Germany in 1861, he obtained the seed from Ferdinand Deuhlke of Erfurt, then Director of the Agricultural School at Potsdam, and gardener to the Emperor at Sans Souci. The German supply had been secured in 1859 by a scientific traveler in the mountains of Manchuria. On trial in Germany, the barley is reported to have given results exceeding those of any other variety and proved

[1] For an interesting full account of this introduction see First Ann. Rep. Wis. Agr. Expt. Sta., pp. 17–21, 1883.

to be excellent for brewing purposes. There are numerous spellings of the name of this barley in literature, but the spelling Manchuria is manifestly the correct one, that being the spelling of the name of the country from which it was obtained, which name was evidently the one intended for the barley.

169. Tests and distribution. — In the records of the Wisconsin Experiment Farm for 1872 is the following entry: "Manshury barley: Seed from H. Grunow, Esq., Miffin, Iowa County, Wisconsin. A six-rowed variety; 14 pounds sown, etc." W. W. Daniells, then in charge of the Experiment Farm, continued to grow the variety and disseminate the seed, along with other seeds, until 1880. The yield to the acre in bushels of the five best varieties for the 10-year period 1871–1880 was, Manchuria 52.9, Probsteier 45.0, Common Scotch 39.9, Saxon 35.4, Chevalier 30.7. In 1878 the United States Department of Agriculture bought 100 bushels from N. W. Dean at Madison, Wisconsin, and distributed it for sowing that year.

Manchuria has the widest distribution of all North American barleys. As stated elsewhere, it is the chief source of the entire production of six-row barley in North America. It is particularly common throughout Canada, and all the northern and northeastern States. Oderbrucker is practically the same thing, but is a strain specially exploited by the Wisconsin Experiment Station (see Fig. 48).

170. Hanna barley.—This variety of nodding two-row barley is so called because it originated in the valley of the river Hanna in Moravia. The principal introduction was made by D. G. Fairchild, for the United States Department of Agriculture, January 16, 1901, a sample having been obtained previously in 1900. The seed was secured from the breeder, Emanuel Ritter von Proskovetz, at Kwassitz, Moravia. It is one of the best brewing barleys, and is noted for earliness, heavy yields, and special mealiness. The last, together with other qualities of the kernel, has made it a great favorite among German and Austrian brewers. It is claimed to be a pedigreed variety, in the breeding of which the period of growth was shortened one week. It is a light straw producer and is suited to light or sandy loam soils. This barley is now well established in the northwestern plains and intermountain states.

171. Swan Neck barley. — Swan Neck, or in German Svanhals, is a pedigreed erect two-row barley, introduced by Barbour Lathrop and D. G. Fairchild, for the United States Department of Agriculture, from Svalöf, Sweden, March 11, 1901. It is a very early-ripening variety developed by the Seed Breeding Institute of Svalöf. This variety has given good results experimentally in the Northwest, but is yet little grown.

172. Hannchen barley. — Hannchen, or Little Hanna barley, is another one of the Swedish pedigreed brewing barleys obtained by the United States Department of Agriculture through D. G. Fairchild. Seed was received April 18, 1904, from the General Swedish Seed Breeding Company at Svalöf. Hannchen is a nodding two-row variety, with unusually thick spikes; spikelets not divergent, light yellow before ripening; awns often deciduous; ripening early. This variety is one of the very best in the northwestern plains and intermountain states, and is already rather generally grown.

173. Smyrna White barley. — This variety of two-row barley was introduced by the United States Department of Agriculture in November, 1901. The seed was received from B. J. Agadjanian at Smyrna, Asia Minor, through Geo. C. Roeding, Fresno, California. It has proved to be an excellent variety, in yield, for the dry northern plains, and has already made an unusual record in the Judith Basin, Montana. In California it has also done well, but Abyssinian varieties are much the best in that state. Smyrna Black barley was also introduced from the same country at the same time, but has not done so well.

174. Beldi and Telli barleys. — These varieties of the common subspecies of barley were introduced by the United States Department of Agriculture, through D. G. Fairchild and C. S. Scofield, from El-Outaya, Constantine, Algeria, in September, 1901. They came from the saline soils on the edge of the Sahara Desert, and are therefore adapted to the southern plains and California. They have given fair to good results in the Southwest, and appear to resist drought very well, though they were originally grown under irrigation. They are not yet widely grown in this country. These barleys are not adapted for brewing, but in their original home are eaten by the Arabs and fed to their horses.

175. Abruzzes rye. — Abruzzes is a superior variety of rye, having very large kernels, much lighter in color than those of ordinary rye. It was secured by the United States Department of Agriculture, from the Province of Abruzzi, Italy, a mountainous district east of Rome, in 1900. It is one of the best rye varieties grown in Italy. This rye has not yet been widely distributed in this country, but it gives very good results, comparatively, in the southern states, particularly in South Carolina and Georgia. It is grown there as a winter rye, and has even done well, fall sown, in Kansas (see Fig. 52).

Other introduced rye varieties that appear to do well in this country, but have not yet become fixed in cultivation, are Pirna, Petkus, and Schlanstedt from Germany; Ivanov from Russia; and Giant Winter from France.

CHAPTER VIII

CEREAL IMPROVEMENT — SELECTION

All improvement of cereal plants is fundamentally a selection of the best individuals, whatever the method employed. Even the introductions discussed in the preceding chapter are only thoroughly accomplished after years of acclimatization, which is virtually adaptation through selection, natural or artificial. Hybridization attains no end without intelligent selection of the progeny. On the other hand, much of the work commonly called selection is practically a sorting of mixtures. Selections proper may be made *en masse* or by separate individuals. The subject will be discussed, therefore, under the headings: (1) sorting and roguing of mixtures, (2) mass selection, and (3) pure line selection.

176. Sorting. — Almost all the common or standard varieties of cereals are aggregations or mixtures of two or more distinct varieties or strains. The first step in selection, therefore, is a sorting out of these strains. Sorting is usually accomplished by hand picking the seed or by a separation of single plants in the sheaf.

Introduced cereals are particularly likely to be mixed, as they are usually obtained because of resistance to severe climatic conditions, in regions where primitive agricultural methods are practiced (see 75). As already mentioned (161), the Chul wheat, when introduced, had light amber and dark amber kernels, and, on planting, produced both white-chaffed and brown-chaffed plants. There are many other similar instances. In some cases the mixture is so even that it is difficult to decide which type is the one intended in the introduction, and occasionally some other type than the one intended proves to be the best one of the mixture. Sometimes different species or subspecies are represented in a single introduction.

The standard varieties of the country, whatever their origin, are commonly found mixed on the farm. Even if descended from a pure strain, they soon become mixed through thrashing operations, and from using more than one variety on the same farm. The re-sorting of mixtures again and again, and re-distribution of good seed, will probably always be a large part of the agronomic work of the experiment stations.

177. Roguing is the operation of eradicating foreign plants from the standing crop; for example, the practice of cutting rye out of wheat. It differs from sorting, in that the latter is done on a smaller scale and not usually in the standing crop. It differs from weeding, in the fact that only foreign plants of the same or allied species are involved, such as the eradication of wild oats from the oat field, or of awned wheat from a field of awnless wheat. This is one of the few crop improvement operations that the farmer himself can and sometimes will perform.

178. Cleaning and grading. — These two operations may usually be performed by the same means, and at the same time, and are therefore discussed together. They are on the border line between actual selection and simple mechanical conditioning or purifying, but the same air blast, for example, that drives away chaff, dirt, and weed seeds will also blow out many shriveled and small light seeds of the crop under treatment. There are three methods of cleaning and grading grain: (1) by air movement or wind, (2) by simple gravity, and (3) by specific gravity. The same general principle, differences in gravity, is effective in the first and third methods, while in the second the size and shape of seed are also effective.

179. Air movement. — The simplest and the most primitive operation of cleaning by force of air is the winnowing process, in which the grain is held aloft in a bucket or basket and allowed to spill in a thin stream in the face of a strong breeze or wind. Even in this process the grain is also roughly but incompletely graded. In oriental countries this winnowing process is commonly the only method of cleaning ever employed, and often follows similarly primitive thrashing operations.

In recent times the fanning mill has come into use. Though a fan is attached to all thrashing machines, it is sometimes the practice to use a fanning mill following the thrashing, as by means of it and its numerous sieves of different sized meshes, the grain can also be graded.

180. The gravity method is the only one which essentially is not a gravity process at all, but is so called because the grain passes through the machine by its own weight, and there is no machine motion. The machine is principally a vertical series of sieves set each at an angle with the one next below, the sieves becoming finer toward the bottom. It is chiefly a method of grading, though some foreign seeds may be eliminated. The grading is effected by differences in the size and shape of meshes in the different sieves. The seed passing through each may be caught separately or the products of two or more sieves may be run together. Of course the separation in this process is chiefly on the basis of size and shape of kernel.

181. Specific gravity method. — In this method the seed is immersed in a liquid of such density that the kernels of average weight will just sink, while the lighter kernels, chaff, and many foreign seeds will float and may be skimmed off. Grading and also a certain amount of cleaning are effected by differences in specific gravity.

Fig. 60. — Apparatus for cleaning and grading seed grain by the specific gravity method.

As the medium for cereals, water can usually be employed, to which salt may be added to increase the density as required.

A simple arrangement for separating cereal seeds is the following: The apparatus consists only of two tubs or half barrels. A hole is bored through the side of each at the bottom, and wire netting tacked over the hole inside the tub. In the holes pine plugs are fitted. Rope handles are attached near the top and one tub is set above the other on a trestle. The upper tub is partly filled with water, and the seed poured in, leaving enough space for stirring. After stirring thoroughly, everything floating should be skimmed off, the plug taken out, and the water allowed to drain into the lower tub. The seed in the upper tub is then emptied upon a clean floor or canvas and spread out thinly to dry, after which the tubs are reversed as to position, and the operation is repeated. The seed is swollen as a result of this treatment, and the rate of seeding should therefore be proportionally increased. By substituting a formalin solution of 1 pound of formalin to 40 gallons of water, in place of water, the smut treatment may be combined with this grading process to great advantage (Derr, 1910 a, pp. 3–4) (Fig. 60).

182. Heavy and light seed. — Many experiments have been conducted to determine the relative value of large or heavy, and small or light kernels for seed. While there has been some conflict in results, they have usually favored the use of large, heavy seed. Particular attention has been given to the subject at the Kansas, Ohio, and Ontario experiment stations. An 8-years test was conducted at the Kansas station in which heavy seed oats gave an average yield an acre of 30.90 bushels, common seed 29.89 bushels, and light seed 27.50 bushels. The common seed used was the seed as it came from the thrasher, the light and heavy grades being obtained by the use of the fanning mill. The grades were taken usually from the ordinary seed each year, but in the last year of the experiment, when the greatest difference was noted, the heavy and light seeds were taken from the corresponding grades the previous year. At the Ohio station, in a 7-years test, the average acre yield for heavy seed oats was 46.3 bushels, for common seed 44.8 bushels, and for light seed 42.6 bushels. In a similar 9-years test with wheat, little or no difference resulted in favor of the heavy or large kernels. In both these series of experiments the same weight of each grade of seed was sown to a unit area. In a report on some investigations of methods of improving the quality of wheat, Lyon (1905, p. 75) states that after the first year, light seed wheat, sown at the same rate to the acre ($1\frac{1}{2}$ bushels) as heavy seed, gave yields of grain each year more nearly approaching that from heavy seed, until in 3 or 4 years there was little difference in yield. Also after the first year the light seed produced a larger quantity of protein to the acre than the heavy seed.

183. Large and small seed. — More striking results were obtained by Zavitz (1910, pp. 98–104) at the Ontario station, where the grading was done by size instead of weight. They are best given tabulated as follows: —

TABLE I. RESULTS OF THE SELECTION OF LARGE AND SMALL SEED AT THE ONTARIO STATION

Crop	Years Tested	Grade of Seed	Average Yield to the Acre		Weight to a Bushel
			Tons of Straw	Bushels of Grain	
Oats	7	Large . . .	1.9	62.0	33.2
		Medium . .	1.8	54.1	32.2
		Small . . .	1.8	46.6	31.8
Barley . . .	6	Large plump	1.5	53.8	49.5
		Small plump	1.5	50.4	48.8
Spring wheat .	8	Large plump	1.4	21.7	59.1
		Small plump	1.3	18.0	58.3
Winter wheat	6	Large plump	2.6	46.9	59.4
		Small plump	2.2	40.4	59.2

In this series of experiments, the selections were made each year from the general crop, being therefore a repetition but not continuous. Actually the same number of kernels were sown to each unit of area. The seed was hand-picked, and even small seed was sound and not shriveled. Out of 40 separate tests 37 gave best results from large seed. Besides a larger yield of grain, the large seed also gave better average weights a bushel in all cases. The yield of straw from the large seed was usually better and never less than from small seed. Similarly good results were obtained in 12 years of continuous selection of light and heavy seed from the corresponding previous selected crop of Joanette oats, the difference increasing constantly (Fig. 61).

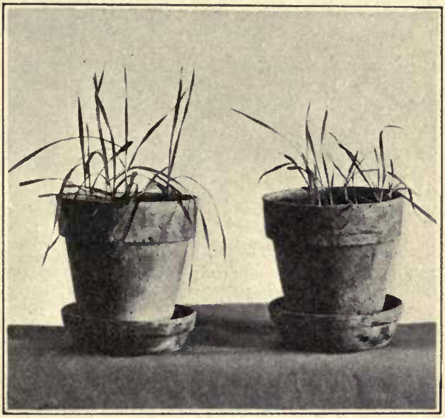


FIG. 61. — Pot experiment with Manchuria barley, showing beneficial effect of selecting large seed: pot on left sown with large seed, on the right with small seed.

184. Experiments in New South Wales. — Investigations of the relative value of large and small seed wheat were made for several years by Cobb (1903) in New South Wales, in which uniformly better results were obtained with large seed. Four different trials were made and in the third trial 29 varieties were employed. Specially made millimeter sieves were used in the grading, and the seed separated into the following grades indicating the diameter of the kernels: 3.25 mm., 3.00 mm., 2.75 mm., 2.50 mm., 2.25 mm., 2.00 mm., and tailings. In the third and fourth trials only four grades were used: very large, 3.25 mm.; large, 3.00 mm.; medium and small, all remaining sizes. The most common size of kernel in ordinary seed wheat was found to come nearest to 2.50 mm. in diameter. It was concluded that Australian wheat could and should be improved to the stage of at least an average diameter of 3.00 mm. In addition to the better yields resulting generally from the large seed in these experiments, there was better germination of such seed, and the plants from large seed were more vigorous and their grain of better quality. It was found that the superior yield from large plump seed was always sufficiently pronounced to justify the cost of first-class cleaning of ordinary wheat for seed to the extent of 10 per cent of the value of the yield to the acre, without loss to the grower.

185. Many factors influencing seed tests. — In connection with Cobb's experiments a calculation was made of the number of kernels contained in equal weights and equal volumes of seed. The interesting results are here tabulated:

TABLE II. *A*. NUMBER OF KERNELS IN EQUAL WEIGHTS OF DIFFERENT GRADES OF PURPLE STRAW WHEAT

Grade	3.25	3.00	2.75	2.50	2.25	2.00	TAILINGS
Number of kernels	348	369	402	463	579	715	1000

B. NUMBER OF KERNELS IN EQUAL VOLUMES OF DIFFERENT GRADES OF WHEAT

Grade . .	3.25	3.00	2.75	2.50	2.25	2.00	TAILINGS	VARIETY
Number of kernels .	381	408	459	550	684	793	1000	Purple Straw
	303	313	355	441	587	736	1000	Allora Spring
	284	311	372	463	585	731	1000	Hudson Early Purple Straw

Three things are shown by this calculation: (1) the difference between the number of kernels of any grade to the unit of weight and unit of volume, (2) the very great difference in number of kernels of the different grades in the same weight or volume in the same variety, and (3) the varietal variation in number of kernels of any grade to the unit of weight or volume. It is evident from these facts that much variation in results must follow the planting of the same number of kernels to the unit area, even from the same grades of seed, if these grades are made indiscriminately on the basis of size or weight, and that the influence of the variety is very great. Differences in rate, date, and space of planting and climatic differences may also so affect the experiments as to be a partial cause of some conflicting results that have been obtained in widely different localities.[1]

186. Mass selection. — Aside from the selection of seed in bulk through mechanical grading, for a long time there has existed a practice of selecting the best spikes or the best plants from a plat or field, and sowing the seed

[1] In Proc. Amer. Soc. Agron. II, 59–69, 1910, Montgomery has reviewed the methods employed in various series of tests of the value of heavy and light kernels, and shown the widely different conditions under which the many tests were conducted.

of these *en masse* in a separate place. This is known as mass selection, and if the process is repeated in the resultant crop, the selection is continuous. This method has been practiced heretofore particularly by German breeders, and is followed on the principle that there is effected a gradual accumulation of slight favorable variations, a view not generally held at present. Some improvement seems to have been made by this method, but apparently there is no assurance of its permanency, unless the selection is continued. The best known work in this line of cereal breeding has been done by Rimpau. He began with a complete sample of the best spikes obtainable in a field crop, expecting to retain in the new strain all desirable characters of the original variety, and then by further selection, take advantage of slight favorable variations to improve on old characters and possibly develop new ones.

187. Schlanstedt rye. — This rye is the best known example of the work of Rimpau who lived at Schlanstedt. It is the result of breeding operations begun in 1867, with a selection of best spikes from the Probsteier variety. It has stiff, long culms, and spikes filled with large kernels. Selections were made again in 1896, and in 1899, the last having shorter straw and shorter square-shaped spikes, selected from uniformly good tillering plants.

188. Usefulness of mass selection. — Besides its use in actual improvement, mass selection is of much help as a preliminary to pedigree selection from old mixed varieties, as, thereby, many inferior types are at once discarded, leaving a much less number to be separated into pedigree cultures. Mass selection is valuable after crossing, also, in helping to eliminate undesirable progeny.

A mass selected sort may be in itself of particular value, as, being made up of two or more types, it may be adaptable to more varied conditions than a pure line selection.

189. Mass selection at Svalöf. — Even at Svalöf, mass selection was at first practiced wholly, and has never been entirely abandoned. Several good new varieties were produced by that method. A selection for density of spike was made from the native Plumage barley, with the idea that this quality is correlated with strength of straw, which was afterward found not to be true. However, there resulted from this work two new barley varieties. One thousand selected spikes were divided into two groups showing the two extremes of density, and a third group representing the average density of all. From the seed of the group containing the most open spikes, density 40 to 41 (see 110), was ultimately developed a sort which remained relatively lax, and was called Clay barley. From seed of the other extreme group, density 45 to 48, the variety Moss was produced, which at the end of three years still possessed very dense spikes. By the same method Princess barley, Renodlad Squarehead wheat, and Probsteier awnless oat were developed.

190. Maintaining the purity of varieties. — An important use of frequent mass selections is for maintaining the purity of all varieties, including pedigreed sorts. In the report on seed wheat by Cobb (1903, p. 48), previously mentioned, it is stated that "no farmer should allow himself to forget that all the various items of cost in connection with grading and selecting seed are much reduced by selecting from his crop, before it is harvested, certain good portions to be taken off specially for seed purposes." The use of a special seed plat on every farm is strongly recommended by the Svalöf cereal breeders, and has been described and advocated by the author and other American writers in various publications. It is so important a part of farm operations, though rarely employed, and so easily carried out, that it seems very desirable to give here a description of the method.

191. The seed plat. — This plat should be located at different parts of the farm every year or two years, preferably in alternation with clover or other leguminous crops. Just before harvest a field of a good, hardy, standard variety, that has given the best results in the locality, should be gone through and plants marked that exhibit to the highest degree the special quality which it is desired to increase, such as freedom from rust, fertility of spike or panicle, or otherwise, and which are at the same time at least as good as the average in other respects. At harvest time enough of these marked plants for sowing the plat should be cut with a sickle and, after thrashing them by hand, the largest and most vigorous seed selected for this purpose, by means of a screen or even by hand picking. The plat should be sown early, drilling it at the average rate to the acre for that crop. Next season none of the field crop should be used for seed, but in the same manner enough of the best plants should be selected from this breeding plat for re-seeding the plat and all the remainder used for sowing the general crop. In each succeeding season the operation is repeated. In this way seed is never taken from the general crop, which cannot be given the same care as the small plat, and there is a constant selection of seed which is more and more rigid every year. Moreover, there is no extra labor involved except the small amount required for seed selection each year. Of course the seed plat should be kept constantly free from foreign plants and weeds. It will be one or more acres in size, depending upon the acreage of field crop grown.

192. Pure-line selection. — Individual or pure-line selection is selection from a single, superior, mother plant, which plant and its progeny are kept protected from outside pollination. The latter is not difficult in any of the small cereals except rye. This method of selection was practiced by H. Vilmorin at Verrieres, France, and has been called the Vilmorin System of selection. Later at Svalöf, Sweden, it has been referred to usually as the System of Pedigree Culture. The basic principle of the system is to separate from a commercial variety the greatest possible number of forms, to propagate each of these separately, and finally through a process of elimination to isolate a few of the best for increase and distribution.

193. Work of Le Couteur. — The method of form-separation, in German "Formentrennung" (Früwirth), was long ago employed as a means of discovering superior individuals, as a starting point in developing new strains, by an English breeder, Le Couteur (1837, p. 119), at Bellevue, on the island of Jersey, in the early part of the last century. La Gasca, of the University of Madrid, showed Le Couteur that his grain was a composite of many distinct types, and not pure, as he supposed. Le Couteur therefore saved spikes of 23 types indicated and sowed the kernels of each spike separately. Some of the types were found to be poorer and some better than the average of the parent variety. New varieties were isolated in this way and put on the market. One of them is yet grown considerably in western Europe, and is said to be a pure and uniform type. It was isolated from Talavera wheat in 1838, and distributed by Vilmorin as Bellevue Talavera.

194. Work of Shirreff. — Patrick Shirreff (1873) lived at Mungowells Farm in Haddingtonshire, Scotland, and during the same period selected wheat in the same manner as Le Couteur. He searched for exceptional plants, and made these plants the mothers of varieties. His exceptional plants were seemingly rare, as in 40 years' work he isolated only 4 new varieties which had permanent value. His Mungowells wheat was selected in 1819 as a single strong plant surviving the winter in a badly damaged wheat field, from which the new variety was developed and distributed.

195. Work of Hallett. — F. Hallett (1861), at Manorhouse, Brighton, England, also practiced pure-line selection about the middle of the last century, but not exactly in the same manner as Le Couteur and Shirreff. He believed that each plant has one spike superior to all its other spikes and that spike one kernel superior to all its other kernels; also that this kernel will transmit to its progeny the qualities which it possesses. He made selections accordingly, which he repeated through several generations, during the same time giving the mother plants exceptionally favorable conditions. For a few generations large increases in yield were obtained, but later on little or no increase. Hallett considered continuous selection to be essential, while Le Couteur and Shirreff emphasized only the initial selection, and afterward gave attention only to the multiplication of the variety. Hallett practiced the pedigreeing of ordinary varieties a great deal, retaining the original name in the new name of the pedigreed strain. Some of his new wheat strains are: Hallett Pedigree Hunter White, Hallett Pedigree

Victoria White, Hallett Pedigree Red, Hallett Nursery Red, and Hallett Pedigree Golden Drop.

196. Work of Hays at Minnesota Experiment Station. — The best example in this country of pure-line cereal selection on an extensive scale is the work of W. M. Hays (1899) at the Minnesota Experiment Station, which began in 1888. Valuable as were the Fife and Bluestem wheats already being grown, the yield was unsatisfactory. Several hundred varieties were obtained from other parts of the United States and from foreign countries, but none were found to be better than those already under cultivation. Therefore "wheat breeding was resorted to, that the best available wheats might be improved and others be originated." The field methods employed are discussed elsewhere (202). Out of thousands of new strains produced, two were widely distributed and have become well known. Minnesota numbers were given to each of these new strains, a practice not to be commended.

197. Minnesota selections. — Minn. No. 163 wheat is a selection from Power Fife. In 8 years' test it averaged 5.2 bushels an acre more than Haynes Bluestem. By 1903 it was planted on more than 100,000 acres. Minn. No. 169 was selected from Haynes Bluestem. It yielded 4.2 bushels an acre more than the parent variety in an 8 years' test. Fifteen hundred bushels were grown on the University farm in 1902, in which year it was distributed. The following year, it is estimated 150,000 bushels were grown. The mother plants of these new varieties were grown in 1892. Minn. No. 2 rye is a selection from Swedish rye begun in 1897. It was selected for hardiness during winter killing of the parent variety, and distributed in 1908 as a new commercial sort. Minn. No. 26 oat is a selection from early Gothland. It has medium coarse straw and long, well-filled white kernels. It yields well and has been grown rather widely.

198. Work of Nilsson at Svalöf. — The center of pure-line selection work in recent years has been at the Swedish experiment station at Svalöf. At first only mass selection was practiced. When Hjalmar Nilsson became Director, he had already noted the regularity with which many different botanical types appeared each year. In 1891, it was noted further that, in 200 types or groups of winter wheat, sorted out of a large number of spike selections, while many of the types included many individuals, in a number of cases there were forms with no duplicates. Each of these forms therefore represented a group alone. These groups were planted in separate plats and only by accident in studying the results in the following harvest was it discovered that of all the hundreds of cultures only those few which came from a single spike or plant produced a uniform progeny. It appeared evident therefore that the quickest way, if not the only way, to obtain a uniform sort was to begin with a single plant. Ever since, the unit of improvement at Svalöf has been the single plant instead of the group. Later on it was learned further that different types are not to be distinguished always by visible characters; that is, there are physiological as well as morphological types.[1]

[1] About the year 1900 the administrative duties of Nilsson became so heavy that the work with wheat and oats, his specialty to that time, was given entirely to H. Nilsson-Ehle, who remains in charge of it. At the same time the barley work was assigned to Hans Tedin. Later rye was added to the list of subjects, of which Erik Ljung is now specialist in charge.

199. Views of De Vries and Johannsen. — Nothing could appear more opportune than the expression of the views of Hugo De Vries (1901–3) and W. Johannsen (1903), simultaneously with the operations at Svalöf. These views, which appear to be rather generally, though slowly, accepted, have served, together with the rediscovery of Mendel's Law (see 217), to place the entire phenomena of variation and development in a new light

The main principle in the views of De Vries is that of the existence of "elementary species," an unfortunate wording, referring to the types actually separated originally by Le Couteur and Shirreff and later by Nilsson and associates. These "elementary species" or types are unchangeable, in any permanent way, except through occasional sudden variations or "mutations" or by hybridization. Even these processes do not change the composition of the type, but add to or effect a recombination of the "unit characters" of which the type is composed (220).

200. Immutability of pure lines. — Johannsen showed the scientific necessity of working with pure lines by which he meant the progeny of a single self-fertilizing individual. The constituents of all his pure lines showed fluctuations, it is true, in different directions, but when some of these constituents which deviated to the farthest extreme, were selected and propagated separately, instead of producing a progeny similar to the mother plant, they reverted to the original type of the line. Further experiments finally forced Johannsen to conclude that continuous selection with pure lines cannot produce permanent changes, and that there is no hereditary variation within pure lines.

201. Examples of the fixity of pure lines. — In some pure-line selections of oats conducted several years by the United States Department of Agriculture, the same process was attempted with Swedish Select oat, a pure strain already selected at Svalöf years ago. Much better yielding strains were separated from several standard varieties, but the progeny from selected individuals of the Swedish Select showed little or no change from the parent variety, one way or another. Nilsson records several similar examples at Svalöf, giving also negative results. Hutcheson (1914, pp. 459–466) gives the results of 13 years of continuous selection in pure lines of six wheat varieties, in which there has been " no permanent improvement." In 3 years' work only, Williams (1912, pp. 409–412) found that there is " no encouragement for believing that there is any heritable variation in pure lines of wheat with respect to size of kernels or protein content." Thatcher (1913) states that after 5 years of line selection for high and low nitrogen content at the Washington Experiment Station no change has been accomplished.

202. Centgener method in pure-line breeding. — There are two methods of individual selection, the centgener and the plant-row. The first was originated by Hays (1899, pp. 127–134) at the Minnesota Experiment Station. The method begins with foundation beds from bulk seed, planting one kernel in a place at equal distances apart each way. From these beds 10 to 75 of the best individuals are selected for mothers of centgeners. The following year 100 seeds from the progeny of these best plants are planted in square centgener plats, in the same manner as in the foundation beds. After choosing the best plants from the best centgeners for further breeding, the remaining seed of each is harvested in bulk and multiplied and soon forms a variety to be entered in the competitive field trials.

203. The plant-row method, erroneously called "head-row," in its best form, differs from the centgener method in that exceptional plants, or the best spikes from each, are selected from the field or from new composite varieties in the nursery, and all the seed from each plant is

Fig. 62. — Cereal nursery, where months of work are spent each year in selecting and hybridizing. The rows run across the long plats.

sown in a separate row, giving uniform spacing to the different kernels. The best seed from these rows is planted in longer or several rows next year, which are then at about the same stage in this method as the centgener plants, thus gaining one year's time. The following year the new strain goes into a small-sized plat, and the next year probably into a tenth-acre plat, if considered worthy of further trial. Besides a saving of time, this method has the advantage of a continual comparison of strains from the first year. The method of seeding also is more nearly the same as under field conditions, which, with winter varieties, may be of much advantage (Fig. 62).

204. Specific results of selection. — The large yield increases obtained by Hays with selected wheats has been mentioned (197). At the Ohio Experiment Station, in a 2 years' trial of single wheat plant selections, Williams (1909, pp. 175–176) found a wide difference in yields in the progeny from the best and the poorest plants of the same variety. In the third year hundredth acre plats were planted with seed of the high yielding strains in comparison with corresponding plats with bulk seed of the parent variety. The average excess of yield to the acre of the pure strains over that of the parent variety was 4.57 bushels. At the Nebraska Experiment Station, 26 pure strains of Turkey wheat from plants selected in 1902 were grown four years in field plats, in comparison with checks of the original variety in every fifth plat. The checks averaged 35.18 bushels to the acre; the highest yielding strain 40.75 bushels, an excess of 5.57 bushels; and the lowest yielding strain 28.88 bushels, a decrease under the checks of 6.30 bushels (Montgomery, 1912 a, pp. 11–12). In the experiments one of the strains showed an ability to stand in striking contrast with that of its neighboring strain, which was badly lodged.

205. Work of Von Rümker with rye. — Von Rümker (1911, pp. 332–335) at Breslau, Germany, was able, after 7 years, to establish, by rigorous and continuous selection, pure strains of rye for color of kernel as follows: (1) greenish blue, (2) yellow, (3) deep brown (the color of parched coffee). The following other colors have been observed, but strains pure for these colors have not yet been established: sulfur yellow, rose, green, and azure. Attention was also given to yield and winter resistance, and these characters were also slightly increased by the same selection which resulted in the three pure color strains.

During twelve years' work with rye Von Rümker has established the following facts concerning that cereal:—

1. In order to obtain pure races as regards kernel color, selection should be continued 7 or 8 years.
2. The phenomenon of Xenia occurs as in maize.
3. The color of the kernel is a constant character.
4. This color is produced by a pigment in the aleurone layer, next the epidermis.
5. Those races (greenish blue and yellow) which have hitherto been in commerce are satisfactory both for milling and baking.

206. Selection of cereals for disease-resistance has apparently made little or no progress. Farrer and others in Australia have given attention to the subject but with indifferent results. They found Rieti to be the most rust-resistant wheat, also that Medeah, Florence, and Genoa wheats were somewhat rust-resistant. In this country Iumillo and some other durum wheats, einkorn, Khapli emmer, and Persian Black wheat are strongly resistant to rust. Durum wheats and emmers are resistant to the Hessian fly. Burt and Early Ripe oats are almost if not quite immune to smut. It would seem, therefore, that pure lines selected from the most resistant individuals in all these instances should give good results. On the other hand, when resistance is obtained, other qualities are found lacking. Much further investigation is needed. A re-combination of characters through crossing is probably the most promising method.

207. Fultz wheat. — In 1862, in Mifflin County, Pennsylvania, Abraham Fultz, while passing through a field of Lancaster wheat, which is an awned variety, found three spikes of awnless wheat. He sowed the seed from these spikes the same year, and continued sowing a larger amount each year, until he obtained sufficient seed to distribute it pretty well over the country. It soon became a well-marked and popular variety, called Fultz from the name of the breeder, and is now the best known of American wheats. In 1871 the United States Department of Agriculture distributed 200 bushels of the wheat for seed. This variety is rather early in ripening, fairly hardy, and possesses a semi-hard, red kernel of good quality. It comes nearest being a general purpose wheat of all our varieties, being grown with good success in nearly all parts of the country and in several foreign countries. It is a parent of several important crosses (Fig. 63).

Fig. 63. — Fultz wheat.

208. White Clawson. — Next to Fultz, one of the best known of our native wheats is White Clawson, or simply Clawson. This variety originated in Seneca County, New York, in 1865, through the selection of certain superior spikes from a field of Fultz by Garrett Clawson. On planting the grain from these spikes, both a white and red kerneled sort resulted the following season. The white wheat was considered the best, and the pint of seed obtained of this sort was sown, producing 39 pounds the following season. The third year after this 254 bushels were harvested, and that season the variety was distributed to other farmers. In 1871 this variety took first premium at the Seneca County fair, and in 1874 seed was obtained and distributed by the United States Department of Agriculture. Though judged inferior by millers at times, this variety became a very popular one. It must not be confused with Early Red Clawson, a very distinct variety. White Clawson is an awnless wheat, rather hardy, with soft white or light amber kernels. Early Red Clawson, because of its earliness, has taken the place of this variety to a great extent.

209. Gold Coin wheat. — A good variety of white wheat, Gold Coin, was produced by selection by Ira W. Green, at Avon, New York. While passing through a field of Diehl Mediterranean, an awned red-kerneled wheat, he found an awnless spike with white kernels. He planted every kernel, and next year found that he had spikes with very long awns, some with short awns, and others with none at all. The kernels were also mixed, some red and some medium, or yellowish white. He desired an awnless wheat, as the awns interfered with his success in wool growing, hence only the kernels from the awnless spikes were again planted. From this as a beginning, a practically new variety resulted, which he called No. 6. It proved to be of considerable value for certain localities, and is already well known. Forty-Fold is probably the same wheat. There are strong indications that this new variety was the result of a natural cross.

210. Other American selections. — One of the best of the more recently produced varieties is the Rudy, which was originated at Troy, Ohio, in 1871 by M. Rudy, through a careful propagation of the seed from a superior and distinct stool of wheat found in a large field. It is a semi-hard or soft reddish-kerneled wheat, awned and with white chaff. It is widely grown in Ohio, Indiana, and adjoining states.

A number of the different varieties of Fife and Velvet Bluestem of the spring wheat states were also produced by simple selection. Wellman Fife is a good example. In 1878 D. L. Wellman, of Frazee City, Minnesota, received a sample package of Scotch Fife wheat from the Saskatchewan Valley, in Manitoba. This was sown the following spring and as a result it was found that the seed was badly mixed. Removing all plants but those of the true Fife, and propagating carefully from year to year, Wellman gradually developed a pure strain of the Fife, which became known as the Saskatchewan Fife. From the crop of 1881 were selected some unusually large heads, and from the seed of these as a beginning he finally produced a rather distinct sort now known as Wellman Fife. In a similar manner Power Fife, Haynes Bluestem, and Bolton Bluestem have been produced by the men whose names they bear.

Early Pearl oat was selected by R. L. Copeland of Brewer, Maine, from seed coming originally from a clump of oats growing by the roadside. It is apparently a pure line, has stiff medium-sized straw, and a long plump kernel with a pearly tint to it.

Currell Prolific wheat was selected by W. E. Currell of Virginia, from a field of Fultz in 1881. The original seed was from three spikes. In 1884 it was first sold for seed.

211. Pure-line selections at Svalöf. — Several of the Svalöf barleys have already been described. Others of importance are: (1) Gold barley, a selection from Gothland barley of the nutans group; (2) Chevalier II., a pedigreed sort from Horsfords cross bred Chevalier of this country; and (3) Primus, selected out of Diamond, which was an unfixed product of a cross of Chevalier and Imperial, the last an erectum variety.

Grenadier II. wheat is a selection from English Shirreff, a square-head sort. Pudel wheat was isolated from English Squarehead. It is from the dense-spiked, velvet-chaff type, and is the hardiest pedigreed sort selected from the less hardy imported varieties. The variety Bore was isolated from a Probsteier wheat. It is almost as hardy as Pudel, and has a very stiff straw. These two wheats and Renodlad Squarehead are the three leading sorts in central Sweden.

Victory oat, a white selection from Probsteier, is the leading white oat produced at Svalöf (see Fig. 29). Gold Rain is a yellow oat also separated from Probsteier, and has the qualities of earliness, yielding power, and strong straw combined. Yellow Nasgaard oat, selected from Danish Island by Vestergaard of the Abed Station, Denmark, in 1899, ranks with Victory at Svalöf. Great Mogul, a black oat, is a pure-line selection from Tatarian Black; kernels tolerably large, long, well filled, plump, thin hulled, and long awned; plants very tall with unusually stiff straw.

212. European rye selections. — Pirna is an old established variety of the Pirna plateau, in Saxony, but has been improved by Steglitz of Dresden. It has long, slender, thin-hulled kernels, square, well-filled spikes, and is very winter hardy. Petkus rye has been bred since 1881 by F. Von Lochow of Petkus in Germany. It is derived from Pirna rye. It has a medium long but strong and tough culm, and stands up well, a square, well-filled spike of medium length, an average winter resistance, and an average growing period. Heine Improved Zeeland was bred by F. Heine continuously from 1868. It has a thin-hulled kernel, tillers much, yields large in straw and grain; winter resistance low. Selection of this rye for green color gave origin to Hadmersleben Kloster rye. Welkenhauser rye has been bred since 1894 by Von Köpen of Söst, from a spontaneous variation. It is medium in yield of grain and straw, in height, tillering, and period of growth, and has high winter resistance. Sagnitz rye was selected from the heaviest spikes of Probsteier by Graf Berg at Sagnitz, Livland, Russia. It has long kernels, tightly inclosed in the chaff.

213. Australian selected wheats. — Ward Prolific was selected from a single rust-free plant in a badly rusted crop of Du Toits wheat, by Mr. Ward, in South Australia, in 1881. This wheat soon became the best known in all Australia. It is fairly rust-resistant in that country, very prolific, and is a parent of many of the best Australian wheats. Marshall No. 3 was selected from Ward Prolific by Richard Marshall of South Australia. It is fairly rust-resistant in Australia, fairly prolific, and does best in cool districts. Steinwedel, named after a farmer in Balaklava, South Australia, who originated it, is the most extensively cultivated variety in that state. It is very prolific and drought-resistant, but shatters somewhat. Le Huguenot was selected by Joseph Correll from a single plant, with awnless spikes, in a field of Medeah wheat, at Arthur River, West Australia. It was apparently the result of a natural cross. It is particularly valuable as a hay wheat. Dart Imperial was selected by Thomas Dart in South Australia. It is of the Purple Straw group, but later in ripening than the others of that group. It is rust-liable, but stands drought and is adapted to a hot climate. Bobs was originated by William Farrer, and is commonly stated to be a cross of Blount Lambrigg and Nepal barley. This must be an error, as such a cross is, so far, considered impossible, and besides, the wheat has no resemblance to any barley. It is a good wheat, however; a quick grower, drought- and rust-resistant, and has small, hard, translucent kernels. It has done well in California. Gluyas was selected from Ward Prolific. It yields well and is fairly rust-resistant, and has met with much favor in south Africa.

CHAPTER IX

CEREAL IMPROVEMENT — HYBRIDIZATION

COMPARED with the results of introductions and selections, very little improvement of cereals has been accomplished through hybridization in this country and Canada. Much more proportionally has been done in that line in other countries. Every year there is some addition to our knowledge of principles and methods.

214. Need of hybridization. — While few successful hybrids of cereals have been established, it is probable that more attention will be given to the subject in the future. Qualities very desirable or even necessary for a particular district may be entirely lacking in varieties which are, in other respects, admirably adapted to it. In such an instance a recombination of characters, by crossing the adapted variety with another having the special character desired, may bring together in some one of the progeny just the qualities wanted. For example, rust-resistance is not strong in any of the wheats preferred for bread flour, therefore crosses of such varieties with very resistant ones of other groups are now under experiment, with the aim of securing a good milling wheat that is rust-resistant. So it is often desirable to add earliness to the characteristics of a variety otherwise good. These accomplishments are not generally considered as possible otherwise than through hybridization, as it is not believed that additional characters are acquired by selection.

The possibilities of improvement through hybridization, accompanied by discriminating selection, in the hands of skillful breeders, seem to be practically unlimited.

215. Manner of natural pollination. — Under the discussion of each cereal separately, its flowers have been described. It may be stated further that the flowers are anemophilous. It is a fact of much importance in connection with breeding operations that all small cereals except rye are generally self-pollinated. The degree of closeness of fertilization of wheat, oats, and barley appears to increase in about the order named, barley being extremely exclusive. In fact, the development of the barley plant, and particularly the relation of time of flowering to that of emergence of the spike, are such that natural cross-fertilization is, in many instances, probably impossible, and even artificial crossing of certain groups is accomplished with difficulty. It is no doubt partly for these reasons that there are a greater number of established varieties of these cereals than there are of rye, as varietal distinctions in the former are not constantly obliterated by natural crossing. However, the number of varieties probably depends largely also on the number of foundation species of the cereal and its age in cultivation.

216. Pollination of rye. — That the rye flower is usually self-sterile there seems little doubt (see Ulrich, 1902). However, a single spike of rye when isolated may produce a few kernels;[1] and several spikes of the same plant, inclosed with each other, but isolated from others, may produce a still larger number of kernels. There is apparently a varietal difference in this regard, some varieties producing a larger number than others, although none

[1] A spike is occasionally found which sets a large number of seeds, but this may be due to accidental crossing.

shows a great degree of self-pollination. Two isolated spikes on different plants inclosed with each other are much more fully fertile, and it seems certain that every variety of rye must depend upon cross-pollination between different plants for normal fecundation and grain production. Since rye is necessarily cross-fertilized, it is difficult to separate and establish distinct commercial varieties. Even when such varieties are established, the difficulty of maintaining them pure is great and probably demands concerted community action. The difficulty is increased in direct proportion to the size of neighboring fields of rye. On the other hand, the fact that color of seed is a dependable segregating character will assist greatly in maintaining purity of strain, as the results of crossing may be at once detected in the kernels.

217. Mendel's law of hybridization. — In 1865 Gregor Johann Mendel published an article on plant hybrids in the Proceedings of the Natural History Society of Brünn, Austria, in which he discussed fundamental principles of hybridization and heredity.[1] This paper appears to have remained unknown for 35 years. In 1900, De Vries, in searching plant-breeding literature, came across the paper and published an account of it that year. Afterward, Correns, Tschermak, Bateson, and others discussed the theory of Mendel in various papers. Webber introduced the subject in this country, while Spillman found numerical results in his own study of wheat hybrids, corresponding to those reported by Mendel, before the latter's views were republished.[2] The published restate-

[1] There is an English translation of the paper in the Jour. R. Hort. Soc. XXVI, 1910.

[2] An interesting statement of the rediscovery of Mendel's Law is given in Bailey and Gilbert, Plant-Breeding, pp. 155–156.

ment of Mendel's views in connection with those of De Vries on " mutations " and " elementary species " and of Johannsen on pure-line selection has effected recent plant-breeding discussion and practice to an extent that is revolutionary.

218. Explanation of the theory. — The theory of Mendel, known generally in recent years as "Mendel's Law," may be explained as follows: Suppose that in 1915, 16 flowers of a Fultz wheat plant having awnless spikes are successfully fertilized with pollen from a Turkey wheat plant having awned spikes. The 16 kernels resulting, when planted next year, will produce 16 new hybrid plants, all of which will be awnless or slightly awned. Absence of awns is therefore said to be dominant. This is the first generation, indicated in technical literature as F_1. If 100 kernels from each of these plants are planted in 1917, the 1600 plants of the F_2, or second generation produced, will segregate, as to the character of awns, into three groups, of (1) 400 plants with awned spikes, (2) 400 plants with awnless spikes, and (3) 800 plants that are true hybrids; but as absence of awns is dominant these hybrids will also be awnless or some of them slightly awned. Practically, therefore, there are, in appearance, 2 groups resulting, one of 400 constant awned, and another of 1200 all awnless, but theoretically one third of the latter are constant awnless and two thirds are inconstant awnless. The progeny of the 400 awned plants remain constantly awned through all succeeding generations, and the presence of awns is therefore known as a recessive character. If 10 kernels from each plant are again planted in 1918, there will result the third or F_3 generation, in which 4000 plants are constant awned and 4000 constant awnless, while from the 800 F_2 hybrids will result 2000 more constant awned plants and 6000 awnless, of which 2000 are constant and 4000 are inconstant.

219. Verbal expression of the law. — Mendel's Law may be expressed verbally as follows: Differentiating characters in the parents of plant hybrids reappear pure and in mathematical regularity in the second and succeeding generations of their progeny; each character separates in each of these generations in one fourth of the progeny, and remains constant thereafter. The mathematical formula is, 1D : 2DR : 1R. 1D and 1R come true, but 2DR breaks up again into dominants and recessives in the ratio of 3 to 1.

Mendel did his work with garden peas which are self-fertile, and therefore the behavior of his hybrids was similar to that of hybrids of the small cereals. He chose a special set of parents to illustrate each character, one set for seed shape, another for seed color, another for pod shape.

When the parents differ in two or more characters there is effected a recombination of characters, of much value in breeding.

220. Unit-characters. — From the work of Mendel, De Vries, and others has resulted the conception of unit-characters, so called because it is asserted that they may be really treated as units of the plant under consideration. These units are even regarded by Bateson (1909) as corresponding in a sense with atoms in chemical elements.

On this basis, all hybrids are defined as recombinations of unit-characters of the two parents. No intergrading or modification of characters occurs. Extremes are not resolved into means by crossing. Medium colors of kernels in hybrids are explained by the fact of dominance. A hybrid of black and white oats breaks up in the second generation into 25 per cent black, 25 per cent white, and 50 per cent brown, because of the dominance of black color, but in the next generation half of the brown hybrids are split again into absolute black and white. These unit-characters are often called segregating or Mendelian characters. The fixity of unit-characters has been disputed by some.[1]

221. Dominants and recessives. — The application of Mendel's Law is best seen when the two parents possess characters that are opposed to each other, as in the instance of awned and awnless wheats. In such a case the opposing characters are termed a character pair. If one of the characters is stronger, it is said to be dominant, and it alone will appear in the first generation, the other remaining concealed or recessive. Presence of awns is recessive, and therefore completely awned plants will not appear until the second generation, but the progeny of these will afterward breed true. There is evidently some advantage in knowing what characters are recessive, as hybrids showing such a character in the second generation are at once fixed as to that character. Some examples of dominant characters and their corresponding recessives are as follows: —

Dominant characters: —	Corresponding recessives: —
Spikes awnless	Spikes awned
Red chaff	White chaff
Gray chaff	White chaff
Black hulls (oat kernels)	White hulls (oat kernels)
Red kernels	White kernels

[1] See Castle, W. E., The Inconsistency of Unit Characters, Am. Nat. XLVI, 352–363, 1912. Also Pure Lines and Selection, Jour. Hered. V, 93–97, 1914.

Dominant characters: —	Corresponding recessives: —
Keeled glumes	Rounded glumes
Hollow culms	Solid culms
Pubescent chaff	Glabrous chaff
Broad leaves	Narrow leaves
Hard kernels	Soft kernels
Rust liability	Rust resistance

Many of the above-mentioned dominants and recessives were determined for wheat by Biffen (1905, pp. 23–48), who began investigations in 1900, having in view the improvement of English-grown wheat. More recently Thatcher (1913, pp. 37–50) has determined certain of these characters for oats and barley, as follows: —

Dominants: —	Recessives: —
Barley	
Hulled kernels	Hulless kernels
Hooded spikes	Awned spikes
Two-row spikes	Six-row spikes
Oats	
Black hull	White hull
Spreading panicle	Side panicle

222. Occurrences of aberrant forms. — Many occurrences of strange forms in a field of grain, which have been called reversions to ancestral characters or mutations, are rather to be considered as new combinations of existing units, as the result of natural crossing. Some may also be outcropping recessives from intermediate progeny remaining in selections from dominants in cases of artificial hybrids; for it must be remembered that, according to theory, the splitting of intermediates should continue indefinitely. Some of these aberrant forms that are most common are awned spikes in awnless wheat, white or gray oat kernels in black oats, side oat plants in spreading oats, and white kernels in red-kerneled wheat.

223. Correlation of characters. — It has long been supposed that certain pairs of characters are constantly coexistent within the same plant, so that the discovery of one indicates at once the presence of the other; but it is only in recent years that many such instances have been demonstrated. These associated characters are said to be correlated.

The value of correlation in breeding, when once established, is evident. It is of advantage in two ways: (1) if one character of a correlated pair is found in the study of hybrid progeny, or of a variety under selection, the other is known to be present, though it may be only potentially. There is a gain in time, therefore, if the second character is not yet visible or otherwise suspected. (2) Also any means of increasing a desirable character will probably increase the other. For example, from the weight of grain per spike one may predict the relative extent of tillering in the following crop. Results of recent investigations show that both variability and correlation are increased, or rather more clearly exhibited, in proportion as the environment becomes less favorable to the plant; *e.g.* through lack of fertility, lack of moisture, or crowding of individual plants.[1]

224. Examples of correlation. — Correlative characters in cereals have been studied by Tschermak, Proskowetz,

[1] There is not entire unanimity of opinion as to the validity of correlation. Tedin (1908, pp. 8–9, *vide* Newman) says, "I do not believe in the existence of correlations between different simple characters by which a certain character is said to indicate the nature of another, but regard such as being simple manifestations of the same unit character." Johannsen (1909) and others have also expressed skepticism on the matter.

and others in Europe and recently by several investigators in this country. (1) Lyon (1905, pp. 49–72) found that high protein percentage in wheat is correlated with small kernels, having slightly lower absolute and specific weight than those of lower percentage of protein. Heavier kernels contain a greater weight of protein, but a smaller percentage. (2) An interesting case occurs in hulless oats, wherein the hulless character of kernel is always associated with an extension of the spikelet axis and a large number of flowers to the spikelet. The correlation is really triple, as there is associated also a membranous structure of the lemma. These are, in fact, the three chief characters of hulless oats. A very similar correlation occurs in Polish wheat. Such correlations, in which the characters have no direct or causal relation to each other, are called by Webber (1906, pp. 75–81) coherital.[1] (3) Myers (1912, pp. 69–72) reports an absolute relation between weight of straw and weight of grain. It should be remarked, however, that the proportion of grain to straw in different varieties varies exceedingly. (4) In connection with the discussion of the value of large or heavy seed (180–183), Love (1912, pp. 109–118) reported the results of investigations in wheat and oats, showing that tall, heavy yielding plants produce large seed from which a correlation of these characters may be inferred. (5) Roberts (1912, pp. 80–109) concludes that tillering is highly correlated with weight of grain to the spike. (6) Love and Leighty (1914, p. 64) found that in oats, height and number of culms and average yield of culms are directly correlated.

Numerous other examples of correlations are reported

[1] Love and Leighty (1914, p. 68) use the term stable instead, in opposition to fluctuating or environmental correlations.

by American investigators, and a very exhaustive list belonging to each cereal is given by Tschermak (Früwirth, 1910, pp. 119–121, 195–197, 248–253, 332–334).

225. Discrimination in cereal breeding. — Much loss of time is avoided if the cereal breeder will form in mind a purpose or ideal, and then work definitely to that end. Just one important quality should be sought in the same cross. Permitting others to be considered will only interfere and delay the work, unless some very striking form appears which is seen at once to promise something of unusual additional value for a particular purpose. If, for example, it is attempted to add, by crossing, rust resistance to a wheat already good in many other respects, that quality only should be kept in view. Manifestly the most difficult thing, requiring critical knowledge and good judgment, is the selection of the parent varieties and then the individual parents. To give ample opportunity for variation, numerous crosses should be made of the same parent varieties. The crosses themselves are only starting points. The greater part of the work is the discriminating selection from the progeny. It is highly important that all breeding be done in the district where the new strains are to be distributed, in order that the breeder may work with a full knowledge of the conditions and give the varying progeny an opportunity to fit the environment.

226. Method of cross-pollination. — The parent plants having been selected, it will depend chiefly on the circumstances of flowering which shall be chosen as the female parent. If no other conditions need be considered, the one ripening later should be chosen. The essential tools needed in artificial crossing are forceps, preferably self-closing, and small scissors. Supplies of paper bags and very small, white tags, with strings attached, for labels are also required. The operation of artificial cross-pollination is as follows: The lemma and palea of the flower to be cross-pollinated are spread apart, and, with the forceps, the three stamens are taken out bodily, thus completely emasculating the flower, if the operation has been done at the proper time, just before the anthers are ripe. At the same time, or soon after, pollen is taken from the fully ripened flowers of the plant selected for male parent, and scattered within the opened flower that is emasculated, after which it is smoothed back into its former condition as nearly as possible. After pollination, and during the interval between emasculation and pollination, if the latter is at all delayed, the spike or panicle should be covered with a paper bag, as a precaution against the accidental introduction of foreign pollen (Fig. 64).

FIG. 64. — Hybridizing barley.

227. Accompanying details. — In practice there is much variation as to details of the work. Usually about 16 flowers on each spike are operated on, these being the

8 outside flowers of the 4 best spikelets about the middle of each side of the spike, the middle flowers being emasculated but not pollinated. All other flowers on the spike are either emasculated or removed. For a label, a small white tag is tied to the culm, and the names of the parents and date of the operation written upon it. An average of about 60 per cent of flowers artificially cross-pollinated set seed (Fig. 65).

228. Limits of hybridization. — Apparently varieties of all the cultivated subspecies of cereals may be successfully crossed artificially. Until recently the forms of einkorn were never crossed with other subspecies, but even this has now been done. Several successful crosses have been made between wheat and rye, though very rarely have these hybrids produced any seed. No such crosses have succeeded, however, with rye as the female parent. Leighty (1915) has described several cases of natural wheat-rye hybrids.

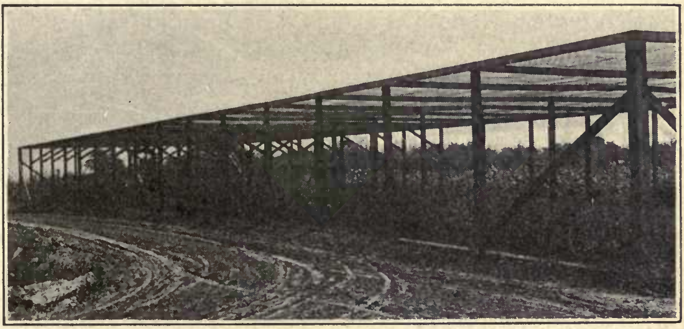


FIG. 65. — Cereal hybridizing nursery cage, for protecting the grain from the ravages of birds.

Oats and barley have not been crossed with rye or wheat, or with each other. The wild emmer already referred to (38) has been successfully crossed with several cultivated forms of wheat.

229. Composite crossing. — Hybrids are usually the direct result of crosses between varieties rather closely allied. Even so, the recombination of characters thus resulting give opportunity sometimes for the choice of new forms adapted for certain purposes, which might never be secured otherwise. When one of the parents is already a hybrid, or if two hybrids are crossed, the resources thus opened for a choice of new forms are very much greater. The variations will be still further increased if the crossing is between groups widely different; *e.g.* if the four parents of a double cross should be an emmer, a poulard, a durum, and a common wheat. Farrer has probably done the greatest amount of composite crossing. Garton has combined the practice of composite crossing with the selection of parents from widely separated groups.

230. Pringle's hybrids. — The pioneer in the production of wheat hybrids in this country was C. G. Pringle of Charlotte, Vermont. Defiance, now the best known of his varieties, and still ranking as an excellent wheat, is the result of a cross of a club variety with a Pacific Coast common white wheat, in 1871. It is an awnless, white-chaffed wheat with white kernels, and is rust-resistant. It was distributed by Bliss and Sons in 1878. Champlain is a cross of Black Sea and Golden Drop, made in 1870, and distributed in 1878. It is an awned, white-chaffed wheat, with reddish white kernels, and is rust-resistant. Other good varieties were his No. 4, No. 5, No. 6, and Pringle Best, apparently none of which is now cultivated. Pringle Excelsior oat is a hybrid of Chinese Hulless with the common variety Excelsior, introduced in 1881. It did not appear to be satisfactory.

231. Work of Blount. — A. E. Blount, while connected with the Colorado Agricultural College, did much work in crossing wheats, and among a comparatively large number of hybrids, produced some that are now not only well known in this country, but are among the most valuable sorts in Australia. They have been used by Australian wheat breeders probably more often than any other foreign sorts, as the parents of hybrids produced in that country. The most important of Blount's wheats are perhaps the following: Amethyst, Improved Fife, Hornblende, Gypsum, Blount No. 10, Felspar, Ruby, and Granite. Gypsum (Blount Lambrigg), Hornblende, Quartz, and Improved Fife are the most popular in Australia. In New Mexico, where field tests of all his hybrids were last made, Ruby and Felspar have been most extensively grown. An important characteristic of several of Blount's hybrids is that they are rather rust-resistant, and it is partly for this reason that they are so much used in Australia. Improved Fife has also an excellent quality of kernel.

232. Fulcaster wheat. — One of the most popular wheats of the eastern United States, ranking easily next to Fultz, is the variety Fulcaster, produced by S. M. Schindel of Hagerstown, Maryland, in 1886. It is a hybrid of Fultz and Lancaster, and is an awned, semi-hard, red-kerneled, white-chaffed wheat. It is grown particularly in the region from Pennsylvania to Oklahoma and southward. It is now probably even more generally grown than Fultz (Fig. 66).

233. Work of Jones. — The work of A. N. Jones of Le Roy, New York, has had a very great influence in wheat

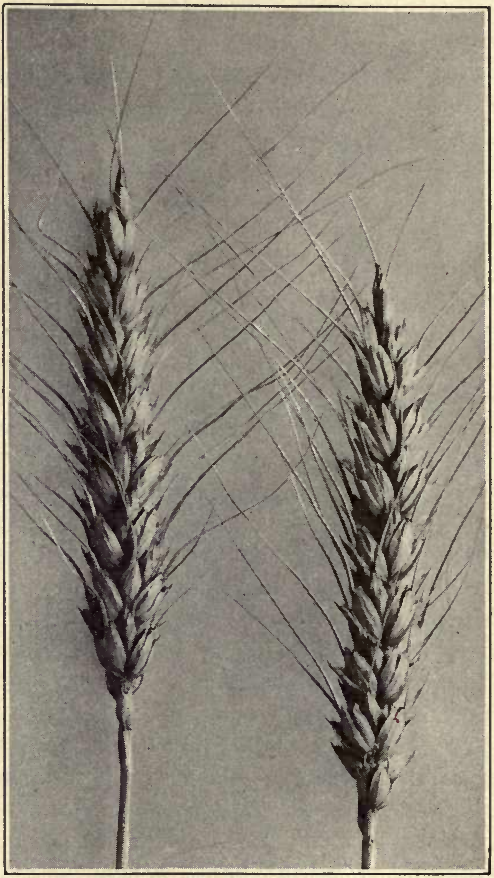


FIG. 66. — Fulcaster wheat.

culture in this country. His varieties are numerous, and some of them have been widely used. Jones ranks with Farrer and Garton in his practice of composite crossing.

He also adhered to a particular aim in all his work. The wheats previously grown in New York and other eastern states were inclined, on account of the nature of the soil and climate, to be soft and starchy. Jones therefore gave much attention to raising the standard of eastern varieties in respect to gluten content, and in some measure succeeded. Of his first varieties the two most popular are his Winter Fife and Early Red Clawson. The former is descended from Fultz, Mediterranean, and Russian Velvet, and is an awnless, velvet-chaff wheat with amber grains, soft or semi-hard. It is grown chiefly in the eastern and north central states, and would be of great value in the Palouse country were it not for its shattering. Early Red Clawson is a hybrid of Clawson and Golden Cross, the last named being a hybrid of Mediterranean and Clawson. It has a reddish kernel, and is in some respects similar to Clawson, but matures earlier and has a stiffer straw. Probably the next best known variety is Early Genesee Giant, which has been much grown throughout New York and Pennsylvania.

Diamond Grit and Bearded Winter Fife most nearly approach the Great Plains wheats probably in gluten content. The former, a direct cross of Jones Winter Fife and Early Genesee Giant, is an awned, white-chaffed, semi-hard, red-kerneled variety. The latter has Jones Winter Fife as one parent, but is harder and has a better quality kernel. Early Arcadian is an awnless, red-chaffed variety with club- and square-shaped spikes and light amber kernels. It is a direct cross of Early Genesee Giant and Early Red Clawson.

234. Work in Canada. — William Saunders of Ottawa produced a number of new hybrid wheats adapted for growing in the northern states and Canada. Some of the most important are Preston, Stanley, Percy, Dawn, Huron, Alpha, Bishop, Progress, Early Riga, and Countess. Preston is now widely grown. Both Preston and Stanley are selections from the progeny of a hybrid of Fife and Ladoga. Huron is awned, and is prolific and early. Percy is also earlier than Fife. Early Riga is a hybrid of a Russian variety Onega and Gehun, from an altitude of 11,000 feet in British India. It is very early, ripening 8 to 9 days earlier than Fife. Bishop is a product of Ladoga crossed with Gehun; kernels yellowish, spikes awnless, yellowish chaff, ripening early, yield fair. Pioneer wheat is a selection from the progeny of a cross between Riga and Preston made by C. E. Saunders in 1903. It is awned, has red, hard kernels, and is very early.

235. Marquis wheat. — The Canadian hybrid wheat which has made by far the greatest reputation is Marquis, though Preston has met with much favor. Marquis wheat is one of the descendants of a cross between Calcutta Hard Red, an early ripening Indian wheat, and Fife. The cross was apparently made by A. P. Saunders, probably at the Agassiz (British Columbia) Experiment Farm in 1892. In 1903, Dr. C. E. Saunders continued the investigations with this wheat, and made a series of selections from it. Its high bread-making strength and color of flour were demonstrated in tests at Ottawa in 1907, and all surplus seed was sent to the Indian Head Experiment Farm for propagation.

The progress of Marquis on trial in the western prairie region was remarkable. In 1907 there was much rust, and cool wet weather. Marquis, being very early, and therefore rust-escaping, headed the list of varieties in plats and fields alike. In a 5-years trial at Indian Head, Marquis gave an average yield of 50 per cent more crop than Fife. For northern localities in Canada, Marquis wheat is chiefly valuable for its earliness, strength of straw, heavy bushel weight, fine appearance of the kernels, and excellent baking strength. The distinguishing marks in form of the kernel are the shortness in proportion to the breadth and the accentuated trough-shaped crease.

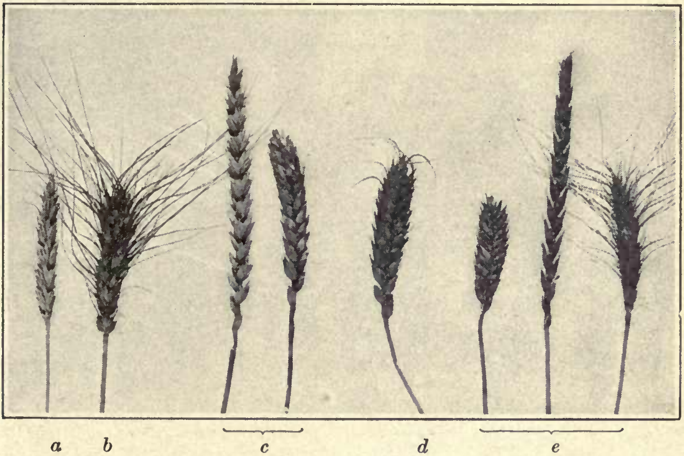


Fig. 67. — U.S.C.I. wheat hybrid 119. Ghirka Winter × 1392: *a*, female parent; *b*, male parent; *c*, first generation; *d*, second generation; *e*, third generation.

236. Work of Rimpau. — W. Rimpau, of Schlanstedt, Germany, in addition to his mass selection work, made a number of important hybrids, some of which show the results of crossing with parents from different subspecies. Some of the most interesting, showing great variations from the parents in form and color, are: Rivett Bearded × Red German Bearded, Rivett Bearded × Squarehead, and Mainstay × Squarehead (Rimpau, 1891, pp. 335–371).

237. Garton's hybrids. — John Garton, of Newton-le-Willows, Lincolnshire, England, has done very interesting work in cereal breeding. The principle on which he operates is that a variety of wheat, oats, or barley, after

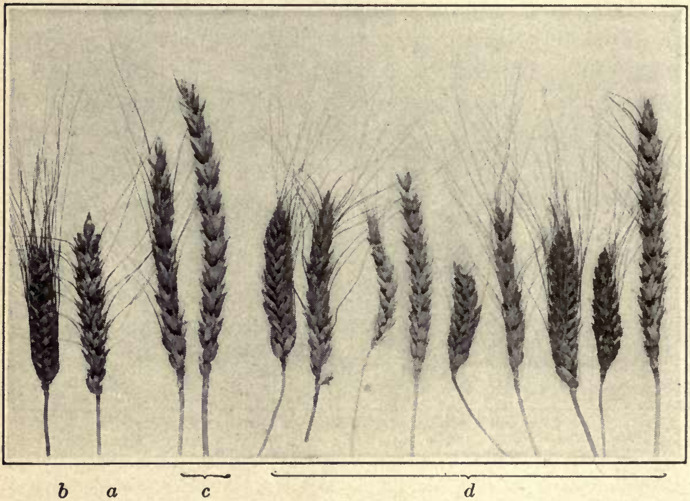


FIG. 68. — U.S.C.I. wheat hybrid 155. Banat × 1409 (durum): *a*, female parent; *b*, male parent; *c*, first generation; *d*, second generation.

many years' cultivation, being close-fertilized, deteriorates and needs "regenerating" by a cross within the variety, in order that it may give best results. Even the already well-bred oat variety Swedish Select, he has thus "regenerated," and maintains that it is now yielding much better than the parent variety. Crossing of different subspecies is also practiced to obtain qualities not present in existing varieties. Crosses are made between two-row and six-row barleys, between common oats and wild and hulless oats, and between common wheat and almost all other subspecies of wheat. In this way, durums and spelts have given the qualities of rust-resistance and non-shattering to new wheats, hulless

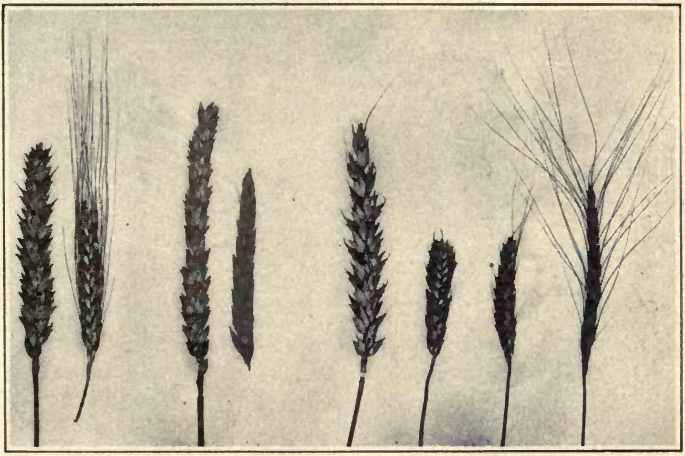
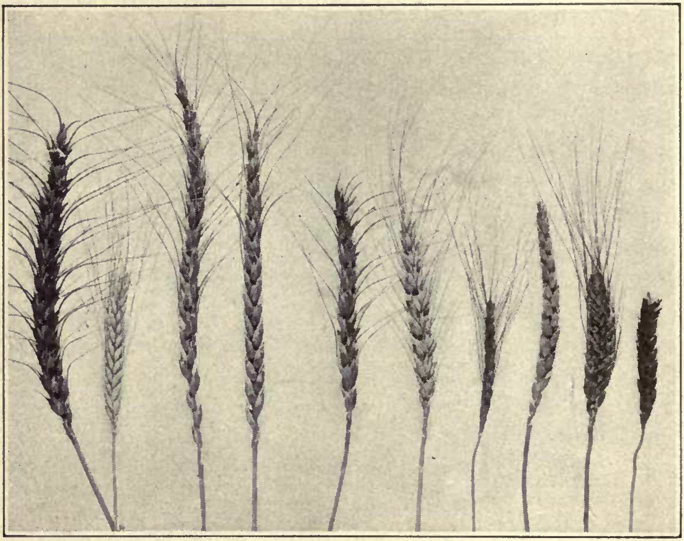


FIG. 69. — U.S.C.I. hybrid wheat 167. Jones Winter Fife × Ufa emmer: *a*, female parent; *b*, male parent; *c*, first generation; *d*, second generation.

oats have contributed length of spikelet in oat hybrids, and six-row barleys have increased the fertility of hybrids with two-row sorts, while the quality of the latter is retained.

238. Examples of the Garton hybrids. — Victor oat was "bred from six different parents, two of which are fall oats." It has very long, symmetrical, wide-spreading, drooping panicles and jet-black kernels, and stools well. The young plants tend to spread out on the ground in the manner of a true winter cereal. Garton No. 46 spring wheat is descended from a hybrid of Early Russian and Fife, which was recrossed on Fife. It has a hard, glutinous kernel, and is claimed by the originator to be extremely early. Regenerated Fife is the result



a b *c* *d*

FIG. 70. — U.S.C.I. wheat hybrid 48. Theiss × Ufa emmer: *a*, female parent; *b*, male parent; *c*, first generation; *d*, second generation.

of a cross within the variety. Garton No. 158 barley is a result of a composite cross of two-row and six-row varieties, but is itself six-rowed. Other new strains by Garton are Tatar King, President, and Garton No. 5 oats and Garton No. 98 barley (two-row), of which the Tatar King oats is well known. The No. 5 oat is a hybrid of Senator and Regenerated Swedish Select.

239. Work of the United States Department of Agriculture. — Investigations of cereals by the United States Department of Agriculture have been heretofore largely a study of cereal groups and standard varieties and the introduction and acclimatization of adapted foreign varieties. A considerable amount of breeding work, however, has been done. Wheat breeding began in 1898, oat breeding about 1902, and barley breeding about 1904, and very recently some breeding experiments with rye have been started. With many of the important practical results the breeders are not yet satisfied, but much gain has been made in the addition of earliness in hard winter wheats and of rust-resistance in spring wheats. Over 1000 hybrid selections from about 500 original wheat crosses have been under observation at one time or another. For rust-resistance, Khapli emmer, Persian Black wheat, einkorn, and several durums have been found, so far, to be the best parents, but still better ones are sought. For earliness in winter wheats, Zimmerman has appeared to be a good parent (Figs. 67–70).

Fig. 71. — Spike and spikelets of Arlington Awnless barley.

240. Examples of United States hybrids. — Arlington Awnless barley is an interesting result of one of the barley hybrids. In 1904 a cross of Tennessee winter (six-row) with Arabian Black (two-row) was made. In the third generation a peculiar form appeared in which some lateral spikelets produced rudimentary kernels with short awns. From these kernels, planted, through rigid selection a six-row form finally resulted, having extremely short or no awns. It was hoped to make it a winter barley, but it is not yet particularly winter hardy. Other so-called awnless barleys are rather of the hooded type (Fig. 72). Of the oat crosses the following have furnished some excellent selections: Burt × Sixty Day, Danish Island × Asia Minor Rustproof, Sixty Day × Probsteier.

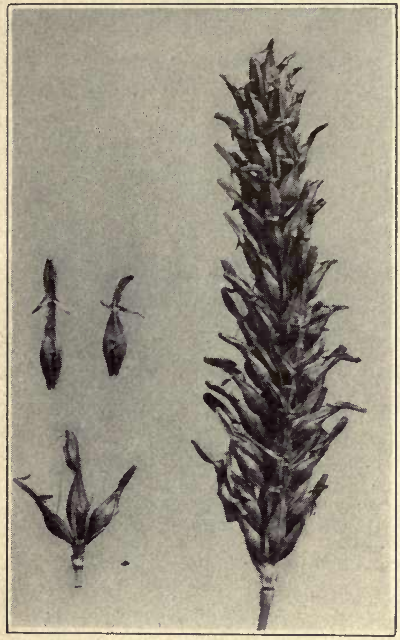


FIG. 72. — Spike and spikelets of a hooded barley.

241. Work of Farrer. — Probably no one man has made so many new hybrids in any plant species that have come into practical use as William Farrer of Lambrigg, Queanbeyan, New South Wales, who worked with wheat. He was a good example of persistence in attaining an ideal. He also kept constantly in mind the milling value of his new varieties and made milling tests of each. At first, Farrer made much use of Blount's wheats, which were found well adapted in

Australia. He continually practiced composite crossing. Formulas indicating his crosses would often run like the following actual instance: $14 \times (\overline{1300 \times \text{Beloturka}} \times 57) \times (193 \times \text{Ward White})$.

242. Farrer's principal hybrids are as follows: Federation is descended from a cross of Purple Straw and Yandilla, the latter itself a Fife-Indian cross. It is "the first successful attempt to improve the flour strength of the wheats grown in Australia at the time." It is now the most popular grain wheat in Australia. Comeback is a composite hybrid having Fife and Indian parents; early ripening, fairly prolific, drought-resistant, white-chaffed, white-kerneled, slightly inclined to shatter, not adapted for cold winters. Bunyip is a cross between Rymer and Maffra, the former being descended from Fife and Purple Straw. It is a very early white-chaffed variety with attractive kernel. Cedar, another wheat descended from Fife and Indian parents, is called "the best of all the milling wheats created by Farrer." It is a red-kerneled wheat, and for flour production is classed as "Australian Strong-red." Firbank, a cross of Zealand and Maffra, is noted as a good hay wheat; white-chaffed and white-kerneled; hay of good quality. Florence, a composite of several varieties including White Naples and Fife, is said to strongly resist bunt, for which purpose it was produced; a good milling, white-kerneled wheat; early and fairly rust-resistant and drought-resistant. Genoa, Rerraf, Cleveland, Thew, Bayah, and Warren are also Farrer's hybrids. The first named is said to be bunt-resistant. Thew and Warren were bred for rust-resistance.

243. Other Australian hybrids. — The following varieties were created by Hugh Pye, Principal of Dookie Agricultural College and formerly associated with Farrer:

College Purple Straw wheat, a variety created from Dart Imperial, Purple Straw, and Fife-Indian varieties, has clubbed spikes, awned at the end, is somewhat liable to smut, prolific, drought-resistant, non-shattering. Warden wheat is said to be the most popular hay wheat in Victoria. It is a composite cross as follows: (Quartz $\times$ Ward White) $\times$ Red Bordeaux. It is prolific as a grain wheat and drought-resistant. Wallace is a composite cross of Dart Imperial, Purple Straw, Fife, and Indian varieties. It is prolific, drought-resistant, tillers well; straw slightly purple; spike clubbed and awned at end; kernel soft white. Commonwealth is a cross between Federation and (Queen Jubilee $\times$ Australian Talavera). It is drought-resistant, and has exceeded Federation in yield, — 8 bushels to the acre. Currawa, Moira, and Major are also hybrids created by Pye.

Yandilla King wheat is a hybrid of Yandilla and Silver King, created by Richard Marshall of South Australia. It is late maturing, prolific, stools heavily, is liable to smut, and has a large, medium-hard kernel.

PART II

CEREAL ENVIRONMENT

CHAPTER X

SOIL RELATIONS

SOIL in this connection is considered as a part of the cereal environment. Soil fertility will be discussed in other chapters.

244. Favorable soil environment. — It is sometimes said that any soil will produce good cereal crops if there is plenty of water. But many very sandy soils are not at all suitable for the small grains, though they may be good for maize, sorghums, and legumes. Also, while certain substances are necessary as foods for all plants in common, the kinds most needed, and amounts of each, vary for different crops.

It has been found that the roots of cereal plants extend ordinarily to a maximum depth of 40 to 50 inches, though extreme cases are known where they have reached a depth of 7 feet or more (see 30 and Fig. 10). The feeding range of cereal roots is therefore usually within the first 5 feet of soil. The small cereals are also short-lived, the period of growth being commonly from 90 to 110 days, or a little less for barley. It seems, then, for best cereal production, there must be adequate water and mineral food furnished to the plant within about 5 feet of soil, in three to three and one half months' time. Even the few winter cereals are in an inert condition during the winter, and are dependent, largely, on the following summer rains.

The soil requirements may therefore be summarized as follows: (1) at least 5 feet of soil in the proper physical condition for storing a large percentage of the rainfall; (2) mineral foods in sufficient abundance in the same depth to furnish quickly the amount of these necessary in the short life of a cereal crop; (3) plenty of lime to help render available other foods; (4) humus as a source of nitrogen and for increasing the water-absorbing and retaining capacity of the soil.

245. Black prairie soils. — The conditions just described are found to exist most perfectly in prairie soils. They are, in general, a deep, black silt, clay, or sandy loam, or heavy clay, rich in humus and mineral bases, and supported by a subsoil, varying greatly, but often little different from the upper soil. The depth of black soil in the Red River-of-the-North Valley and in extreme eastern Russia reaches several feet. The bulk of the small-grain production in the two principal cereal regions of the world, the Great Plains of North America and the Black Earth belt of Russia, is supported by a prairie soil formation. The more important of these, the Russian Black Earth, is characterized by a more perfect development of this formation.

246. Mineral bases, phosphates, and nitrogen. — In all cases where a soil is found to be naturally imperfect in its food supply for cereal production there is a lack of one or more of the substances, potassium, phosphorus, and nitrogen. These, with other mineral bases, such as calcium and magnesium, are usually abundant in prairie soils, and are very important for the production of grain of good quality. It is a fact well known to Russian agriculturists that in the Black Earth belt the hardness of the wheat kernel and its protein content increase in the same direction in which the proportion of humus and mineral bases increases, which is to the east and northeast. In the Great Plains such increase occurs to the north and west. It is true that protein production is largely dependent upon climate (317), but its source, to begin with, must be in the soil.

247. Humus. — Experiments show that the loss of food materials from the soil after continuous cropping is not simply a decrease in the amount of these present. There is also a gradual loss of humus, and the soil gets out of the proper condition for using the valuable salts that may be present. An important influence of the humus in this connection is its ability to conserve moisture. Humus, therefore, appears to play a double rôle, of furnishing nitrogen and conserving moisture (Snyder, 1896).

Such facts may at least partially explain why grain soils in places in the middle West and Northwest have failed to give such returns in recent years as formerly, apparently from some other cause than unfavorable seasons. By crop rotation and other means, the humus content should be restored.

In the direction of diminishing rainfall and as the native grass covering becomes more scant, the depth of humus diminishes, until finally, in the strictly arid regions, there is little or none. As an offset to this condition, it is also a fact, as shown by Hilgard and Jaffa, that the humus of arid regions is much richer in nitrogen than that of humid regions. The actual percentage of humic nitrogen in the soil, therefore, is apparently about the same in arid regions as in semi-arid regions.

248. Importance of lime. — One must always keep in mind the great importance of lime as a grain soil constituent. It is indirectly an indispensable substance. The necessity for lime applications in humid areas for correcting soil acidity is well known. There are several other ways in which lime is useful, however, that are not usually recognized. Hilgard has often remarked upon the presence of lime in our prairie soils, and mentions the following ways in which it acts as a soil factor: "It causes (*a*) a more rapid transformation of vegetable matter into active humus, which manifests itself by a dark or deep black tint of the soil, and (*b*) the retention of such humus against the oxidizing influences of hot climates. (*c*) Whether through the medium of this humus, or in a more direct manner, it renders adequate for profitable culture percentages of phosphoric acid and potash so small that in the case of deficiency or absence of lime the soil is practically sterile. (*d*) It tends to secure the proper maintenance of the conditions of nitrification whereby the inert nitrogen of the soil is rendered available. (*e*) It exerts a most important physical action in the flocculation and therefore tillability of the soil. (*f*) In the same connection it tends to increase the absorption coefficients of soils for moisture and gases."

249. The origin of prairies. — Much has been written on the origin of prairies without any agreement in conclusions. Various theories have been offered by Winchell, Lesquereux, J. D. Whitney, and others in this country. Russian investigators have given far more attention to the subject than any others and agree upon the theory of the presence of vegetation itself as the chief factor in black soil formation, but modified and controlled to a great extent by other factors such as temperature and moisture.[1] However theories as to origin may differ,

[1] So persistent have been the activities of Russian investigators of the botany and surface geology of the Chernozëm that a school of geo-botanists has arisen pursuing practically a distinct new science of geo-botany. The leaders were Ruprecht

it is commonly agreed that prairie soils have, from a previous indefinite time, been composed of finely divided particles. How far back vegetation began to be concerned in their formation is not well established, though Russian writers maintain that it was very long ago, nearly or quite as long as the beginning of the soils themselves.[1] As to the formations underlying these soils, they are known to be of the most diverse kinds, ranging in this country from carboniferous to the uppermost tertiary and loess. In the Red River Valley of the northern Great Plains they overlie the deposits of the ancient lake Agassiz. Along the Mississippi River and branches they overlie glacial drift. A similar diversity prevails in the underlying formations of the Russian prairies. As over one third of the small grain of the world, exclusive of rice, is produced in Russia, North America, and Argentina, most of which is grown in the prairie regions, it will be well to state briefly the general characteristics of these areas.

250. The Russian chernozëm. — The Russian word, chernozëm, is a derivative from two root words, "chernui," black, and "zemlya," earth. It is, therefore, literally the black earth of Russia and Siberia. It coincides, nearly, with the steppe region as distinguished from the

and Dokuchaev (who was the actual founder of the school), who have been followed more recently by Kostichev, Krasnov, Tanfiliev, and many others. The literature has already reached several hundred volumes. It would be of great benefit to American students to have at least abstracts of these publications put into English.

[1] The three distinctions of these soils must be kept in mind: (1) the grass humus (indicating cereal adaptation) with mineral salts, (2) a dry climate, and (3) a summer rainfall. So-called prairies (lowland meadows or marshes) within timbered or humid regions are very different, as are treeless plains with a winter rainfall.

forest area, and is such a well marked physiographic feature of the country, that it forms a basis for its division for agricultural purposes into two distinct regions

Fig. 73. — Map of European Russia, showing the extent and divisions of the Chernozëm or Black Earth.

— the chernozëm and the non-chernozëm. According to the accompanying map (Fig. 73), based upon one by Tanfiliev, it is seen that the chernozëm occupies almost all the southeast portion of European Russia, and extends northeast and southwest. North of it lies the non-chernozëm, which includes the gray forest lands. The area of the chernozëm is said to be about 270,000,000 acres. Within it there are occasional small forest tracts, as might be expected, and also other variations in the form of calcareous districts, especially on the west of the Volga River. In the direction of the Caspian Sea, as the climate increases in dryness, are numerous salt marshes and other alkaline wastes, and nearer to the sea great stretches of drifting sand. These are well known characteristics of all dry steppes, but are mentioned to indicate similarity to our western Great Plains.

It should be stated that the chernozëm in the southwest really begins in the plains of Hungary, where the excellent Hungarian winter wheats are grown. In the east it also extends across the Ural River far into Siberia.

251. Soil divisions of the chernozëm. — Dockuchaev, in mapping the soils of the chernozëm, divides it into three parts, the southwestern, the central, and the district east of the Volga. (*a*) In the southwestern part the soils are dark brown, with humus 4.5 per cent, soil thickness 32–36 inches, maximum 5 feet, and usual subsoil sandy-clay loess. (*b*) In the central part there are black soils with humus 8.9 per cent, soil thickness 26–28 inches, maximum 45 inches, and a usual subsoil of sandy-clay loess, more rarely a mixture of efflorescent chalk with a cretaceous clay. (*c*) In the part east of the Volga, the soils are black, with humus 9–10 per cent, soil thickness 24–26 inches, maximum 38 inches, derived from Permian and Triassic rocks. Adjoining the last-named part there is in western Siberia a continuation of the black soils, with 10 per cent of humus in the best chernozëm and a soil thickness of 12–20 inches.

Outside the strictly chernozëm soils, but adjacent to them, and bordering the great inland seas, there are (1) near the Black and Azov seas, dark brown soils and gray soils, forming a transition from typical chernozëm to the brown or light brown soils of extreme south and southeast Russia, having as subsoils tertiary sandy-clay sediments, usually marl and clay, sometimes impregnated with gypsum and common salt. Also (2) in Astrakhan and adjacent territory, there are light brown soils, sometimes dark brown or light yellow, with humus 2.3 per cent, soil thickness 10 inches and having a subsoil usually of Caspian sediments very often full of sea salts.

252. The Great Plains of North America. — The general features of our Great Plains are known to almost every reader. It is chiefly important here to call attention to the great similarity of this region to that just described. The principal difference is that the relative positions of different portions of the two are reversed. The encroachment of forest and prairie upon each other is, in this case, on the east instead of the west and north, while the approach to aridity of climate and alkalinity of soil is toward the west instead of the east and south.

The fact that our black prairie soils have been so little studied makes it difficult to give the extent of their area. A painstaking but necessarily rough estimate shows that there are about 275,000,000 acres in the United States alone, with a large area to be added in Canada. In the United States the prairie region includes, in general, almost the whole of the States of the Great Plains proper, as well as parts of Missouri, Iowa, and Minnesota, and apparently an eastward extension as far as western Ohio, and on the west a large part of Montana and small portions of other mountain states. However, as in the chernozëm, there is an approach to perfect prairie soils from the forest lands westward, and the arid lands eastward, up to about the meridians 95 to 98. In Canada the

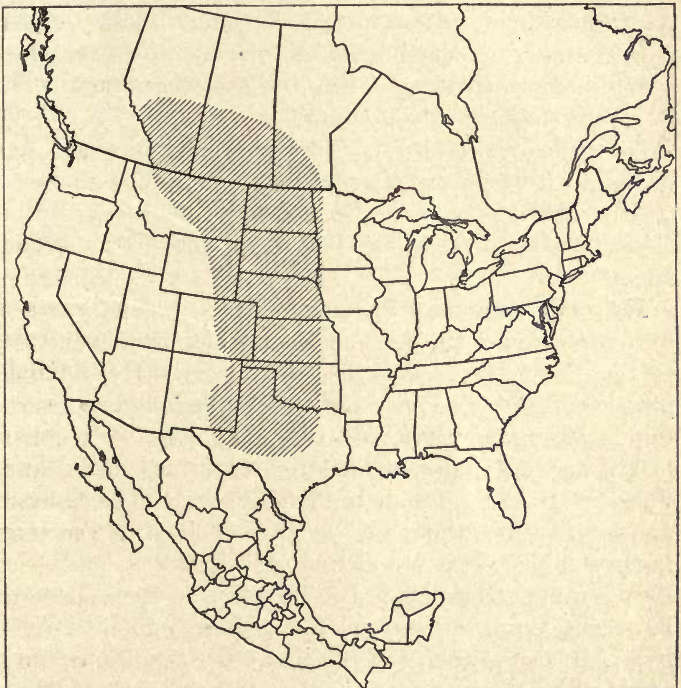


FIG. 74. — Map showing very roughly the extent of the Great Plains in the United States and Canada.

prairie region lies between the 96th and 114th meridians, and narrows rapidly northwestward, reaching as far as the Saskatchewan River, but in Alberta, not much beyond the Battle River (Fig. 74). Taking into account the factor of climate also, the Great Plains is usually considered to extend eastward only to about the 96th meridian.

253. Depth of soil. — The depth of Great Plains soil varies from 6 inches to several feet. It is unusually deep and black in the valley of the Red River of the North. At the different substations of the Great Plains, under federal and state control, the soil of real use to the crop varies in depth from 2 to 8 feet, but sometimes terminates in a subsoil practically the same.

In the southwestern plains are large areas of "red beds," with which are often associated impregnations, at considerable depth, of gypsum and rock salt, similar to the deposits above mentioned as occurring in southeast Russia.

254. The Argentina Pampas. — In Argentina exists a formation known as the Pampas, similar in many ways to the Great Plains and the Chernozëm. The Pampas proper appears to be only a part of a much larger formation including the Chaco, and extending over 700 miles in length and 400 miles in breadth, northward and southwestward from the Rio de la Plata estuary. The climatic and soil features, though as yet little studied, are such as favor a large cereal production, which fact is confirmed by the rapid strides made by Argentina in cereal exports in recent years. However, the greater rainfall over a large part of the area, and possibly other conditions, have resulted in a less protein content in Argentina wheats than in those of the Russian and North American Plains.

South of the Rio Negro there is a second steppe, the plains of Patagonia, in a portion of which, at least, conditions are more ideal for wheat production than in the north, but the region is yet little developed. It is higher and drier, and the winters are colder. In all the plains portion of the Republic, altitude, aridity, and humus progress westward toward the mountains, as in the Great Plains.

255. Prairie and steppe cover. — Grasses are the chief native vegetation in prairie regions. In the Chernozëm a common species is the feather grass (*Stipa pennata*), and the name "Feather Grass Steppe" is, consequently, often applied to portions of it. In the Great Plains feather grasses are also frequent, but the principal species are blue-stems in the eastern, and gramma and buffalo grasses in the western portion.

256. Chemical composition of prairie soils. — Many analyses of Chernozëm soils are reported, of which an important series was made by Schmidt with samples collected by Dokuchaev. Of the Great Plains soils, analyses were made by Ladd of samples from two points in the James River Valley and from Minot and Sykeston, all in North Dakota. About the only analyses of samples from the Canadian area of the Great Plains were made by Shutt and Alway (1909). From what depth Shutt's samples were taken is not stated. The samples analyzed by Alway were taken from a ten-acre fallow field on the Experimental Farm at Indian Head, Saskatchewan, in November, 1904, which field produced over 46 bushels to the acre of oats in 1905. These analyses, being made by different parties on different bases, do not, in some places, exactly harmonize, but all show large to very large percentages of potassium, calcium, and phosphorus, a large proportion of humus, and great water-holding capacity. Often there is also a good percentage of magnesium.

257. Mechanical analyses of prairie soils. — The fact that prairie soils are composed of a large proportion of finely divided particles is well shown in the mechanical analyses made under the direction of Milton Whitney, Chief of United States Bureau of Soils. Comparing the results of those of the Chernozëm samples with those of the samples from North Dakota, a very close similarity is noted, each series showing a large proportion of the small particles, but especially very fine sand, silt, and fine silt. There is thus provision for great absorption and retention of water. Samples from the famous "Blue Grass" district of Kentucky, as would be expected, seem to be in good physical condition. Nevertheless, the smaller actual moisture content and much smaller percentage of organic matter even in these samples indicate less water capacity and a smaller source of nitrogen.

Samples of the Argentina steppe soils, including those of the northern part of the plains of Patagonia, have also been studied by the United States Bureau of Soils, and the mechanical analyses have shown the same special qualities found in the prairie soils of Russia and North America, namely: (1) a large percentage of finely divided soil particles, (2) a high percentage of organic matter, never less than 4 per cent, and from that to 7 per cent, and (3) a percentage of moisture in air dry samples ranging from 3.28 per cent to 9.68 per cent, with only two samples out of 25 under 5 per cent. Of the 8 samples showing 8 per cent or more of moisture, all but one came from Chubut. All samples showing very high percentages of clay, 50 per cent or more, also came from Chubut, where the wheat of best quality in Argentina is grown. These Chubut soil samples also contain the highest average percentage of organic matter.[1]

[1] All these soil samples, from the Great Plains, the Russian Chernozëm, and Chaco-Pampean Plains, were obtained by the

258. Other large cereal areas. — That the plains of Roumania and Hungary, noted for their cereal crops, are practically an extension southwestward of the Russian chernozëm, has been mentioned. The hard kerneled wheats of these plains compete in quality with those of the Russian portion, and have even a greater reputation in foreign markets. Other areas particularly adapted for cereal cultivation lie in different parts of Siberia, in the Indo-Gangetic plains of India, and in Australasia. There are smaller districts even in forested areas which, except for soil acidity, have natural cereal adaptation, so far as soil conditions alone are concerned, such as the prairie lands of Mississippi, Arkansas, and Alabama, and the Clarksville and Hagerstown loams. Soils not well adapted may often be made so by certain amendments discussed in chapters XIV–XVI.

259. The subsoil. — The similarity of surface soil and the lower layers in prairie soils is a fact commonly observed. The change in composition and structure is often very slight for many feet in depth. The richness in plant-food of the lower layers has been shown by analyses of Alway (1909). Lime is particularly abundant as a subsoil constituent, and often increases in proportion to depth. This condition is a fortunate one, and seen to be practically necessary in connection with the nature of the rainfall. As pointed out by Alway, the slight rainfall in the Great Plains often cannot be correlated with the crop production of a particular season, in view of the known water requirement of the crop, without consideration of the water conserved in the lower soil layers

author for the United States Department of Agriculture, and analyzed by the Bureau of Soils, except in cases of analyses made by Ladd, Alway, and Shutt.

through summer tillage or other means. It is therefore important that plant-foods shall also exist in considerable abundance in the lower layers, to the depth of 3 to 6 feet, for solution by the subsoil water, and that the crop plants shall be deep rooted.

260. Soil water. — After all is said as to soil structure and composition, it is clear that the most important constituent of any soil is the water it contains. The food of the richest soil is unavailable without it, and, on the other hand, with it, in unrestricted movement, almost the poorest soil will furnish nutriment for a fair crop, extreme conditions, such as presence of toxins, of course excepted. The water supply for cereal crops is of particular importance, as so large a part of the world production is grown in regions of comparatively low rainfall. In all these regions the necessary mineral constituents being usually present in abundance, as previously shown, the value of different soils may be measured, practically, by their water supply. However, in the humid areas also, there is often a serious lack of available water, and periods of drought occur, which, for these areas, appear equally severe to those occurring in drier regions, where the actual precipitation is much less. In the humid areas, the soil structure and topography of the land are such that much water is lost before reaching the roots. Also because of the greater water requirements of the adapted crops, than in drier areas, a drought of equal intensity apparently causes greater injury.

261. Variation in water supply in different soils. — There is probably no agricultural subject about which there are so many conflicting ideas and theories as the question of the best kind of soil for crop production. At the same time, information on this subject among agronomists themselves is either not extensive or not well defined or harmonized. Field crop students have not looked below sufficiently, but have made their studies entirely above ground, as a rule, while the soil specialists usually have not sufficiently connected their soil studies with the crop as an index. An interesting fact brought out in one's association with farmers, and in the general literature of the country, is the prevailing emphasis given to the food value of soils for certain crops. The truth is that, in a given large area of country, the real basis of comparative values in almost all cases is a question of water supply.

The ability of different soils to absorb and retain water is dependent chiefly upon their mechanical structure, though the presence of alkaline salts and possibly other factors have influence. According to the soil classification adopted by the United States Bureau of Soils, the types of agricultural soils as to texture are as follows: sand, fine sand, sandy loam, fine sandy loam, loam, silt loam, clay loam, and clay. Water absorption and retention increase in proportion to the fineness of the soil.

262. Sandy *versus* heavy soils. — Of course any particular soil will have a mixture of several types and be designated by the name of the preponderant type. In common talk, soils are lumped into two general classes, of light or sandy, and heavy or clayey soils. In the southwestern plains the latter are usually called "tight lands." As the heavy soils, composed of a larger percentage of finely divided particles, will absorb and retain more water it might naturally be supposed that they are the better soils. In actual farm practice there are perhaps about as many advocates of sandy soils as of heavy soils, so long as the former has not reached such a degree of sandiness as to allow "soil blowing." As a matter of fact, practical crop growing shows that both soils possess advantageous qualities, and either kind may be the better under certain conditions. A much better understanding of this subject is now possible through very interesting results of recent investigations of Briggs, Shantz, and McLane, on the moisture equivalent and wilting coefficient of different soils.

263. The moisture equivalent of different soils is the percentage of water they can hold in opposition to a centrifugal force 1000 times that of gravity. To determine it, samples of soils of different texture "are placed in perforated cups and moistened with an amount of water in excess of the quantity they can hold in opposition to the centrifugal force mentioned. After standing 24 hours, the cups are placed in a centrifugal machine which is operated at a constant speed so chosen as to exert a force 1000 times that of gravity upon the soil moisture. Each soil then rapidly loses water until the capillary forces are increased sufficiently to establish equilibrium with the centrifugal force employed. The moisture content of each soil is now not only in equilibrium with a force 1000 times that of gravity, but is also in capillary equilibrium with every other soil which has been similarly treated, so that if the soils are placed in capillary contact in any combination whatever, no movement of water from one soil to another will occur. The moisture content of each soil under these conditions is the moisture equivalent of that soil" (Briggs and McLane, 1912).

264. Application of the principle to different soils. — The soils of finer texture, of course, retain more water. As between a coarse sand and a clay loam, the latter will sometimes retain 30 times as much water as the former in opposition to the same force. In crop growing, it is the transpiration force of the individual plants which corresponds to the centrifugal force of the machine, and pulls upon the water in opposition to soil capillarity. In response to the force, the moisture content of the sandy soil will be reduced to a lower point than that of the heavy soil. It will depend upon several varying conditions whether a sandy or heavy soil is better in any particular locality or season. A clay loam will obtain and hold more water in a season of summer tillage for the next crop. However, owing to the greater ease of absorption of torrential rains by sandy soils, these soils of the Great Plains often have more available moisture an acre than the heavier soils.

265. The wilting coefficient. — In 1912, Briggs and Shantz reported the results of their investigations of the wilting coefficient for different plants in different soils. This is the moisture content (in percentage of the dry weight) remaining in the soil at the time when permanent wilting of the plant begins, as a result of deficiency in the soil moisture supply. A very important result of the investigations is the proof that the wilting coefficient in any soil is practically the same for all plants. Drought-resistance, therefore, does not mean any special ability on the part of the crop to obtain water, but varies inversely as the water requirement. No fact is of greater agricultural importance in attempts to improve cereal crops. As in the case of the moisture equivalent, the wilting coefficient is less in the coarser or sandy soils, showing that these soils will support life in the plant with a much lower moisture content than will heavy or clay soils.

266. Alkalinity of the soil. — The large percentages of mineral bases in naturally adapted grain soils have been mentioned (246). So long as these substances do not occur in extreme amounts, they are very beneficial in furnishing plant-food, and in their good effects on the physical condition of the soil. In the drier portions of prairie regions near the mountains, these substances occur in excess, producing alkali lands. As the cereals are adapted to prairie lands, one would also expect them to be rather tolerant of alkali. This is true to a considerable degree.

267. Alkali tolerance in cereals. — While all the small cereals are somewhat alkali-resistant, they differ considerably from each other in that respect. Barley is the most resistant, according to field experiments of Loughridge (1901, pp. 26–27). Barley was grown to a height of 4 feet in land containing 12,000 pounds of carbonate of sodium to the acre, in 4 feet depth, and produced more than one ton of hay in presence of over 5000 pounds of common salt to the acre. It is better adapted for alkali land than wheat.

The limit of tolerance in wheat reached 1480 pounds of sodium carbonate to the acre. Common salt began affecting wheat injuriously at a concentration of 3920 pounds to the acre-4 feet. So-called gluten wheat made excellent growth in the presence of 24,300 pounds of alkali to the acre, of which nearly 1500 pounds was common salt. From all results so far, the conclusion was drawn that wheat should do well in deep loose soils, having not more than 20,000 pounds total alkali to the acre-4 feet, if there is not over 1200 pounds of common salt or sodium carbonate. Rye, although grown at the same time, was not fairly tested as to alkali tolerance.

268. Pot experiments on cereal tolerance of alkalies. — Leather found in pot experiments that maize was least affected of all cereals by alkalies. Analyses of soil samples from cultivated fields were also made which showed that wheat grew well in presence of 0.137 per cent of sodium carbonate, but was destroyed by 0.2 per cent. The carbonate ("black alkali") was found most harmful, and the sulfate ("white alkali") least harmful. Legumes were more affected than cereals. Two per cent of carbonate in soil around the roots was fatal to cereals.

Black alkali is said to be more serious: (1) because of its corrosive effect on the plant at the crown, and (2) because of its "puddling" action on the soil, making it difficult of tillage.

Harter determined that the degree of injury to wheat seedlings by toxic salts decreases in the order, magnesium sulfate, magnesium chloride, sodium carbonate, sodium bicarbonate, sodium sulfate, and sodium chloride; that wheat varieties from humid regions are less resistant; that resistance varies greatly in individuals of the same variety; and that the same toxic salts act as stimulants in dilute solutions.[1] Kearney and Harter (1907), in later experiments, found (1) great variation in different species of the same family and different varieties of the same species in their degree of tolerance of alkali salts; (2) that calcium sulfate in excess in the same solution greatly diminishes the toxicity of magnesium and sodium salts, in case of all plants tested; and (3) that the comparative resistance of plants and salts in mixed solutions comes nearer that observed in connection with combinations of alkali salts occurring naturally in western soils than when these plants are grown in pure solutions of single salts. Wheat was

[1] The author also obtained the same results with toxic salts in dilute solutions in experiments with spores of the rust fungi.

found to be more resistant on the whole than oats, and maize more than either of these.

269. The calcium-magnesium ratio. — The results of Kearney and Harter, showing the neutralizing effect of calcium on the toxicity of magnesium salts, are in accord with those of Loev (1903) and others, who found that the best harvests of certain crops are obtained only when the amount of lime in the soil is of at least a sufficient quantity to bear a certain ratio to that of the magnesia. For certain cereals, the amounts should be about equal, but the magnesia should particularly not be in large excess. Daikuhara (1905) was able to obtain a barley harvest from 50 per cent to 150 per cent greater by correcting the lime-magnesium ratio so as to increase the amount of lime considerably above that of the original soil. Miyake (1913–14), in recent literature, has shown in experiments with rice seedlings the antagonistic and neutralizing effects of potassium, sodium, magnesium, and calcium salts upon each other, the calcium being especially effective in neutralizing the poisonous action of other salts.

270. Soil temperature. — Much of the good effect resulting from favorable soil conditions is indicated in the rise of the soil temperature. This is a factor of considerable importance in early spring. At such a time a "warm soil" is of great advantage in giving the cereal crop an early start, whether it be spring sown or a winter variety renewing its growth. Better aëration permits a higher temperature in sandy soils. As a high soil temperature hastens growth, we have here, probably, a good basis of fact for the common idea that coarse or sandy soils are adapted for early crops. The flocculating effect of lime in favoring aëration of clay soils is of importance in this connection.

On the other hand, the cooler temperature of the soil than that of the air, without question, has great influence in counteracting the injurious effects of high temperatures of the latter, during periods of excessive midsummer heat. A large part of the benefits of cultivation of intertilled crops may be due to this cooling influence of the turned-up soil.

CHAPTER XI

CLIMATIC RELATIONS

Climatic features of natural grain regions are, if any difference, more constantly similar than the soil features. For the large prairie regions the general features common to all are: (1) low precipitation; (2) the large proportion of this precipitation occurring during the summer months; (3) the character of the precipitation, falling in quick thunderstorms, as a rule, with very few days of mists or fogs; (4) the great number of clear days of the summer; (5) extremes of temperature, especially excessive heat in midsummer; (6) high winds; and (7) a comparatively light snowfall.

271. Climatic extremes. — The temperature and total precipitation of these regions, if more evenly distributed throughout the year, as in forested areas, would not be sufficient even for cereal crops. However, the seasonal rainfall is sometimes one half to two thirds of the total for the year. Also certain points having mean-annual temperatures little above freezing, and mean-January temperatures little above zero Fahrenheit, have nevertheless mean-July temperatures about the same as those of points in humid regions at much lower latitudes. Great extremes, therefore, of both temperature and moisture, are the climatic characteristics of prairie and steppe regions, where the most of the world's small grain (excluding rice) is grown.

272. Conditions in the Chernozëm and Great Plains. — The following table, taken from another publication of the author (1901, p. 14), will illustrate some of the temperature characteristics: —

TABLE III. TEMPERATURE AND RAINFALL IN SEVERAL LOCALITIES IN RUSSIA AND IN THE UNITED STATES [1]

PLACE	NORMAL MEAN-JANUARY TEMPERATURE		NORMAL MEAN-JULY TEMPERATURE		NORMAL MEAN-YEARLY TEMPERATURE		NORMAL TOTAL RAINFALL, GROWING SEASON		NORMAL ANNUAL RAINFALL	
	°C.	°F.	°C.	°F.	°C.	°F.	mm.	in.	mm.	in.
Kazna . . .	−13.7	7.1	19.5	67.1	2.9	37.2	261.9	10.3	387.6	15.2
Ufa	−13.5	7.6	20.8	69.4	3.0	37.5	278.0	10.9	421.8	16.6
Simbirsk . .	−12.9	8.7	20.6	69.0	3.3	37.9	256.6	10.1	408.4	16.0
Samara . . .	−12.7	9.0	21.3	70.3	4.1	39.3	251.1	9.8	396.4	15.6
Orenburg . .	−15.2	4.5	21.6	70.9	3.2	37.8	201.9	7.9	395.3	15.5
Orsk	. .	. .	. .	. .	. .	. .	146.6	5.7	270.1	10.6
Saratov . . .	−10.1	13.7	21.7	71.0	5.4	41.7	191.9	7.5	423.1	16.6
Sarepta . . .	−10.5	12.9	23.9	75.0	7.4	45.4	. .	. .	. .	. .
Kerch . . .	.8	33.4	23.9	75.1	11.5	52.7	206.0	8.1	383.8	15.1
Taganrog . .	− 6.6	20.0	21.5	70.8	7.6	45.7	265.3	10.4	565.6	22.2
Eastport . .	− 6.4	20.4	15.7	60.4	5.2	41.5	451.6	17.7	1147.5	45.1
Oswego . . .	− 4.2	24.3	20.5	69.0	8.0	46.4	375.6	14.7	889.5	35.0
Lynchburg .	2.6	36.8	25.2	77.5	13.8	56.9	492.7	19.4	1094.7	43.1
Moorhead . .	−18.2	− .9	19.7	67.6	3.1	37.6	394.7	15.5	603.7	23.7
Bismarck . .	−15.2	4.5	20.8	69.5	4.2	39.6	292.1	11.5	469.9	18.5
Huron . . .	−13.8	7.0	21.5	70.9	5.8	42.5	346.7	13.6	534.1	21.0
Yankton . .	− 9.8	14.2	23.1	73.6	7.6	45.8	436.8	17.2	655.3	25.8
North Platte .	− 6.6	20.0	23.9	73.5	8.8	47.9	325.1	12.8	459.7	18.1
Valentine . .	− 8.3	16.9	22.9	73.3	7.9	46.3	299.7	11.8	486.4	19.1
Concordia . .	− 4.8	23.2	25.0	77.1	11.2	52.2	433.3	17.0	647.4	25.4
Dodge City .	− 3.0	26.6	25.3	77.6	11.7	53.2	347.9	13.7	502.9	19.8
Abilene (Tex) .	6.0	42.8	28.1	82.7	17.4	63.4	348.4	13.7	629.6	24.7

[1] The figures in this table are averages of many years' observations and are given by the following authorities: Wild, Die Temperaturverhältnisse des Russischen Reiches, Tabellen, S. LXXII–CCXL, and Die Regenverhältnisse des Russischen Reiches, S. 12–28; Kaiserl. Akad. der Wissensch. St. Petersburg, 1881 and 1887. Klossovski, Klimat Odessui (Russian); Meteorological Observatory of the Imperial New Russian University, Odessa, 1893. Moore, Report of the Chief of the Weather Bureau, U. S. Department of Agriculture, for 1896–7, Washington, D. C., 1897.

The normal mean temperature for January, July, and for the year, and also the normal rainfall for the year and for the growing season (May to September inclusive), are given for ten meteorological stations representing the eastern and southern Chernozëm, and also similar data for nine stations corresponding to these in the Great Plains. For contrast with humid regions, similar facts are also given for three points in the eastern United States.

273. Temperature. — Interesting contrasts are shown by the temperature figures for the Chernozëm region. Great extremes of heat in July are opposed by just as great extremes of cold in January, while the yearly means are normally very low. Similar extreme conditions are found in the northern and central Great Plains, of which probably the best examples are at Huron, Bismarck, and Moorhead. The extremes at these points are not quite as severe, however, as at Orenburg, Samara, and Ufa, in the Chernozëm, where the July temperatures are especially high, considering the very low winter temperatures. Points in the Volga River region having correspondingly low winter and mean-annual temperatures always show a July temperature a little higher than those of the Great Plains. The figures for the points in the humid region of the eastern United States contrast strikingly with those for the plains regions. Though the January and mean-annual temperatures at Samara and Orenburg, Russia, are much lower than those at Oswego and Eastport, on the other hand the July temperatures at the former places are higher than July temperatures at the latter. The January and July extremes at Orenburg and Sarepta are remarkable. Orenburg, with a January normal extremely low and an annual mean normally nearly 5 degrees lower than Oswego, yet possesses a July normal over 1.5 degrees higher. The January normal at Lynchburg is above freezing and the normal yearly mean over 6 degrees higher than at Sarepta, yet the latter point, with a January normal 10.5 degrees below freezing, lacks but little over 1 degree of being as hot in July as Lynchburg (Figs. 75, 76).

FIG. 75. — Climatological map of European Russia.

274. Rainfall. — The anomalies of rainfall in prairie regions are equally interesting. At Kazan, Ufa, and Simbirsk, Russia, the mean yearly precipitation is only

15.2 to 16.6 inches, but about $\frac{5}{8}$ of that amount falls in the growing season (May to September inclusive). At three points in the Great Plains, Bismarck, North Platte, and Dodge City, the yearly mean runs from 18.1 to 19.8

Fig. 76. — Climatological map of the United States and Canada.

inches, while the seasonal average is about $\frac{2}{3}$ of that amount, ranging from 11.5 to 13.7 inches. In respect to rainfall, the conditions in the Chernozëm are again a little more severe than in the Great Plains. The yearly rainfall is 1 to 3 inches less, and the proportion falling in the growing season is a little less.

At none of the Chernozëm points does the yearly mean reach 17 inches. Comparing this with the conditions in the eastern United States, we find at Oswego a yearly mean of over twice 17 inches, and at Eastport and Lynchburg over $2\frac{1}{2}$ times that amount. Huron has less than $\frac{1}{2}$ the yearly mean of Eastport, but only 4.1 inches less in the growing season. Considering now, in addition, the greater ability of the prairie soils to catch and retain water, it is seen that the amount of water finally held in the soil in the growing season may be considerably greater in the semi-arid plains than in the humid region.

At other points in the prairie regions mentioned in the table, the yearly mean is greater, extending the range to about 26 inches, the particular points discussed being extreme cases, and selected because of the greater contrasts offered. Nevertheless the fact remains that a large part of the cereal production in the two greatest grain regions of the world is grown with 16 to 26 inches annual rainfall, a condition quite remarkable, and only possible because of the large proportion occurring in the growing season, and because of the unusual water-holding capacity of the soil.

275. The humidity of the air is a feature of climate often entirely ignored, but which has a great influence upon plant growth. In the relations of climate to the development and maturity of the kernel, there are some things not yet thoroughly understood, but the degree of humidity is known to be of great importance. The influence of high humidity upon cereal crops is, in general, unfavorable if long continued, particularly if it occurs near the time of ripening. Great humidity retards maturity, interferes with protein production in the kernel, and thereby indirectly softens it, causes an overproduction of starch, weakens the straw, and produces conditions favorable for the attacks of various fungus pests (556, 577). In humid areas, it is not so much an excess of rainfall that causes an inferior quality of kernel as the great humidity and lack of sunshine. Indeed the rainfall of the growing season, as before stated, may be as much or more in the drier areas. Edmond Gain (1892, p. 890) has well stated the law in regard to this matter, that "Ripening is promoted in a dry air and a humid soil, but is retarded in a humid air and a dry soil." It is commonly admitted in respect to many crops, that the quality of the fruit or grain is injured by excessive humidity, but the fact is especially important for those crops which are characterized by a large proportion of protein or sugar in the fruit or kernel.

276. Comparative humidity of prairie and forest regions. — In the following table, also taken from the author's paper above cited, are given the absolute and relative humidity for several points in east Russia and the Crimea, and localities in the Great Plains, in contrast with similar data for the three points in the humid area already mentioned. The absolute humidity is given in the form of vapor pressure, and therefore stated in inches. The average total number of clear days in June, July, and August is also given for as many of the localities as possible.

From the table it is seen that the humidity for the summer months in the east Russian region corresponds very well with that of the semi-arid Great Plains, but is quite low compared with that of the three points in the humid area of the eastern United States. The mean

TABLE IV. ABSOLUTE AND RELATIVE HUMIDITY FOR THE GROWING SEASON AND FOR THE YEAR, AND THE AVERAGE TOTAL NUMBER OF CLEAR DAYS IN JUNE, JULY, AND AUGUST[1]

PLACE	MAY			JUNE			JULY			AUGUST			SEPTEMBER			YEAR			Total clear days in three months
	Absolute humidity		Relative humidity	Absolute humidity		Relative humidity	Absolute humidity		Relative humidity	Absolute humidity		Relative humidity	Absolute humidity		Relative humidity	Absolute humidity		Relative humidity	
	mm.	in.		mm.	in.		mm.	in.		mm.	in.		mm.	in.		mm.	in.		
Kazan . . .	7.1	0.279	64	9.6	0.377	66	11.7	0.460	67	10.5	0.413	72	7.3	0.287	76	5.6	0.220	77	. .
Orenburg .	7.3	.287	58	9.5	.374	57	11.6	.456	64	10.5	.413	64	7.3	.287	68	5.6	.220	75	. .
Simbirsk . .	7.6	.299	64	9.9	.389	66	11.6	.456	66	10.2	.401	70	7.2	.283	75	5.6	.220	77	. .
Samara . .	7.0	.275	54	11.1	.437	66	13.0	.511	61	11.4	.448	65	8.1	.318	73	(2)	(2)	(2)	. .
Saratov . .	7.8	.307	59	9.8	.385	56	11.8	.464	61	10.7	.421	61	8.1	.318	65	6.1	.241	74	. .
Uralsk . .	7.0	.275	50	9.8	.385	54	11.4	.448	53	9.9	.389	53	7.5	.295	59	5.7	.224	70	. .
Simferopol .	9.5	.374	70	10.9	.429	67	12.0	.472	61	11.7	.460	61	9.5	.374	69	7.4	.291	73	38
Genichisk .	10.4	.409	75	12.8	.503	70	14.9	.586	70	13.6	.535	70	10.9	.429	75	8.4	.330	59	28
Eastport . .	6.1	.241	77	8.3	.330	81	10.4	.410	81	10.6	.420	83	8.9	.353	81	4.9	.194	76	24
Oswego . .	7.3	.289	73	11.1	.438	74	12.6	.497	72	12.2	.482	73	9.5	.375	74	5.6	.223	75	28
Lynchburg .	10.2	.404	69	14.4	.569	71	15.9	.627	72	15.5	.611	75	12.6	.499	78	7.6	.302	71	29
Moorhead .	5.9	.236	66	11.1	.437	71	12.8	.504	73	19.8	.427	71	7.8	.311	72	4.0	.159	76	29
Bismarck .	6.2	.247	66	10.6	.418	70	12.1	.480	66	10.3	.408	63	7.3	.290	65	4.2	.166	71	30
Huron . .	6.0	.240	61	11.0	.434	66	12.3	.485	64	10.7	.425	64	7.3	.288	62	4.2	.168	69	33
Yankton[3] .	7.0	.278	67	11.8	.468	71	14.0	.555	71	12.4	.492	72	9.1	.359	69	5.1	.201	69	33
Valentine .	6.4	.253	64	10.1	.399	66	11.6	.459	64	10.8	.426	64	7.5	.298	62	4.8	.189	67	30
North Platte	6.7	.266	62	10.7	.421	66	12.8	.506	67	11.7	.463	67	8.0	.317	63	4.9	.197	66	32
Concordia .	8.3	.327	65	12.8	.506	66	14.7	.581	66	13.7	.540	68	10.1	.400	67	6.1	.242	68	32
Dodge City .	8.1	.321	61	11.8	.467	61	13.1	.519	61	12.5	.496	63	9.2	.364	62	5.7	.228	63	38
Abilene, Tex.	11.6	.458	64	14.6	.575	63	15.0	.593	58	15.0	.593	64	12.8	.504	67	8.6	.339	65	42

[1] The data for Russia are obtained from the excellent work of A. Kaminski, "Vertheilung der Freuchtigkeit der Luft Russland," pp. 34–351, St. Petersburg, 1894, and from A. Klossovski's "Contributions to the Climatology of Southwest Russia, Odessa, 1899." The data for the United States are taken partly from the Annual Report of the U. S. Weather Bureau, 1896–97, and partly from unpublished reports kindly furnished by that Bureau.

[2] No figures given. All other data for Samara are meager and cover but a few years' time.

[3] Relative humidity calculated from three daily observations instead of two, as in case of the other stations.

annual relative humidity for all Great Plains points south of Bismarck is under 70 per cent, while that for the summer months for points in the Chernozëm also range below 70 per cent. On account of the close proximity of the Russian point Genichisk to the Azov Sea, its summer humidity is much greater than it would be otherwise, the rainfall being very light.

The most important feature of these humidity relations is that, while the rainfall of the growing season may be actually greater in the semi-arid prairies than in the forested region — a fact of much significance as already pointed out — the relative humidity is, as a rule, less; that is the rain of the prairie regions falls in quick storms, which alternate with clear hot days, ideal conditions for the perfect development of cereal kernels.

277. The Chaco-Pampean plains region of Argentina has climatic conditions similar to those above described, but of course solar temperatures decrease in the reverse direction of north to south. The severity of climatic extremes is not so great, but the same kind of extremes of both temperature and moisture occur. For example, in the latitude 30° to 35° going west from Rosario, even the isotherm of mean annual maximum temperature turns southward in the central plains area, while the absolute maximum isotherm of 42° C., after leaving Rosario, dips sharply far south to northern Chubut, then back north again, on reaching the Andes, to the northern Argentine boundary. The mean annual temperature of the Chubut locality for this isotherm is, however, 11° (19.8° F.) lower than those of the northern points through which the same isotherm passes. Quoting from Davis (1910, p. 604): "These conditions recur nearly every year, it being an exceptional summer when the daily maxima do not rise as high in the Rio Negro and the Pampa as in Missiones and Paraguay." While summer temperatures are much higher in the plains region than on the eastern coast, in the same latitude, mid-winter temperatures are colder, and the winter isotherm of the same latitude bends a little northward in the plains. The precipitation, as would be expected, decreases from the Atlantic westward, but, as in other prairie regions, points in the Chaco-Pampean plains have greater summer seasonal rainfall than points eastward in the same latitude. In the southern portion of Argentina, the rainfall increases only to the westward. The belt of 8 to 24 inches annual precipitation is a comparatively narrow one, but includes a large part of the prairie region, extending from about the northern boundary of the Republic to and including nearly all of Patagonia. A still narrower belt of lowest precipitation (16 inches and under) lies due north and south near the mountains, but reaches the Atlantic coast in the south. In the northern part of this belt, as above stated, a large portion of the precipitation falls in the summer season (Fig. 77).

278. Isoclimatic lines. — With such extremes of climate existing in prairie regions, naturally the isothermal and isohyetal lines take peculiar directions. The odd course of the absolute maximum isotherm in the Chaco-Pampean region, already mentioned, is a good example. In the Chernozëm, even the lines representing average data take very unusual courses sometimes. For example, the July isotherm of Orenburg passes southward and is the same as that of the eastern Black Sea, or practically subtropical, while the January isotherm of Orenburg passes northward to the Arctic Ocean. In many instances,

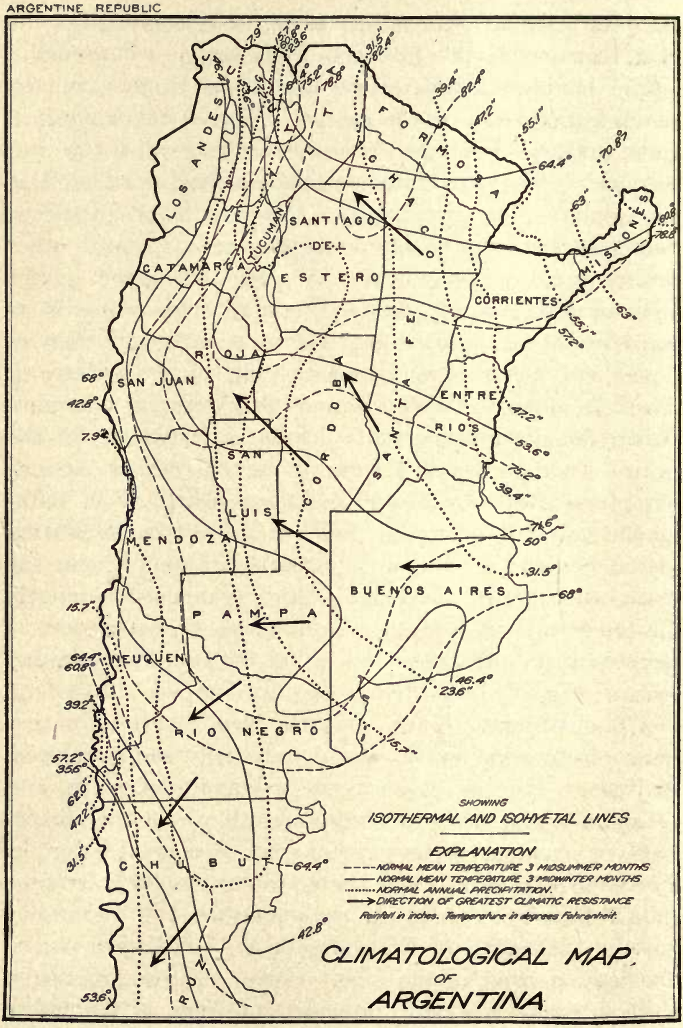


FIG. 77. — Climatological map of Argentina.

July and January isotherms cross each other almost at right angles. Isohyetal lines run, usually, north and south, but two of these near Poltava and Kherson pass northeastward to the Volga River and Ural mountains, then bend to the northwest and extend into Finland. Similar peculiar relations exist in the Great Plains, but are not so marked.

279. Directions of climatic resistance. — As heat is an important requirement in the maturity of good kernels, summer temperatures, even in plains regions, are rarely too high for the small-grain crops. The summer rainfall, however, is usually more or less deficient, although greater in proportion to the total for the year than in forest regions. In summer, therefore, the limiting climatic factor is dryness. In winter, precipitation is less important, though it may be very helpful, but low temperature often aided by dryness causes winter-killing in winter grain districts, and is, therefore, the limiting climatic factor in winter. These two factors act greatest as a hindrance in certain directions, and the resultant direction of increase in the combined effects of the two is the direction of climatic resistance to the cereal crop. For example, winter temperature decreases usually northward in the northern hemisphere, while the rainfall in South Dakota decreases westward. In South Dakota, therefore, the direction of greatest climatic resistance to cereal crops lies midway between these two, or to the northwest, supposing the two factors to be equally severe. Sometimes the direction of decrease of temperature is much affected by ocean currents or continental features, so that in Saratov, Russia, for example, temperature decreases practically eastward. Here then, as precipitation decreases to the southeast, the direction of greatest climatic resistance lies between east and southeast. In the accompanying maps (see Figs. 75–77) these directions of climatic resistance are, very roughly, indicated by arrows. Sometimes evaporation becomes so great that it must be considered as an additional factor (282).

280. Water requirements of cereals. — Under the heading transpiration (27), some of the benefits resulting to the plant through that process are mentioned, but also the fact that the loss of water often becomes serious. This loss is so great in semi-arid districts in addition to light rainfall, that the one great problem is the water supply.

In Wisconsin it was determined by King that barley required 392.9 tons of water to produce 1 ton of dry matter, and oats 522.4 tons. Hellriegel found that barley used 310 pounds of water for each pound of dry matter produced, spring rye 353 pounds, oats 376 pounds, spring wheat 338 pounds, and buckwheat 363 pounds. Such variation in the water requirement of different crops shows the importance of elaborate experiments in this line under dry conditions as an aid to the selection of crops for dry lands.

281. Experiments of the United States Department of Agriculture. — Experiments of the kind above mentioned were conducted by Briggs and Shantz (1913, 1914), with most interesting results, and form a fitting companion work to that on the wilting coefficient for different plants. Results of the latter investigations show the water efficiency of different soils, while results of the former show the water efficiency of different crops. In these investigations, there was found to be great variation in the water requirements, not only of different cereal crops, but also in those of different varieties of the same crop. The measure employed in the experiments is the ratio of the weight of water absorbed during growth to the weight of dry matter produced. This ratio is surprisingly low in corn, being 239 in the Esperanza variety.

The Kursk millet, introduced by the author from Kursk Government, Russia, showed the smallest water requirement, 187, so far recorded for any crop. In the experiments of 1910–11, Kubanka wheat was the most efficient of all varieties of wheat, oats, barley, rye, and rice. In 1912–13, Turkey and Kharkov wheats were first used in the experiments and gave a lower ratio than Kubanka.

The water requirement ratio for several important varieties of each cereal at Akron, Colorado, is given below: —

TABLE V. THE WATER REQUIREMENT RATIO FOR DIFFERENT CEREALS

WHEAT		OATS		BARLEY	
Turkey . .	364	Canadian . .	399	Awnless . .	403
Kharkov . .	365	Swedish Select	423	Beldi . . .	416
Kubanka . .	394	Burt . . .	449	White Hulless	439
Emmer . . .	428	Sixty-Day . .	491	Hannchen . .	443
Bluestem . .	451	RICE		RYE	
Ghirka Spring	457	Honduras . .	519	Spring . . .	496

282. Evaporation. — It has been known for some time that the minimum annual rainfall required for so-called dry land farming, runs about 3 to 5 inches greater in the southern than in the northern Great Plains. This fact could not be explained until the corresponding fact of the greater evaporation in the southern area was taken into consideration. Evaporation increases so much from north to south, that even within the limits of the United States it must be seriously considered as a third factor with temperature and rainfall in the establishment of new crops. From southwest Kansas southward, this factor is so important comparatively, that the line of greatest climatic resistance turns actually to southward in spite of the winter temperature factor, which would tend to turn it to the north. The amount of evaporation is affected, locally, of course, by several conditions, including the degree of clearness of the atmosphere. An example of the effect of atmospheric haze is given by Briggs and Belz (1913). In their observations, they found that during the haze of four months following the eruption of Mt. Katmai, the average evaporation, as measured at 15 stations, was reduced about 10 per cent from normal.

283. Winds. — Evaporation is greatly increased by high winds. Results of recent experiments seem to show a much less effect upon plant transpiration, but the increase of the latter from this cause is, without question, considerable. Constant winds, amounting to a gale during the day and continuing for several days at a time, which often occur on the high plains, also cause much damage to crops in a mechanical way, through soil blowing, and whipping of plants against each other. On the southwestern plains high winds are probably the chief obstruction to successful "dry-land farming," and therefore the great help to the latter will lie in the planting of drought-resistant shrubs and trees in a form to best protect the crops, such as hedges or narrow belts running at right angles to the direction of prevailing winds. At certain points there are known to be over 60 days of gales during the year, a gale being defined as a wind blowing at the rate of 40 miles an hour.

284. Sunlight. — Knowing that sunlight is an essential factor in plant growth, it appears evident that any considerable increase in the total amount of light which the cereal crop receives, must exercise a great influence in its development, whether such increase means more hours of sunlight in the day or a greater number of clear days in the season. It is known that clear weather hastens maturity, and favors a greater production of protein in the kernel, but temperature and dryness are also concerned in protein production. To the northward the period of growth of spring crops decreases as the length of the summer days increases. If the mean daily temperature be multiplied by the number of days in the period of growth of the crop, the product, known as "day-degrees," will increase from north to south. The product of the mean daily temperature by the total number of hours of sunshine, during the same period, known as "sunshine-hour-degrees," increases in the same direction. Therefore, as the total amount of sunshine itself increases in the opposite direction — south to north — it would appear that there is a large effect of the light rays proper, independent of heat rays, in assimilation and growth. Sunlight also apparently increases transpiration, greatly, independent of temperature. Nearly all is yet to be learned as to the optimum light conditions for the different cereals (see MacDougal, 1903).

285. Phenology of the cereals. — The study of the different periodic phenomena which occur during the life of a crop, such as heading and ripening, as influenced by its environment, is known as phenology. As only climatic factors are usually considered, the phenology of the cereals will be discussed in this place, although varying soil conditions would have some part, probably, in a full treatment of the subject.

As before stated (14), there are four important stages in the life of the plant; the seedling, jointing, heading or flowering, and ripening stages. The jointing stage is so extended and so irregular as to individual plants in the same field, that it is practically impossible to fix an average date for it, and therefore observations of this stage are not usually recorded. The actual dates of occurrences of these phenomena are only important as means of measuring the periods between. The period from the date of emergence of the seedling above ground (the first visible sign of germination) to the date of heading will be termed here the vegetative period. The period from date of heading (equivalent to date of flowering) to date of ripening is already known as the fruiting period, while the sum of these two is the entire period of growth.[1] The varying lengths of these periods or their ratios with each other are found to be correlated with certain characteristics of the cereal plants in an interesting way.

286. Variations in the period of growth. — While the life period of spring grains decreases northward, the period from date of emergence to date of ripening of winter grains decreases southward. The explanation usually given for the first condition is the greater length of summer days toward the north, thus permitting more sunlight. This fact is at least partially counterbalanced by the corresponding one of less intensity of the sunlight in the north, because of slanting of the sun's rays. Prob-

[1] In winter crops there is also properly a resting period (see 287–288).

ably a more important reason is that the sum total of heat during the period of growth, above the minimum temperature requisite for cereal development, is greater in proportion to the total for the year in the north than in the south. In the case of winter cereals, the shorter period toward the south is caused by both longer days in the winter, and greater angle of the sun's rays with the earth's surface, and also by the shorter winters, thus permitting a greater number of days with temperatures above the minimum required for growth.

High altitudes also shorten the period of growth of spring grains. Altitude increases the length of days slightly, and the light intensity is not lessened, in fact may be slightly greater the higher the altitude. Other local and minor factors affect the period of growth to a less degree, such as precipitation and soil conditions. Cereals of the Great Plains mature quicker as a rule than in humid localities in the same latitude. Sandy soils are often said to be adapted to early crops (see 270).

287. Seasonal variations in this country. — An approximate general idea of the varying lengths of cereal crop seasons can now be obtained from an exhaustive collection of information recently made by Covert (1912) of the Bureau of Crop Estimates covering that portion of the United States westward from the Atlantic to and including the States of the Plains. The information is not exact, as the dates given are those of seeding and harvesting and not the more definite ones of emergence and ripening. Based upon the data contained, charts are presented below showing the decrease in length of the period in days between seeding and harvesting of spring sown oats going northward, and the decrease in length of the same period for winter wheat going southward

(Figs. 78, 79). It is seen that this period for oats runs from 102 days in Maine and New York to 122 days in Texas. The average period for the great oat district of the central Mississippi River Valley States is about 106 days.

For winter wheat, the period from seeding to harvesting varies from 216 days in Georgia to 314 days in Minnesota, a range of nearly 100 days. The average for the

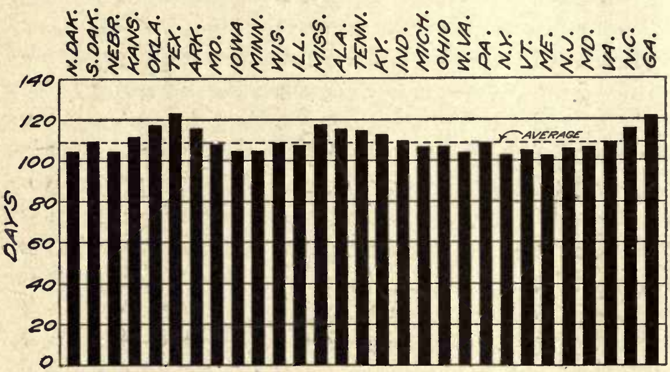


FIG. 78. — Chart showing the period between seeding and harvesting spring oats in states east of the Rocky Mountains.

great wheat area of the middle plains is about 280 days. The range would be much greater if data were available for Montana, Washington, and Alberta, Canada. In these districts, harvesting is scarcely out of the way before the next seeding begins, and the two often overlap. Of course the greater portion of this period in northern districts is not a period of growth but a period of rest, in the case of winter crops.

There are many variations from the rule of decreasing length of the growing period northward, because of local conditions, as would be expected. The most striking of these, according to the information of the statisticians here given, occur in South Dakota, where

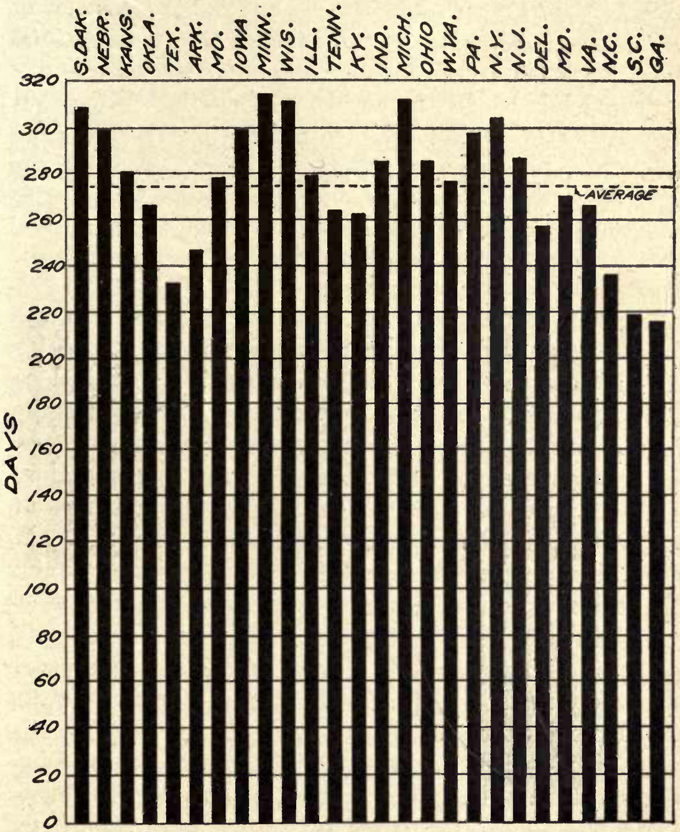


FIG. 79. — Chart showing the period between seeding and harvesting winter wheat in states east of the Rocky Mountains.

the period is five days longer than in Nebraska on the south. The explanation is said to be the common tendency of corn-growers in

South Dakota to "rush the season"; to plant early in order to escape frost, which practice is also reflected in other spring crops. However, in case of oats, unlike that of corn, early planting makes little or no difference in time of ripening, hence necessarily lengthens the period of growth. (See 289.) On the other hand, the unusual decrease in the length of this period in Nebraska, under that of Kansas, with no further decrease even in North Dakota, may be explained by the greater proportion of the cropping in Nebraska under dry conditions (because of the greater extension westward of that state than of Kansas, and the smaller percentage of farming done in the western portions of North and South Dakota), for length of growing period decreases with dryness.

288. Investigations. — In this country, complete phenological observations have not yet been made for any crop at one place for any considerable time, much less for different varieties of the same crop at different places in comparison. The best source of accurate information in this line, so far, exists in the cereal experiments now being conducted by the Office of Cereal Investigations, United States Department of Agriculture, at twenty-eight points in the United States. At most of these stations six to eight years' work has already been done, but the observations, which are now quite complete each year, have not yet been brought together and made available for publication. A serious defect in observations heretofore made is the lack of notes now being taken by the United States Department of Agriculture, on the time of cessation of growth of winter cereals in the fall, and the time of beginning growth of the same the following spring, — in other words, taking account of the period of rest already mentioned (285).

289. The fruiting period. — The most critical period in the life of the crop is that between heading and ripening, including the flowering stage. Intense heat at flowering time may cause "blighted" or sterile heads. An abundance of rust in this period will shrivel the kernel. At this time, smuts and wheat scab appear, and in high latitudes and altitudes there is the danger of frosts.

In 1905 the author first applied the expression "fruiting period" to this interval in the life of cereal crops,[1] and called attention to the correlations existing between the length of this period and certain other characteristics of the crop, as yield and protein content. Also the ratio of length of this period to that of the whole period of growth was determined for many varieties, under the same conditions, and called the fruiting ratio or coefficient. Late varieties and late plantings of the same variety have shorter fruiting periods than others. The protein content increases inversely with the length of the fruiting period. Blanchard first noted in print (1910, pp. 29–30) the practical significance of a shortening of this period, in reporting results of experiments with Chul and Fretes wheats in California. The later these wheats were planted, the shorter were both the growing and fruiting periods, and the greater the content of protein. The yields, however, decreased slightly as the protein content increased. Thatcher (1913, pp. 39–47) and his students studied this subject extensively, and arrived at the following conclusions: (1) the average weight of kernel varies directly, and the percentage of nitrogen inversely, as the length of the fruiting period. (2) The length of this period is the determining factor in the final composition of grain. Schindler (1893), Lyon (1905), and others also came to similar conclusions.

[1] In a paper, still unpublished, presented before the Agronomic Seminar of the United States Department of Agriculture during the winter of 1905–06.

290. Heat requirements in cereal development. — The variation in length of the fruiting period indicates that the total heat required for maturing the kernel is furnished quicker in one place or in one season than in another. In Europe, considerable study has been given this subject for more than 150 years, particularly in an effort to secure some thermometric constant by which may be calculated the total heat required for maturing a given crop in a given locality. Gasparin, Marie-Davy, Linsser, Angot, and others have investigated the subject. In calculating the sum total of heat, one thing was certain, that all temperatures included should be above a certain minimum necessary for plant growth. This minimum was variously stated to be from 0° C. to 6° C. The sum of all mean daily temperatures above a minimum of 6° C., for instance, during the life of a crop, would constitute the sum total of heat required for maturity of that crop.

291. Linsser's Law. — Is the sum total of heat required the same for the same crop in every locality? Linsser decided not, and made the following statement known as "Linsser's Law": In two different localities the sums of positive daily temperatures for the same phase of vegetation are proportional to the annual sums total of all positive temperatures for the respective localities. A natural corollary from this law is that seeds taken from high latitudes or altitudes to lower ones, tending still to utilize the same proportion of the total annual heat which was less in the former localities, will ripen earlier than the native crops of the warmer localities. This corollary, if true, may explain a fact well known to agriculturists, that spring varieties brought from the north usually ripen earlier than native varieties. The fractional part of the annual sum total of heat required for maturity of a crop, or completion of any stage of its growth, is, according to Linsser, the same wherever the crop is acclimatized, and was called by him the "physiological constant."

Recently Merriam (1894) has studied this subject, and does not think that the distribution southward of plants and animals can be explained by any previously stated law of temperature control. He proposes, therefore, the following additional fundamental law: Animals and plants are restricted in southward distribution by the mean temperature of a brief period covering the hottest part of the year.

292. Retardation of the harvest. — Angot studied the retardation of the harvest in France as affected by altitude, and found that the harvest of rye and spring barley is retarded at the rate of about 4 days to 100 meters of altitude. He also found that the date of harvest, reduced to sea level, begins with June 5 in southern France and ends with July 25 on the northern border. Incidentally, Angot also determined, from observations at several hundred stations, that in France rye requires less heat than winter wheat for maturing the crop, but for the fruiting period alone, rye requires more heat than winter wheat.

Abbe (1905) has brought together a large amount of phenological information in one place, extracted from writings of the above-mentioned investigators and many others, and gives an extensive bibliography.

CHAPTER XII

CEREAL ADAPTATION AND ASSOCIATION

In the immediately preceding chapters, certain soil and climatic features are discussed, which characterize those regions where cereal crops are most perfectly adapted. These areas may be considered as cereal crop zones or natural cereal regions.

Adaptation

293. Cereal regions. — The most important of the natural cereal regions, located in a very approximate way, of course, are as follows: the Great Plains of North America, the Russian Chernozëm, the Chaco-Pampean Plains of Argentina, Australasia, the Indo-Gangetic Plains of India, the Balkan-Hungarian region, the Mediterranean region, the east China-Japan region, and Turkestan (Fig. 80). There are other areas which must be considered in this connection for special reasons, though they are not perfectly adapted for cereal cultivation. On the one hand, there are the German-Austrian and the French-Italian regions, which produce a large quantity of cereals by virtue of intensive farming, attention to soil fertility, and constant pressure of food demand. Their proportional production, however, is gradually decreasing. On the other hand, there are other regions which are either well suited for cereals or deserve mention

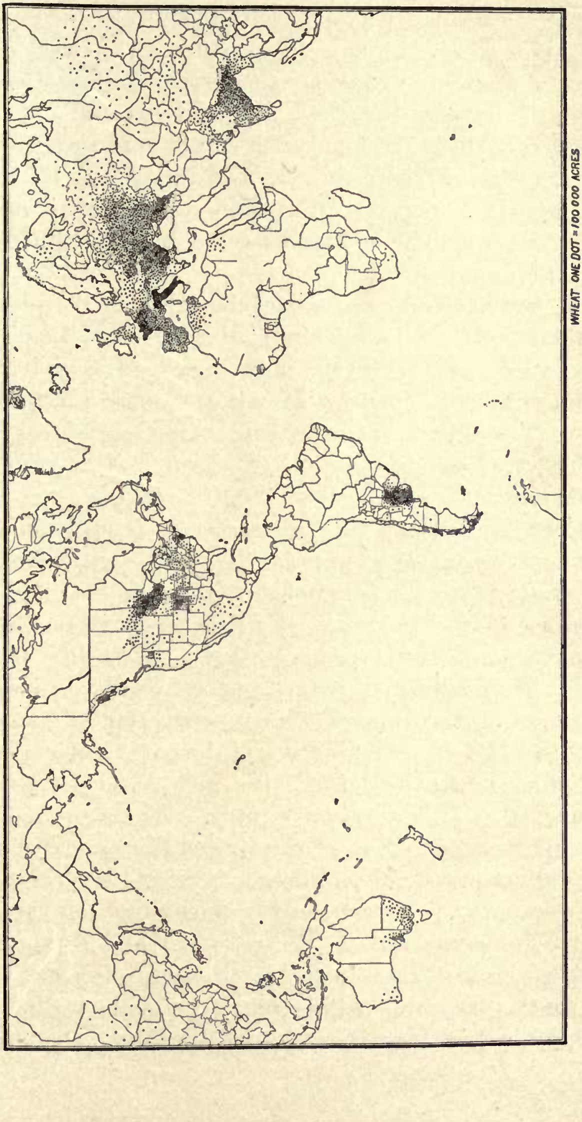


Fig. 80. — Map of the world, Mercator projection, showing the distribution of wheat.

because of certain distinctive characteristics of their cereal crops, but which do not yet produce any considerable quantity of grain. These are the Syrian-Arabian-Persian region, the Tibetan-Himalaya highlands, central and eastern Siberia, Abyssinia, and South Africa. In such regions as west China, Afghanistan, Baluchistan, Jungaria, Mongolia, and large portions of central Africa and northern South America, little or nothing is yet known as to cereal adaptation and cultivation.

294. Russia. — As might be inferred from the preceding discussions, the best example of a region well adapted for cereal cultivation is the large area in Russia, including practically the Chernozëm, which extends indefinitely into western Siberia. The accompanying map shows how well the heaviest distribution of wheat in Russia corresponds with the extension of the Chernozëm (Fig. 81). European Russia has the largest cereal production (exclusive of corn) of all countries, though the entire area of the country is less than that of the United States.

Because of the extremes of dryness, winter cold and summer heat, native Russian cereals are the hardiest in the world. They are also usually of the best quality. Nearly two thirds of the present wheat production of Canada and the United States, and much of the oats, is of varieties originating in Russia. More rye and proso are grown in Russia than in any other country. Wheat production also ranks well with that of the United States. Rye and barley are grown chiefly in the northern and central parts of the country. Winter cereals, including soft winter wheats, are grown in the center, west, and southwest. Spring grains are found in the north, east, southeast, and even south. Because of the strong turn of the isotherms, the relative positions of spring and winter cereals are often the reverse of that which is common. For instance, spring wheats may be seen near Odessa and Kherson, due south of winter wheat districts.

FIG. 81. — Map showing the distribution of wheat in European Russia: 1, hard spring; 2, hard winter wheat; 3, durum wheat.

295. The United States and Canada. — Conditions in the great cereal region of North America are radically different from those of other regions in the respect that everything is of recent development, both as to the varieties of cereals established and methods of handling the same. There is nothing distinctively American. It is probable, therefore, that, after many years, there will

Fig. 82. — Map showing distribution of wheat in the United States and Canada.

be more clear-cut distinctions between groups of cereal varieties of local adaptation, and also a greater extension of cereal cultivation into localities where it is not now considered possible. However, certain definite groupings have already come about. The most interesting and most recent case is the segregation of the hard winter wheat district, central in Kansas.

In North America the directions of climatic resistance are usually opposite to those of Russia. Cereal extension, therefore, finds its greatest obstacles to the west and north, instead of the northeast, east, and southeast, as in Russia. The spring wheat district of the northern plains states and Canada is constantly encroached upon by winter wheat in its northward extension from Iowa and Nebraska, and in Montana and Alberta. Barley is now grown chiefly in the north central and northern plains states, and in California, its production having increased greatly in the latter states. Rye is found in Ontario and the north central and New England states, being employed for hay in the last-named district. Wheat and oats are more generally distributed, but are grown in the largest quantity in the prairie region of the Great Plains and central states, as would be expected (Fig. 82).

296. Argentina. — Climatic resistance, with regard to dryness, increases to the westward in Argentina as in the United States, but with respect to winter cold, it increases to the southward. The quality of cereals, therefore, and, within limits, the quantity, increase in the same directions. The Chaco-Pampean Plains, constituting the natural cereal zone, cover the largest part of the Republic. Wheat is the only cereal grown to any considerable extent, but the production of this crop has increased remarkably in recent years. The cereal varieties now grown are those adapted to warm sub-humid regions. There is durum wheat, however, in the drier districts, and a rather hardy winter wheat of excellent quality in Chubut (Fig. 83).

FIG. 83. — Map showing distribution of wheat in Argentina.

297. The Balkan-Hungarian region. — This region includes the plains of Hungary and Roumania, and large districts in the Balkan states. It is largely an extension southwestward of the Russian Chernozëm. There are occasionally extreme droughts in Hungary and Roumania, and also some high altitudes. The winter wheats, inured to these extreme conditions, are very hardy, but not to an equal degree with the Russian winter wheats. The Theiss and other winter wheats of the Hungarian plains

FIG. 84. — Milling district in Budapest. Danube River in foreground.

furnish the basis for the great milling industry of Budapest (Fig. 84).

Interesting varieties of proso of the compact head type (mein roça) are found in Roumania. In the Balkan states, many distinct varieties of spelt, emmer, and einkorn are found. Some very hardy winter wheats also exist, especially in Servia, Bosnia, and Bulgaria. Cereal cultivation in many localities in these states is yet little known to the outside world.

298. The German-Austrian region. — This and the region next discussed are not, in the main, perfectly adapted cereal areas, but intensive farming and the pressure of food demand cause a comparatively large cereal production. The chief cereal in this region is rye, which has been much improved and locally segregated into hundreds of different varieties. Barley is also important, and is chiefly of the two-row type. The wheat and oat varieties are those adapted to humid areas. Much spelt and emmer are produced.

299. The French-Italian region. — This region, in respect to cereal cultivation, is similar to the preceding, but there is a smaller proportion of rye. Hardy winter wheats of very good quality, including the well-known Rieti, are grown in the highlands of Italy. In southern Italy, durum wheat is found largely because of the partiality of Italians for macaroni, and not entirely because of adaptation for this kind of wheat. An excellent black winter emmer and certain poulard wheats are grown in France.

300. India. — In proportion to total production, the cereal varieties in India are numerous. The same thing is true of rice, in both India and China. Such a condition is probably due to the great age of agriculture in those countries, thus permitting extensive local adaptations, that would only be possible in a long period of time. Earliness is a common characteristic of Indian cereals. Many of the wheats are of the soft, white or red-kerneled types of the common subspecies, adapted for considerable rainfall, but there are also many durum and club varieties adapted to drier districts. A few fairly hardy winter wheats are found in the Northwest Provinces and near the Himalaya Mountains. Early and hulless barleys are also found in the latter district.

301. East China-Japan region. — The most striking characteristic of the cereals of this region is their dwarfness. The plants are almost always short, and spikes also are usually short but compact. Nearly all varieties are early. The region is generally humid, and consequently no varieties possess any considerable drought-resistance. Through earliness, some varieties from this region, on introduction into the United States, are able to escape severe attacks of rust. Barley varieties are of both the two-row and six-row groups. There are a number of club varieties of wheat, some of which are bearded. Cereals have been grown in China from the most ancient times, but even at present there is little information as to the quantity produced.

302. The Siberian-Manchurian region. — In this region are included the divisions of Yeniseisk, Irkutsk, Yakutsk, Transbaikal, Amur, and Primorsk, in Siberia, and the larger portion of Manchuria. It is an extremely large region, and yet little developed. Little or no winter grain is grown. In Transbaikal, spring rye, called yaritsa, is the most important cereal, and forms the chief food of the people. Oats and wheat also are grown to the extent of 25 per cent to 40 per cent of the cultivated area. Rye is grown in Kamchatka, and all small grains in the rugged island of Sakhalin. In Manchuria are very large districts admirably adapted for cereal crops. Many modern mills have been erected. Its present annual wheat production is about 10 million bushels, while it is estimated that 300 million bushels could be produced. In the vicinity of Yakutsk, the Scoptsi people have grown small cereals for some time, using American machinery. Rice is grown in Manchuria without irrigation.

303. Russian and Chinese Turkestan. — In this region, which includes the fertile districts of the Tarim River, in the Chinese portion, explored by Sven Hedin, and the Amu (ancient Oxus) River in the Russian portion, are found nearly all of the cereals. The Russian portion is characterized by early, drought-resistant varieties. Some of the most hardy and otherwise interesting prosos are found there. In the Chinese portion, all the cereals, including rice, are grown in the Tarim Basin, in Kashgaria, and at Khotan. The rice and often the other cereals are irrigated. Seeds of several of the cereals have been found in excavations of old cities in this region.

304. The Tibetan-Himalaya Highlands. — The large Tibetan plateau, the Himalaya mountain districts, and Kashmir are included in this region. Here cereals are found growing at their highest known altitudes. It is particularly a region of early, hulless, and blue-kerneled barleys. Hulless barley flour roasted (tsamba) and boiled with tea often forms the principal food of the natives. Cereals are in no place abundant, and are always grown under the severest climatic conditions. Irrigation is often practiced. In the basin of Dangra Yum Lake in Hor Province, Tibet, barley is grown in considerable amount at an altitude of 15,200 feet, or higher than the summit of Pikes Peak. The Himalaya and Kashmir districts are noted for their barleys.

305. The Arabian-Persian region. — The region including Arabia and Persia is, in large part, yet to be explored agriculturally. Some of the most drought-resistant cereals are native. Black-chaffed barley and brown-chaffed wheats are found somewhat dwarfed, with stiff glumes and hard kernels. The cereals so far seen from this region are distinctive and very hardy, but require further study.

306. The Mediterranean region. — In this region is included, in general, the entire Mediterranean shore land, but particularly North Africa and Syria. This region is the home of the red oats, such as Algerian Red and varieties from Asia Minor. It also ranks third as a durum wheat region. There are also many drought-resistant barleys. As there is much high temperature and the winters are mild, there are no strictly winter varieties.

307. Abyssinia. — Many of the cereals of Abyssinia are distinct from those of any other region. Purple-kerneled wheats exist there, but are found nowhere else. There are also emmers having purple kernels, and purple-glumed and black-kerneled barleys not found elsewhere. Distinct hairy oat varieties, drought-resistant, also occur. These peculiar forms, locally adapted, appear to have developed through a long period of isolation and freedom from mixtures with foreign varieties.

308. South Africa. — In South Africa there are large districts adapted for cereals, but the country is newly settled, and cereals are being introduced there from Australia and other regions. In general, the cereal varieties adapted are such as are grown in our North Central states or in west Russia. Certain districts, however, have little rainfall, and require drought-resistant varieties. The topography and rainfall distribution are such that winter cereals are grown toward the south and not toward the north as would be expected.

309. Australasia. — In the case of Australasia, including Australia, New Zealand, and Tasmania, practically an entire continent is adapted for cereal cultivation. Large districts in South and West Australia are very dry, and therefore require durum wheats and other dry land cereals. No winter cereals proper are adapted. Earliness is a general characteristic. Wheats similar to those in California are well adapted, and oats of the sterilis group.

310. Cereal introductions. — A knowledge of the soil and climatic features of natural cereal regions, and the cereal groups characteristic of each, furnishes the basis for intelligent introductions of cereal varieties from one region to another. For instance, cereals from Australia or Algeria would likely be adapted to California, but those from Russia would be of no value, though the latter are perfectly suited to the Great Plains states.

None of the cereals, except corn, is native in America. The entire establishment of small-grain crops, therefore, to date, is a history of cereal introductions, with the exception of a very few successful new varieties produced through breeding.

311. Suggestions for proper cereal introductions. — The Volga River district of Russia, from Kazan to Saratov, should have varieties adapted to the northern Great Plains from southern Canada to Nebraska, and the reverse should be true. Actual transfers have proven this adaptation. Cereals of the lower Volga district, and in the vicinity of the Black and Azov seas, are similar to, or the same as, those which succeed in the southern Great Plains from Kansas and Colorado to the Texas Staked Plains. In New Mexico, Arizona, southern California, and Texas, varieties of the Mediterranean region are adapted, and to some extent those of India and Australasia.

Cereals in the western Chernozëm are adapted in the district from Iowa eastward to Ohio. Spring grains from Russia, sufficiently hardy to be of use in central and eastern Canada, should come from the district including the governments of Ufa, Perm, Vyatka, and Kostroma. The cereals of our Middle Atlantic and Southern states are similar to those of France, Germany, Austria, and northern Italy. Tibetan-Himalaya varieties are adapted in northern Rocky Mountain districts, in central Canada, and in Alaska. The best cereals in California have come from Mexico, Australia, the Mediterranean region, and Russian Turkestan. Abyssinian varieties seem to be adapted there also.

Environment

312. Acclimatization. — The firm establishment of an introduced cereal crop is much more than the mere introduction, and is sometimes a tedious task, requiring years for success. A good example is the introduction of durum wheat into the United States from Russia (155). The process of introduction may become one of acclimatization. The difference between a simple introduction and acclimatization may be illustrated by the case of the Swedish Select oat (163). This is a pure-bred oat, developed in Sweden. It was first introduced direct from Sweden to the United States, and found not to be well adapted, as might have been predicted from the dissimilarity between the two countries. During many years, the same variety was grown in Finland and Petrograd Government, Russia, under the name Swedish Select, and further selected and acclimatized. This improved strain was then (1900) introduced to this country, and gave excellent results.

313. Change of seed. — A change of seed is something very different from a change of variety. Often an improvement of a cereal crop may be made by introducing better adapted varieties, but a change of seed within the same variety is not often an advantage, and may be a detriment.[1] There are certain special cases, however,

[1] In case of the potato crop, often mentioned as a striking exception in favor of a change of seed, it should be noted, of

in which seed from a distance appears to give better results (318). For instance, in a dry district, seed from a locality still drier is safer for planting than seed of the same variety from a more humid locality. Also, seed gathered in a dry season is to be preferred to seed of the next year's crop for planting the second year, if the latter seed has advantage of a good rainfall. A real survival of the fittest will have occurred in the dry season, through destruction of the weaker plants by drought, and seed of the surviving plants will therefore in turn produce plants better able to survive another drought.

314. Principles to be observed in obtaining new seed. — In obtaining new seed, whether of a new variety or of the same variety, it is important to observe certain principles. It is a general principle that seed from the best of those plants that have survived the most strenuous existence of whatever nature, other things being equal, will be the best. To specify: (1) Seed of the best plants surviving a dry season is better than seed gathered in a wet season; (2) seed from a drier locality is better than seed from a more humid locality; (3) for cold resistance, seed from a colder locality than the one for which it is wanted is desirable; (4) for resistance to diseases, seed from resistant plants from those localities where such diseases are the most common is best. A second general principle is that certain qualities are best secured in seed from localities where opposing conditions are so severe that such qualities are not common. To specify: (1) Seed for winter hardiness will be most likely found where winter varieties are rarely and with difficulty grown, that is, in a spring wheat district; (2) dwarfness will be se-

course, that the tuber is a form of underground stem and not a seed.

cured in seed of the smallest plants from localities where the plants are commonly large; (3) on the other hand, for large plants, seed of the largest individuals where dwarfness is common and forced by the environment is best; (4) for earliness, usually seed of spring cereals from the north and seed of winter cereals from the south are best, with apparent exceptions.

315. Effects of environment. — The fact that commercial varieties will change their characteristics on being grown in a new and different environment is well established. A variety as ordinarily observed is a mixture. It is easy to see how the individuals better able to resist severe weather conditions will survive, and the weaker ones drop out, thus changing the complexion of the variety as a whole. Pure-bred varieties are not affected to so great an extent in the same time, but even these may be modified after a long period, as in the case of the Swedish Select oat (312).

316. Environmental experiments. — Until recent years, very little investigation has been made in this line. Beginning in 1907, the United States Department of Agriculture, through the Office of Cereal Investigations and Bureau of Chemistry, conducted experiments for nine years in Maryland, Kansas, Texas, South Dakota, and California, to determine the effects, if any, of changes of climate and soil on the wheat plant. Two series of experiments were made with wheat, one in which seed every year from each of three points in different states, was sown at the other two points, and another in which soil from each of three states (Maryland, Kansas, and California) was transported to points in the other two, and home-grown seed each year sown on the three soils at the same point. The results of these two series of experiments confirmed each other, and demonstrated certain facts: (1) That a change of environment has marked temporary effect upon the plant, but that (2) such effect takes no permanent hold, and is not heritable; (3) that these temporary effects are usually caused by changes of climate; (4) that certain effects in certain instances, however, are caused by soil differences; (5) that no effects upon fundamental characters are produced, such as alterations of form or structure, or physiological

Fig. 85. — Soil exchange plats of Crimean (Turkey) winter wheat at Davis, California; nearest, Maryland soil; middle, California soil; farthest, Kansas soil.

activity so far as yet determined; that all effects were changes in characters that are fleeting or elastic, such as color and height of plant, tillering, size of head, and color, hardness, and chemical composition of kernel; (6) all soil effects were apparently, because of differences in physical structure of the soil, independent of chemical composition (Fig. 85).

317. Effect upon protein content. — A special aim of these experiments was to determine the environmental effect upon the protein content of the wheat kernel. This effect is sometimes very great, but, as stated, is only temporary. California seed taken to Kansas produced wheat with high protein, but seed of that wheat returned to California the next year, produced kernels with the same low protein as that of the original California seed (Le Clerc and Yoder, 1914). Extensive investigations of Thatcher (1913) gave results similar to these just described.

318. Cumulative effects in long periods. — Many agricultural experiences, including the instance of the acclimatization of Swedish Select oat (312), appear to demonstrate the cumulative effects of environment in long periods of time. Lyon (1907) has brought together and interpreted such instances from various sources. Two of these instances show an apparently cumulative effect upon earliness. Seed originally of the same variety, but afterward long grown at different points, when planted in Nebraska, produced plants which ripened at widely different dates, corresponding to the dates of ripening in their different native localities. Usually the crop from southern or western seed ripened earlier. The crops from seed of all sources, after several years in Nebraska, gradually came to ripen at the same time. While a change of seed, as ordinarily understood, is not to be recommended, the importation of seed, even of the same variety, from a very different district where it has been long and continuously grown, is likely to prove advantageous, if the crop in that district is known to be of better quality than in the locality where it is to be taken (see 314). A good example was the Kansas millers' importation of new Turkey wheat seed from the Crimea in 1901.

The Cereal Plant Community

319. Plant ecology. — The study of a cereal crop is fundamentally a study in plant ecology. It is much more extended, however, than the latter, as ordinarily considered, because of the tremendous influence of human agencies.

Native plants commonly group themselves into associations, comprising but a few species, but many individuals of each, in certain localities or over rather extensive uniform areas, where conditions of environment are favorable for these particular species. In such cases, the individuals of a species exhibit characters considerably different from those possessed by more isolated individuals in other places. The crowded individuals may become dwarfed, etiolated, slender, or may possess small (especially narrow) leaves, or small seeds which mature quickly.

320. Agronomy or study of the crop. — If now human agencies intervene to put individuals of the same species under cultivation and therefore out of competition with other species, then, aided by soil tillage, regular seeding, and perhaps fertilizers or irrigation, the differences in characters of these individuals from those of individuals more isolated will be still greater, but in the other direction of larger size and better quality. Cereal crops, because of the mutual protection of crowded individuals and the favorable environment given them through cultivation and soil adaptation, will succeed under conditions so severe that the same individuals, if isolated and without cultivation, could not survive. On the other hand, the individuals of a crop must also compete with each other, sometimes to their disadvantage. They appear to become antagonistic to each other in a way yet to be explained, but partly, no doubt, from use of the same kinds and quantities of food constituents. Therefore, sometimes a mixture of two crops, such as barley and oats, will produce better results than either one sown alone at the same proportional rate to the unit area. It may be that individuals of the different crops have a stimulating effect upon each other. The investigations of the interrelations of crop individuals and their relations as a whole to their environment constitute the applied science of Agronomy. The unit is the crop or plant community.

321. The stand. — The crowding together of individuals in the form of a crop necessitates the consideration of questions that are not concerned in the behavior of isolated plants. An important one of these questions is the number of plants to a unit of area, or the stand. The optimum stand is dependent, partly at least, upon the amount of tillering (2, 14), as manifestly every new culm from the same kernel is equivalent to another single culm plant, so long as the single spike or panicle of each is of the same size and quality. The latter condition, however, is probably not always true, for if it were, a high tillering variety would always be undoubtedly desirable, since less space would be required for the same number of spikes. As a matter of fact, it is yet an open question whether, beyond certain limits, a high tillering or a low tillering variety is preferable. There is probably an optimum of a medium number of tillers to a plant as well as an optimum stand.

322. Variation in tillering. — There is great variation in the tillering of different cereals and in different cereal varieties. Oats and barley usually tiller less than wheat and rye, and spring varieties of any cereal tiller less than the winter varieties. Durum wheats tiller less than common wheats. To offset low tillering in any variety, thicker seeding must be practiced (355). The application of fertilizers or any favorable soil treatment or amendment will increase tillering.

323. Winter hardiness. — One of the beneficial effects of the plant community, increased greatly by tillering, is the protection thus afforded against cold. The large number of culms to the unit area permits the exposure of a comparatively small extent of surface to the weather. Naturally, therefore, a winter variety must tiller more than a spring variety. Tillering, however, does not entirely determine the matter of hardiness, for some of the least hardy winter cereals tiller greatly. What is more important than tillering is, that the winter-hardy variety produces quickly a large number of strong roots, but grows little above ground before winter. The hardiest varieties have narrow, dark green (sometimes partly purplish) leaves, which soon spread out on the ground.

324. Distinction of spring and winter varieties. — The question, what is a winter wheat, distinguished from a spring wheat, cannot be definitely answered. It can be stated positively, however, that certain supposedly distinct characters are not distinctive. In commercial circles there is a strong tendency to class spring wheats generally (thinking of the kernels only) as red, hard, and glutinous in opposition to soft, starchy winter wheats; though, as a fact, some of the most starchy, soft wheats in this country (Oregon and parts of Washington) are spring wheats, while the winter Turkey wheat of the central Great Plains is one of the hardest and most glutinous. Neither are spring varieties always grown in cold latitudes, though this is usually true. In Turkestan, Mexico, and India, certain spring varieties (especially durum wheats) are grown because of the brief rainfall period, or because of their comparative resistance to attacks of fungi and insects. Winter hardiness is sometimes not a varietal distinction, even where winters are severe. For instance, the Odessa or Grass wheat, formerly grown in Kansas and Nebraska, succeeded well whether sown in fall or spring. Rustproof oats and Beldi barley are examples of southern winter varieties sown in the spring in the North.

In almost all cases it is possible, however, to identify a true spring or winter variety, as such, in the seedling stage in the field. If any cereal, after spring sowing, makes a small leaf growth and does not at once grow erect, but spreads out (in apparent anticipation of winter), it is certainly a winter variety and will not mature that season. This spreading habit of growth is the most essential gross distinction separating spring and winter cereals. The opposite tendency of a true spring variety to grow erect if sown in the fall is not quite so dependable, but can usually be trusted in connection with the two other characters of color and size of leaf. There may be other characters distinguishing winter and spring varieties yet to be determined.

325. Effect of numbers on the food supply. — An important effect of crowding in a plant community is a more rapid exhaustion of the food supply than in cases where individuals of the same variety are isolated. If a second crop of the same variety is grown the following season on the same land, the exhaustion of essential foods (which may have existed in comparatively small amounts at first) becomes still greater (331). It may soon be necessary either to increase the store of these foods by application of proper fertilizers (336), or, by a proper system of rotation (342), to introduce crops having different food requirements, or which may return to the soil the very foods chiefly required by the preceding crop.

326. Soil sanitation. — Another possible injurious effect of the crop upon itself, if grown several years in succession on the same land, is the gradual accumulation of toxic substances in the soil, resulting from the presence of imperfect fungi or other causes. These toxic substances greatly reduce the yield (579). A kind of sanitation of the soil in such a case is required which may be accomplished by a complete reform in its treatment, involving thorough cultivation — using some intertilled crop — and a good crop rotation.

PART III

CEREAL CROPS

CHAPTER XIII

CEREAL CULTIVATION — EASTERN AREA

On the basis of certain differences in cereal environment previously discussed, it seems desirable, for the proper presentation of the subject of cereal cultivation, to consider the country as divided into three large areas, from east to west: (1) the Eastern area, comprising all of the United States and Canada from the Atlantic Ocean to about the 96th meridian; (2) the Great Plains area, extending from about the 96th meridian to the Rocky Mountains proper; and (3) the Western area, including the territory of the Great Basin and Pacific Coast.

Every subject under the treatment of small cereals as crops, constituting Part III, will be discussed for the cereals wheat, oats, barley, and rye at the same time. Afterward rice and buckwheat will be treated independently as to all subjects.

327. Description. — In the Eastern area, the rainfall is fairly abundant throughout the year, but is proportionally less in the growing season than in the Great Plains. The eastern portion is largely timbered, and has usually a shallow surface soil, which is acid and has little humus. Excepting the corn belt (97), there is commonly a deficiency in one or more of the chief plant-food constituents. In the hilly districts, there is considerable trouble from soil erosion.

Soil Treatment

328. Soils. — The best soil for cereals is some kind of loam, silt loam, clay loam, or clay, with considerable humus and a compact subsoil. Sandy loams may give fair results, but are better for corn, sorghums, and legumes. Good examples of cereal soils are the Hagerstown loam and the Clarksville silt loam. Rye and oats require more water than wheat or barley (280, 281), but also will give better returns on a poor soil. Rye will do better on sandy soils and apparently withstand a larger percentage of acid in soils than the other cereals.

329. Topography and drainage. — For proper drainage, the land should be slightly rolling. Low, heavy, undrained clay soils are very unfit for small cereals. Winter cereals are much more easily winterkilled in low wet lands because of alternate freezing and thawing, resulting in heaving of the soil. In low lands there is greater trouble from lodging, and cereal diseases are more common because of the moisture. Good drainage of low heavy soil is therefore of great importance. The greater the proportion of humus, the better the drainage. In certain silt loam soils having subsoils almost impervious to water, tiling for drainage is advisable. Instances are known where tiling has increased the crop yield nearly 100 per cent.

330. Soil erosion is sometimes serious in the Eastern area. It is produced by water flowing over the soil surface, and is of two general types: (1) Sheet erosion and (2) gully erosion. The second type develops where, because of depressions, the water runs off in streams, making gulches of great depth and nearly vertical sides. It is extremely difficult to check, and ruins the land

(Fig. 86). In the first type, the water runs off the whole surface uniformly, taking soil from all parts of the field alike, producing only parallel, incipient gullies. This type is much less destructive and may be largely overcome by different means.

(1) Deep plowing and the incorporation of large quantities of organic matter in the soil will check erosion

FIG. 86. — Soil erosion in Maryland.

by greatly increased absorption of the surface water. (2) Cover-crops are effective in checking the surface flow. (3) In the southern states, where erosion is common and where the large winter precipitation is all rain, much more winter cropping should be done. Rye is a strong winter crop, especially good for holding the soil. (4) Contour farming or terracing may sometimes be necessary, and is already a common practice in the southern and Atlantic Coast states (Fig. 87). (5) Finally it should be noted that soil erosion is less frequent where there is good drainage.

331. Soil efficiency. — Over a large part of the Eastern area, particularly the timbered portions, the soils are well known to be lacking in one or more essential cereal plant-foods or inefficient in other respects, or both may be true. This condition may simply show the soil to be originally deficient, or may be the result of long

FIG. 87. — Terrace or contour farming at Tennessee Agricultural Experiment Station, Knoxville.

periods of cropping without proper soil replenishment. Whichever the cause, it is true that the productive power of the soil decreases after years of cropping, if not properly treated. In previous chapters, the efficiency of the cereal plant and its improvement have been considered. It is equally important that the soil be efficient.

332. Soil amendments are means employed to overcome certain soil deficiencies. The defects that may exist in the soil are several. (1) It may lack one or more of the essential foods, nitrogen, potash, and phosphorus. (2) These foods may exist, but not in the form that is available to the plant. (3) The soil may be acid. (4) Substances may be present that are toxic to the crop. (5) A condition such as the presence of impervious clay may exist that impedes water movement. Note that only one of these refers to the actual food supply. A soil may be well supplied with plant-food, and the crop not be able to get it. The principal amendments employed are liming, application of fertilizers, green manuring, and crop rotation, in addition to good cultivation methods.

333. Liming. — An application of lime to the soil may be effective in a number of ways: (1) As a direct plant-food it is as necessary as potash or nitrogen, but being nearly always present in some form, its value in this respect is not apparent. (2) It renders available potassium and phosphorus much more rapidly than would naturally take place. (3) It neutralizes the acidity in "sour" soils. Whether the soil is acid or not may be determined by placing a piece of blue litmus paper in close contact with the moistened soil for a half hour. If the paper changes color from blue to pink or red, the soil is acid. (4) It counteracts the poisonous effects of salts of magnesium and sodium. The carbonate of the latter is best corrected by the sulfate of lime, known as gypsum. (5) It promotes the nitrification of humus which cannot take place in acid soils. (6) Its presence is favorable for the action of those organisms which fix atmospheric nitrogen. (7) A very important effect of lime is its flocculation of fine clay, changing it from a stiff, impervious condition into a friable, mellow soil, warmer and better aërated.

334. Sources of lime. — Aside from gypsum and the lime phosphates, there are three forms of lime most commonly applied as soil amendments — quick or burned lime, hydrated or slaked lime, and limestone. For all purposes except the neutralizing effect upon sodium carbonate by gypsum, any of these forms may be used. However, quicklime, being very caustic, should not be applied where there is little humus or on light sandy soils, as it quickly exhausts the humus. On the other hand, it may be preferable to the limestone form where there is great soil acidity and much organic matter. In the experiments at the Maryland Experiment Station, it was found that shellmarl, very abundant in Maryland, gave better results in crop yields than any other of many forms of lime used. As magnesium carbonate will neutralize more soil acidity than the same weight of calcium carbonate, and as magnesium is an essential plant-food, it would seem desirable, where convenient, to use dolomite or magnesium limestone, but it should not be applied in excessive quantities. Ground limestone should not be made too fine, as it will then be used too rapidly and much of it wasted through leaching. An 8-mesh or 10-mesh sieve (64 or 100 holes to the square inch) is probably fine enough for economic screening, while nothing coarser than a 4-mesh sieve should be used.

335. Applications of lime may be made at such times as other farm work and weather permit, but are probably better done after plowing, the lime being harrowed in. Ground limestone or lime carbonate should be applied first at the rate of about 4 tons to the acre, and, for permanent maintenance, 2 tons every 4 years thereafter. In strength, 100 pounds of lime carbonate equals about 56 pounds of quicklime or 74 pounds of freshly slaked lime. These other forms of lime should, therefore, be applied in proportional quantities.

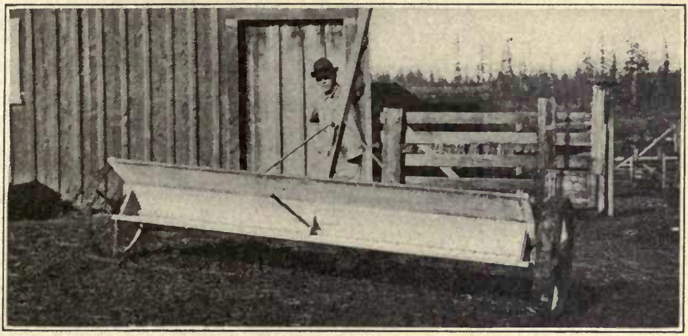


Fig. 88. — A lime-spreader, upper view.

Slaked lime is best applied with a lime-spreader or fertilizer drill (Figs. 88, 89). Ground limestone may be easily spread with a shovel from a wagon box, or from equal sized piles on the ground placed at regular intervals.

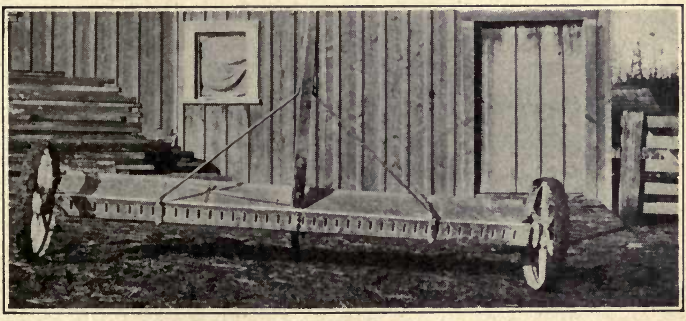


Fig. 89. — A lime-spreader, under view.

A pile of 100 pounds every 24 feet each way, makes about 4 tons to the acre. Quicklime placed in similar piles must first be slaked by treating it with $\frac{1}{2}$ its weight of water, covering it with soil, and allowing it to remain so for 2 or 3 weeks before using.

336. Fertilizers. — As previously stated, the plant-food constituents in one or more of which almost all the older agricultural soils are deficient are nitrogen, phosphorus, and potassium. It is therefore necessary to supply these foods in some form or another in order to provide a balanced ration for the cereal crop. It has been determined at the Missouri Experiment Station that a 30-bushel crop of wheat to the acre, producing also $1\frac{1}{2}$ tons of straw, removes from the soil 49 pounds of nitrogen, $7\frac{1}{2}$ pounds of phosphorus, and 33 pounds of potassium, and that a 60-bushel crop of oats, including $1\frac{3}{5}$ tons of straw, removes 55 pounds of nitrogen, $8\frac{1}{2}$ pounds of phosphorus, and 39 pounds of potassium. The total cost of fertilizers necessary to replace these foods lost from one acre is $11.61 for the oats, and $10.43 for the wheat.

Nitrogen is furnished by barnyard manure, cottonseed meal, and in nitrate fertilizers, but its principal source is from the air. Cottonseed meal is often employed in wheat fertilizers, but is considered to be less effective and economical than an equal value of nitrate of soda. Potassium is ordinarily present in the soil in sufficient quantity, but is often unavailable, until rendered so by the presence of other substances, such as lime. When absent, it is supplied usually in the form of the mined product kainit or the manufactured muriate of potash. It is particularly essential in fertilizers intended for light, sandy soils. Phosphorus is generally deficient in the older wheat soils, and must be supplied in the form of acid phosphate, bone meal, rock phosphate, or basic slag. It appears from results of experiments that, in the presence of decaying organic matter, such as cowpeas turned under or barnyard manure, raw rock phosphate acts as effectively as the superphosphate, while the cost of the former is materially less.

Hopkins (1913) describes a 10-year treatment of a 40-acre field of originally poor land, cropped with a 6-year rotation of corn-oats (or cowpeas)-wheat-clover and timothy (3 years). The entire field was manured with 6 loads of barnyard manure an acre, using a 50-bushel spreader. On nearly all of the field, there was applied also, at different times during the 10 years, 4 tons an acre, in all, of ground limestone and 2 tons an acre of fine ground raw rock phosphate. With all other conditions the same, the land only manured produced $11\frac{1}{2}$ bushels of wheat an acre, in 1913, while the land manured and also treated with the limestone and phosphate produced $35\frac{1}{2}$ bushels an acre (Fig. 90).

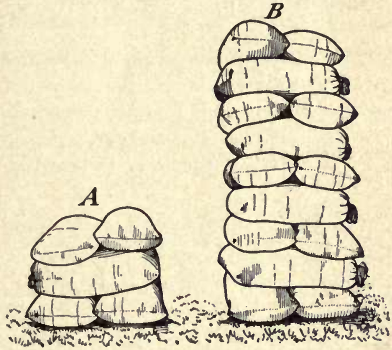


Fig. 90. — Acre-yields of wheat from manuring alone (*A*), and from manuring with the addition of limestone and raw rock phosphate (*B*).

337. Quantities of fertilizers required. — In the southern states, it is recommended that the following quantities of fertilizers to the acre be applied to wheat soils not in the best condition: —

200 pounds acid phosphate
25 pounds muriate of potash
100 pounds nitrate of soda

Little or none of the nitrate of soda will be needed if the preceding crop is cowpeas. The quantity of each fertilizer necessary of course varies with local conditions of soil and the kind of rotation used, if any. Phosphorus is usually the most needed plant-food for wheat. At the Ohio Experiment Station, the following is considered a complete fertilizer for wheat: —

200 pounds steamed bone meal
100 pounds acid phosphate
40 pounds muriate of potash, applied in the fall
60 pounds nitrate of soda, applied in the spring
Total 400 pounds, having the formula 4–16–5

On heavy loam and clay soils a good complete fertilizer for oats is one made up of 3 parts, by weight, of acid phosphate to 1 of nitrate of soda and applied at the rate of 200 pounds to the acre. To this may be added 20 to 40 pounds muriate of potash for sandy or gravelly soils. In the usual soil of the cotton belt, the most universal need of oats is for nitrogen, where it is profitable to apply an average of 80 pounds of nitrate of soda to the acre.

It should be noted that large quantities of nitrogen applied in any form will induce lodging, and favor the occurrence of rust and other fungi. On the other hand, it is believed that kainit and phosphates have a tendency to strengthen the straw and reduce the danger of lodging. Over fertilization is especially possible in case of the oat crop.

338. Time and method of application. — All commercial fertilizers, except nitrate of soda, are applied about the time of seeding. Nitrate of soda, being immediately available, should not be applied until the roots of the plants are well developed and ready to absorb the soluble nitrates, that is, about two months before harvest time. The lumps should be carefully crushed and the fertilizer sown broadcast as a top dressing.

Acid phosphate may be run through the fertilizer attachment of the grain drill. Contact with the seed will not affect germination. It is not safe, however, to use the grain drill for sowing cottonseed meal or other nitrogenous fertilizers or potash salts, because of their interference with germination.

339. Barnyard manure would seem to be the most natural fertilizer for cereal crops, but it is usually impossible to obtain it in sufficient quantity, and besides it is not a complete fertilizer, being specially deficient in phosphorus. It is, however, of great benefit when applied to cereal soils. If 40 to 50 pounds of some form of phosphate are added to each ton of such manure as it is being made in the stable or before hauling to the field, probably no better form of fertilizer can be found. About 8 tons to the acre of this treated manure should be applied once in four years.

In any case of the use of barnyard manure for cereals, it is better not to apply it directly to the cereal crop, but previously to growing some other crop in the rotation such as corn. The cereal will then get the benefit of the added humus in the soil, with less danger of lodging, fungous diseases, and a rank growth of straw, at the expense of grain production.

At the Ohio Experiment Station, a corn-oats-wheat-clover rotation on a scale of 10 acres to each crop, has been established, with a plan of fertilizing, involving the use of all stable manure, that is remarkably successful and should be applicable to a large part of the Eastern area. The manure, after being reënforced with acid phosphate or raw rock phosphate (ground) dusted in the stable at the rate of 1 pound to each 1000 pounds weight of animal each day, is taken directly from the stable to the field. This phosphated manure is spread on the clover sod in the fall or early winter at the rate of 10 tons to the acre, and then plowed under for corn, the plowed land being dressed with limestone, 1 ton to the acre. The oats receive no treatment, but the wheat receives a complete fertilizer of 200 pounds steamed bone meal, 100 pounds acid phosphate, and 40 pounds muriate of potash, in the fall, and 60 pounds nitrate of soda in the spring. The result has been an 8 years' average of 77 bushels corn to the acre, 61 bushels oats, 33 bushels wheat, and $3\frac{2}{3}$ tons hay, an increase over the unfertilized yield of 50 bushels corn, 31 bushels oats, 21 bushels wheat, and more than three times as much hay.

340. Green manures are any crops grown and plowed under green for soil improvement. Through their decay, soil humus is increased, and certain mineral elements already present are rendered available. They become a necessity for successful crop cultivation, in absence of barnyard manure, but may also profitably supplement the latter.

Aside from the plant-food added, green-manures affect favorably the physical condition of both sandy and clay soils. Light sandy soils are prevented from rapidly drying out by reducing the evaporation and percolation. They are made more compact also, and the added humus increases the moisture capacity. On the other hand, clay soils are opened and aërated by green-manures, and made less stiff and less liable to wash where hilly. Extreme soil temperatures are modified by green-manuring. Green-manures, like stable manure, tend to increase soil acidity and therefore their application must be accompanied by liming.

The humus from green-manures not only holds moisture, but retains in the soil soluble nitrates, potassium, and other foods, which otherwise would be leached away especially in the summer months or in the winter in the South.

341. Crops for green-manuring. — Rye is a good green-manure crop. It gives good results alone, but is better combined with a legume. Rye is especially suited for

FIG. 91. — Plowing under rye for green-manure in Virginia.

fall seeding where the land would otherwise remain bare during the winter (Fig. 91). Buckwheat is a valuable green-manure for poor soils, and may be used in the opposite season from that of rye, during the hot summer months of July and August, preventing the loss of much plant-food which ordinarily occurs at this time. It also adds considerable humus.

The legumes or nitrogen-gathering crops are the most valuable for green-manuring. They include the clovers, field peas, soybeans, cowpeas, vetches, and sweet clover.

These not only improve the physical condition of the soil, add humus, and make certain existing mineral foods available, as stable manure does, but they are much the cheapest means of supplying nitrogen, which they obtain from the air (Fig. 92). With green-manures in a good rotation, and returning straw, cornstalks, and other plant residues, not fed, to the land, the humus supply can be fairly maintained without stable manure. However, all of the

Fig. 92. — Plowing under cowpeas to improve the soil in Virginia.

latter that it is possible to obtain should be used. In a complete cropping system such as conducted by the Ohio Experiment Station previously described (339), if stable manure is unavailable, a green-manure is readily provided by turning the clover under, and the phosphate used in reënforcing the stable manure may be applied directly to the clover sod.

342. Crop rotations. — All the various soil amendments previously discussed are only made thoroughly effective when joined with a proper rotation of crops into a complete cropping system. Continuous cropping of any cereal on the same land results in depleted soil fertility, poor condition of the soil, increase of weeds, mixtures of cereal varieties, and low yields. A rotation of cereal crops alone is little better. A perfect rotation series must include a legume and a cultivated crop. As to other details, local conditions will determine the nature of the rotation and particular crops to be used. In the North, the clovers are the chief legumes, and corn and tobacco the cultivated crops. In the South, cowpeas, soybeans, vetch, crimson clover, and lespedeza are the chief legumes, and cotton and corn the cultivated crops.

343. Examples of rotations for the North. — For all the North Central and Eastern states, including the "corn belt" (97), there is probably no better rotation for general purposes than the 4-year rotation previously mentioned (339) as so successful in Ohio — corn, oats, wheat, and clover. The chief cereals are employed, the chief legume and the main cultivated crop. The order in which the crops occur is also good from all standpoints. If a meadow grass is wanted, 2 years of timothy may be added, making a 6-year rotation. In tobacco districts this crop may take the place of oats. In other places where oats do not pay, barley may be substituted or wheat grown twice, or another legume, such as cowpeas, may be inserted if adapted.

Much the best yields of wheat were obtained at the Ohio Experiment Station in a rotation including potatoes (potatoes-wheat-clover), but the potato acreage is ordinarily too limited to be practical in a rotation of large fields. In Maine, however, a potatoes-oats-clover rotation is practiced. In Iowa and Illinois, in both the oat and corn belts, a common rotation consists of corn, oats, and grass or clover. It is usually a 5-year rotation, having two corn crops in succession, while the grass is seeded with the oats and remains two years as a meadow pasture. In Minnesota, a 3-crop rotation of corn, barley, and grass has proven satisfactory, depending in length upon the number of years in grass, the grass seed sown with the barley. The following has proved to be an excellent rotation at the Central Experimental Farm, Ottawa, Canada.

First year — corn, 15 tons manure to the acre applied in spring and shallow plowed shortly before planting time, turning under the clover (sown with wheat previous year) and manure.

Second year — oats, seeded down with 8 pounds red clover, 2 pounds alsike, and 10 pounds timothy to the acre.

Third year — clover hay, two crops, top dressed in fall with manure at 15 tons to the acre.

Fourth year — timothy hay, field plowed in August, top worked and ribbed up in October.

Fifth year — wheat, seeded down with 10 pounds red clover to be turned under the following spring.

344. Rotations for the South. — In the oat districts of the South, a good rotation is corn-oats-cowpeas-cotton, a 3-year series in which cowpeas are grown the same season the oats are harvested. Often cowpeas are planted with the corn, giving the soil the benefit of two leguminous crops in succession. Where wheat is profitable, it is substituted for oats. A 4-year rotation, including either wheat, oats, or barley, and three leguminous crops, may be arranged advantageously as follows: (1) Cotton, with crimson clover sown later between the rows; (2) cotton; (3) corn with cowpeas; (4) wheat followed with cowpeas. Another very suitable rotation in some places includes 3 cereals, as follows: (1) Cotton with crimson clover sown at the last cultivation and plowed under the following spring; (2) corn with cowpeas sown between the rows at the last cultivation; (3) wheat, followed by cowpeas and then by rye sown the same season. The cowpeas following wheat are either cut for hay or disked in or plowed under as a green-manure. Note there is a legume each year. The rye may be plowed under green in the spring in time for cotton, or if allowed to mature, the series becomes a 4-year rotation. From Alabama westward, lespedeza does well, and in that district, a good rotation is corn, oats, and lespedeza. Oats and the lespedeza are sown together the second year and the lespedeza is alone the third year, the latter reseeding itself the last season.

345. The place of each cereal in the rotation is important, and depends upon local conditions and other circumstances. Wheat should be preceded by a legume, but if the crop turned under is a heavy one, and the wheat must follow shortly, it is preferable to insert corn between them. For example, in a rotation including a clover sod manured and turned under, corn should follow first, then wheat or oats. In the corn-oats-cowpeas-cotton rotation, oats follows corn as the cotton would come off too late for the fall seeding.[1] Spring-sown oats could as well follow the cotton.

346. Cereals as nurse crops are very satisfactory. Less seed should be used than when sown for other purposes. Oats is often used for clover and grass. It is usually less satisfactory than the other cereals, however, as it shades the young clover and grass plants too much, and the sudden change to full exposure to the sun on harvesting sometimes injures them. Winter wheat is better because

[1] Except in cases where oats is sown between the cotton rows. which is sometimes done.

of less shade and early harvesting, leaving the young plants the benefit of more moisture remaining in the soil. Winter barley is probably still better in the South, as it matures earlier and does not grow so tall. When cereals are used as nurse crops, the stubble should be left high as

FIG. 93. — Oats as a nurse crop for red clover at Tennessee Agricultural Experiment Station, Knoxville.

possible, to furnish protection and support to the young grass or clover (Fig. 93).

347. Cereals as cover-crops have been mentioned (330). For winter cover rye is best, though in the South barley ranks with it. For summer cover in northern orchards oats is best. Vetch or peas sown with the cereal increase the value of the cover, as they add nitrogen as well as humus to the soil.

348. Cereal crop mixtures. — The cereal crops themselves may be grown together, sometimes with considerable advantage in yields. The practice is an old one. Mixtures of rye and wheat called meteil, and of spelt and wheat called maslin, have been grown in southern and southeastern Europe for a long time. Very few trials of cereal crop mixtures have been made in the United States. At the Illinois Experiment Station, it was attempted to improve the spring wheat crop by sowing it with oats, which failed of attainment. At the Iowa Station, different combinations of wheat and oats at various rates of seeding were tested for two years. The best combination was wheat and oats at 4 pecks each, but all mixtures were better than either crop sown alone. In Minnesota, mixtures of wheat and oats at various rates of seeding of each were tested in 1891, compared with two rates of seeding for oats alone and two for wheat alone. Mixtures of $2\frac{1}{2}$ bushels of oats and $\frac{1}{2}$ bushel of wheat sown to the acre gave best results.

349. Experiments in Canada. — In the 5 years, 1900–1904, tests were made of crop mixtures by Grisdale at the Central Experimental Farm, Ottawa, Canada, as follows: Oats and barley; barley, oats, and peas; and wheat, barley, oats, and peas; compared with peas alone, barley alone, and oats alone. Much the largest yield was of oats alone, 3751 pounds to the acre. Mixed oats and barley ranked second, and barley alone third.

Experiments in Ontario with cereal crop mixtures are much the most complete that the author has noted. These have been conducted by Zavitz at the Ontario Experiment Farm, each series covering 5 or 6 years' time. The first experiment included oats, barley, wheat, and peas, in all possible combinations, including every two, every three, and then all together, making eleven separate tests, in which the highest yield was of oats and barley. In 90 per cent of the tests the mixtures yielded better than the same cereal grown alone. Afterward it was attempted to determine the proper rates of seeding, and best variety of each cereal to use. In still other experiments, emmer, durum wheat, hulless barley, and flax were added, in a proportion of $\frac{1}{2}$ bushel of each to a mixture of $1\frac{1}{2}$ bushels of barley and 1 bushel of oats.

The oat-barley mixture yielded best in all experiments. The varieties Early Daubeney oat and Manchuria barley made an excellent oat-barley mixture, and Siberian or Banner oats and Chevalier barley gave good satisfaction.

Growing the Crop

350. Preparation of the land for fall seeding. — The general principle of soil preparation for sowing small cereals is that the seed bed must be firm and moist, compacted beneath, with a fine mellow surface. For fall seeding following another cereal crop, the stubble should be plowed at least 6 or 7 inches deep, immediately after harvest, and, if possible, harrowed the same day. Thereafter the harrow, disk, or drag should be used several times, particularly after heavy rains, to conserve moisture, firm the soil, and kill weeds, and finally once again just before seeding. If the fall-sown cereal follows a cultivated crop, simply disking and harrowing the ground is sufficient, if cultivation of that crop has been well done. If corn is the preceding cultivated crop, the grain may usually be drilled directly in the corn ground without previous treatment of the latter. If the stalks are still standing, a one-horse drill can be used between the rows, and the stalks broken afterward in the winter.

There is too often a neglect of thorough tillage in the humid area, and frequent losses from drought would be avoided with more attention to moisture conservation.

351. Preparation of the land for spring seeding. — Because of considerable winter precipitation in this area, plowing for spring seeding should, as a rule, be done as

Fig. 94. — Sowing oats on unprepared corn ground, with the endgate seeder.

soon in the fall as the previous crop is removed, leaving the ground rough over winter. Early in the spring, the ground should be double-disked by disking each way or lapping half. A plank drag may be used to crush the large clods, if any. Just before seeding, a fine seed bed should be made with the smoothing harrow. In the fall or spring, if the roller is used, it should be done before seeding.

Less attention is probably given to seed-bed preparation for oats than for any other field crop, though for no good reason. In the corn belt, where oats very commonly follows corn, the seed is often sown broadcast on the corn land without any preparation. In 1905 it was determined accurately that nearly three fourths of the growers in a section of the corn belt followed such a

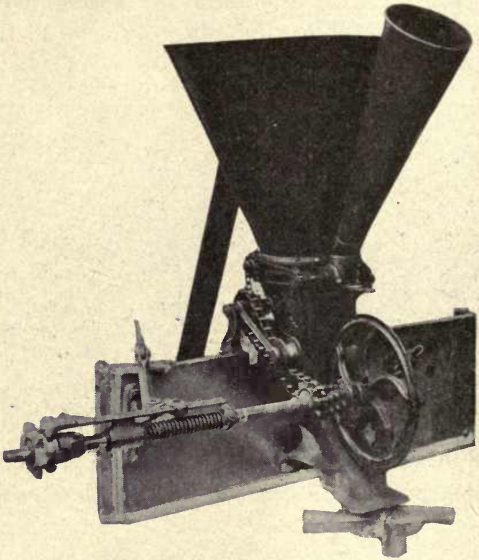


FIG. 95. — Closer view of the endgate seeder.

plan. An implement known as an endgate seeder, fastened to the rear end of a wagon, is commonly employed in such broadcast seeding (Figs. 94 and 95).

Plowing is not usually done for spring grains following a cultivated crop, but at least two diskings and one harrowing are always required (Fig. 96). Where the cereal is to be sown on corn ground, the stalks that are still standing should be broken before disking, which is easily done on frosty mornings by dragging a heavy pole or iron bar broadside across the field. The stalks are then cut with a disk harrow. Sometimes the stalks are cut down with a stalk cutter in the fall, which hastens their decay. After a thorough double-disking with a machine having sharp disks set to run 3 to 4 inches deep, and harrowing with a spike-toothed harrow, the ground should be in good condition (Fig. 97).

Fig. 96. — Disking corn ground with the cutaway disk machine, in preparation for oat seeding.

352. Preparation of seed. — Cleaning and grading grain is discussed in another chapter (178–181). These operations will remove a large percentage or all of the kernels of poor quality. However, if there is still some question as to germination, the seed being old or weathered, a test should be made which is readily done: Several lots of 100 kernels each are counted out from different portions of the bin or from different sacks, placed between clean blotters or canton flannel or in sand, and kept moist at a temperature of 70° F. for several days, after which the number of kernels that show good sprouts is counted. If the latter amount to 90 or more from each 100 tested, the seed is satisfactory from the standpoint of germination. Treatment of seed for smut prevention is described in Chapter XVIII (563–566).

353. Time of fall seeding. — As a rule, the small grains should be sown early, whether in fall or spring (Fig. 98), though early seeding is considerably more important in the spring. Winter cereals should be sown early enough for the formation of strong roots before the winter begins, but not so early as to permit jointing. The latter does not usually occur before freezing in the Northern states and Canada. Seeding must often be delayed to avoid damage by Hessian fly (see 522). In the South there is more danger of jointing in the fall, because of the long growing season. If the crop is to be a cover, jointing does not matter, and if it is to be pastured, the pasturing will check the jointing. If the crop is started in excellent condition, though late sown,

FIG. 97. — Putting in oats near Bloomington, Illinois.

it will often gain on the crops sown early but under less favorable conditions.

A definite date of seeding cannot be specified even for a particular locality, as it will depend upon the kind of crop, its intended use, and the nature of the season. In general, there should be a difference of one day in time

FIG. 98. — Date-of-seeding test of winter barley at Arlington, Virginia: on left, sown Nov. 24; on right, sown Sept. 15; condition on April 15 following.

of seeding for each 10 miles of latitude, the date being earlier to the north or later to the south of a given point. Also the seeding should be one day earlier for each 100 feet increase in elevation. There is a considerable period, in any part of which winter grain may be sown with about the same results, which period is longer toward the south. Usually the order of seeding winter cereals is first oats, then barley, then wheat, and last rye.

354. Time of spring seeding. — In general, the spring isotherms and spring seeding move together northward, while the autumn isotherms and fall seeding move southward. Also fall seeding becomes later and spring seeding earlier from the mountains toward the sea-coast.

Usually spring seeding of small cereals should be done just as early as weather conditions permit. True enough, in the extreme South, that rule would make it practically fall seeding, which, however, is as it should be, for spring seeding, except for some special purpose, is not justified in that latitude. Frosts or even freezes just after the seed is sown rarely injure it. In fact, spring cereals are sometimes sown in the fall and left to lie over winter and germinate in the spring — a practice not to be commended, however. On the other hand, late seeding renders the crop liable to injury by early drought, which the earlier sown crop may escape. Spring seeding begins in the South about February 1, and is not completed in the North until in May. In the latitude of Kansas and Kentucky, it ranges from March 10 to March 25. From Pennsylvania to Iowa, the period is from March 25 to April 15. In the states still further north, the latter half of April is usually best, though earlier seeding in favorable seasons may be an advantage, while seeding in May will sometimes be necessary in a late spring.

355. The rate of seeding the same cereal crop depends on the locality, condition and fertility of the soil, method of seeding, and size of seed. Always more seed is required in the Eastern area than in the Great Plains and Western areas. Drilling requires less seed than sowing broadcast. More seed is needed on poorly prepared or weedy land. On rich land the plants grow larger and tiller more than on poor land, hence the former requires less seed than the latter. More pecks of a large-kerneled variety (not more kernels) should be sown on an acre than of a small-kerneled variety. The increase in stand from a bushel of small kernels more than balances the ranker growth and greater space occupied by the plants from the bushel of large kernels. The usual rate for wheat under ordinary conditions is 6 pecks to the acre. Rye is seeded at about the same rate. Normal seeding of oats runs from 8 to 12 pecks, while the rate for barley is about 8 pecks to the acre. Usually there will be a larger proportion of straw in the thinner seeding.

Zavitz (1913, pp. 39–42) made 32 tests of the thickness of seeding oats, each continuing 4 years. In each test the oats was sown at 7 different rates, running from 0.09 to 12.34 bushels an acre, in which the plants were spaced respectively 12 to 1 inches apart each way. The best yield was secured from seeding 3 inches apart each way or at the rate of 1.36 bushels an acre. The most straw resulted from the highest rate of seeding, 12.34 bushels an acre. However, 3 pounds of seed produced more than half as much straw as 414 pounds of seed. It is interesting that both the percentage of rust and length of period of growth increased exactly in the inverse proportion to the rate of seeding.

356. Depth of seeding. — As stated in previous chapters, the crown from which arises the permanent roots of the cereal plant is formed just beneath the surface of the ground, less than an inch. It is needless therefore to sow deep. Experiments bear out this idea. At the Ohio Experiment Station, experiments in this line resulted in an average yield of 3.56 bushels of oats to the acre larger for the 1-inch than for the 2-inch depth, and 7.73 bushels more for the 1-inch than for the 3-inch or

4-inch depth. At the Arkansas Station, a 3-year test was made of shallow, medium, and deep seeding of wheat, without specifying the actual depth in each case, resulting in 25.4 bushels average yield to the acre for the shallow, 21.6 bushels for the medium, and 20.0 bushels for the deep seeding. It was concluded that seeding of winter wheat should not, under ordinary conditions, be much deeper than 1 inch. At the Minnesota Station, in tests of the depths of seeding barley, the shallowest seeding gave the largest yield of straw and smallest yield of grain, while the deepest seeding gave a larger yield of grain and a smaller yield of straw. It is probable that an average depth of all cereal seeding for the whole Eastern area should be from 1 to 2 inches. In dry localities or in dry seasons, the depth must be increased to $2\frac{1}{2}$ or 3 inches, that the kernels may reach the moist earth.

357. Method of seeding. — The two methods of seeding small cereals in most common use are drilling and broadcasting. The use of the drill is gradually increasing, but it is probable that the greater portion of the oat crop is even yet sown broadcast and the seed covered with the disk harrow or smoothing harrow (351). The seed should be distributed evenly and at a uniform depth, both of which are possible with the drill, but neither result is obtained in broadcasting. The seed is covered more uniformly, there is a better percentage of germination, and consequently less seed is required when the drill is used. The drill furrows catch the snow and rain and (if these furrows are at right angles to the surface slope) hold the moisture for the benefit of the cereal plants. In 3-years experiments at the Arkansas Station in methods of seeding wheat, the average gain in drilling over broadcasting was 3.6 bushels to the acre. In 3-years experiments by the Illinois Station at De Kalb, there was an average gain in drilling oats of 2.7 bushels to the acre over broadcasting. Clover sown with the oats was found to be less liable to injury on removal of the cereal crop if the latter were drilled than if broadcasted. The shoe drill, hoe drill, and disk drill are all about equally good.

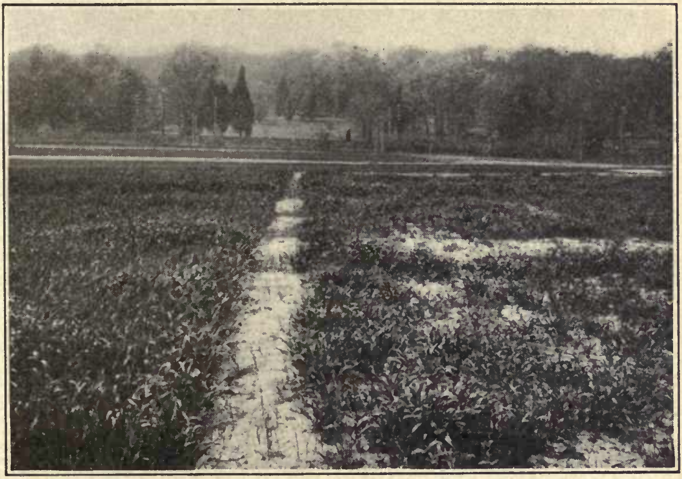


FIG. 99. — Comparison of drilled and broadcasted winter barley at Arlington, Virginia: drilled, 8 pecks an acre, on left; broadcasted, 10 pecks an acre, on right.

The particular kind preferred will depend upon the nature of the soil, kind of rotation, or other local conditions. Drill rows should be 6 inches apart or not more than 8 inches (Fig. 99).

To insure winter survival, winter oats is sometimes seeded by the "open-furrow" method. By this method a machine is used on which the hoes are considerably farther apart than on the ordinary drill, each preceded in front by a shovel which opens a furrow similar to the lister furrow in corn planting, though not so wide and deep as the latter. By this method, the seed is put deep in the compacted soil, thus favoring germination and root formation, and the plants are thereby protected from danger of exposure to the weather through heaving of the soil by freezing. The rate of seeding, also, is a little less to the acre by the open-furrow method than by the use of the drill.

358. Cultivation of the crop. — The winter grain crop is not often benefited anywhere in the Eastern area by cultivation of any kind in the fall or spring. On heavy soils in the very dry seasons a light harrowing in the spring may prove profitable, or the use of a corrugated roller where the soil is badly heaved may be advisable. If rolling is done at all, it should be followed by light harrowing. In Iowa, it is found that harrowing winter wheat in the spring, lengthwise of the rows, is desirable, if the surface soil is baked at the time. This method also gives clover seed that is sown in the wheat in the spring a chance to take root.

359. Mowing and pasturing. — Winter cereals, in good seasons, often make too rank a growth in the fall, especially in the Southern states. This condition will result in winter injury if jointing occurs, and it becomes necessary in such cases to cut back the crop with a mower, or, what is better, to pasture it. Rye or barley may even be sown early on purpose for a pasture or cover crop. Excessive pasturing any time, pasturing when the soil is wet, and late spring pasturing are injurious, and should not be practiced if a crop of grain is desired. Mowing or pasturing may decrease lodging. Spring oats may be cut back sometimes to advantage for the same purpose when the crop is early, which process may also slightly increase the yield through greater tillering.

Gathering the Crop

360. Time of harvesting. — The crop is ripe and ready for cutting when the straw has nearly all become yellow,

Fig. 100. — Cutting small patches with the cradle at the Maryland Agricultural Experiment Station, College Park.

and the kernel can still be slightly indented by pinching. In all the Eastern area, where practically all the grain is bound, the crop should not be allowed to reach the "dead ripe" stage. If so, the kernels will become bleached or otherwise discolored, and there may be some loss from shattering. On the other hand, cutting too early results in shriveling. The condition reached by the kernels at the proper time for cutting is commonly called the "hard dough" stage. Cutting should begin 1 to 3 days earlier than usual where there is a large acreage to handle. If the crop ripens unevenly, it should be cut when the most of it is ready, without waiting for all of it to fully ripen, cutting the riper portions first, if possible. Varieties differ as to the ease with which their degree of ripeness may be determined by appearance. Red and black chaffed varieties are ripe before they appear to be, as the spikes do not turn yellow. Barley for brewing should be cut a little later than if intended for other purposes.

FIG. 101. — The round style of shock with cap sheaves.

361. Cutting the crop is now usually done in all the Eastern area with the self-binder. The cradle is still occasionally used on very hilly land, or for small patches, where wheat is not an important crop (Fig. 100). When the straw is very short in dry weather, or when it is badly lodged in wet weather, it may be necessary to use the mower. The grain is then raked like hay, and put into cocks, which must be well made, in a way to shed rain. The crop should not be fully ripe when cut with the mower, in order that shattering through tramping of the horses may be avoided.

362. Shocking. — The grain should ordinarily be shocked in the field immediately after cutting and binding. If it is in good condition, the usual round shocks are satisfactory, which should be capped to prevent damage from rain and dew (Fig. 101). To begin the shock, stand two sheaves in nearly an upright position, but with heads leaning slightly toward each other, jamming

Fig. 102. — A field of oats in Dutch shocks, near Minneapolis, Minn.

the butts into the stubble enough to insure firmness. From eight to twelve sheaves or more are then set up about these two, until a shock of the desired size is formed. The size of the shock will depend upon the degree of ripeness, length of straw, quantity of weeds present, and nature of the weather. Two sheaves are usually used in capping, the spikes of each being broken down at the band, so as to form a cap. If the grain is very weedy, or necessarily cut rather green, or the weather very wet, the long form or Dutch shock two sheaves wide should be made to permit greater aëration. In this form, about three pairs of sheaves should stand firmly upon their own bases, while two additional pairs at each end should lean toward the central pairs, and still another single sheaf be added at each end. Two sheaves as cappers are usually placed lengthwise of the shock with their butts pressed together to interlock them. The number of sheaves in this shock will depend upon the length of the two capping

FIG. 103.—A method of cap-shocking at Georgia Agriculture Experiment Station, Experiment.

sheaves unless cap sheaves are not used. If there is danger of this narrow shock blowing over, place one or more pairs of sheaves and a single one on each side of it at the middle, with two more cap sheaves as before described, thus forming a cross-shaped shock. The long, narrow shocks are often made in this country and Australia (Peacock, 1911, pp. 9–10), and are common in the north Caucasus (Fig. 102). Occasionally shocks are protected with several cap sheaves, bound together, placed with the spikes downward (Fig. 103).

363. Stacking. — Throughout the Eastern area the grain is usually stacked or stored in mows as soon as dried out in the shock, and allowed to remain so a few weeks or months until thrashing can be done. Thrashing directly from the shock, however, is sometimes practiced. The cost of the latter method is a little less than the cost of stacking and stack-thrashing. The advantages of stacking are the protection of the grain from the weather, resulting in its improved quality, and avoiding the necessity for storage space for thrashed grain for some time if not entirely, if it is not desired to market it at once after harvest. Color and soundness of the kernel are particular qualities in the sale of barley, making it important to stack this crop.

It is important to do the stacking very carefully, in order that the stacks may shed water. Barley is usually more difficult to stack than wheat or oats, because of its short straw. The bottom of the stack should be kept from contact with the ground by pieces of wood, dry straw, or brush. A ditch should be cut all around the stack after it is completed, to carry off surface water during rains. The operation of stacking is one requiring considerable skill. The essentials are (1) to maintain a full middle, (2) to construct a proper "bulge" without slipping, and (3) to top off the stack so as to shed water. Ricks should probably be covered with straw or wild grass.

364. Thrashing. — All grain should be thoroughly dry when it is thrashed. It will then thrash better, while both grain and straw are likely to heat and mold if damp when thrashed. It is important to see that the thrashing machine is thoroughly clean before beginning the thrashing, in order to prevent the mixing of varieties and check the spread of weeds, carried from place to place in the separator. All straw should be saved and carefully stacked, or running the straw into the barn is still better, if there is available room for it. The operation of the machine must be constantly watched to see that all grain is separated from the straw, that none of it blows over, and that the cleaning is thorough. It will often be necessary to readjust the concaves.

CHAPTER XIV

CEREAL CULTIVATION — GREAT PLAINS

In the region known as the Great Plains, the soil is a prairie formation, as opposed to forest soils. It has great water-holding capacity, but the rainfall is very light and most of it falls in the early summer (Fig. 104). The great problem, therefore, is the conservation of moisture. Plant-food is usually abundant, but the utmost ingenuity in cultivation methods is required to utilize the precipitation.

Soil Treatment

365. Soils. — The surface soil in this area is usually a dark loam of varying texture, but with clay or silt predominating, rich in humus, and 6 inches to several feet in depth. Westward toward the mountains the humus decreases, and in large portions in the western part of the area, west of the Missouri River, in the Dakotas, and in the extreme southwestern plains, the soil is light sandy or gravelly, and considerably lacking in humus. Also in the "Bad Lands" of North and South Dakota is a large district with practically no agricultural soil. In much the larger portion of the area, however, the soil is just the kind adapted for small cereals, as previously explained (Chapter X), and only requires water to be extremely fertile.

366. Topography and drainage. — The land throughout this area is either quite level or gently rolling. The

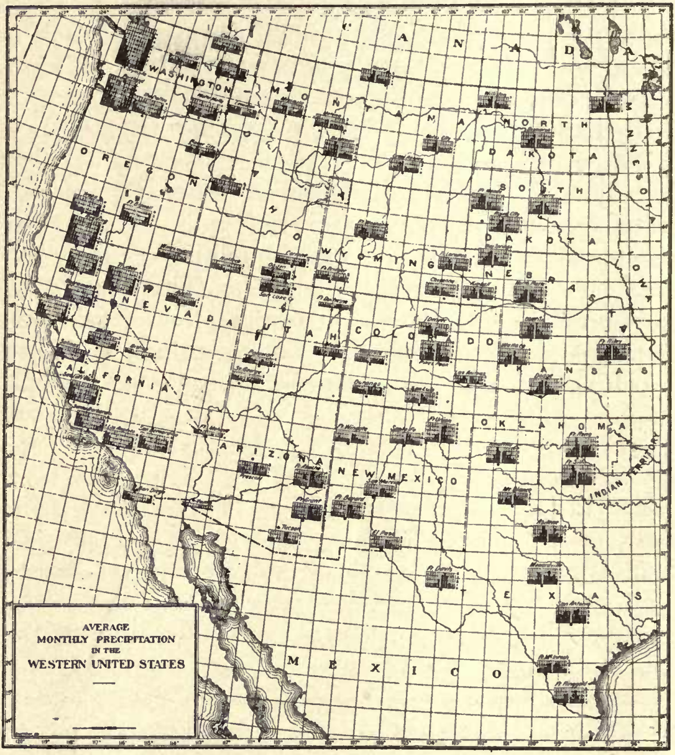


FIG. 104. — Map showing the average monthly precipitation in the Great Plains and Western area of the United States. Each rectangular diagram represents the precipitation at one station, beginning at the left with January and showing monthly averages. The black columns in each diagram, therefore, give the precipitation averages, although the details are too small on this size of page to be seen; but the differences of summer and winter rainfall on the Great Plains and the far Western area, which is the point here to be brought out, are clearly shown.

rainfall is not sufficient to furnish surplus water, there are no marsh lands worth considering, and, therefore, drainage is nowhere, at present, a serious problem. There are, however, places in the Red River-of-the-North Valley where drainage is needed for the best farming operations.

367. Soil amendments. — As the soil in this area is usually fairly well supplied with plant-food and is seldom or never acid, soil amendments are not so necessary as in the Eastern area. Stable manure, green-manuring, crop rotations, and good cultivation are the chief means of increasing crop production. Whether commercial fertilizers are really needed in this area, considering present benefits, cost, and future welfare of the land, is a question not yet satisfactorily settled. According to Ladd (1901, p. 702), soils, fertile as those of the Red River Valley, should, under a system of cropping including 2 humus-producing for every 3 humus-consuming crops, "yield good crops without the aid of commercial fertilizers for a thousand years. This assumes the proper use of all barn manures, and the prevention of unnecessary loss from the soil." However, in Victoria and New South Wales, with a rainfall averaging 10 to 12 inches, applications of superphosphate fertilizers, and, in certain cases, sulfates of potash and ammonia, gave from 20 to 30 per cent increase in yields of wheat, an increase nearly twice as great as that resulting from summer fallow (Guthrie, Helms, and Howell, 1901, 1902, 1904).

368. Barnyard manure. — There is very little information of value on the effects of barnyard manure in the Great Plains area. In some places certain plant-foods may be lacking, and, what may be more important in this area, the organic matter will bring into use mineral foods present but not available. There is in addition to be considered the probable improved physical condition of the soil that will result from an increase in humus. At the Edgeley, North Dakota, substation, in 6 years of experiments in applying manure to fallow followed by a cereal crop, there was an average increase of yield of oats following the manured fallow of 3.4 bushels to the acre, though in 2 years of the 6 the unmanured land gave the higher yields. Wheat on the manured fallow averaged 3.6 bushels to the acre more than on the unmanured fallow, with some increase over the latter each year. Corn grown the second year after the fallow yielded an average of 760 pounds more to the acre after manured than after unmanured fallow. There was an apparent residual effect upon oats 3 years after the manuring, causing an average increase of 5.9 bushels to the acre, but no such residual effect upon wheat (Thysell, McKinstry, Towle, and Ogaard, 1915, pp. 188–189).

369. Green-manures. — Results would be expected from green-manuring rather similar to those secured in the use of barnyard manures in the Great Plains. Unfortunately, very little more investigation has been made of the former than of the latter subject. Green-manures would seem to be even more important in this region as a source of humus than in the Eastern area, as there are no pasture or meadow crops to turn under except where brome-grass is grown, and field cropping is so extensive that the quantity of barnyard manure available is usually insignificant. Brome-grass has not filled the need of a drought-resistant meadow grass to the extent that was expected. In the northern portion of the area, rye and field peas are probably the best green-manure crops, while rye and cowpeas may be used in the southern portion. Sweet clover is being tried, but so far does not appear promising. The cost of green-manuring is great comparatively, and may be sufficient to eliminate the practice in this area, unless the residual effects of these manures should be considerable.

370. Results of experiments in green-manuring. — Chilcott, Cole, and Burr (1915a, p. 43) report that "the most expensive method (of spring wheat production) under trial is green-manuring. It has produced less profit or greater loss than any other method under investigation." They also found that green-manuring for barley production gave the highest yield at Huntley, Montana, where it was in competition with spring-plowed land and disked corn ground, in only a 2-year test. The green crops turned under were rye and peas. The net profit in this soil treatment was $3.45 to the acre against $9.50 for disked corn ground and $6.15 for spring-plowed land. Green-manuring was also followed by higher yields of oats than either fall or spring plowing or disked corn ground at 9 out of 13 stations. However, "the cost of production by this method was so high that it showed a profit at only 2 stations" (Chilcott, Cole, and Burr, 1915b, 1915c). It is significant that the only stations, Huntley and Judith Basin, Montana, where grain followed green-manures with a profit in all these experiments of the United States Department of Agriculture are on the border of the Western area where the addition of humus is one of the chief problems (70–72).

371. Rotation of crops. — One of the purposes of crop rotation is the same as that of green-manuring, — to add humus to the soil. In the Great Plains a more important present purpose for cereal cropping is the storage of soil moisture effected through a previous cultivated crop.

There are also the advantages of increase in nitrification, increase in availability of mineral foods, and such a diversification of crops as will permit the keeping of live-stock. Ladd (1901, pp. 685–704) investigated the effects of humus in the soil and emphasized the use of grasses in a rotation, stating that plowed grass lands are more beneficial to the following crop than green crops turned under. Bromegrass in a rotation was recommended, as it "seems to put the soil more nearly in the condition of native prairie than timothy."

372. Results of experiments. — As early as 1899, Shepperd and Ten Eyck (1899, pp. 451–457) had obtained 6 years' results with rotations that began in 1892, after 9 years' continuous wheat cropping on all plats. Even then, it was concluded from these experiments "that it does not pay to raise wheat continuously. Land which produced 3 crops of wheat and one cultivated crop in 4 years, gave almost as much wheat and more profitable returns than land which produced 4 crops of wheat in succession. Cultivated crops give better returns in the following wheat crops than does the summer fallowing, and if the (cultivated) crop produced will pay for the growing, summer fallowing is an expensive practice."

A 5-years' rotation which "is proving a decided success on the Experimental Farm" at Brandon, Manitoba, includes (1) wheat, (2) wheat, (3) corn, manured preceding fall, (4) barley seeded down with clover, and (5) clover. This rotation, it is said, demonstrates the possibility of eliminating summer fallow. The corn and clover at least pay for themselves and leave the soil in condition for as good a grain crop as summer fallow. In 1913 the profit from barley after corn was $18.75 to the acre, while that from barley after oats (in another rotation) was $11.51.

Wheat after clover gave a profit of $11.76 and wheat after wheat $9.21.

At the Kansas Experiment Station, wheat after oats, in a corn-oats-wheat rotation, yielded as follows, compared with continuous cropping (Fig. 105).

TABLE VI. A COMPARISON OF ROTATION WITH CONTINUOUS CROPPING FOR WINTER WHEAT AT THE KANSAS EXPERIMENT STATION, THE ROTATION BEING CORN — OATS — WHEAT. THE LETTERS REFER TO FIG. 105

TIME AND DEPTH OF PLOWING	ACRE YIELD OF WHEAT IN BUSHELS		
	Rotation	Continuous Cropping	Difference
August 15, 7 inches deep	A. 41.16	B. 32.83	8.33
July 15, 7 inches deep	C. 44.66	D. 34.95	9.71
July 15, 3 inches deep	E. 44.08	F. 21.57	22.51
September 15, 3 inches deep	G. 25.50	H. 16.38	9.11

373. Experiments in the western Great Plains. — Chilcott, Cole, and Burr (1915a, 1915b, 1915c) have

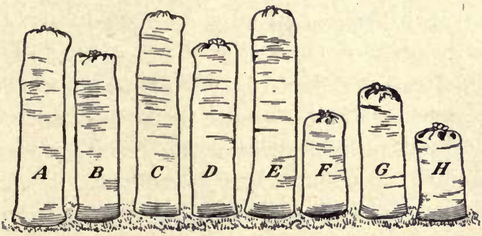


FIG. 105. — Comparison of rotation with continuous cropping for winter wheat. For explanation of letters see Table VI.

reported results of two to eight years' experiments in crop rotations at 14 stations in the Great Plains. In these experiments, spring (durum) wheat, oats, and barley follow summer tillage, small-grain crops on both fall and spring plowing, alfalfa, brome-grass, clover, corn, and flax. In addition to these, rye, peas, and sweet clover are sometimes used for green-manures as previously discussed (370). The chief results obtained were as follows: —

(1) As already stated, the green-manure crops often caused better yields of the following cereal crops than any other soil treatment, but the cost was very great. (2) Alfalfa, clover, or brome-grass sod turned under usually gave indifferent or poor results even compared with cereal after cereal. It should be noted that brome-grass appears better than either of the others. (3) At all except 1 of the 7 northern stations where oats followed flax, the yields were less than when oats followed other cereals. (4) Much the best yields of all the spring cereals at nearly all the 14 stations were obtained on summer tillage. (5) The next best results were usually secured following corn, the ground being disked before spring seeding. (6) The cost of summer tillage was so great compared with the difference in yields between these 2 methods that the profit from the cereal crop on disked corn ground is considerably greater than that from any other method. (7) At the 2 stations, Hettinger, North Dakota, and Belle Fourche, South Dakota, where oats and spring wheat were on disked potato ground, the results were close to those obtained on disked corn ground, and better in one case. (8) Oats did not do as well following sorghums as following corn, though in one case, Hays, Kansas, the yield was better after sorghums.

As a general rule, "Seasonal conditions have produced much wider variations in yields than have been produced by differences in cultivation. Reducing the cost in production has in most cases in these investigations, proved a more important factor in determining profits than increasing yields by cultural methods."

374. Cereals following a cultivated crop. — The results just described, together with those of other rotations conducted in this country and Canada, including a cereal following potatoes or a root crop, show conclusively that cereals always give excellent results after a cultivated crop, and confirm a previous statement that the latter

FIG. 106. — Corn and sunflowers as an intertilled crop, preceding winter wheat, in the Molochna Valley, Taurida, Russia.

should be included in every rotation (342). The cultivated crop is particularly essential in the Great Plains, as it affords not only the benefit of the storage of soil moisture, the most important feature of cropping in that area, but also promotes the eradication of weeds. In southern Russia, where such a crop sequence is practiced, sunflowers grown for the seed sometimes form a part of the cultivated crop (Fig. 106).

A striking example of the influence of corn cultivation on a succeeding crop of small grain was shown at Highmore, South Dakota, substation in the very dry year 1904. Four wheats, 1 emmer, 2 oat varieties, and 2 barleys were sown in tenth-acre strips directly across 3 pieces of land, separated only by roads, one of which pieces had been in wheat, one in corn, and one in fallow the year before. All plats yielded from nothing to 3.3 bushels to the acre on the wheat ground. On fallow they yielded from 8.3 bushels to 54.4 bushels, and after corn from 11.8 bushels to 48.1 bushels to the acre. All except the 2 oat varieties yielded considerably better after corn than on fallow, and from 11 to 50 times as much as after wheat (Cole, 1906, pp. 56–59).

Corn appears to be the best general crop for preceding a small cereal in the rotation, but it will not do well in all parts of the Great Plains. In the extreme northern portion, field peas may precede the cereal, or potatoes, where practicable from other standpoints. If field peas are used, humus will also be added to the soil. In the southern and extreme western portions, where the drought is too severe for corn, the sorghums or cowpeas may be used, the latter serving also as a green-manure. Well adapted cultivated crops are yet needed in this area, though even in North Dakota corn is demonstrated to be superior as a forage to the hay crops. In 6 to 8 years' experiments at Edgeley, Dickinson, Williston, and Hettinger, corn furnished an average weight of forage from 3760 to 7657 pounds, brome-grass the next highest from 810 to 2670 pounds, alfalfa from 1950 to 2040 pounds, and clover from 625 to 1660 pounds (Thysell, McKinstry, Towle, and Ogaard, 1915, pp. 179–180).

375. A winter wheat following corn must often replace a spring cereal in the middle Great Plains, which, however, is not a difficult arrangement. Where oats follows corn and is seeded down with clover, winter wheat can replace oats, but should be drilled in the standing corn in early September. Clover is then added in the spring. Special one-horse drills are made for driving between the corn rows (Fig. 107). It may be desirable to put only a part of the corn ground in winter wheat and the remainder in oats or barley, thus lengthening the period of harvesting.

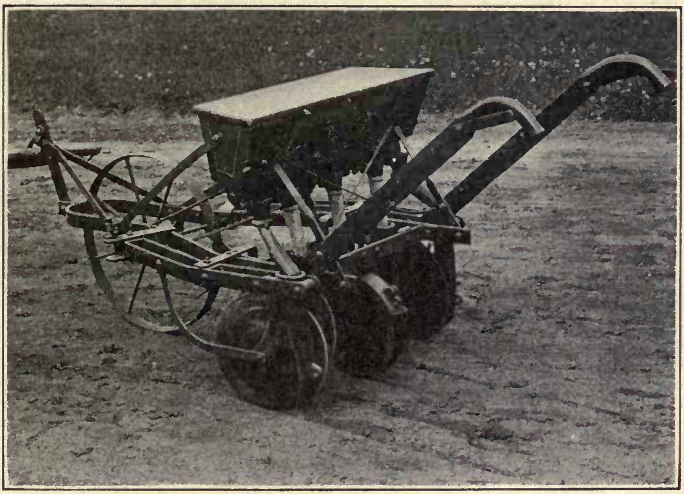


FIG. 107. — One-horse drill for seeding small grain between corn rows.

376. Summer tillage is the cultivation of the soil throughout an entire season without growing a crop, and is practiced in preference to other methods, primarily for the storage of soil moisture. There is also a considerable liberation of plant-food, and, as nothing is returned to the soil, it is an exhaustive cropping method. It is not a fallow, as the latter was often formerly understood, but directly opposed to it. The land is plowed, either in the fall after the previous crop is removed, or the following spring, and then kept clean throughout the season. When the period between the crops is very long or if there is an extreme tendency to weediness, there may be a second plowing. The time and manner of plowing, treatment if any before plowing, and the methods of tillage, will vary with the local conditions of soil and time of occurrence

FIG. 108. — Summer tillage or bare summer fallow.

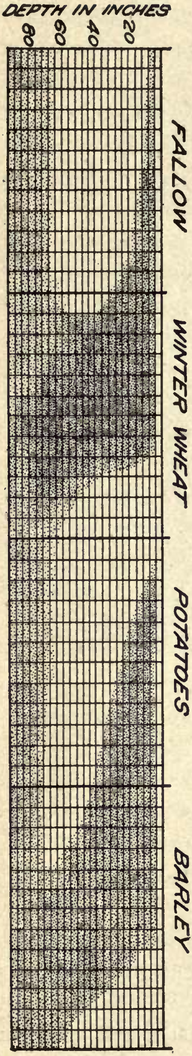
of precipitation, the same as though a crop were to be grown (Fig. 108).

377. Storage of moisture in summer tillage. — Summer tillage has been found to be the most efficient of all methods for storing water in the soil. Some actual figures are given by Burr (1914, pp. 19–29), showing the percentage of moisture stored in this way, at the North Platte, Nebraska, substation. (1) In one case of summer tillage after spring wheat, the moisture content of the soil August 24 the preceding year was 9.8 per cent, which was increased to 16.8 per cent by September 11 the next year, a gain of 7 per cent, equivalent to about 6.5 inches of water. As the rainfall during the interval was 19.7 inches, about 33 per cent of it was stored. (2) In another instance of summer tillage following oats, similar records and figuring show that 24 per cent of the season's rainfall was retained. (3) In a third field, summer-tilled following sorgo, during the entire period from harvest to the next seeding date only 2.5 inches of water were accumulated, and from March to August there was only 1 per cent of increase. The rainfall intervening was 12.2 inches, of which 21 per cent was retained. Even with this small quantity of stored moisture, this field and one other given similar treatment, both sown with winter wheat, were the only fields that produced any small grain in 1911.

The quantity of water which can be stored varies greatly in different seasons, but is from 10 per cent to 33 per cent at this station. With a dry soil surface and high evaporation, as much as a half inch of rain may be of no use in water storage, though of much benefit to a crop.

378. Moisture layers of semi-arid soils. — In the Russian Chernozëm, the same conditions of semi-aridity exist, and the same methods of dry-farming are practiced as in our Great Plains. As the soil is very dark because of its high percentage of humus, summer tillage is called the "black fallow," in contrast to green-manuring and uncultivated fallow. Rotmistrov (1913, pp. 28–34) has made soil moisture studies at the Odessa Experiment Farm, and in a report of his work has, by illustrative terms, presented some of the facts concerning the storage of soil moisture in an interesting way.

The feeding depth of cereal roots, extending to about



50 inches, Rotmistrov calls the root-inhabited layer. Observations show that this layer under cropping becomes more humid or drier, according to the time of year or nature of the season, so he also calls it the periodically humid layer. Under this layer, to a further depth of 6 feet, is an intermediate dry layer, containing only unavailable water, that is, 10 per cent or less. Below this still lies the permanent humid layer, containing 2 per cent to 3 per cent of available water in the upper portion, and 7 per cent to 8 per cent in the lower portion, and extending to the ground water. After summer tillage or after an intertilled crop, the soil moistens from the surface entirely through the intermediate dry layer to the ground water, resulting in an uninterrupted moist layer. In continuous cropping, the intermediate layer is always dry, and toward July the periodically humid layer loses its reserve moisture. Figure 109 shows the distribution of moisture in the soil at different stages of a 4-year rotation.

379. Comparative value of summer tillage. — In the experiments of the United States Department of Agriculture previously discussed (370, 373), it

Fig. 109. — Distribution of moisture in the soil at different stages of a 4-year rotation.

was found that summer tillage without a crop gave the highest average yields of spring wheat following it at twelve of the fourteen stations where the experiments were conducted, but on account of its high cost it had not been the most profitable practice.

Oats did best after summer tillage at all stations except Hettinger, North Dakota, where disked corn ground gave a better yield. It is concluded that "the degree of assurance which summer tillage affords against failure of the feed crop might justify its practice in oat production in at least some sections of the Great Plains."

In barley production, summer tillage gave the highest average yields at eleven of the fourteen stations. On the average it increased the yields nearly half over those produced on land cropped the preceding year. Yet because of its cost, it has not been the most profitable method. The yields in continuous cropping generally average a little more than two thirds as much as after summer tillage.

There appears to be greater response to summer tillage by winter wheat in the winter wheat district than by spring cereals in the spring wheat district.

In the report on dry-farming investigations in western North Dakota previously referred to (368, 374), it is stated "that alternate cropping has not proved to be a profitable practice at any of the North Dakota stations where this work has been conducted, except at Dickinson. A strong argument in favor of summer tillage is that, in a certain measure, it insures a fair yield in a season of drought, but when considered from the standpoint of average production, it appears that it is of doubtful value in western North Dakota."

Four years' results have been obtained at the Hays, Kansas, Branch Experiment Station, in a comparison of summer tillage with early and late plowing for winter wheat in which the average acre yields for these different methods were 21.1, 11.0, and 5.8 bushels respectively.

380. Summer tillage in Montana. — Next to the storage of soil moisture, the chief value of summer tillage is the prevention of weeds. The former feature, in fact, depends largely upon the latter. If the land is not carefully tilled, its very purpose may be defeated and it will become a fallow in the old meaning of the term. This matter is discussed in a report of experiments of three years by the Montana Experiment Station with spring wheat after cultivated and uncultivated fallow, which resulted in an average yield on the former of 19.26 bushels to the acre, and on the latter of 13.92 bushels.

In experiments at the Forsyth, Montana, station to determine the value of alternate cropping in the years 1908–1910, the total yield of three continuous crops of Kubanka wheat was found to be 13.19 bushels an acre, while two crops after one fallow (cultivated) gave a total of 33.09 bushels, and one crop after two fallows yielded 25.83 bushels, even the last one crop making nearly twice as much as three continuous crops. Sixty-Day oats in a similar experiment gave 35.55, 84.24, and 70.69 bushels total yields respectively with the same three methods on one acre. White hulless barley in a third similar trial yielded 12.73, 49.23, and 29.63 bushels respectively.

381. Summer tillage in Saskatchewan. — The larger number of farmers in Saskatchewan practice a triennial fallow, instead of alternate cropping, the rotation being usually wheat-wheat (or oats)-summer tillage. After taking two crops from new land (prairie sod) it is also summer tilled. Trials at the Indian Head Experiment

Farm show that best results are obtained with two plowings, the first one being in May or June, with as much surface cultivation as possible between the plowings.

382. Wind erosion and soil-blowing. — The loss of soil by water erosion in the Eastern area has been discussed (330). In the southwestern and central western parts of the Great Plains, where there is much sandy soil and strong winds are frequent, soil removal occurs under opposite conditions of dryness and a light soil, instead of great rainfall and an impervious soil. The agent is the wind, and the effects are probably equally destructive. The wind, usually from the southwest, first picks up particles of sand from a specially loose portion of the field and, with these as tools, erodes the surface ahead, increasing its effect rapidly from rod to rod until great clouds of dust and sand are formed. Soil-blowing, long continued, will actually excavate the soil sometimes as deep as it is plowed. The effect upon young plants is to cut them off as though with a knife, and then bury the portion remaining. One field or portion of a field will affect another, so much so that often the latter would probably lie undisturbed if isolated.

383. Prevention of soil-blowing. — First, much soil-blowing would be avoided if, at the time of original breaking of the sod, the latter were not carried so far into the sandier part of the farm. This sandier part, when broken, will blow, and will then affect adjacent portions which might not otherwise be disturbed. Soil-blowing may be partially or wholly prevented in the following ways: (1) Immediately when blowing begins, prompt use of a disk or smoothing harrow to roughen the surface will at least check the effect greatly; (2) increasing the soil humus by application of barnyard manure is a more permanent preventive measure; (3) plowing under green manure crops, such as rye, sweet clover, cowpeas, and field peas, which will have the same effect as barnyard manure; (4) listing narrow strips of land at right angles to the direction of the wind; (5) planting tall growing sorghum crops in long fields at right angles to the wind, and sowing the following crop without removing the sorghum stalks and without plowing; (6) probably the most effective and permanent prevention, but one requiring time to develop, is the establishment of long, narrow belts of trees running east and west, and growing the annual crops between these belts. To be thoroughly effective, the widths of tree belts and crop belts should have at least the ratio of 1 : 7, while 1 : 4 is better. Considering both rapidity of growth and hardiness, the best trees for this purpose are osage orange, cottonwood, green ash, honey locust, and Russian mulberry, with always a hedge of tamarisk on the south side of the belt. Where there are no borers, black locust is excellent.

384. Cereals as nurse crops are not uncommon occurrences in the Great Plains. They serve in this way for alfalfa, clover, sweet clover, and grasses. Seeding down wheat or barley with clover or grass seed or both is practiced both in this country and in Canada. Brome-grass is seeded with wheat on disked corn land, and remains two years after the wheat is removed.

Growing the Crop

385. Preparation of the land for fall seeding. — In preparation for rye or winter wheat in this area, it is generally agreed that early plowing is important, unless the crop is to follow summer tillage. The early plowing, when following another crop, in fact permits a brief summer tillage. At the Kansas station, Call (1913, p. 7) investigated this subject as to winter wheat, both in a rotation with corn and oats and in continuous wheat cropping. The best date and depth of plowing, considering both yield and cost, was the plowing July 15, 3 inches deep, in case of the rotation, giving a yield of 44 bushels to the acre and net profit above cost of preparation of $30.91. In the continuous cropping, the best results were from plowing July 15, 7 inches deep, the acre yield being 35 bushels, and net return above cost of preparation $23.11. The average results for 3 years, in continuous cropping, were in favor of deep plowing (Fig. 110). Grace (1915, p. 6) gives results of 6 years' trials of early and late plowing for winter wheat, in which the yields from early plowing were always better.

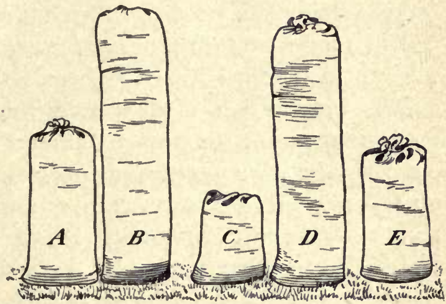


Fig. 110. — Comparison of different methods of preparing the ground for winter wheat in continuous cropping: *A*, Plowed July 15, 3 inches deep; *B*, Plowed July 15, 7 inches deep; *C*, Disked at planting, not plowed; *D*, Plowed August 15, 7 inches deep; *E*, Plowed September 15, 3 inches deep.

Double-disking early after harvest, followed by plowing within a month afterward, is found to be a good plan, particularly if the ground cannot be plowed or listed at time of disking. Weeds are killed and moisture is held in the soil. Disking without plowing is a poor method.

By determinations of soil moisture at different dates, Burr (1914, pp. 39–42) has shown that moisture is conserved by disking stubble following the binder, if there is sufficient water in the soil after harvest to start weeds.

Listing is now often practiced in the middle Great Plains as a preparation for winter wheat, and appears to give good results. In double listing, the ridge formed by the first listing is split a month later by the same machine. After listing, the ridges are worked down with a cultivator and then by other implements, as may be necessary to keep down the weeds, until seeding time.

The practice of drilling winter grain in standing corn without any preparation has been mentioned (375).

386. Preparation of the land for spring seeding. — Some years ago there was a common impression throughout this area that spring seeding should always be done on fall plowing. Results of recent investigations do not as a rule support this idea. In the experiments of the United States Department of Agriculture previously discussed, spring plowing for spring wheat gave average results at fourteen stations exactly the same as those for fall plowing. Spring plowing for oats was slightly better than fall plowing, as an average for all stations; but fall plowing at Hays, Kansas, and stations south of there, gave better yields than spring plowing, while the reverse was true at stations north of Hays. For barley, there was little difference in the general average of results between fall and spring plowing, but the 4 most southern stations had slightly better yields after fall plowing. Grace (1915, pp. 14–15) concludes that, in eastern Colorado, to plow in the fall or spring depends upon the further question whether a greater quantity of water will be accumulated by snow in the standing stubble than will be dissipated by weeds. At the Lethbridge, Alberta, Experiment Farm, spring plowing invariably gave better results than fall plowing.

Listing in the fall and leaving the surface ridged during the winter has often proved a better method than fall plowing, in preparation for spring crops. Disking is universally the best method of treating corn ground (see Fig. 96). Shepperd and Churchill (1907, p. 307) give results of 3 years' experiments on preparation of corn ground for wheat, which show that spring disking was better than either fall or spring plowing, the first yielding at the rate of 28.8 bushels to the acre, the second 27.4 bushels, and the third or spring plowing 24.8 bushels.

387. Breaking and backsetting. — In many localities in this area, there is yet considerable new prairie land to be broken, which is invariably sown with small cereals or flax. Breaking the sod where it is tough and strong, as in all the middle and northern Great Plains, should be done in very thin slices, before the early summer rains are over. In August or September, after the sod is well rotted by the rains and sunshine, it must be plowed again (backset) 1 to 3 inches deeper. By following this operation with disking and harrowing, the soil is put in excellent condition. Sometimes in the extreme north, 2 crops are grown without further treatment except to burn the stubble of the first crop. Use of the roller after breaking will sometimes hasten the rotting of the sod (Fig. 111).

In the southern plains, the sod is often sufficiently loose that deeper breaking may be done, and cultivation very soon afterward will reduce it almost to the condition of old ground.

388. The seed-bed. — The advantages of a firm seedbed in this area, resulting from early plowing or listing followed by frequent cultivation, cannot be emphasized too much. In loose, poorly packed soil, most of the available moisture to the depth of seeding will be lost by the simple process of drying out to the full depth to which the soil has been plowed, thus producing very unfavorable conditions for the germination and early growth of the crop. Early and thorough preparation of the seed-bed not only prevents weeds, which are the worst means of

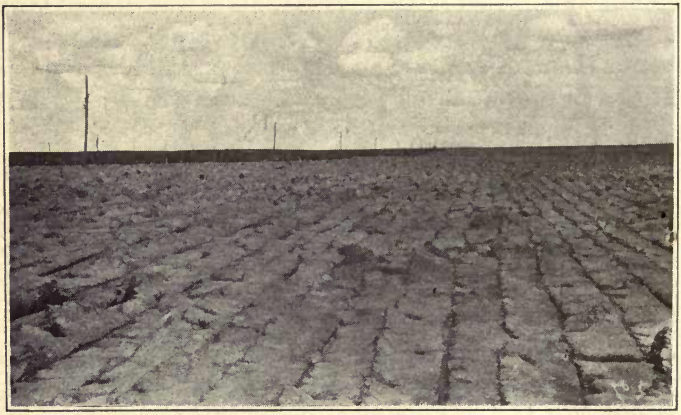


Fig. 111. — Breaking properly done, in thin slices, with the turned-over sod lying flat.

dissipating moisture, but also causes a compact seed-bed. In a compact early worked seed-bed, there is more available plant-food than in soil later and less thoroughly cultivated. When the time between plowing and seeding is very short, or if the soil is unusually loose, it may be advisable to use the packer.

389. Packing the soil artificially is commonly practiced in Saskatchewan, and often in the United States. Two kinds of machines are employed, the surface and subsurface packer, of which the former is more common. The surface packer has its wheels flat or nearly so, and their edges deeply notched (Fig. 112). The effect of the use of this implement is to leave the surface compressed and pulverized but not smooth. The subsurface packer has wheels disk-shaped or, in cross section, V-shaped, and

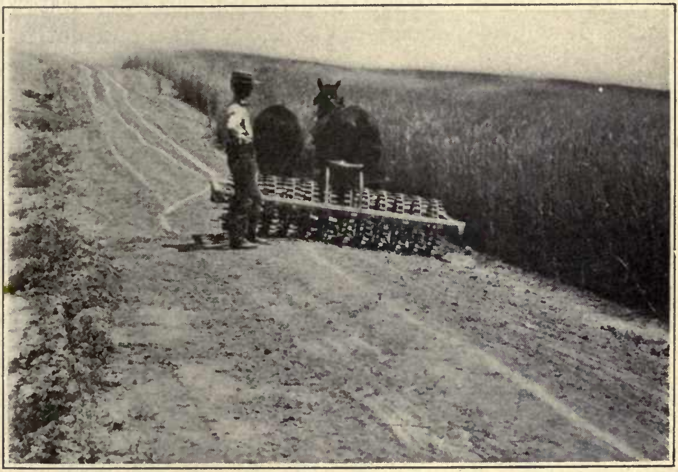


FIG. 112. — Surface packer or Dunham roller.

its pressure is therefore exerted beneath the surface (Fig. 113).

In the North the packer is commonly used after the seed is sown, the usual order being seeding, harrowing, packing. Some, however, use it only before drilling. In the cases of fall plowing and summer tillage, it is often recommended that the packing be done at once after plowing, followed by the harrow, particularly when the subsurface machine is used. This procedure is not followed, however, in Canada, and apparently is not common in the United

States. Many farmers report that packing prevents soil-blowing.

390. Methods of summer tillage. — Mackay (*vide* Grisdale, 1913, p. 15) gives the following as the best method of handling the summer fallow in southern Saskatchewan: "Deep plowing (7–8 inches) before the last of June; surface cultivated during the growing season; results in sufficient moisture for a dry year, and not too

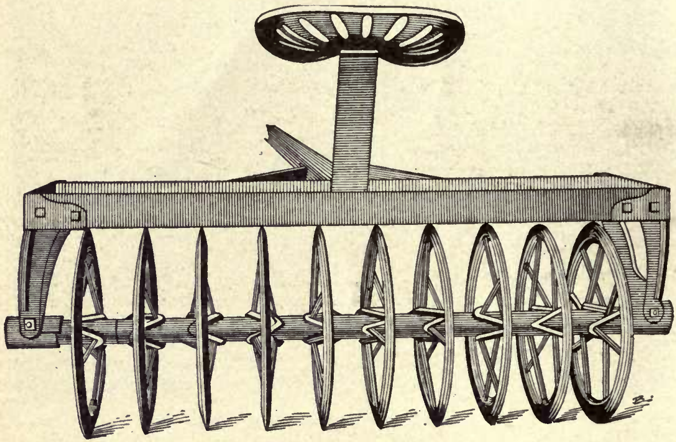


FIG. 113. — Subsurface packer.

much for a wet year; few or no weeds, as all the seeds near the surface have germinated and been killed; surface soil apt to blow more readily than when other methods are followed; for the past 14 years the best, safest, and cleanest grain has been grown on fallow worked in this way." Plowing for summer tillage in the North should always be done in the spring. Usually packing the soil after plowing for summer tillage is not needed, as the long time before seeding allows the soil to become packed.

391. The soil mulch. — Some years ago there was much discussion of the "dust mulch," considered by many then to be essential in checking evaporation. A dust mulch is now known to be very undesirable in the very localities where evaporation is greatest, as it promotes soil-blowing. It is probably not nearly the effective means of conserving moisture that it was supposed to be,

Fig. 114. — Time-of-seeding test of winter wheat at the Newell, South Dakota, substation. The plat on the right was sown much earlier than the other.

and, moreover, it soon forms a hard crust in heavy soils. A better mulch is one of coarser particles, 3 inches or more deep, and which leaves the surface rough (see Fig. 108). A cultivator used lightly is a good implement for surface cultivation of light sandy soils. Mulch of hay or straw is very effective for conserving moisture. This may be raked off afterward, or if not in the way of the crop, can be plowed under later.

392. Time of fall seeding. — Usually it is best to sow winter grain early (Fig. 114). Sometimes after continued dry weather, rather late seeding is necessary in order to have a good seed-bed. The latter is then more important than early seeding. The particular date will of course be earlier toward the north. In northern Kansas, winter wheat seeding should be about September 15–20, in southern Kansas, September 20–25. Rye can be sown a little later. Winter barley should be sown a little earlier than winter wheat. When the Hessian fly is prevalent, it may be wise to delay seeding (522). In Oklahoma, September 25 to October 5 appears to be about the right period for seeding winter grain.

Results of experiments at the Amarillo, Texas, Cereal Field Station show that winter wheat should be sown in Texas Panhandle about October 15 to November 1. In similar experiments with winter barley at Channing, Texas, about October 7 seemed the best date for that crop. At this place late seeding of winter barley seemed to reduce strikingly the quantity of loose smut in the crop (Ross and Leidigh, 1913, pp. 29, 45–47).

At the Judith Basin, Montana, substation, experiments on the date of seeding Turkey winter wheat for 5 years resulted in August 1 giving the best average yield, though September 1–7 was nearly as good, and better than August 13. As September 15–20 gave still poorer results, it seems only that some date in August is the proper time (Atkinson, 1914, p. 155). In Alaska, winter rye and winter wheat must be sown early in August or last of July.

393. Time of spring seeding. — For spring cereals, also, comparatively early seeding is usually preferable, in order that the crop may escape the midsummer drought. The proper date is later toward the north. The actual date will often be governed largely by the quantity of moisture in the soil. If the soil moisture is deficient for some time, seeding may be much delayed. On this account, the range in time of seeding may be considerable. It extends from about February 25 to April 15, at Amarillo, Texas, though in one year best results with oats were obtained from May seeding. Late-sown spring grain is apt to rust.

Results of experiments, so far, indicate that April 15 to May 1 is the best period for seeding spring grains at Archer, Wyoming, which would apply to considerable adjoining portions of Nebraska and Colorado. In North Dakota, it appears to be the general experience that a medium date of seeding is safer than either late or early seeding. Near April 15 seems a good average time in the state. In Saskatchewan, it is recommended to sow from May 15 to 25. In Alaska, spring grain is sown May 10 to 20.

In Oklahoma, early seeding of an early variety is considered to be important. At the Kansas Station, in two years' experiments, about March 30 was found to be the best time for seeding both oats and barley. It is stated that oats should be sown "as early in the spring as the soil is in fit condition; and in order to prepare an early seed-bed, and have the soil well settled and in good tilth, the ground should be fall plowed for oats" (Ten Eyck and Shoesmith, 1904, p. 190).

394. Rate of seeding. — In the Great Plains area, the best rate of seeding is usually less than in the Eastern area. For eastern Colorado, the following rate to the acre has been recommended: Wheat 45 to 60 pounds; oats 40 to 60 pounds; barley 50 to 60 pounds; rye 35 to 50 pounds; and emmer 45 to 60 pounds. There should be little or no difference in rate of seeding in different latitudes, but the rate should decrease a little as dryness increases.

In experiments at the North Dakota station for 2 years, the best rates of seeding spring wheat, oats, and barley were $5\frac{1}{2}$ pecks, 8 pecks, and 8 to 10 pecks respectively. It should be noted that this locality is much more humid than the western Great Plains. At the Dickinson, North Dakota, substation, the seeding of winter wheat above 4 pecks to the acre increased the winter killing. Thicker seeding reduces the supply of moisture to each plant. The plants therefore become weakened by lack of moisture and are more easily killed. Durum wheat at 5 pecks, common spring wheat at 4 pecks, winter wheat at 3 to 4 pecks, and oats and barley at 6 pecks, seem to be the proper rates of seeding to the acre, for these cereals in western North and South Dakota.

In Saskatchewan, it is stated that long experience has shown that best results are obtained from sowing $1\frac{1}{2}$ bushels of wheat and 2 bushels of oats or barley to the acre. On summer-tilled heavy soil, a seeding of $1\frac{3}{4}$ bushels of wheat and $2\frac{1}{2}$ bushels of oats or barley to the acre may be a little better, and will cause the crop to ripen earlier. Atkinson and Nelson (1914, pp. 154–155) found, in 5 years' experiments with rates of seeding for winter wheat, that 3 to 4 pecks gave the best yields, 3 pecks being apparently better than 4 pecks. For oats and barley, about 40 pounds to the acre seemed to be the best.

Experiments conducted so far at the Archer, Wyoming, substation indicate that about 3 pecks of wheat and 4 pecks of oats or barley are the best quantities of seed to the acre. Invariably a little less seed will be required for any cereal in drilling than in broadcasting. In experiments by Montgomery (1910, pp. 7–9) at the Nebraska station for several years, 10 pecks of oats in broadcasting and 8 pecks in drilling were found to be the best rates of seeding for that crop, using the variety Kherson.

In the trials of only one year at the Kansas station, the best rate of seeding was found to be 5 pecks for winter wheat, 8 pecks for winter barley, and 10 pecks for oats and spring barley. The humidity of the locality is above the average for the Great Plains.

395. Depth of seeding. — The one essential thing in depth of seeding is that the kernels shall reach moist earth. It will therefore often be necessary, in this area, to sow a little deeper than in the Eastern area. Also in a dry season, deeper seeding is more desirable than in a normal season. In Saskatchewan, it is considered important to force the seed down to moist earth even if it is over 2 inches.

In a trial at the Kansas station, seeding of winter wheat at 2 to $2\frac{1}{2}$ inches gave the best results. At the North Dakota station, the depths of seeding which appear to be the best from experiments of one year only are: Spring wheat, $2\frac{1}{4}$ inches; oats, 2 to 4 inches; and barley, 3 inches. In experiments of 8 years at the Indian Head, Saskatchewan, Experiment Farm, spring wheat seeded 2 inches deep averaged 2 bushels more yield to the acre than where seeded 3 inches.

396. Method of seeding. — Drilling is always the best method of seeding small grains, but in the Great Plains, it is absolutely essential. It is impossible, because of the uncertain depth of moisture, to put the seed into moist earth with certainty and at a uniform depth by any other method, unless the seed is sown like corn in listed furrows. The latter, in fact, may be a good method in the drier districts, and has already been tried. Drilling also prevents winterkilling to a great degree. The drill rows should usually run east and west, or at right angles to the wind. At the Nebraska station, in experiments of 4 years, drilled oats, cultivated after coming up, gave better yields than broadcasted oats cultivated, but broadcasted wheat not cultivated did better than drilled wheat not cultivated.

Drilling always requires less seed than broadcasting. There are 4 kinds of drills, — the disk, the shoe, the

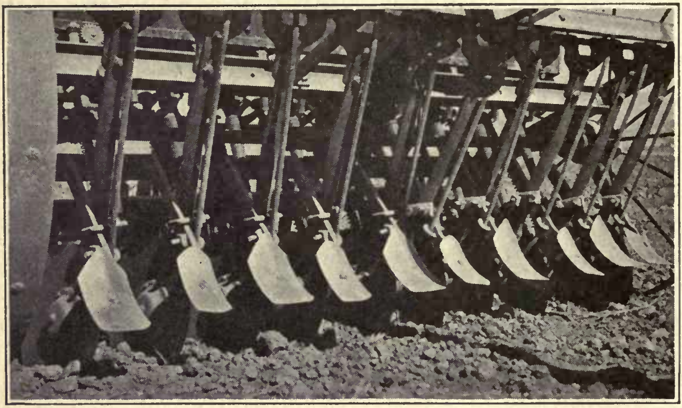


FIG. 115. — Disk drill, with shovel attachments in front of disks.

hoe, and the lister. The disk drill, which is probably the most common, is of 2 forms, the single and double disk (Fig. 115).

397. Cultivating growing cereals. — The few series of experiments in cultivating grain have given results not always in accord with each other. In seasons of more than normal rainfall, the effect is sometimes injurious. As the purpose is to conserve moisture, naturally cultivation should give better results in the drier seasons. Both harrowing and rolling of winter grain in the spring have been practiced. The rolling may be of advantage after an open winter, when the ground is loose and dry, or as a corrective of heaving of the soil caused by alternate freezing and thawing. The latter, however, does not occur much in this area outside of northern Texas. The harrowing may be of value on soils having a tendency to crust, and in a dry period following winter or early spring rains.

Harrowing the small cereals after they are up is considered to be of much value in Manitoba and Saskatchewan. In many instances of the employment of the surface packer in Saskatchewan previously mentioned (388), it was used after the plants were 2 to 4 inches high, with beneficial results, it is claimed. From experiments at the North Dakota station, it appeared that "harrowing wheat conserved the soil moisture and proved beneficial." An average of the results of 2 and 3 years' trials at demonstration farms in Montana shows no benefit from harrowing winter wheat in the spring, but a direct loss, to which must be added the cost of cultivation.

In 4 years of experiments at the Nebraska station, no increased yield was obtained from the cultivation of winter wheat. There was considerable loss in cultivating broadcasted wheat, because so many plants were destroyed by the harrow. Rolling early in the spring when growth had started gave an average increase in yield of 5.1 bushels to the acre. Harrowing after rolling always reduced the gain from rolling alone. The weeder was better than the harrow. The average yields in 7 years' trials in cultivating oats showed 4.8 bushels to the acre gain in favor of cultivation (Montgomery, 1908).

398. Pasturing the grain crop. — In the Great Plains, except in unusually wet seasons or long-continued autumn weather in the southern portion, it is rarely necessary to check the growth of winter cereals to prevent winter-killing, but pasturing is commonly practiced for the feeding value of the forage. Both wheat and rye are employed for fall and winter pasturage, but rye is not so commonly grown. Occasionally the crop remains green nearly all winter. As the cereals furnish the chief pasturage other than alfalfa, they are particularly valuable for supplementing the latter, at a time of year when other green food is not available. Both cattle and hogs are put on the grain crops. In the southern plains, hogs are turned from alfalfa to wheat or rye pastures in November, and may be left there during the winter if the ground is dry. About April they go back to alfalfa. From Kansas to Texas inclusive, rye is probably not grown nearly so much as it might be profitably. It is about the best winter cover-crop, and after considerable pasturing, can yet be turned under as a good green-manure. In Texas and Oklahoma, winter barley may be used as well as rye or wheat. These cereals will not support as many animals as alfalfa, but will carry from 6 to 10 hogs to the acre (Quinn, 1907, pp. 10–12).

In the North, and for spring forage in the South, oats are employed for pasturing. It is stated that hogs do better as a rule on oats than on wheat. Rape is sometimes sown with the oats intended to be pastured.

Gathering the Crop

399. Harvesting. — In the Great Plains area, where the acreage in small cereals is very large, cutting the crop is done chiefly with the self-binder, the best method for thoroughly curing the grain (Fig. 116). Harvesting occurs generally in the beginning of the dry season, when there is little danger of damage from rains. Sometimes in the middle and southern districts there are severe storms just at cutting time which delay operations or knock the grain down, so that it is difficult to gather. The one great difficulty generally is to get sufficient help to have the work done in good time as, in the hot dry atmosphere of this region, the crop ripens rapidly and, if cut when over-ripe, much loss results from shattering. The harvest problem is therefore now largely a labor

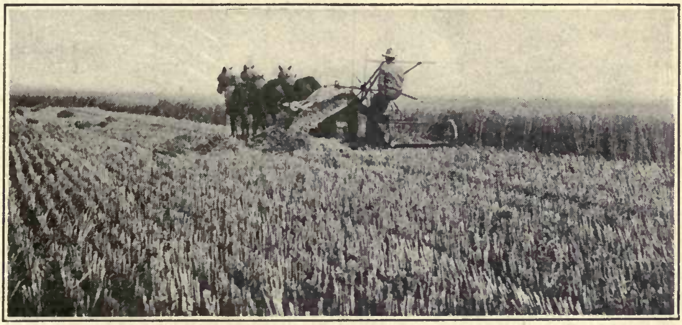


FIG. 116. — Cutting Swedish Select oats with a self-binder at Edgeley, North Dakota.

problem, even though machines do much of the work. As the header removes the crop much more rapidly, that machine is used to a considerable extent in the drier districts.

400. Shocking in this area is a quick operation immediately following the self-binder. No drying out of the sheaves is necessary. If many weeds are present, they simply furnish moisture to help cure the grain, unless the weather is unusually wet. Cap sheaves are without question an advantage, but it is difficult to prevent the wind from blowing them off, and often they are not used

(Fig. 117). When the shocks are thus exposed to alternate showers and sunshine, the kernels swell, their bran coats loosen, and they become discolored or "bleached." Moisture is absorbed, and the test weight of the measured bushel is decreased. These conditions lower the grade of the wheat, and directly affect its market value. The same conditions badly affect the quality of barley for brewing, for which purpose a large part of the barley crop

Fig. 117. — Sixty-day oats in the shock at the North Dakota Agricultural Experiment Station, Fargo.

in the northern Great Plains is used. Even oats may be so dulled or stained in color or lose so much in weight in the same way that its value when sold for feeding is curtailed.

401. Stacking. — The larger part of the bound grain of the Great Plains is thrashed from the shock. Millers and elevator operators, however, generally prefer wheat that has "gone through the sweat," and it is claimed that it is much improved in quality by sweating in the stack. When the difference in quality is considerable, the buyer will pay a little more for the stack-thrashed wheat. The process of sweating has never been satisfactorily explained. It is known that after cutting, reserve foods continue to be stored in the kernels from the straw, which is usually still a little green. The heat developed in this continued process, together with the moisture evaporated, may constitute the sweating. If the wheat is thrashed before

FIG. 118. — Thrashing winter wheat in Texas Panhandle.

sweating, chemical action may continue within the kernels, causing sweating in the bin. The sweating process is more severe and occurs quicker as the grain is greener at harvesting time, or more moist. Sufficient heat may thus be evolved even in the stack to produce "stack-burnt" wheat. It is more likely to be injured in the bin, however, as there is there less circulation of air. Milling tests of shock-thrashed and stack-thrashed wheat have been made, resulting in less loss in milling, less bran, more "low grade," more shorts, and more straight flour in the former than in the latter. Baking tests from flour from the same lots of wheat showed greater loaf volume and greater water absorption in bread made with flour from the stack-thrashed wheat (Fitz, 1910).

402. Thrashing. — Throughout this area, thrashing is often done necessarily on a large scale. Large engines are employed and self-feeding separators equipped with straw blowers. Usually the entire crew of hands is supplied by the owner of the outfit.

In the Great Plains, the grain is often very dry when thrashed, and great care is required in setting the concaves to prevent cracking of the kernels. The separator should be as thoroughly cleaned of all grain lodged within it as possible, on beginning a new job. If there has been considerable rain, the top and bottom sheaves of stacks and the cap sheaves of shocks should be thrashed separately, so the grade of the remainder of the crop may not be impaired (Fig. 118).

CHAPTER XV

CEREAL CULTIVATION — WESTERN AREA

THE region westward from the Rocky Mountains to the Pacific Ocean, discussed here under the heading Western Area, is, almost throughout its extent, very dry like the Great Plains, though there is a district of heavy rainfall in the extreme Northwest. The chief characteristic distinguishing it from the other two areas is the winter rainfall. Also the soils generally contain considerably less humus than those of the Great Plains. In the upper depths they contain even less humus than those of the Eastern area, but more mineral plant-food. There are often excessive deposits of alkali.

SOIL TREATMENT

403. Soils. — The soil types vary greatly in this area. In the mountain valleys the soil ranges from sandy loam to clay, and is sometimes underlain with coarse gravel. In the Great Basin the soils are alluvial and those of the eastern portion included in a large part of Utah were made chiefly by the ancient Lake Bonneville, while in the western portion, in Nevada, much of the soil is a product of Lake Lahontan. In nearly all of Idaho and the eastern and central parts of Washington and Oregon is one vast lava bed. Here, therefore, the soils are all of volcanic origin. They are composed of very finely divided particles and, in the Palouse country, have, in recent times, been shifted by wind action and deposited as dunes. In California the principal cereal section lies in the flood plains of the Sacramento and San Joaquin rivers. In many places the soil is heavy and sticky, and, when dry, is worked with much difficulty. The Imperial valley soil is an enormous silt deposit brought by the Colorado River and said to be over 700 feet deep in places.

404. Topography and drainage. — The surface features between mountains in most of this area are similar to those of the Great Plains, except as to the plant cover, which, wherever there is any, is composed generally of shrubs instead of grasses, because of the lack of summer rains. The volcanic soils of the northwest absorb and hold water tenaciously. The usually light precipitation makes drainage, of course, unnecessary, under dry-farming. There is, however, much irrigation throughout the area, and wherever that is practiced, drainage is very necessary to prevent excessive deposits of alkali. These deposits at or near the surface constantly increase through irrigation, until they become a serious menace to the crop, unless the applications of water are moderate or there is good drainage.

405. Soil amendments. — Acid soils are found occasionally in the Pacific Coast lands, but in the Western area generally there is little need of lime for correcting soil acidity. Lime, in many places, may be of use in loosening heavy, clay, adobe soils. Under irrigation, gypsum may be profitably used in some localities, as a corrective for sodium carbonate called "black alkali." Potassium is rarely needed for present uses, and a potash fertilizer will not, therefore, usually need to be applied, except as it may be considered necessary for keeping up the future supply. Phosphorus is the most likely of all mineral foods to be insufficient. It is lacking in Colorado soils, and in soils of a large part of the Great Basin. This food may be supplied in barnyard manure, but only to the extent, it is said, of about two pounds to a ton of the manure. It may also be added in the form of the commercial product, as superphosphate or raw rock phosphate.

The chief soil amendments in this area will be accomplished by (1) applications of barnyard manure, by (2) green-manuring, and (3) in crop rotations. Humus probably always contains phosphorus in combination. In California soils it comprises. 01 to .08 per cent of the humus, throughout the entire depth to which humus reaches, though the quantity is always greatest in the upper few feet.

406. Commercial fertilizers. — In view of the conditions just described, it is an open question whether commercial fertilizers may be profitably employed in this area, considering their cost. As in the Great Plains, there is little or no reliable information on the matter resulting from experiments. Such experiments have been conducted in Australia where conditions of climate and crop adaptation, at least, are similar to those of portions of this area, particularly California and Arizona. At Wagga, New South Wales, 2-years trials of many fertilizers for wheat were made in which superphosphates gave results uniformly good, and better than any other fertilizer. The addition of only 100 pounds of superphosphates to the acre resulted in a gain of 13½ shillings an acre above the cost of manure, and an increase in acre-yield of 4 bushels above that of the unmanured plat. The rainfall was 8 to 12 inches during the time the wheat was on the ground (Guthrie and Helms, 1902, p. 5). In northern Victoria, superphosphates were applied in 3-years trials on the demonstration farms, in connection both with continuous cropping of wheat and wheat following summer fallow. The average results on the 3 farms for the third year, 1903, showed 6 bushels to an acre more wheat on plats with superphosphates than on plats not manured, under continuous cropping. On summer fallow, the difference was about 6½ bushels in favor of superphosphate fertilizers. The average rainfall at one of these farms for three years was about 12 inches, but was 19 inches in 1903 (Howell, 1904, pp. 31–39).

407. Humus is, without doubt, the greatest need in soils of the Western area. The term humus is not correctly applied to all organic matter of the soil, as often supposed, but only to a peculiar product of the partial decay of such matter accomplished in a warm, moist soil, in the presence of lime. Ordinarily fresh or coarse organic matter only loosens the soil, sometimes injuriously, and does not furnish nitrogen and mineral foods until humified.

Humus is of value to the soil in a number of ways: (1) It improves the texture somewhat as lime does by causing aggregation or flocculation of the clay particles into a granular condition, and so favors aëration, warmth, and easier cultivation; (2) prevents crusting of the soil surface; (3) absorbs water and water vapor; (4) renders mineral plant-foods available; (5) is the most reliable source of nitrogen, which is kept in reserve and gradually furnished to the roots of plants when most needed through the action of bacteria; (6) contains small quantities of mineral plant-foods that are considered to be immediately available.

Humus is black or brown and gives the same color to the soil, though occasionally a soil may be black from some other cause, and not have a large percentage of humus. When solutions of caustic alkali and sodium carbonate are present they dissolve portions of the humus, giving rise to the name " black alkali " (465).

408. Deficiency of humus. — The Western area is partly distinguished from the Great Plains by a general deficiency of humus. In the surface soil there is even less humus in this region than in the Eastern or Humid area. In soils of the latter area there is an average of 2.73 per cent of humus or 109,200 pounds to the acre, in the first foot; while in the soils of California, for example, the average is 1.35 per cent. But the sharply defined change from the black humus color to gray or yellow, in soils of the Eastern area, occurs usually at a depth of 6 to 9 inches, while in western soils, humus occurs to a depth of 12 feet or more.

In the upper 3 feet of California soils, which is the chief feeding range for the roots of cereal plants, the total humus is 3.17 per cent or 126,800 pounds to the acre. Adding to this the humus occurring still lower down within 12 feet, the total humus to the acre is found to be 236,000 pounds. In the soils of the San Joaquin Valley, the humus is 2.91 per cent of the soil in the upper 3 feet, but only .8 per cent in the first foot. The nitrogen content of the humus is 6.27 per cent in the upper 3 feet, and .04 per cent of the soil. In the Sacramento Valley, the soil is not only richer in humus in the first foot than that of the San Joaquin Valley, but in every foot to a depth of 12 feet. The nitrogen content of the humus in the upper 3 feet is 5.79 per cent and .04 per cent of the soil.

While, therefore, humus is lacking in the surface soil in this area, it is so well distributed downward that western soils are well adapted for deep-rooted plants such as alfalfa and other perennials. Stewart (1910) also found that in Utah the store of nitrogen is drawn upon in grain farming from considerable depths. This condition, together with the addition of humus from straw returned to the soil, permitted either continuous cropping or wheat cropping alternating with summer tillage, without decrease of nitrogen or humus in the surface foot of soil. The second foot of grain-cropped land contained less nitrogen and humus than the second foot of adjacent virgin soil.

409. Increasing the humus and thereby the supply of nitrogen, by any practicable means, is the most important soil improvement to be made in this area. As before stated, the simplest, cheapest, and most effective means is usually the application of barnyard manure but, to date, this method is here not practicable at present, any more than in the Great Plains, because of the lack of livestock. Long-time experiments with barnyard manures in the Western area have been few or none, but the probability of their beneficial effects is strong, judging from conditions and the results of experiments elsewhere.

Probably the most important benefit of manuring, next to the supply of nitrogen, is the greater utilization of the rainfall thus made possible. The drier the season, the more marked is the influence of the organic matter in this respect, and the influence appears to extend below the level at which the manure is applied. While the moisture content of the first three feet is increased over that in soils not manured, it is slightly decreased in the next three feet, indicating that the manure is effective in bringing more water from below to the surface soil. Both stable and green-manures, unless the soil is wet at the time of turning under, will have an opposite tendency at first to dry out the surface soil by breaking the connection of the latter with the lower moisture layers, which may account for the objection sometimes made to manures on western farms. Manures should be plowed under during or just before a wet period, if practicable, and the plowing may often be advantageously followed with the packer. Sometimes local conditions may make the application of barnyard manure difficult or impracticable (see King, 1895, pp. 288–291).

A system of farming which involves keeping live-stock and enables the farmer to return as much of the crop as

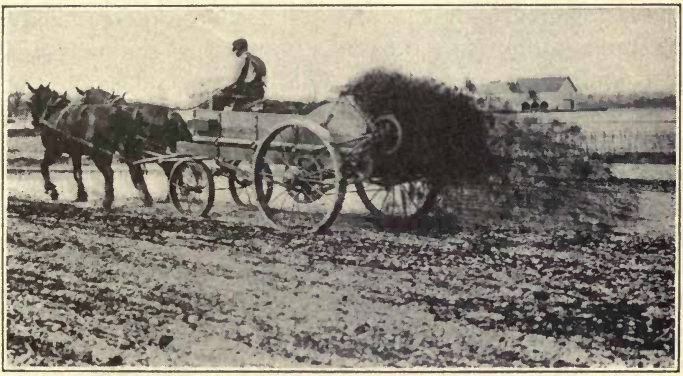


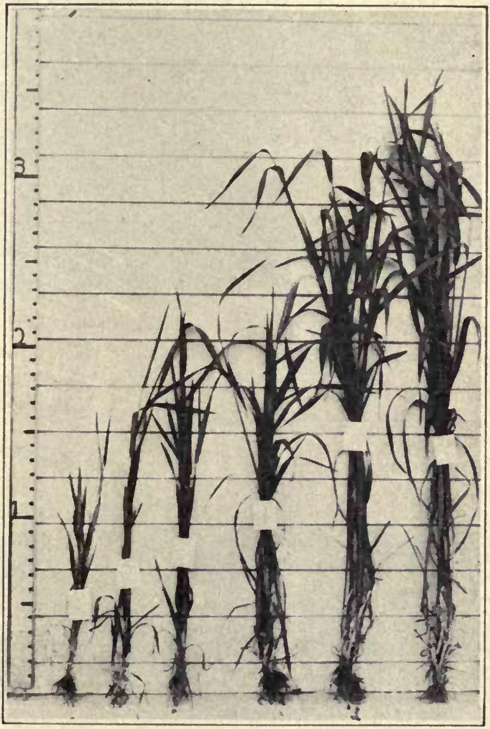
FIG. 119. — Manure-spreader at work.

possible to the soil in the form of manure cannot be too strongly recommended. No more important farm implement has been made than the manure-spreader (Fig. 119).

410. Preservation of manure. — The special need and scarcity of manure in this area, together with the extreme dryness of the atmosphere, affecting its value, make it desirable to mention the means of preserving manure under semi-arid or arid conditions. In a dry climate, nitrogen, in free ammonia, is the substance most easily lost. Piling manure loosely causes bacterial action and hence loss of free ammonia. It is best, therefore, to leave the manure in the corral or stable until it can all be hauled and spread directly on the ground and plowed under; or if it must be removed, it should be piled compactly in a shady place, and occasionally moistened. If possible, the stable or corral should be cleaned during wet weather. Every means possible should be taken to keep the manure moist and to keep air out of it until finally used. Where both cattle and horse manure are produced, the latter may be put into proper condition more quickly by mixing the two, occasionally wetting the manures afterward. Sheep manure should not be put upon the land until it has rotted for at least six months (Headden and Douglas, 1910, pp. 30–31). Because of the prevalence of winter rains, it may be better always to apply manure in the fall or winter rather than in the spring.

411. Green-manuring. — Under present conditions the most practicable means of increasing the soil humus in any considerable acreage of land, in this area, is by the use of green-manures. Green-manure crops and the arrangement of rotations so as to introduce such crops will always be of prime importance. It is true that in the Great Plains in only a few places have green-manures given profits above the cost of cropping, if we exclude possible residual effects upon the soil (370); but results of investigations to date appear to show greater gains in yields of cereals after green-manure crops over those in continuous cropping, and better adaptation of the green-manure crops themselves in this area than in the Great Plains.

At the Cereal Field Station, Modesto, California, 2 years' experiments were conducted, to determine the



a *b* *c* *d* *e* *f*

FIG. 120. — Difference in growth of individual plants of wheat in different methods of cropping: *a*, continuous cropping; *b*, wheat after fallow; *c*, wheat after horse beans; *d*, wheat after Canada peas; *e*, wheat after rye and vetch; *f*, wheat after rye; in the last four the preceding crops turned under.

value of green-manuring, compared with other methods of cropping for wheat, with results as follows: —

TABLE VII. — EFFECT OF DIFFERENT METHODS OF CROPPING ON THE YIELD OF WHEAT AT MODESTO, CALIFORNIA

TREATMENT	ACRE YIELD IN BUSHELS
Wheat after wheat (1 year only) . . .	15.66
Wheat after summer tillage	33.3
Wheat after field peas turned under . .	36.5
Wheat after horse beans turned under .	37.6
Wheat after rye turned under	52.3
Wheat after rye and vetch turned under	54.0

The first year the cost of the summer tillage method was \$2.70, and that of the improved method of wheat after rye as a green manure \$7.30 to the acre, up to the time of harvesting. At \$1.00 a bushel for wheat, the summer tillage method gave a profit of \$28.00 − \$2.70 = \$25.30, and the green-manure method \$51.33 − \$7.30 = \$44.03, —

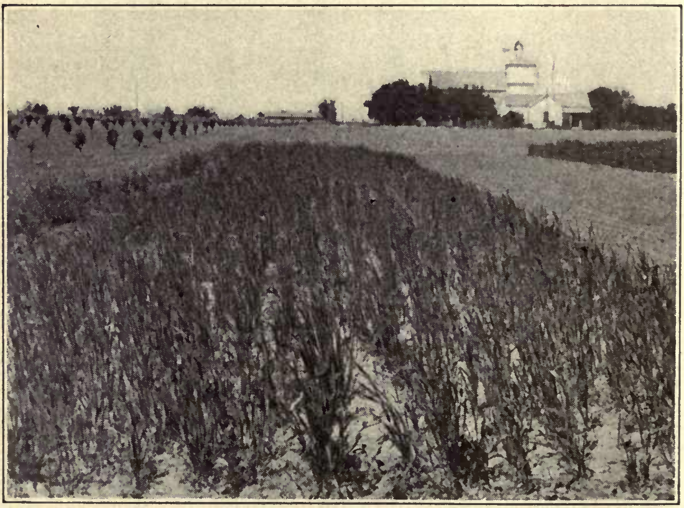


FIG. 121. — Wheat after wheat at Modesto, California, 1908. Compare with Fig. 122.

FIG. 122. — Wheat after rye and vetch turned under at Modesto, California, 1908. Compare with Fig. 121.

less cost of harvesting and thrashing in each case, — the difference in profit in favor of the latter method being $18.73 (Figs. 120–122).

Experiments in green-manuring were also conducted at the California State Experiment Farm during the 4 years 1907–10, with results as given in the table following: —

TABLE VIII. — EFFECT OF DIFFERENT METHODS OF CROPPING ON THE YIELD OF WHEAT ON HEAVY SOILS AT DAVIS, CALIFORNIA, 1907–10

TREATMENT	ACRE YIELD IN BUSHELS
Wheat after wheat	32.7
Wheat after fallow	41.6
Wheat after horse beans turned under .	43.1
Wheat after field peas turned under . .	43.3
Wheat after wheat	38.6
Wheat after horse beans turned under and followed by Kafir corn	42.3
Wheat after rye and vetch turned under	44.4
Wheat after burr clover turned under .	48.2

In these trials the character of the cultivation, including depth of plowing, was the same on the several plats as at Modesto, but the results were less striking, probably because the soil on the State Farm is normally richer in humus, and naturally more retentive of moisture (Shaw, 1911, pp. 261–271).

Any residual or permanent effect upon the soil by the green-manuring is not considered in these comparisons,

FIG. 123. — Plowing under rye for green-manure, in preparation for wheat, at Modesto, California.

and yet is important, especially as summer tillage on the other hand is an exhaustive method. The course of operations with green-manure crops is about as follows: The stubble ground is double-disked as soon as possible after the wheat or barley is removed. The rye and vetch, or rye and field peas, are sown as soon as it is possible to plow the land 4 to 5 inches in the fall. There is usually sufficient moisture for seeding green-manure crops by December 1. The crop is turned under about 8 inches deep early in March of the following year, before the soil is too dry for deep plowing (Fig. 123). The ground is then harrowed and afterward kept clean during the summer, the same as summer tillage. About December 1, it is again plowed 5 inches deep and sown with barley or wheat (Blanchard, 1910, pp. 15–17).

412. The crops adapted for green-manuring in this area are rye and vetch previously mentioned, field peas, sweet clover, Tangier peas, and perhaps in some places horse beans.

The field pea is found to be a very valuable crop on its own account under dry-farming in eastern Oregon, in addition to its value as a green-manure crop preceding a cereal. At Moro, Oregon, the best variety yielded an average of 19.3 bushels an acre in a 3-years trial, worth at that time $35 in the regular market. This value is obtained in the place of nothing from summer tillage and even the roots plowed under benefit the following cereal crop and there is the use of the fodder besides, and the possible residual effect upon the soil (Stephens, 1915, p. 38).

An interesting example of the benefit to wheat of preceding intertilled crops, one of which is a legume, is given by Cardon (1915, pp. 39–43). Experiments at the Nephi, Utah, substation, covering 5 years, resulted in an average yield of wheat following peas of 14.39 bushels an acre, while wheat following summer tillage averaged 12.89 bushels an acre, or 1.5 bushels less. Wheat after potatoes and wheat after corn made still better yields. The pea crop was harvested, so the value of that crop above ground was obtained, in addition to the permanent benefit to the soil of the remaining portions of the plants turned under.

413. Rotation of crops. — There is no doubt that the general adoption on the farms in the Western area of rotations, including primarily a green-manure and a cultivated crop with one cereal, even to the extent that can already be recommended by the experiment stations, will cause the most rapid progress in western agriculture. Eighteen different crop rotation series are under trial at the Moro, Oregon, substation, and, although it is not yet

FIG. 124. — Potatoes in rotation with wheat at the Nephi, Utah, substation.

determined which are the most profitable of these series for farm practice, results already indicate that such crops as field peas, corn, and alfalfa in cultivated rows can, in a large measure, be substituted for summer tillage.

In the 5-years experiments previously mentioned, conducted at Nephi, Utah, the best yield of wheat was made following corn. This crop, poorly adapted as it is in that part of Utah, furnished considerable feed in 2 or 3 instances, and gave an average yield of wheat following it of 15.5 bushels an acre, 2.61 bushels more than after summer tillage. The potatoes averaged 34.24 bushels an acre, and gave an average yield of wheat following them of 14.94 bushels an acre, 2.05 bushels more than after summer tillage. These crops were given about the same amount of cultivation as the summer tillage (Fig. 124).

Alfalfa is about the best general purpose crop in the Western area. It is adapted for rotations, for a pasture and hay crop, and is excellent as a restorative crop for improving the soil. Alfalfa roots penetrate even the hardest soil layers to the depth of 9 to 12 feet. It feeds much lower than the wheat plant, and therefore rests the soil to some extent where the wheat roots feed. Also one can obtain the hay and seed, and still turn under a much larger quantity of roots for the benefit of the soil than in the case of any other legume. Experiments in Wyoming with wheat following alfalfa continuously resulted in giving a residual benefit to the wheat, in increased yields, for 3 years. Under dry-farming, it should usually be grown in rows and cultivated. It should not be plowed under before 3 years, and from that time to 5 years. Usually at least one cutting of the alfalfa each year may be obtained. The entire crop should be fed on the farm. Plowing under alfalfa is somewhat difficult on account of the strong roots. It should be done when the ground is moist.

414. Summer tillage. — In the dry-farming districts of the Western area summer tillage is a general practice. The occurrence of winter rains in this area appears to make summer tillage more desirable than in the Great Plains. All things considered, it is at least better than continuous cropping (Fig. 125). At the Moro, Oregon, dry-farming substation it is found that "a summer fallow once in every 3 to 4 years may in the long run prove beneficial," but that "a summer fallow every other year is unnecessary. The results of 3 years indicate that wheat yields after field peas are about as high as after summer fallow."

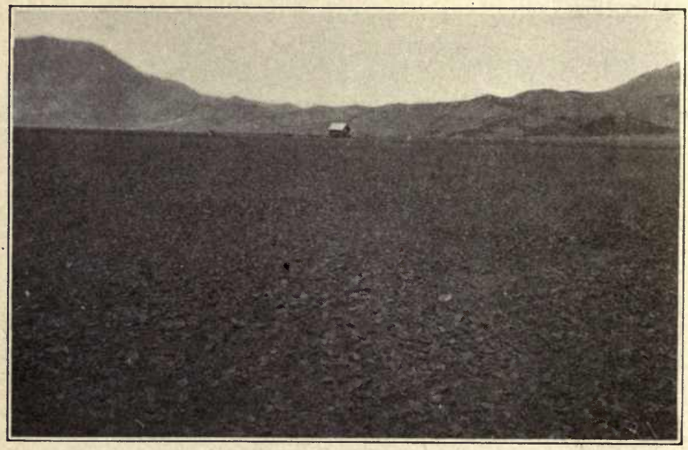


Fig. 125. — Summer tillage in Utah.

415. Summer tillage in Utah. — Cardon (1915, pp. 37–39) reports results of a ten-years trial of continuous cropping of winter wheat, in comparison with 2 crops of the same and 1 of fallow in 3 years, alternate cropping, and 1 crop and 2 fallows in 3 years, at the Nephi, Utah, substation. The total acre yields for 10 years, by the different methods, in the order above given, were 112.19 bushels, 98.76 bushels, 98.16 bushels, and 65.27 bushels, respectively. Though the total acre yield of 10 successive crops, in this instance, was nearly 14 bushels more than that from alternate cropping, it was reckoned that the cost of growing and harvesting wheat was $3 an acre more than the cost of maintaining a fallow throughout the year, or $15 more in the 10 years, which is considerably more than the value of the 14 bushels of wheat at ordinary wheat prices. Moreover, there was much winterkilling in this experiment which tends to obliterate the advantages of a storage of soil moisture. In August, 1910, after 7 years of the experiments had elapsed, soil moisture determinations were made, when the percentage of moisture found in each foot of soil to the depth of 6 feet, in a fallowed and continuously cropped plat, was as follows: —

TABLE IX. — PERCENTAGE OF MOISTURE IN EACH OF THE FIRST 6 FEET OF SOIL IN FALLOWED AND CONTINUOUSLY CROPPED PLATS

	FALLOWED PLAT PROPERLY CULTIVATED	PLAT CROPPED 7 YEARS
First foot	13.90	9.20
Second foot	18.80	12.90
Third foot	18.85	12.40
Fourth foot	17.00	13.25
Fifth foot	17.35	9.45
Sixth foot	13.50	11.80

416. Summer tillage in California. — Grain production in California was originally continuous cropping, practiced on as large an acreage as possible with a minimum cost. The land became so weedy by this method, that summer tillage was found to be necessary to clean the land. The latter method has since become the regular practice, but careless operations are so frequent that it can often be more properly called summer fallow in the old sense.

In the experiment at Modesto, already discussed (410), wheat after wheat yielded 15.66 bushels an acre compared with 28 bushels for wheat after fallow. Even in this instance, the latter method was more profitable because of the greater cost of the 2 crops in the former, but no doubt the difference in favor of summer tillage would ordinarily be greater, as even the wheat after wheat, in this experiment, was only the second crop from a summer fallow. However, a rotation including a green-manure crop and, if possible, an intertilled crop, is the method most needed.

417. Summer tillage in the Columbia Basin. — In this district, summer tillage is an established practice of long standing. The soil is of such a texture that more water is retained in it than in the soils of other districts. It is probably necessary to summer-till every second year when the rainfall is 16 inches or less. With a rainfall of 16 to 20 inches, a fallow every third year may be sufficient. Where the rainfall is 20 inches or more, as in the Palouse country, summer tillage seems unnecessary. If summer tillage, under such a condition, increases the yield, it is likely to be due to an increase in the available plant-food, rather than available moisture. Even with a rainfall of 12 inches and over, it may be possible to substitute profitably an intertilled crop in place of the summer tillage alone.

418. Soil-blowing. — Almost throughout the Western area, the soils are in many places subject to blowing and drifting. The tendency is specially strong in the volcanic soils of the Columbia Basin and eastern Oregon and, where not irrigated, in those of the Imperial Valley. As in those parts of the Great Plains where soil-blowing occurs, so also in this area, there is always a lack of humus associated with this condition. It is said that soil-blowing, except in very dry and sandy sections, is due primarily to the practice of summer fallowing. This practice, by laying the soil bare, no doubt does increase the tendency; but its most serious direct effect is the exhaustion of the humus. The permanent remedy for soil-blowing is an increase in the quantity of soil humus.

Some of the means of checking soil-blowing temporarily have been given (383). It is important to keep the soil coarse or lumpy at the surface (see Fig. 125). This is practically impossible in sandy land, in which case such implements of cultivation should be used as will leave the surface as uneven or ridged as possible. If whole fields of wheat are being blown out, cropping in strips may be practiced. The fields are divided into strips 5 rods or more in width, and each alternate one sown with winter wheat (or other cereal), and the unsown strips listed the same fall. The listed furrows are not disturbed the following spring until the wheat in the cropped strips has made sufficient growth to resist blowing, after which the listed strips are given clean cultivation through the summer (Thom and Holtz, 1914, pp. 18–20).

419. Burning the stubble is a practice too common on the large grain farms, and is a cause of serious loss to the soil. Heavy stubble is difficult to plow under, and burning is an easy way to get rid of it, but is also, in time, a costly practice. The previous use of some other implement, as disk, drag, or mower, will usually put the stubble ground in condition to be plowed, and the manurial value of the decaying straw will exceed the cost of all extra work, in its beneficial effects upon following crops.

420. Crop burning or drying out occurs frequently on land summer fallowed, in the uplands of the Columbia Basin, during dry, hot periods. Often the burning cannot be traced directly to the weather conditions, and for such cases several causes have been assigned. Sometimes it is said to be due to too much available plant-food, causing an overgrowth of the plant above ground compared with the roots. The roots are thereby not able to furnish moisture to the plant in a dry period as rapidly as it is evaporated, and the plant dries out or burns, and the spikes fail to fill. As a partial proof of this cause, it is stated that winter cereals are not so affected, as they have larger root systems. However, winter cereals are so nearly mature before the hottest weather begins, that usually they cannot be injured. If crop burning is due to an over supply of plant-food, either summer fallowing should be done every third year or some cultivated crop should replace the fallow (Thom and Holtz, 1914, pp. 25–27).

The following tabular statement will be of interest in this connection, showing the excess of nitrate foods that are formed in the soil under summer fallow. The investigations were made at the Longerenong Agricultural College in Victoria, and are given by Richardson (1912–13).

TABLE X. — FORMATION OF NITRATES IN FALLOWED AND NON-FALLOWED LAND AT LONGERENONG AGRICULTURAL COLLEGE (VICTORIA), 1911–12. THE FIGURES ARE NITRATE NITROGEN IN PARTS TO THE MILLION OF THE SOIL.

DEPTH OF SOIL SAMPLE	DEC. 11, 1911		JAN. 4, 1912		FEB. 6, 1912		MAR. 28, 1912		MAY 20, 1912 (At seeding)		AUG. 7, 1912	
	Fal.	Non-fal.	Fal.	Non-fal.	Fal.	Non-fal.	Fal.	Non-fal.	Fal.	Non-fal.	Fal.	Non-fal.
(1) 0 to 12 in.	10.3	Not tested	13.28	3.20	25.2	1.60	20.5	2.10	20.60	1.07	18.07	2.34
(2) 12 to 24 in.	Trace		3.12	2.27	2.4	Trace	3.7	1.10	Trace	1.00	5.40	1.35
(3) 24 to 36 in.	1.4		3.16	1.65	1.63	Trace	2.40	2.8	Trace	Trace	0.72	0.46
(4) 36 to 48 in.	3.1		1.71	1.67	1.77	1.41	1.40	2.02	3.46	1.67	0.72	1.44
(5) 48 to 60 in.	1.9		1.73	2.10	2.78	2.47	2.02	1.70	2.17	2.31	0.72	0.82
Average nitrogen content in first 5 feet.	3.4		4.6	2.18	6.76	1.10	6.00	1.94	5.25	1.20	5.12	1.28

In eastern Oregon "drying out" is generally considered to be due to overseeding during a wet period followed by a dry period. Too many culms to a square foot are produced for proper filling of the spikes in the dry period.

421. Cover-crops. — Cereals as cover-crops have such definite value for green-manuring in this area, that there is little to be said about them, except in that connection (410). Orchards are usually kept clean under dry-farming. Where soil-blowing occurs, rye is sometimes sown to hold the soil in place for a later crop. Alfalfa may thus be started in the spring in fall-sown rye.

Growing the Crop

422. Methods of summer tillage. — The essential features of summer tillage in this area are as follows: (1) The ground is plowed or double-disked, either at once after harvest or early in the following spring. (2) The packer is usually employed immediately after plowing, if at all. Often the packer is not used in summer tillage, the soil being allowed to settle itself into a compact condition in the time that elapses. (3) A coarse mulch is maintained at the surface, but only stirred when it is moist. (4) Cultivation is done with such implements as will leave the surface ridged or furrowed. (5) To destroy weeds in dry weather, a form of knife weeder may be used. (6) Pasturing the summer fallow with sheep to keep down weeds, where sheep are adapted, is both profitable and effective as to the weeding.

423. Fall and spring plowing. — Heretofore it has been the practice of the farmers generally in the dry-farming districts of this area, to plow in the spring, whether for a spring crop or as a beginning of summer tillage. In recent years experiment station men have recommended fall plowing, because of results of observations and experiments they have made. Fall plowing would also appear logical, because of the occurrence of so large a percentage of the rainfall in the winter.

Merrill (1910, pp. 129–133), after citing experiments showing a greater moisture content in the soils of plats plowed in the fall than in those plowed in the spring, also reported the results of 3 tests on the time of plowing, in which there was a gain of 2.4, 4.11, and 4.27 bushels of wheat on fall plowing over that on spring plowing, other conditions being the same. He decided that "with the invariable increase in yield and in the light of the many experiments favorable to fall plowing, we may safely conclude that it is a profitable practice." At the same time the fact is mentioned that "fall-plowed fields are more likely to be weedy and covered with volunteer wheat than are the spring-plowed fields."

In certain experiment station bulletins from Washington, Idaho, and Wyoming, fall plowing is recommended, without citing particular experimental evidence. At the same time it appears that the most common methods actually practiced in the Columbia Basin are (1) early plowing in spring followed by summer tillage, and (2) early disking in spring followed by plowing several weeks later. Even for spring crops, plowing is usually done in this district in the spring. However, "it is generally conceded that better yields are secured from fall plowing than from spring plowing, provided the land is reasonably clean" (Hunter, 1907, p. 22). At the Lethbridge, Alberta, Experiment Farm, land plowed in the fall has given poorer returns than that plowed in the spring, for several years. The time of plowing will often be settled by a necessary distribution of labor, requiring a part to be done in the fall and a part in the spring.

424. Coöperative experiments in Utah. — In experiments at Nephi, Utah, in coöperation between the United States Department of Agriculture and the Utah Experiment Station, the average results of 4 years' work showed a gain of 1.7 bushels an acre of winter wheat in favor of spring plowing compared with fall plowing (Cardon, 1915, pp. 6–11). The spring-plowed plats were also observed to be more free from weeds and volunteer grain during the fallow period, than fall-plowed plats. It was also calculated that the cost of the fall plowing method was $1.75 an acre more than that of the spring plowing method. As these results are considerably different from those above mentioned (423), and opposed to them, it seems probable that local differences of soil and climate have much influence. There is a lack of reliable information on this very important subject in the Western area.

425. Early and late plowing or disking. — There is little or no difference of opinion on the value of early plowing or disking in the fall or spring. Thom and Holtz (1914, p. 12) found that between April 1 and September 1, 9.6 per cent of soil moisture was lost from stubble soil plowed April 1 and packed, while 37.5 per cent was lost from the same kind of soil plowed June 1 and packed. Fall-plowed soil disked April 1 lost 12.3 per cent soil moisture in the same period, while fall-plowed soil disked June 1 lost 26.8 per cent.

In 2 years' experiments at Moro, Oregon, on the time of spring plowing of summer fallow for winter wheat, Stephens (1915, p. 35) obtained results as follows: —

Table XI. — Results of 2 Years' Experiments at Moro, Oregon, Substation, on Time of Spring Plowing for Summer Fallow for Winter Wheat

	Acre Yield in Bushels		
	1913	1914	Average
Early plowing April 1	24.3	28.2	26.2
Mid-season plowing May 1	18.5	25.2	21.8
Late plowing June 1	10.6	21.5	16.0
Gain of April 1 plowing over May plowing			4.4 bushels
Gain of May plowing over June plowing			5.8 bushels
Gain of April plowing over June plowing			10.2 bushels

Nevertheless it is not uncommon in eastern Oregon for farmers to plow for summer fallow, without previous cultivation, as late as June, though spring disking of the stubble is now more practiced than formerly.

426. Depth of plowing. — The general attitude throughout dry-farming areas is probably less favorable to deep plowing than formerly. Many varying local conditions affect the question, and there is need of further investigation.

Experiments in Utah are not convincingly favorable, so far, for either deep or shallow plowing. It only appears that plowing should not usually be deeper than 10 inches, though certain results in light soils seem to favor even greater depth.

In Washington it is recommended to plow 6 to 8 inches deep, whether in fall or spring, without basing the recommendation on any particular experiments.

In the experiments with green-manuring in California previously discussed (411), plowing was done from 6 to 8 inches deep, and if weeds are bad, it is recommended to plow 8 to 12 inches deep, between March 1 and 15. On the California State Farm at Davis, 40 trials were made of deep and shallow plowing for wheat and barley during 3 years, the former referring to depths of 7 inches or over and the latter ranging from 3 to 5 inches: —

TABLE XII. — RESULTS OF DEEP AND SHALLOW PLOWING FOR GRAIN. AVERAGE OF 40 TRIALS IN 3 YEARS

	WHEAT	BARLEY	EFFECT ON SUCCEEDING CROP OF BARLEY
	Bushels	Bushels	
Deep plowing . . .	29.78	75.98	25.36
Shallow plowing . . .	21.67	69.30	17.32
Gain for deep plowing	8.11	6.68	8.04
Percentage of increase	37.40%	9.70%	46.50%
Increased money value	$7.78	$3.34	$4.02

In Oregon, the depth of plowing recommended is 7 to 10 inches with a mold-board plow, and 10 to 11 inches with a disk plow, which is frequently used in the Western area. Steam disk plows in gangs are often employed on large farms, though both steam power and the disk form of plow are now less commonly used than formerly in some localities (Figs. 126, 127). The Wyoming Experiment Station recommends plowing to the depth of at least 8 inches.

427. Subsequent tillage for spring seeding. — The details of cultivation after plowing or disking, whether for immediate seeding or in summer tillage, vary greatly in different districts.

After spring plowing for seeding the same spring, usually there is no further treatment than 1 or 2 harrowings and drilling the seed. It is in this case that the corrugated

FIG. 126. — Disk plows in 3 gangs, drawn by steam power, in Juab Valley, Utah.

roller (Fig. 128) or subsurface packer (see Fig. 98) should be profitably used, at once after plowing. If no roller or packer is at hand, a disk harrow weighted and set straight may be substituted.

FIG. 127. — Disk gang plow at the Branch Experiment Station, Hays, Kansas.

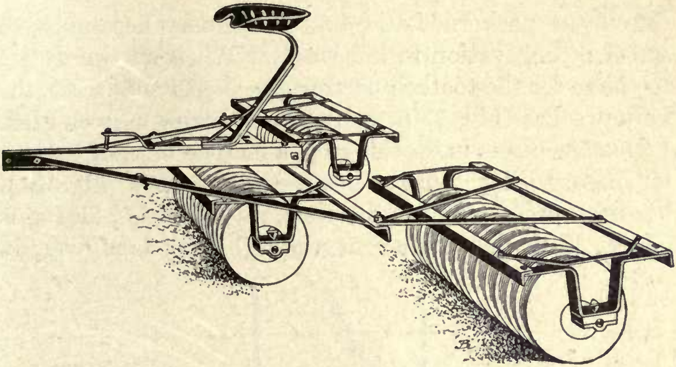


FIG. 128. — Corrugated roller.

428. Summer tillage after plowing or disking. — After early plowing for summer tillage, it is usually best to follow the plow closely with the toothed harrow, unless the soil seems loose and light enough to justify first the

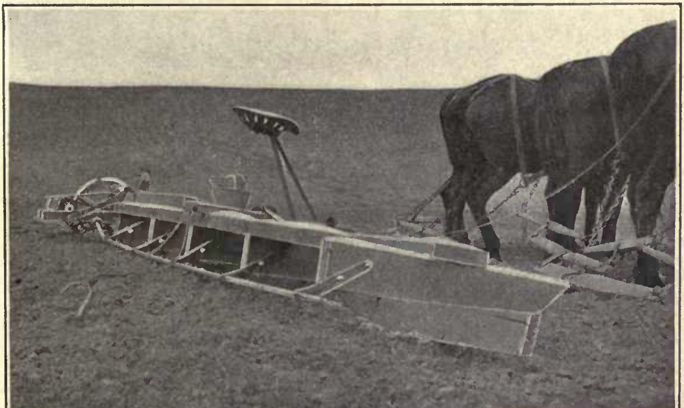


FIG. 129. — Slicker, with a rod behind, square in cross section, which revolves under the surface of the soil.

use of the packer. Later in the summer there must be sufficient cultivation to kill weeds. When the weeds get too large for the toothed harrow, the slicker (Fig. 129), the knife weeder (Fig. 130), or the disk harrow may be used.

In a few places in Washington, a method of right lapping for summer tillage, with a cut-away disk harrow (Fig. 131), has been practiced for some time, in which no plowing is done. With this implement, the right half laps over, in

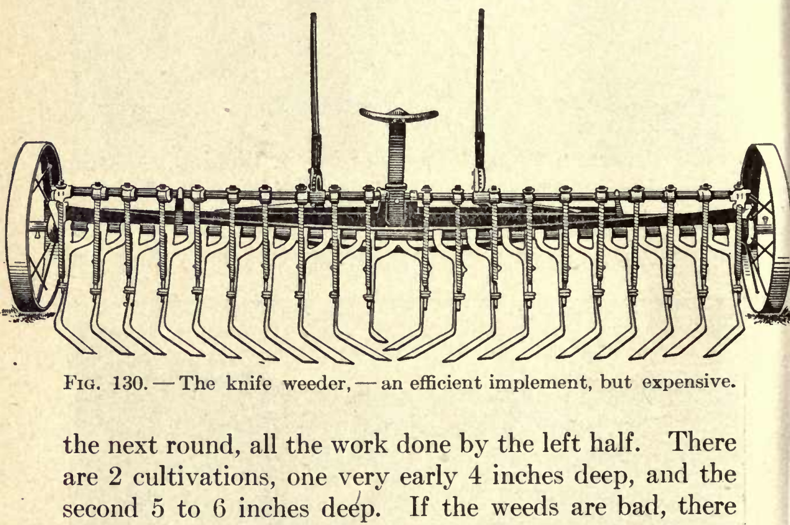


FIG. 130. — The knife weeder, — an efficient implement, but expensive.

the next round, all the work done by the left half. There are 2 cultivations, one very early 4 inches deep, and the second 5 to 6 inches deep. If the weeds are bad, there may be a third cultivation, or the harrow or slicker may be used afterward.

In a large portion of the Columbia Basin, early spring disking for summer tillage is done before plowing. Some double-disk and then use the toothed harrow. Moisture is thus conserved early and rapidly, weed seeds are caused to germinate, and the young weeds are afterward destroyed by the plow. The land is plowed from 4 to 6 weeks later, in the same order in which it was disked. Afterward there is sufficient cultivation to subdue weeds.

429. Fall tillage. — Because of the dry summers in the Western area, fall plowing, whether for spring seeding or summer tillage, should usually be preceded by disking. The latter is done at once after harvest to a depth of 3 or 4 inches. This creates a mulch for conservation of moisture, causing easier plowing later, and also cuts up and

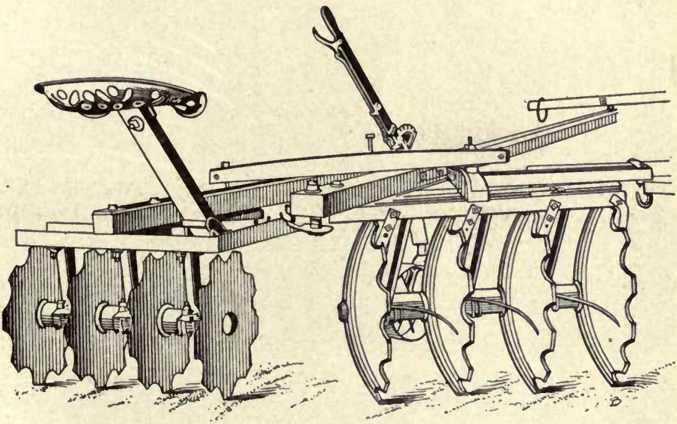


FIG. 131. — The right lap cut-away disk harrow.

mixes with the surface soil the remaining stubble and straw. The cut-away disk harrow is particularly good, because of its efficiency in cutting the straw and stubble (Fig. 96). Double-disking is advisable, if the ground is hard, or there is much stubble or straw. Later in the fall the disked stubble ground is plowed 6 to 8 inches deep.

In the drier sections, fall listing may be substituted for fall plowing. This is preceded by disking as in the case of plowing. Listing should be done at right angles to the slope. By leaving the surface in ridges, listing prevents loss by "run off."

If time will not permit either plowing or listing, a good second disking should be given the soil late in the fall.

430. Treatment of new land. — As the development of dry-farming is comparatively recent in this area, and the acreage under irrigation very small, there is even more new land to be broken than yet remains in the Great Plains. The land is first cleared of its shrubby

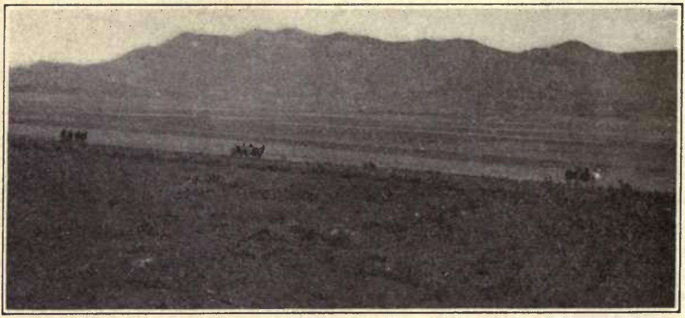


FIG. 132. — Harrowing sagebrush into windrows in Juab Valley, Utah.

growth, which is chiefly sagebrush. This vegetation is grubbed, often by hand, and thrown into piles and burned. Machine grubbers are now made with which a large field can be quickly cleared, the material being dragged into windrows for burning, by other implements following the grubber (Fig. 132). The ground is then plowed 3 or 4 inches deep and thoroughly cultivated. Sometimes the ground is plowed before grubbing, and the brush dragged into winrows afterward.

The condition of the surface soil of new land in the Western area is very different from that of the Great

Plains. There is no tough sod of matted grass roots to be rotted, and immediately after the first plowing and pulverizing of the soil, it is in good condition for seeding

FIG. 133. — Virgin soil of cleared sagebrush land, ready for seeding, in Utah.

(Fig. 133). However, the ground is often cleared and plowed in the spring and summer-tilled.

431. Time of seeding. — Differences in altitude, as well as other varying conditions, make it impossible to give definite statements of general application on time of seeding in this area. It is usually an advantage to sow early, though this is not always true. In Utah it has been found that early autumn seeding may result in an excess of foliage at the expense of grain production. Also in early seeding there is danger of only sufficient moisture being present for sprouting, and the seedlings are likely to perish in the dry soil before the fall rains come.

Actual experiments in Utah to determine the best time of seeding have given confusing results. In the Juab Valley, the best yields of winter wheat appear to have been grown from seeding between September 1 and October 15.

In California, where there is little distinction between fall and spring seeding, barley seeding extends from November to March. Blanchard (1910, pp. 29–30) found that wheat sown comparatively late has a higher protein content than early-sown wheat. Early wheats, like Chul, should be planted November 15 to December 15, in the San Joaquin Valley, but may be sown as late as February 25, sometimes with good results. In the Sacramento Valley, wheat seeding may be a month later.

Experiments on time of seeding wheat and barley have been conducted at the California State Farm during 3 years, resulting as follows, wheat valued at $1.60 a hundred and barley at $1.00 a hundred: —

TABLE XIII. — TIME OF SEEDING EXPERIMENTS WITH WHEAT AND BARLEY AT THE CALIFORNIA STATE FARM

	WHEAT 1907–10	BARLEY
	63 Trials	13 Trials
Early seeding (before Dec. 20)	44.39 bushels	63.79 bushels
Late seeding (after Jan. 25)	40.32 bushels	48.90 bushels
Gain for early seeding	4.09 bushels	14.89 bushels
Percentage increase	10.14 %	30.50 %
Increased money value	$3.93	$8.93

In the Columbia Basin it has not been possible to determine the best time of seeding winter wheat. It should be as near the time of the first fall rains as possible. The dates for spring wheats run from March 20 to April 20, and for oats from March 20 to March 30.

In central Oregon spring wheat should be sown from April 10 to May 1, oats from April 20 to May 5, and barley from April 20 to May 10.

From information obtained by the Bureau of Crop Estimates, it appears that the mean date when winter wheat seeding becomes general in certain western states is as follows: — Montana, September 9; Wyoming, September 5; Colorado, September 16; Arizona, November 3; Utah, September 22; Nevada, September 29; Washington, September 29; and Oregon, October 15.

432. Rate of seeding. — In the Western area, the optimum rate of seeding all cereals is close to that for the Great Plains, but less than that in the Eastern area.

For winter wheat in Utah the results of experiments on rate of seeding are somewhat conflicting, one series of trials showing 3 pecks to the acre to be the best rate, while another series at Nephi (Cardon, 1915, pp. 30–31) indicates that 4 to 5 pecks is best. No doubt, as in the matter of fall and spring plowing, the experiments are influenced by differences in local conditions. Turkey and Kharkov probably require a little thinner seeding than other winter wheats.

At Moro, Oregon, dry-farming substation no definite optimum rate of seeding of winter wheat has been found. The proper rate depends upon time of seeding, quantity of soil moisture, and condition of seed-bed; and varies from 30 to 60 pounds to the acre (420). On the sandy elevated soils of central Oregon, Turkey wheat is sown at 20 to 30 pounds to the acre, spring wheat at 35 to 40 pounds, barley at 50 to 60 pounds, and oats 30 to 40 pounds (*vide* Scudder, 1914, pp. 76–92).

In the Columbia Basin, the optimum rate for winter wheat appears to be from 35 to 45 pounds, the lower rate being applicable for Turkey and where the rainfall is light, and the higher rate for large-kerneled varieties and where the rainfall is 12 inches or over. Spring wheat seeding should run from 45 to 50 pounds an acre. Durum varieties should be sown at least 10 pounds an acre thicker. Oats probably do best at a rate of 40 to 50 pounds, and emmer at 30 to 40 pounds an acre; winter emmer being sown a little thicker than spring emmer.

In Idaho, it is recommended to sow winter wheat at 30 to 40 pounds, and spring wheat at 35 to 45 pounds an acre.

433. Depth of seeding. — In this area, it would seem to be necessary, because of the dry surface, to sow usually a little deeper than in the Eastern area, in order to get the seed into moist soil. Nevertheless, results of experiments appear more often to favor comparatively shallow seeding, though the results so far in Utah are not decisive.

At the Moro, Oregon, substation, shallow seeding of winter wheat, 1 to 1½ inches, gave better results than deep seeding, 3½ inches. In this case, however, it may be noted that the deep seeding was somewhat deeper than is necessary to be called deep seeding. About 1½ inches is the depth recommended by the Oregon Experiment Station, and deep seeding (3 to 4 inches) late in the fall is said to be particularly undesirable.

In South Australia, where conditions are similar to those of a large part of this area, 3 years' experiments were conducted by Perkins and Spafford (1912) on the depth of sowing of some agricultural seeds, in light sandy soil, and heavy clay loam, from which they concluded that the optimum depth of seeding for wheat, barley, and oats, in the two kinds of soil, is as follows: In light sandy soil, wheat 1 to 2 inches, barley 1½ to 2½ inches, oats 1½ to 2½ inches; in heavy clay loam, wheat 1 inch, barley 1 to 2 inches, oats 1½ to 2 inches. Barley and oats could always be safely seeded deeper than wheat.

434. Why shallow seeding is preferable. — That shallow seeding is found preferable in practice, even in a dry climate, may perhaps be partially explained in this way. There is almost always a period so dry after seeding that the grain will not come up anyway, sown at any depth. If, therefore, in deep planting, some kernels find just sufficient moisture to germinate them, or injure their vitality, but not enough to bring them up, it would have been better for them had they been sown shallow and remained dry until the rains came. Perhaps on the same principle may be explained the injury to grain treated with formalin for prevention of bunt, discussed in Chapter XVII, for which, however, another cause is there given (563). Unless the treated kernels are thoroughly dried, which is rarely true in practice, some of them will be just sufficiently moist that the slightest moisture in the soil will be able to germinate them or injure them, but not able to cause growth, and therefore they die. The untreated kernels, being perfectly dry, are proof against the slight soil moisture, and remain sound until the rains come. It is a common practice in arid sections to sow grain in the dry soil and wait for the late rains to come and bring it up.

435. Method of seeding. — It is important in all dry-farming districts to sow small grains with the drill, in order to put the seed in close contact with the fine soil

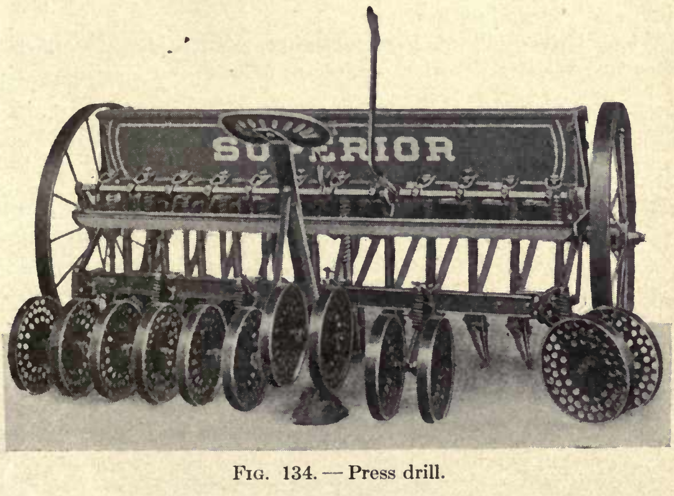


Fig. 134. — Press drill.

particles and at a regular depth for promoting uniform germination. Probably no one kind of drill is best for all conditions, but often the press wheels are desirable for firming the soil around the seed (Fig. 134). If the soil is very loose at seeding time, rolling with a corrugated roller (see Fig. 128) may be advisable. If only a smooth roller is available, it should be used before drilling, or if after drilling, some light cultivation, to leave the surface rough, should follow it.

In one case of 2 experiments with methods of seeding winter wheat in Utah, continued 5 years, broadcasting gave an average yield of 12.9 bushels an acre, and drilling 19.9 bushels; in the other case, 15.6 bushels were secured from broadcasting, and 29.2 bushels from drilling. A less yield was secured from cross-drilling than from ordinary drilling (Merrill, 1910, pp. 139–140). At the Nephi, Utah, substation, a small increase in yield in favor of cross-drilling was secured.

In experiments in Wyoming at 5 substations 4000 to 7200 feet in elevation, barley gave the largest yields sown in drills 8 inches apart and 1 inch apart in the row.

At the California State Farm, experiments (22 trials) on methods of seeding wheat and barley resulted as follows: —

Table XIV. — Results from Drilled and Broadcasted Seeding of Wheat and Barley at the California State Farm

	Average Acre-yields in 22 Trials	
	Wheat	Barley
Drilled	34.85 bushels	70.80 bushels
Broadcasted	31.60 bushels	64.43 bushels
Gain in favor of drilling	3.25 bushels	6.37 bushels
Percentage increase	10.3 %	9.9 %
Increased money value	$3.12	$3.18

436. Cultivating grain. — The use of the roller at seeding time has been mentioned. After spring seeding on spring-plowed land, the soil may be loose enough in some instances to justify packing. At the Lacombe, Alberta, Experiment Farm, on a loose humus soil, the use of the packer after seeding increased the yield of oats from

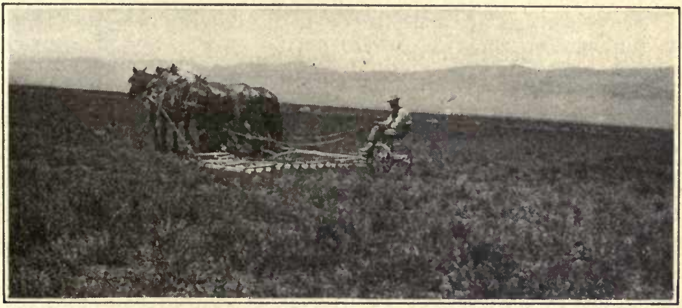


FIG. 135. — Harrowing winter wheat near Nephi, Utah.

69.45 bushels for the unpacked to 83.36 bushels for the packed plats.

Cultivation of the growing crop is often advocated in this area, and is practiced rather generally in the Great Basin. This is usually done with the toothed harrow (Fig. 135). Apparently the practice is sometimes beneficial, particularly the cultivation of winter grain in the spring. The greater part of the experimental evidence, however, seems to be against it, especially when the cost of the operation is considered.

Experiments on the spring cultivation of winter wheat have been conducted at Nephi, Utah, substation since 1909. The average results for 5 years show a gain of 1.06 bushels an acre in favor of non-cultivation. In 4 out of the 5 years, there was practically no difference in the yields from the 2 methods. At the Moro, Oregon, dry-farming substation, a comparison in 1913 of 3 plats of winter wheat harrowed in the spring with 3 not harrowed, and of 5 plats harrowed and 5 not harrowed, in 1914, shows a difference in acre-yields, in favor of non-harrowing, of 19 bushels in the former year and 1.4 bushels in the latter. Nevertheless, in eastern Oregon, spring harrowing of winter grain is a common practice. Further experimentation is needed, for the question is one of immediate importance.

Three things are attempted in harrowing wheat, (1) to break the surface crust of soil and check evaporation, (2) to thicken or thin the stand, and (3) to kill weeds. For thinning the stand, the harrow teeth are set to cut deeply, and for thickening the stand, they are slanted backward, so as to affect the crown of the plants just enough to promote further tillering. How effective these measures are in changing the stand, experiments have not yet determined.

Sometimes following the harrow, the weeder is used until the crop has grown a foot or more in height.

437. Mowing or pasturing cereals in the Western area is seldom or never necessary for checking growth, but pasturing is often done for the benefit of the animals (usually hogs) themselves, while incidentally the land is improved through manuring and turning back the remains of the straw and stubble to the soil. Winter wheat intended for market may be pastured from about April 1 to May 15. Either winter or spring wheat or hooded barley is sometimes sown about May 1 purposely for spring and summer pasture. Barley makes more growth than wheat in the same time, and hogs like it better.

Almost all pasturing, but particularly in the Columbia Basin, is a process of "hogging off," in which hogs are turned on at such a time as will allow them to remove the maturing crop entirely, including the grain. With good management, this method is found to be the most economical and otherwise satisfactory one for utilizing a limited acreage of grain. In addition to the soil improvement and easy means of stock-feeding, there is a saving of the cost of harvesting, thrashing, and marketing the grain. Hunter (1914) gives much information of value on the subject.

438. Hogging off wheat. — The season for hogging off wheat runs from four to six weeks, beginning at the stiff dough stage, and continuing until stubble fields are available, or until other crops are ready for similar use. Soft-kerneled varieties with awnless spikes are preferred, for obvious reasons. Club wheats and other varieties that do not shatter have the advantage of reducing the waste of grain. An instance in Whitman County, Washington, may be mentioned as an example of hogging off wheat, in which 109 hogs were fed on $7\frac{3}{16}$ acres of standing wheat and 1 acre of other pasture from July 30 to August 17. The hogs made a gain of 212 pounds an acre and gave a net value an acre of $15.73. The net gain from the sale of wheat from 44 acres adjoining, yielding $19\frac{3}{4}$ bushels an acre, was $8.04 an acre.

439. Hogging off barley. — Barley, for hogging off, has an advantage of being one of the first crops available. Hooded varieties, which are the kinds preferred, if sown early in the spring, will ripen 10 to 15 days earlier than winter wheat. Mature awned barley is not satisfactory because of the effect of the awns on the hog's mouth. On the other hand, the awned varieties out-yield the hooded. The former are often allowed to stand until the fall rains have softened the awns. This gives time after harvest for the hogs to glean stubble fields. In the Columbia Basin, Coast or Blue barley is usually employed in late fall and winter. It does not shatter and sprout so easily as wheat or other barleys. In one instance in Umatilla County, Oregon, during November, 80 hogs were pastured 18 days and 98 hogs 10 days on 11.4 acres of barley, on a hillside too steep for the use of a self-binder. The gain in weight averaged 230 pounds an acre, valued at $18.34. The estimated yield of the barley was 21 bushels an acre (Hunter, 1914, pp. 7–9).

440. Cereals in crop mixtures for pasturing are used to a considerable extent. One bushel of oats and 4 pounds of rape are sometimes sown together about May 1 for summer pasture. This mixture is used from the time it is 5 to 6 inches high until beginning of winter. First the rape is eaten and later the oats. On ripening, many kernels fall and sprout with the fall rains. The later growth of both oats and rape then make excellent fall and winter pasture.

Wheat and vetch, or oats and vetch, are also grown together for late fall, winter, and early spring pasture. A bushel of oats, or 40 pounds of wheat with 1 bushel of vetch, are sown to an acre, either in corn at the last cultivation, or on spring-plowed stubble land in early fall. If sown in corn, the 1-horse disk drill is used for seeding.

Gathering the Crop

441. Time of harvesting. — It is the general tendency in the Western area to do all harvesting too late for the good of the crop. Natural conditions of dryness and adaptation of non-shattering varieties, and the kinds of machines employed, favor the practice. Aside from the question of quality of kernel, much waste would be avoided by earlier harvesting. Sometimes the ripe crop is left standing 4 to 6 weeks before harvesting. In a 4-years trial at the Nephi, Utah, substation, it was found that winter wheat yielded best harvested in the hard dough stage. Harvesting in the green dough stage resulted in the heaviest loss, due to shriveling of the kernels. Nearly $1\frac{1}{2}$ bushels an acre were lost by cutting when overripe, probably due largely to shattering.

The Bureau of Crop Estimates has determined from correspondence that the average periods of harvesting wheat in the western states are about as follows: —

TABLE XV. — THE AVERAGE PERIODS OF HARVESTING WHEAT IN THE WESTERN STATES

	WINTER WHEAT	SPRING WHEAT
Montana	July 24 to Aug. 21	Aug. 9 to Sept. 5
Wyoming	July 30 to Aug. 24	Aug. 15 to Sept. 14
Colorado	July 16 to Aug. 16	Aug. 2 to Aug. 31
New Mexico . . .	July 5 to Aug. 2	July 29 to Aug. 25
Utah	July 10 to Aug. 6	Aug. 2 to Sept. 2
Idaho	July 21 to Aug. 24	Aug. 8 to Sept. 10
Washington . . .	July 20 to Aug. 20	Aug. 2 to Sept. 2
Oregon	July 17 to Aug. 16	July 31 to Aug. 31
California	June 25 to Aug. 5	No spring wheat
Arizona	May 30 to June 26	June 22 to July 24

Oats ripen about the same time as spring wheat, and barley a little earlier than winter wheat.

442. Cutting the crop in the Western area is usually done with the header or the combined harvester-thrasher. Both these machines cut the grain higher than the self-binder, the object being simply to get all the spikes. The header is pushed before the team, and the grain is taken from the platform by a carrier into a header box, driven by the side of the header. The combined machine has a thrasher attached, and the grain is cut, thrashed,

FIG. 136. — Harvesting with the combined harvester-thrasher in the state of Washington.

and bagged, and the bags dropped along the path of the machine, while the straw is distributed over the field. This machine is pulled either by twenty-eight to forty

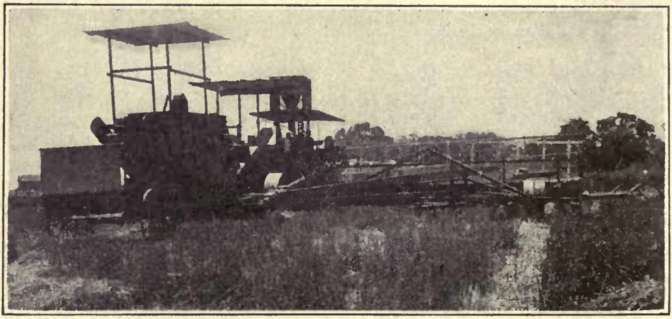


FIG. 137. — Combined harvester-thrasher drawn by steam power.

horses (Fig. 136) or by an engine (Fig. 137). In recent years, a small combined machine, propelled like a header, has come into use in the Palouse country, which appears to be well adapted to small farms (Fig. 138). The power for operating the machine is now sometimes made independent of the propelling power, which method is applied even in self-binders.

In hilly districts and in other localities where shattering varieties are grown, the self-binder is employed. Sometimes a wide-cut push binder is used, propelled like the header.

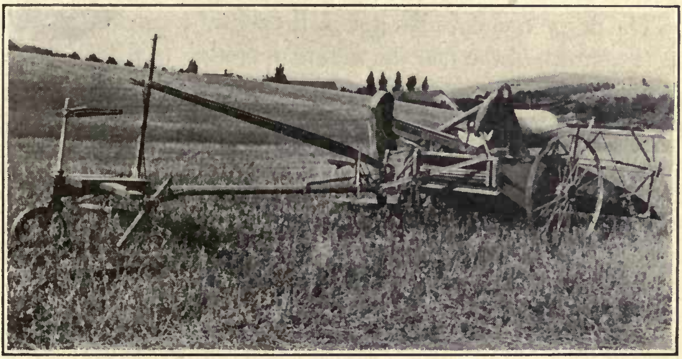


FIG. 138. — The Moscow small combined harvester-thrasher at Moscow, Idaho.

443. Merits of the different methods. — It is chiefly because of rapidity and economy of operation on large farms that the combined machine has come into such general use. This machine permits the return of all straw to the soil, a particular advantage where the exhaustive summer fallow system of cropping is practiced. It is believed that the maintenance of dry-land wheat-farming for over a generation, without manuring, has been made possible by the organic matter added to the soil, as a result of the heading method of harvesting.

Also, of the many instances of thrashing-machine explosions in recent years, a very small percentage has occurred in combined machines.

On the other hand, it is maintained by the millers that the quality of wheat is impaired by the delay in harvesting caused by the use of the combined machine. Weed seeds are also distributed by this machine.

The percentage of nitrogen in the wheat kernel increases as the length of the fruiting period decreases (see Thatcher, 1913, pp. 42–46). Therefore, grain cut by the binder, and slightly under ripe, should have a higher percentage of nitrogen than grain cut and thrashed by the combined machine. The latter method may, however, give a better yield by weight. Stewart (1915) also investigated this subject and concluded that grain in Utah is not injured by harvesting with the combined machine. In determining the change in weight of thrashed grain during storage, Harris and Thomas (1914, p. 310) found that this process was not affected by any method of harvesting or thrashing.

444. The treatment of the grain after harvesting or thrashing is very simple. Shocking or stacking (362, 363, 400, 401) requires little or no care to prevent spoiling from moisture in this area of summer drought, unless the thrashing be done very late. Stacks should be protected from fires by plowing around them. For similar reasons, the thrashed grain requires no attention the remainder of the summer. The bags are piled in long ricks out doors, often in the field.

445. Thrashing. — In the main, the discussion of this subject here would add nothing to what is given in other chapters (364, 402). One serious condition, however, must be mentioned, rarely encountered in the other areas. It is the occurrence of thrashing-machine fires, particularly in the Columbia Basin. As the fires start with a flash, accompanied by a report and considerable force, they are usually referred to as explosions. These fires became so numerous in 1914, in the Palouse country, that many supposed them to be due to incendiarism. Investigation showed that the causes were possibly several, but chiefly the prevalence of bunt or stinking smut, associated with extreme dryness of the grain and of the atmosphere, resulting in heavy charges of static electricity.

The Washington Experiment Station (Cardiff and others, 1914) studied thoroughly the conditions accompanying these fires. It was found that the relative humidities at 5 P.M. at both Walla Walla and Spokane, for August in 1914, were the lowest recorded for 6 years. The percentage of moisture in the grain was extremely low, averaging 3.58 per cent, while the lowest previously noted was 6.17 per cent, and the average for 6 years was 9.98 per cent. The percentage of bunt in the grain was also much above that of previous years. In 10 cases out of 31 that were reckoned, there was 20 per cent to 30 per cent of bunt. It is suggested that on the basis of studies so far made, the following precautions be taken: —

(1) The cylinder of the separator should be grounded by means of an electric brush, connected to the earth by wire and an iron peg. (2) Every separator should be provided with a system of water sprinklers. (3) Barrels of water should be at hand, and buckets be provided for applying the water in case of fire, and for no other purpose. (4) Furrows should be plowed around the setting before beginning the thrashing. (5) The engine should be connected by a strong cable with the separator, enabling the latter to be pulled away from the straw pile at the outbreak of the fire. (6) Members of the crew should be given definite directions just what to do in case of fire.

CHAPTER XVI

CEREALS UNDER IRRIGATION

Where the annual rainfall is less than 10 inches, cereal cultivation by dry-farming is not usually profitable. In such localities cereals are sometimes grown by supplementing the rainfall with applications of water artificially. Irrigation of cereals is done almost entirely in the Western area. Even in this area, however, the proportional acreage of cereals under irrigation is not large. In line with the rapid development of dry-farming, there has been a segregation of crops that are grown for marketing, those permitting extensive methods being handled under the latter system, and the intensive crops, such as truck crops and fruits, being retained under irrigation. However, as first crops on new land, and as aids to other crops, cereals are still found to have some importance under irrigation. In 1914 there were grown on the United States Government Reclamation projects alone, 148,517 acres of wheat, oats, barley, and rye. In 1909 the total irrigated acreage of small grains in the United States was $1\frac{1}{2}$ million acres.

446. Clearing and leveling. — Cereals are usually irrigated by the method of flooding from field laterals; that is, from field ditches branching off from the main or supply ditch. The land must therefore be leveled or graded into a uniform slope. First it is cleared of the sagebrush and other growth in the manner already described (430). After plowing and harrowing, the land is gone over once each way with a rectangular plank or float. This implement leaves the surface smooth, so that the smaller irregularities in slope are easily noticed, which are then leveled with a regular land grader. The grader cuts off the little elevations and dumps the material into depressions.

The flooding method of irrigation involves least preparation of the land, and is therefore preferred by the new settler, but it requires more labor in applying the water. A supply ditch is run down the slope of the land, and from this, field ditches are run across the slope with just enough grade to carry the water, which flows over the lower bank of each ditch and down the slope to the next ditch. A man with a shovel must direct the water.

447. The border method of irrigation is a modification of the flooding method, which requires more preparation of the land before irrigating, but less labor in applying the water. It is a process of flooding between levees or borders. A head ditch runs across the greatest slope at the upper end of the field, and from this, parallel borders are run down the slope at intervals of 40 to 60 feet, dividing the field into lands. Each land is level between the borders, so water will flow down this slope in a sheet extending from border to border. After turning water into a border, no further attention is needed until that part of the field is sufficiently watered, when the water is shut off. This method is used considerably in the Southwest, and is recommended in southern Idaho. The greater the slope the less practicable is the border method, as the field may have to be too small in order to be level.

448. Flooding in checks is provided for by running levees in both directions across the field, dividing it into a series of rectangular basins. On steep or irregular slopes, the levees are run on contour lines. Water is applied in a similar manner to that in border flooding, but on a larger scale. The checks are usually 1 to 2 acres in size. Levees must be broad and low enough for harvesting machinery to cross them. They are sown with grain, and usually receive enough water through seepage and rainfall to mature the crop. This is the method used in rice irrigation (699).

449. Furrow or corrugation method. — In the extreme northwestern states, grain and alfalfa are commonly irrigated by the corrugation method. The water is run in small shallow furrows, from which it percolates laterally through the soil, but does not run over the surface. It is a slow method, that can be used at night, and is proper for heavy soils which take water slowly. On the other hand, it may be better sometimes on light soils, with much slope, to prevent soil washing. It will work on considerable slopes, as the furrows can be run at any angle necessary to give the required grade for the desired velocity of water. The furrows are made just after seeding. Preparation of the land is more expensive than that for flooding, but less labor is required in applying the water. In grain fields, the furrows are made $1\frac{1}{2}$ to 3 feet apart (McLaughlin, 1910). In Utah it appears that irrigation by flooding is commonly practiced in the northern part of the state, while the furrow method is more common in the southern part. The merits of the two methods have not been determined experimentally for small cereals.

450. Comparison of methods. — Nowell (1908, pp. 18–19) experimented with the three irrigation methods as to cost, and concluded that the furrow method was most satisfactory, compared with the flood and check methods, in results secured. The first cost was higher, but labor of irrigation less than with either of the other methods. It was also found that furrows should not be less than 16 inches apart.

451. Succession of crops. — The irrigated grain crop often follows the clearing of sagebrush, as it is the cheapest first crop on new land. In other cases it usually comes after alfalfa or some cultivated crop such as corn, potatoes, or sugar-beets. In Colorado, it is found that a good rotation is alfalfa 3 years, potatoes or beets 3 years, wheat or barley 2 years, then alfalfa again. In Utah, grain often succeeds alfalfa.

452. Preparation of the soil for seeding may follow the order of plowing, harrowing, irrigating, then disking, and later the use of the float. If the method of irrigation is by flooding, leveling will precede that operation, unless done previously. For spring seeding after fall plowing, the disk harrow should take the place of the plow in the spring. Often irrigation is not needed to start the crop, in which case the land is plowed or double-disked (if previously plowed), harrowed, floated, and seeded, and then irrigated afterward. This course is particularly advisable on heavy soils, which dry out very slowly, thus delaying the seeding if not done before irrigating.

453. When to irrigate. — The frequency of irrigation is determined largely by the character of the soil and subsoil. A heavy soil with tight subsoil may be irrigated heavily but at long intervals, as it will absorb a large quantity of water and hold it a long time. On the other hand, light soils, especially if they have also open subsoils, should be irrigated lightly but frequently. The ideal condition is to give the soil sufficient moisture to germinate the seed and grow the crop until it is high enough to shade the ground at the second irrigation. It is afterward irrigated again when the spikes are just appearing, and sometimes again when the spikes are filling, making 3 or 4 irrigations in all.

Winter grain, if well started in the fall, develops much earlier and faster in the spring than spring grain. Therefore the winter and spring moisture are usually enough to bring it to the stage when the spikes are in the boot. One or 2 irrigations are then sufficient to make the crop, the second irrigation, if any, being given at the time of filling the spikes.

454. Time of irrigating spring grain. — It is natural to suppose that applications of water will be most effective if made just at the time of occurrence of the important stages of growth of the plant. These, after the time the crop begins to need water, are chiefly three, — jointing, heading or flowering, and ripening, but they may be further divided into substages of jointing, booting, heading, flowering, soft dough, hard dough, and ripening. The question is, at which of these stages are irrigations most needed, and how many of them should there be.

Welch (1914, pp. 13–17) studied this subject, and determined in 3 years' experiments that water applied to spring wheat, in southern Idaho, is most effective in 3 irrigations given at the jointing, booting, and soft-dough stages. The plat not irrigated, and the one irrigated at the jointing stage, produced grain so shriveled that it was unfit for milling; while 1 irrigation at the jointing stage made a greater yield than 1 at the heading stage, but the grain resulting from the latter was much superior in quality. The second and third best yields, which were nearly the same, were made by 2 irrigations, at the booting and soft-dough stages in one case, and at the jointing and flowering stages in another. The grain which received no water ripened 5 days earlier than that which received the most. In these experiments the water was applied by flooding between borders.

455. Winter irrigation. — The utility of irrigation during the winter or non-growing season appears to have been demonstrated in some localities where the water supply is sufficient. In such cases, water applied in the winter or early spring serves to store moisture in the soil for later use of the crop, when the water supply is constantly needed for other crops. In winter the land is irrigated once or twice before freezing weather, the first irrigation being 2 weeks or a month prior to the second one, which should be given just before heavy frost occurs. Winter irrigation is best done by the furrow method; or the land should be harrowed after the second irrigation, as a mulch surface is desirable to hold the winter precipitation. The soil should be saturated to a depth of 4 to 6 feet (McLaughlin, 1910, p. 15).

456. Fall irrigation where winter rains are lacking has been found very desirable. The localities where it is particularly advantageous are likely to be near the eastern border of the Western area, where there is little winter precipitation, as in the Great Plains. Knorr (1914) has experimented 3 years with fall irrigation on wheat, oats, and barley, at the Scottsbluff, Nebraska, substation. The resulting yields were 5.5 more bushels an acre of wheat, 7 more bushels of barley, and 11 more bushels of oats, after fall irrigation, than on land not so treated, but irrigated afterward as usual. The crops fall-irrigated also grew from 1 to near 2 inches taller, and produced more straw to the acre, but less straw to a bushel of grain. The increased yields were more than sufficient to pay for the cost of fall irrigation of these crops.

457. The quantity of water required at each irrigation depends upon the number of irrigations, the depth of soil, nature of soil and subsoil, purpose for which the crop is grown, climatic conditions, method of application, and other factors. Usually the soil is driest at the time of the first irrigation, and more water is needed than at subsequent irrigations. Water is also plentiful always during the early spring. If the first irrigation occurs when the grain is in the milk, it should be the heaviest; but if it comes when the spikes are in the boot, then the heavier irrigation should be at the milk stage of the grain. New land requires more water than old land.

458. Duty of water may be defined as the number of acres of any crop that can be served to maturity by a certain quantity of water. The unit of quantity is designated by several terms, of which at present the second-foot is the most common. A second-foot of water is 1 cubic foot of water passing a given point during each second of time. An acre-foot is the quantity of water that will cover 1 acre to a depth of 1 foot. The miner's inch, formerly employed a great deal, furnishes in the same time usually about $\frac{1}{50}$ as much water as the second-foot, but varies in value in different states. The term duty of water, however, has in practice no fixed meaning, perhaps necessarily so, under present conditions. It may become more definite as irrigation practices are improved. For example, just how much of the necessary losses of water is excepted or included in stating the duty of water is not always clear. Losses occur in various ways, but chiefly through seepage, leakage, and evaporation. The absolute duty of water is the service of the irrigation water plus the existing soil moisture and the precipitation. The gross duty of water is the crop acreage served by the water at the intake of the canal or large lateral. The net duty of water is the crop acreage served by the water at the farm headgate (see Widtsoe, 1914, p. 335).

459. Duty of water and water requirement must be carefully distinguished. Duty of water measures the efficiency of water in producing a crop, while water requirement measures the efficiency of the crop in maturing with a certain quantity of water (280, 281). The water required is the net quantity used by a crop unit; the duty of water is the acreage served by a gross unit of water.

460. Duty of water in Idaho. — Welch (1914, pp. 17–21) gives average results of 4 years' work at Gooding, Idaho, on the duty of water for spring wheat, oats, and barley. In the spring wheat experiments 90 plats in all were tested, and four varieties employed, — Sonora, Dicklow, Little Club, and Palouse Bluestem. All first irrigations of spring wheat were in the first week of June. There was no difference in the dates of heading, but the maximum application of water delayed ripening 5 days. There was an increase in yield with the increase in water applied up to about $2\frac{1}{2}$ feet, after which any further increase of water was not only unnecessary, but became positively harmful. The conclusion from these experiments is that $1\frac{1}{2}$ to $1\frac{3}{4}$ acre-feet of water, given in 4 or 5 applications, is the proper irrigation for spring wheat on new sagebrush land.

The results of the oats experiments justified the decision that $1\frac{3}{4}$ acre-feet of water, in 4 to 5 applications, is the best irrigation for oats. It was also concluded, however, that an excess application above this amount, though of little or no use to the crop, is not likely to be as harmful to oats as it proved to be to spring wheat. In 3 of the 4 years the crop was grown on raw sagebrush land and Lincoln and Big Four were the varieties employed.

The results of the barley experiments indicated that $1\frac{3}{4}$ acre-feet of water, in 4 good applications, is satisfactory for the irrigation of that crop. The maximum irrigation delayed maturity 3 days. The plants which received the most water were 3 inches higher than those which received the least. Moravian White and California Feed were the varieties used.

461. Duty of water in Wyoming. — In experiments at the Wyoming Experiment Station, on 6 plats of barley given different quantities of water, the highest acre-yield, 35.32 bushels, was secured from a plat receiving 19.56 inches, in 3 irrigations. It was concluded that best results are secured in irrigation of barley when 16 to 20 inches of water is applied in addition to the precipitation. In other experiments at this station it was found that the best yield of oats to the acre-inch of water used was secured with a depth of water of 15 to 18 inches, including the rainfall.

462. Duty of water in Utah. — At the Utah Experiment Station, the best yields of wheat and oats to the acre were secured with 30 inches of irrigation water, the yields decreasing when more was applied. Results of other experiments at this station indicate that the largest yield of grain is produced when there is a heavy irrigation at heading time, with light irrigations earlier. The reverse condition is true as to the weight of straw, which is greater when the first irrigation is heavy and the last one light.

463. Increasing the duty of water. — In the experiments at Gooding, Idaho, described above, the acre-yields of spring wheat in the duty of water tests ran from 15.87 bushels to 26.08 bushels, while those of the time irrigation experiments with the same cereal ranged from 29.22 bushels to 50.12 bushels, with no difference in conditions whatever, except that the former experiments were on raw sagebrush soil and the latter on old alfalfa ground. The yields on alfalfa ground were almost twice those on new land. One lesson learned from the 2 series of experiments compared, therefore, is that increasing the soil fertility also increases the duty of water. The application of stable manure would, without question, have a similar effect. There is not only an immediate gain in crop returns following the alfalfa of nearly 100 per cent, but the soil is put into a condition permitting economy in the use of water probably for some time afterward, a fact of the greatest importance, considering the future scarcity of irrigation water that will certainly occur.

464. Making the most of the precipitation. — Another fact of importance in connection with economy in the use of water is that after all, even in the driest districts, the natural precipitation produces a large percentage of the dry matter of the irrigated crop, often the larger proportion. Much of the water commonly applied in irrigation is never used and may be actually harmful. Unless the rainfall is exceedingly light there is always sufficient, if well conserved, to make a considerable crop. It was the study of these questions of the quantity of water required for a crop and what can be expected from the rainfall alone, with proper soil management, that had much to do with the development of dry-farming. In determining the dry matter to an acre of different crops produced with and without irrigation, Widtsoe (1912, pp. 15–25) found that with 7.5 inches of water applied the percentage of the dry matter due to rain and the soil water, already present, was 85.5 per cent in the case of wheat, and 86.2 per cent for oats. In Utah, with 12½ inches of rain and soil water economically utilized, 7½ inches of irrigation water added, or 20 inches in all, will make a good crop of grain; and, therefore, in an average year very little added above the 7½ inches can be utilized, but is wasted.

465. The yield to an acre-foot of water is much more important in irrigation than the acre-yield. As already intimated, water becomes less efficient the more there is applied. That is, the more water a soil contains to a given depth, the larger the quantity that will be absorbed by the plant and evaporated by the sun in proportion to dry matter produced. The principle as stated by Widtsoe (1912, p. 239) is that "the rate of loss of water from soils increases as the initial percentage of moisture in the soil increases." Briefly, the problem is to secure the maximum yield of dry matter with a given quantity of water, at the least cost. Under irrigation, water is often worth more than the land, and it is important to know what the water will produce. The acre-foot yield is largest with the smallest quantity of water, and least with the largest quantity. Thirty acre-inches of water will produce about 7000 pounds of the dry matter of wheat on 1 acre, but will produce 22,000 pounds, over 3 times as much, if applied over 4 acres. Of course the cost is greater in tilling the 4 acres, but even so, the conditions might be such that 30 inches on 4 acres would give greater net profit than on one acre, considering the relative value of land and water. In experiments with Siberian oats at the Nevada Experiment Station, 2 irrigations gave an acre-yield of 46.1 bushels, but an acre-foot yield of 72.4 bushels.

466. Seeding. — All seeding should be done with the drill. On nearly level land, the drilling should be done in the same direction as the slope, to aid in directing the water. On hill sides, the drill rows should be at right angles to the slope, so as to check the water. Winter wheat is sown at 4 to 6 pecks an acre, and spring wheat at 6 to 8 pecks an acre. Oats should be sown at $2\frac{1}{2}$ to 3 bushels an acre, and barley at about $1\frac{1}{2}$ to 2 bushels an acre. The times of seeding of different cereals in the latitude of Wyoming are about as follows: winter wheat the first week of September, spring wheat at the end of March or as early as possible, oats after April 10, and barley about the same time as oats.

467. Wheat. — Winter wheat, because of its longer period of growth, does not appear to fit in with irrigation farming so well as the spring grains. Prompt seeding is delayed by necessary attention to preceding crops. Hard wheats are not well adapted for irrigation, as the abundance of water softens them, and durum wheats should never be irrigated. Defiance, Sonora, Australian White, Palouse Bluestem, and the Club wheats are good spring wheats for irrigation. If the soil forms a surface crust, it may be an advantage to harrow wheat until it is 4 to 5 inches high. Wheat should not be irrigated until the condition of the soil shows a need for water, but irrigation should not be delayed longer than the soft dough stage. The quantities of water to be applied to wheat will depend somewhat upon the purpose for which it is intended. An increase in the quantity of water will increase the percentage of straw and decrease the percentage of grain.

Before harvesting, all of the field laterals should be worked down. The wheat should be cut in the hard dough stage. If well shocked, it will ripen some in the shock. Stacking the wheat gives it a good color through sweating, and avoids losses from hail and other adverse conditions.

468. Oats and barley. — The methods of handling oats and barley under irrigation are about the same as for wheat. The Swedish Select is a good late variety for irrigation, and the Kherson is good for early maturity. Upon irrigating, oats will recover from the effects of a dry period better than any other small cereal crop.

Barley is more affected by over-watering than other small cereals. The quality of the kernel is injured by too much irrigation, and watering later than the soft dough stage will cause a strong second growth, resulting in mouldy bundles after harvesting. The yield of grain to an inch of irrigation water decreases much more rapidly as the quantity of water applied increases than that of wheat or oats. Barley does not do well after other small cereals. The crop should be cut before it is fully mature to prevent shattering. Where hailstorms are frequent, the shocks should be capped, as hail will shatter the grain even in the shock (Knorr, 1914).

469. Effects of irrigation on the crop. — In the early part of the period of growth, the crop requires less water than during the later growth when the spikes and kernels are forming. According to Widtsoe and Stewart (1912): "(1) Leafy plants and a vigorous growth of the underground parts are produced by much water; (2) relatively large heads (spikes) or pods are produced when little water is employed; and (3) the percentage of protein in all plant parts increases as irrigation is decreased."

In general, a proportional increase in the vegetative growth of the plants, compared with grain production, occurs as the water supply is increased. Also the period of growth is prolonged and maturity delayed by irrigation. A day or less after irrigation, the color of the leaves of barley turns to a somewhat deeper shade. Irrigation not only softens the kernels of hard wheats as already mentioned, but also weakens the straw of all small cereals,

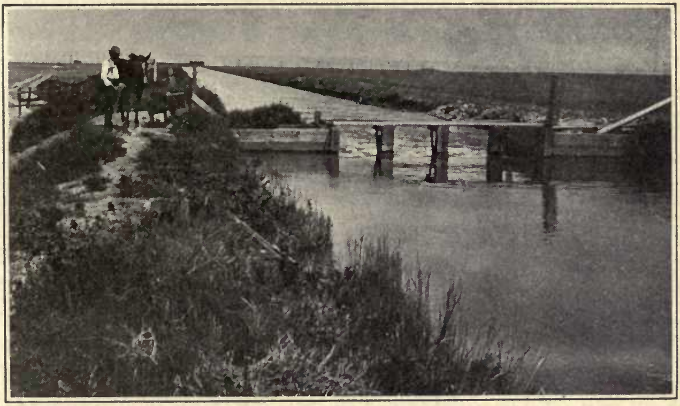


Fig. 139. — Irrigation canal on the Huntley Project, Huntley, Montana.

and increases the tendency to lodge. Early cessation of irrigation will reduce the bad results of this tendency. Frequent applications of water will create conditions favorable to the spread of rust. Naturally cereal crops intended for forage require more irrigation than those grown for the grain. Figure 139 shows an irrigation development in the grain country of the Great West.

470. Cereals as cover-crops are of more consequence under irrigation than in dry-farming, except in so far as they are considered as green-manures.

Barley is grown as the first crop in the Imperial Valley. It mellows the first breaking of the hard lands, and may be grown before the land is permanently leveled. It is considered best to precede alfalfa with two crops of barley. For winter pasture it is seeded about October 1, but if the grain alone is desired, it is sown in December or January. Broadcasting the seed, followed by harrowing, is the common method of seeding. Twenty to 40 pounds of seed is used to an acre, if sown in the fall, and 40 to 75 pounds if sown in winter or early spring, as the fall-sown crop tillers greatly. Usually irrigation is done after seeding. As the ripe grain stands some time before harvesting, it is a common practice to allow the crop to reseed itself after the first year. Sometimes the crop is "hogged down," and even then sufficient seed remains for a volunteer crop.

On the sandy soils of the Columbia River Valley, rye or wheat is recommended among other crops, for fall seeding, for cover-crops in orchards. These cereals are frequently sown with red clover or hairy vetch for the same purpose. For spring or early summer seeding, rye, oats, wheat, or barley is recommended. On the Umatilla reclamation project in Oregon, rye and wheat are recommended for growing as catch or cover crops on bare lands between the regular crops (Hunter, 1909 and 1910).

471. Cereals as nurse crops. — Under irrigation, alfalfa and other legumes are often started with some cereal as a nurse crop. The cereal aids the legume chiefly in three ways: by (1) protecting it from the hot sunshine, (2) checking soil-blowing, and (3) preventing crusting of the surface soil.

On the Truckee-Carson project, it is recommended for starting alfalfa, that wheat or barley be sown some time in March, as early as weather conditions will permit, and when the grain is a few inches high, to drill the alfalfa into it. For the good of the alfalfa, the grain is cut for hay before it is mature, which gives the alfalfa time to make good growth before cold weather (Scofield and Rogers, 1909).

A good method of seeding alfalfa into the grain is to drill it across the grain rows after the latter is up, drilling it much shallower than the grain. As to the rate of seeding nurse crops, Knorr (1914) recommends 3 pecks of wheat, 5 to 6 pecks of oats, and 4 pecks of barley.

In the Columbia River Basin, rye is most commonly used to start alfalfa, because it is hardier than other cereals and will resist the blowing sand. The land is irrigated after the hottest weather, usually the last of August. Immediately after, while the soil is moist, 50 to 60 pounds of rye and 15 to 20 pounds of alfalfa to the acre are sown together with a drill, the latter being provided with a grass seeder attachment for the alfalfa. The seed should be covered about 2 inches deep. The following spring the rye is clipped 2 or 3 times after jointing, to prevent it from smothering the alfalfa. Sometimes the rye is sown alone in October, and the alfalfa drilled into the grain early in the spring (Hunter, 1909).

472. The alkali menace. — The fact has been mentioned that in the Great Plains and Western area, there is a large percentage of mineral salts in the soil (246). These occur in proportionally larger quantities, even, as the humus content becomes less. In normal quantities in the soil, they are essential in cereal production, but some of them, when accumulated in excess, become destructive to all crops, though in varying degrees to different crops. The effect of heavy irrigation is to take up these salts to a great depth, and leave them deposited at the surface through evaporation during a dry period, unless there is good drainage. They are strongly alkaline in reaction, and known as alkali salts or alkalies. The most destructive, sodium carbonate, because of its solvent action on humus, is black in color, and known as "black

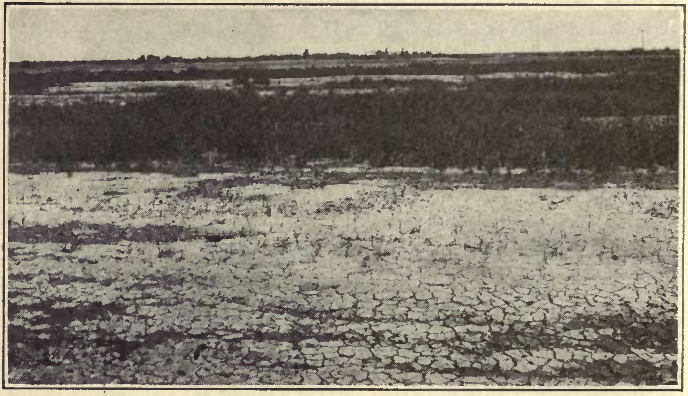


FIG. 140. — Field of wheat badly injured by alkali on Truckee-Carson Project.

alkali." The more common white incrustations are deposits of the white alkalies, sodium sulfate (glauber salt) and sodium chloride (common salt).

In many localities during the considerable time since irrigation was established, alkali deposits have accumulated to an alarming extent, because of needless excessive applications of water, long continued, and lack of proper drainage, if any at all. Black alkali, in addition to its direct effect upon the crop, acts very injuriously upon the soil, by puddling it and making it untillable, and tending to form in the lower layers a tough hard pan, impervious to water (Fig. 140).

473. Prevention of alkali may be accomplished by (1) preventing evaporation and (2) keeping the water table down. Excess irrigation and seepage, with poor drainage, will soon raise the water table, and when less than two feet from the surface, it will be a constant supply of water to take the place of that evaporated, permitting thereby a continual deposit of alkali. The water table can be lowered only by drainage. The drains should be at least three feet deep. Evaporation may be checked by the various means of surface cultivation, mulching, and other methods already mentioned.

474. Resistant crops. — The cereals are all more or less resistant to alkali, barley being the most resistant of all. Alkali tolerance in cereals is discussed fully in another chapter (267, 268). Where the alkali is not yet accumulated in much excess, therefore, the more resistant crops may succeed. Different varieties of the same cereal, even, will offer resistance to a different degree. However, very often the excess deposit is far beyond the power of any crop to resist, and either the alkali must be removed or controlled, or cropping be abandoned entirely.

475. Reclamation. — Black alkali land may be reclaimed by the application of gypsum and turning it under. This has been done at Tulare, California, by the State Experiment Station. On spots where previously not a blade of grass would grow, wheat and barley 3 to 4 feet high have been produced, although the surface of the ground at harvest time was covered by a thick crust of white alkali. Gypsum converts the carbonate of sodium into a sulfate, which is still harmful, but much less so than the carbonate.

Common salt is often present in large quantities, and is more harmful to crops than generally supposed. When the quantity exceeds 5000 pounds to an acre-4-feet, barley should be grown in preference to wheat (Loughridge, 1901, p. 8). Removal of white alkali may be done in two ways: (1) by tile under-drainage into a stream at a lower level, or (2) by bringing it to the surface through irrigation and evaporation, and then scraping it off and carting it away. The second method is hardly practicable on a large scale, though large quantities of salts may be removed in that way.

476. Control of the alkali may be effected in some measure, when it is not present in too great an excess, though too great for the tolerance of crops, by driving it downward by irrigation and keeping it there through mulching of the surface soil or constant cultivation, thus preventing evaporation. Rice is rarely injured by alkali, not because of its tolerance, as often supposed, but because the alkali is kept down by flood irrigation and not permitted to concentrate at the surface. Moreover, a well-managed rice farm is well drained.

The essential feature of perfect irrigation is drainage, while the essential feature of perfect drainage of marshes for cropping is provision for irrigation.

CHAPTER XVII

CEREAL PESTS — WEEDS

Closely related to the subject of crop cultivation from a practical standpoint is another one of much concern to the cereal grower, that of crop pests. Crop rotations and thorough cultivation check or prevent the ravages of certain insects and fungous diseases, and summer tillage is practiced largely for the eradication of weeds. Cereal crop pests are of three classes: (1) weeds, (2) insects, and (3) parasitic fungi.

Weeds

Any plant growing where it does not belong is a weed, even though it be of value when planted for a purpose. A stalk of corn in a wheat field is as much a weed as a sunflower. Even a volunteer wheat plant in wheat of a different variety is a serious weed. It is impossible in thrashing to separate the volunteer kernels, which injure the quality of the regular wheat for milling and for seed. Weeds are usually more troublesome in small grain crops than in intertilled crops, as the former are not cultivated during growth.

477. Weeds are injurious to small grains in a number of ways: (1) they occupy space needed by the crop, crowding out the cereal plants and reducing the stand of the latter. (2) They shade and check the growth of young cereal plants early in the season. (3) They exhaust the soil of plant-food needed for the crop. (4) They also exhaust the moisture from the soil. In all dry-farming this is the chief source of loss caused by weeds. All inter-tillage of crops and summer tillage preceding cropping is largely of value for the killing of weeds. (5) Weeds harbor injurious insects and parasitic fungi which in some cases sooner or later attack the cereal crop. Some weeds, such as quackgrass and wild barley, are affected by the same fungous diseases as are the cereals. The shade and dampness where weeds are rank, even if they are not themselves infested, will favor the rapid spread of cereal diseases. (6) Weeds reduce the value of the crop for hay, and if the seeds get into the thrashed grain, it is also injured, both for the market and for seed. Often the most serious loss from weeds occurs in this way. (7) Weeds increase the expense of gathering the crop when very numerous, because of extra time and labor required and extra twine needed for binding. (8) They delay the curing of the grain.

It is estimated that in one of the grain states alone, the damage to wheat due to weed seeds is about $2\frac{1}{2}$ million dollars annually.

478. Habits of growth. — In order to combat any enemy properly, animal or vegetable, it is necessary to know its habits, so that means of eradication may be attempted just where and when they can be most effective. There are three classes of weeds as to habits of growth: (1) annuals, (2) biennials, and (3) perennials. Only the principal cereal weed pests of each class will be discussed here separately.

479. Annual weeds. — Weeds which complete their entire growth in a year, then mature their seeds and die, are annuals. They usually have small fibrous roots and produce a large quantity of seed. Some of the annual weeds that are pests of grain fields are buffalo bur, chess, mustard, ragweed, Russian thistle, wild oats, penny cress, sunflower, cockle, tumbling mustard, and wheat-thief. Some of these germinate in the fall, live through the winter, and mature their seeds in the spring or early summer, and are therefore to be classed like winter wheat, as winter annuals. Chess, cockle, wheat-thief, and penny cress are of this class.

480. Dissemination of annual weeds. — It is probable that nearly all weeds on any farm have started from seed sown by the farmer himself, which shows the necessity of cleaning seed. Thorough cleaning is difficult, but every effort should be made to accomplish it. One mustard seed in a bushel of wheat sown on an acre of land seems a trifle, but the one weed resulting will produce thousands of seeds for weeds on the same acre the next season. Pulling the one weed on each acre would solve the mustard problem for the time, showing the importance of early attention.

The wind carries seeds such as penny cress or prickly lettuce long distances. Many seeds are no doubt carried in the drifting snowstorms of the winter. Various tumble weeds are driven by the wind many miles away. Bolley (1908, pp. 526–527) tested the seed-carrying power of blizzard winds in January and February. Fifteen minutes after exposure to a 15-mile-an-hour wind, many millet seeds (proso) and some heavy-weight oat kernels were found 80 rods distant from the point of dissemination. Some weeds, like the bull thistle and penny cress, have hairy or winged seeds, adapted for wind dissemination. Seeds of ragweed, wild oats, and mustard are carried on flood waters, while sweet clover, pigweed, sunflower, and mustard seed are carried by irrigation waters. Some

FIG. 141. — Seeds of weeds. Enlarged.

seeds, as the sandbur and buffalo bur, are carried in the hair of animals. Hay, packing materials, and manure are also common means of dispersing weed seeds. They are also transferred from farm to farm by the thrashing

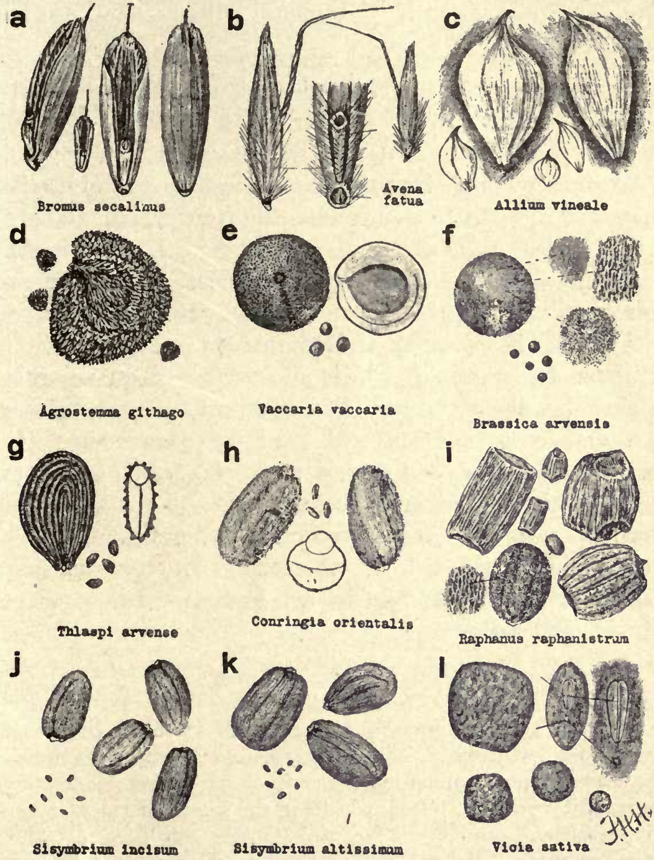


FIG. 142. — Seeds of weeds. Enlarged.

machine. Seeds of a number of weeds are shown in Figs 141 and 142.

481. Corn cockle or purple cockle (*Agrostemma Githago*, Linn.). — This weed occurs often in wheat fields. The name was given it in England where wheat is often called corn.

Cockle grows from 1 to 3 feet high, has large purple flowers $1\frac{1}{2}$ inches across, and dull black seeds which are roughened by ridges of short spines.

Wheat screenings from the Northwest are full of cockle. It is very difficult to separate cockle from wheat, the kernels of which are near the same size (Fig. 142 *d*). Special cockle machines are made for the purpose. The seeds are poisonous to animals if eaten, and flour from wheat mixed with cockle is injurious as human food. The poisonous principle is sapotoxin, which affects the digestive tract, causing headache, nausea, and diarrhea. Clean cultivation and crop rotation will eradicate the weed. The seeds of cow cockle (Saponeria *Vaccaria*, Linn.) are also a frequent impurity in commercial wheat. They are small, however, and readily separated from seed grain.

482. Wild mustard or charlock (*Brassica arvensis*, Kuntze) is one of the best known annual weeds to grain-growers generally.

It produces erect, branching stems, roughened by short stiff hairs. The flowers are bright yellow. The pods are about $1\frac{1}{2}$ inches long, and contain reddish brown or black seeds, the size of clover seeds, with which they are consequently commonly found. The seeds are also common in the grain of cereals from which they are readily separated. They will lie in the ground dormant a long time, and then germinate, a fact which makes this weed as bad as some perennials. Bolley (1908, p. 532) found that the seeds will come up well after being buried $4\frac{1}{2}$ years (Fig. 141 *f*).

Wild mustard is found in grain fields usually where there is continuous cropping. With clean seed and crop rotation, it can be eradicated from cereals. It is quickly killed by spraying with iron sulfate.

483. Tumbling mustard (*Sisymbrium altissimum*, Linn.) is a bad weed in grain fields, and called the worst weed in Canada. The young plants form a rosette of soft, pale downy leaves, deeply incised. On older plants the lower leaves are runcinate-pinnatifid, irregularly toothed, or wavy-margined. Upper leaves smaller, thread-like. Flowers in racemes, cream-colored, pods long, slender. The seeds are $\frac{1}{25}$ inch long and half as thick, reddish yellow in color, oblong, with 1 or 2 delicate grooves or scars usually present (Fig. 142 *k*).

This is one of the tumble weeds, and in the fall, after the seeds have matured, it breaks from the ground and is carried long distances by the wind. It is said that a single plant may produce 1,500,000 seeds.

Tumbling mustard is rather persistent, but can be controlled by thorough cultivation. Fall disking immediately after harvest is a good practice where this weed is bad.

484. Chess or cheat (*Bromus secalinus*, Linn.) is a well-known winter annual, common everywhere, frequent in wheat fields, but occurring in fields of other winter cereals, particularly winter barley. The seeds are a common impurity in winter wheat, and to a less extent in winter rye. Chess is not a specially strong weed and is easily controlled, as indicated by the usual manner of its appearance. It usually occurs in spots in the place of winter grain that has been killed from some other cause, such as the winter or Hessian fly. The chess, after passing the winter, following its winter annual habit grows up quickly in the bare spots in the spring, but is unable to compete with the crop, where the latter is not injured in other ways. An instance is known to the author in which winter barley was almost all winter killed, and was replaced the following summer with a good and fairly uniform stand of chess. Because of this quick replacement of the crop by chess, often observed by farmers, they naturally conceive the idea that wheat changes into chess. Chess is rare in spring grain, unless the latter is grown on fall plowing.

The panicles of chess are loose with drooping branches, and have many-flowered hairless spikelets.

The florets of chess are swollen a little above the middle, the lemma rounded on the back, obscurely 7-nerved and awned. The palea bears a single row of stiff hairs (Fig. 142 *a*). Chess is one of the brome-grasses, of which several are common weeds in different parts of the country. The seeds are objectionable in wheat for milling, as they give the flour a dark color and a disagreeable flavor. Two other brome-grasses (*B. steriles* and *B. tectorum*) are sometimes equally as bad weeds as chess.

Seeds of chess separate from wheat with some difficulty. The seeds should never be allowed to mature. A rotation including an intertilled crop, with thorough cultivation and use of clean seed, will keep out the weed. Chess makes fair hay, and therefore should by all means be cut green for hay, rather than be allowed to ripen seed.

485. Common ragweed (*Ambrosia artemisiæfolia,* Linn.) is a bad weed in grain fields nearly everywhere, but only because of the green plant in the sheaves. The seeds do not often go into the grain, and even then are readily separated. The species here mentioned is frequent in the eastern states and southwest Ontario. In the Great Plains another species prevails (507).

Common ragweed is a coarse branching plant, with heavy stems, 2 to 4 feet high, leaves thin, twice pinnatifid, glabrous above, downy hairy beneath; flowers like those of kinghead but smaller; seeds $\frac{1}{12}$ to $\frac{1}{6}$ of an inch long, light-straw color to dark brown, pear-shaped (Fig. 142 *h*). The pollen from the upper flowers fertilizes the lower flowers. At flowering time, in late July and August, the plants become quite yellow with pollen, which is supposed to induce hay fever. The seeds in wheat injure its flour-making quality.

As ragweed matures its seeds usually after harvest, plowing or disking immediately after cutting the crop, or an intertilled crop following the grain, will eradicate the weed.

Kinghead or great ragweed (*Ambrosia trifida*, Linn.) occurs commonly along roadsides and edges of fields, but is also reported to be frequent in grain fields in the northern states. The leaves and stem are very rough, lower leaves deeply trifid, upper leaves entire. The upper flowers pollinate the lower flowers as in common ragweed. The seeds are usually inclosed in a hull $\frac{1}{4}$ inch long, having a crown and tip of short pointed teeth. They are more difficult to separate from cereal kernels than those of common ragweed.

486. Penny cress or French weed (*Thlaspi arvense*, Linn.). — This winter annual is considered one of the worst weeds in some districts in the East. Because of its disagreeable odor, it is often called "stink weed." It grows from the seed in the spring, from 6 inches to 2 feet high, produces white flowers, $\frac{1}{6}$ inch across, and then seeds before the end of the season. The pods are flattened, $\frac{3}{4}$ inch wide, and light yellow in color when mature. The leaves at the base are petioled, but on the branches they clasp the stem. Seeds reddish-brown, oval, with concentric rings on the surface (Fig. 141 *g*).

Seeds of penny cress occur in millet, clover, cereals, and flaxseed. They are readily separated from cereal kernels with ordinary cleaning machines. The plants should be prevented from maturing their seeds, which is difficult, as they mature at different times. When many of the plants are found in the growing grain, harrowing with the toothed harrow, when the crop is 3 to 4 inches high, will do good. Disking at once after harvest and plowing later will kill most of the weeds. Seeding down to grasses and clovers will effect complete eradication.

487. Wild oats (*Avena fatua*, Linn.). — Several species of oats are wild in this country, of which this one is a pernicious weed, particularly in the northwestern and Pacific Coast states and western Canada. Unlike chess, wild oats occurs more commonly in spring grain than in winter grain.

Wild oats grows from 2 to 4 feet high, in tufts. The plant closely resembles some cultivated oat varieties. The panicle, at first compact, soon spreads out 6 to 12 inches in all directions. The kernels vary greatly in size, but are brown or gray or nearly black, sometimes yellowish white. They are similar to those of many cultivated varieties, but differ in being slimmer and harder, in having a horny appearance, and besides exhibit the following differentiating characters: — The strongly bent and twisted awn, often broken off in thrashing; the slanting, horseshoe-shaped scar at the base of the lemma, sometimes broken off in handling; the stiff bristles surrounding the basal scar, which are not, however, always present in thrashed grain; the rachilla bearing the second kernel, but which remains attached to the lower kernel after thrashing, is larger, and the free end is slanting, roughly triangular, and shows a marked depression; the abundance and roughness of the hairs covering the kernel (Fig. 142 *b*).

Three fixed forms of wild oats appear to have been identified as follows: (1) Wild oats proper, taller than cultivated oats, having dark brown or almost black kernels, resembling those of common black oats, but not so plump and having a more pronounced horseshoe-shaped scar and a long stiff awn and densely hairy base; (2) a white form, the kernel of which resembles that of the form just described except that it is creamy white, like ordinary white oats; (3) a hairy form which differs from the others in having a kernel densely hairy almost to the tip. There are other hybrid forms, having kernels of varying shades of color, but usually gray.

The first step in eradication is to sow clean seed. If the field is already infested, the grain crop should be followed with one or more cultivated crops. Growing winter cereals in place of spring cereals will permit harvesting to be done before the wild oats mature. Disking at once after harvest will induce germination of many of the mature seeds remaining, and later plowing will kill the plants. Some seeds, however, may lie in the ground 20 months or longer before germinating. A rotation including at least 1 or better 2 intertilled crops should be practiced.

488. **False wild oats** are occasionally found in cultivated varieties, which usually possess the horseshoe-shaped scar, or "sucker mouth," at the base of the lemma, and sometimes have the twisted awn. They may usually be distinguished from the true wild oats by their greater plumpness and close general resemblance to the kernels of the variety in which they appear. They are also usually less hairy than the wild oat.

In Canada, Criddle (1912, pp. 8–11) has identified five distinct types of false wild oats, similar to the varieties in which they are found, as follows: (1) the Banner type; (2) the Newmarket or Abundance type; (3) the Old Island Black type; (4) a black oat type; and (5) the

Storm King type, the last having the side panicle. Hillman has found what are apparently similar false wild oats in the cultivated varieties of Colorado.

489. Pigeon weed or wheat-thief (*Lithospermum arvense,* Linn.) is a winter annual common in the eastern states and western Ontario, and troublesome in fields of winter wheat. It is wide branching, white flowered, and produces many early-ripening seeds. The seeds are $\frac{1}{8}$ inch long, and deeply and irregularly grooved, with prominent ridges between the grooves. They are recognized by the oval or obtusely 3- to 5-angled basal scar (Fig. 141 *g*).

The seeds are common in poorly cleaned winter wheat and rye, and are occasionally found in clover seed. The weed may be eradicated by a rotation including an intertilled crop and spring sown grain. Late fall or spring plowing will kill plants that start in the autumn.

490. Sunflower (*Helianthus annuus,* Linn.). — Several species of sunflower are found in grain fields, but this one is most general in its distribution. In large parts of the Great Plains it is the worst cereal weed pest. Its worst effect is in usurping space belonging to the growing crop and filling the sheaves at harvest time, wasting labor and time and obstructing the curing of the grain. Some seeds get into thrashed grain but usually the weed does not mature as soon as the crop.

The stems of the sunflower are stout, sparingly branched, rough or hairy, leaves thick, ridged, and rough; heads very large, nearly solitary, with bright yellow ray flowers, and black disks; seeds $\frac{1}{3}$ inch long, narrowly oblong, egg-shaped in outline, flattened and angular or grooved lengthwise. The seeds are sometimes abundant in the screenings of western grain (Fig. 141 *i*).

Fall plowing at once after harvest will kill many of the plants before they mature seed, but further cultivation, afterward, before winter, may be necessary. The grain crop should be followed by corn or some other intertilled crop.

In the western Great Plains this sunflower is replaced by another (*H. petiolarus*); while in Manitoba the perennial species (*H. scaberrimus*, Ell., *H. Nuttallii*, Torr. and Gray, and *H. Maximilianus*, Schroed.) are common in grain fields, though said to be not very serious weeds, in the Prairie Provinces.

491. Common vetch (*Vicia sativa*, Linn.) occurs frequently in grain fields of the Northwest, and the seeds are often found in wheat screenings. It is glabrous or slightly pubescent, 1 to $2\frac{1}{2}$ feet high, with a simple stem; leaflets 5–7 pairs, obovate-oblong to linear, notched or mucronate at the tip; the 1 or 2 nearly sessile flowers borne in the axils of the leaves, corolla violet purple; pod linear, several seeded, seeds black (Fig. 142 *l*).

Clean seed sown in clean soil is the means of extermination. Crop rotation, as always, should be practiced.

Clark (1911, p. 52) mentions another species (*V. angustifolia*, Reichardt), the seeds of which "are a common impurity in grain grown in the Maritime Provinces, Quebec, and parts of Ontario," and that the seeds "are especially objectionable in oats required for milling."

492. The Russian thistle (*Salsola pestifer*, A. Nelson). — The bulk of the wheat crop of this country and Canada, and much of the production of other small cereals, are derived from seed originating in the plains of Russia. It is natural, therefore, that one of our worst weeds in grain fields, the Russian thistle, should also have come, as it did, from the same plains, and should have first spread rapidly in our northern plains. It is now distributed in all the most important grain-growing districts, and is a common, troublesome weed on the drier lands, and especially on alkaline soils.

This plant grows from 1 to 3 feet high, but covers an area of several inches to 6 feet in diameter. It is herbaceous when young, glabrous or slightly pubescent, much branched from the base, but at maturity forms a sphere which is readily loosened from the soil and carried long distances by the wind, scattering seed as it goes. The stems become streaked with red as the plant grows older. The leaves are fleshy, linear, alternate, 1 to 2 inches long. The lower leaves soon fall, but the upper leaves persist, each subtending 2 leaf-like bracts and a flower; flowers conspicuous, solitary, sessile, without petals; blooms from July to September, and matures seed in August; seeds conical, spirally coiled, base of the cone concave, $\frac{1}{10}$ inch in diameter, and often covered with a thin gray hull. It is estimated that a large plant will produce from 100,000 to 200,000 seeds (Fig. 141 *b*).

The plants are easily destroyed while small, and can therefore readily be prevented from maturing seed by cultivation. It is recommended to harrow the growing grain in which this thistle occurs. Plants that mature should be gathered and burned before they break loose and scatter seeds. Cultivation to induce late summer or fall germination is effective, as the plants thus resulting will not mature seed before frost. Sheep will eat the young plants.

493. Other tumble weeds. — In addition to the Russian thistle and tumbling mustard, there are other weeds found in grain fields that break from the soil and tumble about and pile along fences, such as the amaranths (Amaranthus sp.) and the buffalo bur. Others belong in the genera Chenopodium, Atriplex, Cycloloma, and Corispermum.

494. Wild buckwheat (*Polygonum convolvulus*, Linn.). — This weed is found frequently in grain fields, and the seeds often occur in commercial grain. It is a climbing or twining vine, much branched, rather rough, with naked joints, and 1 to 4 feet in length; leaves thin, glabrous, arrow-shaped, and situated on long petioles; flowers, which arise in small clusters in the axils of the leaves, small, greenish, and produced on short, slender stalks; flowers also occurring on loose terminal racemes. Flowering goes on from June throughout the summer. Seeds are matured in July, and are dull jet black, 3-sided, and elliptical to obovoid in shape. The angles of the seeds are rounded and the faces concave (Fig. 141 *c*).

The seeds can be removed from seed grain by screening. Rotations, including intertilled crops and a grass crop, will control the weed. Disking immediately after harvest, to induce germination, and plowing under the resulting plants later, are recommended.

495. Buffalo bur or bull nettle (*Solanum rostratum*, Dunal). — This is one of the worst weeds of the middle and southern Great Plains. The plant is herbaceous, but woody when old, hoary or yellowish, 8 inches to 2 feet high, and covered with stellate pubescence. The branches and main stems are covered with yellow sharp prickles; leaves melon like, 1 to 3 times pinnatifid, lobes roundish or obtuse and repand, covered with short pubescence, hairs stellate; flowers yellow, an inch in diameter, nearly regular; fruit a berry, but inclosed by a close-fitting prickly calyx; seeds thick, irregular, rounded, wrinkled, with numerous small pits, surrounded by a gelatinous substance (Fig. 141 *f*). Late in the fall the plant loosens from the soil, and is blown about as a tumble weed (492).

In general, clean cultivation, which will prevent seeding of the plants, is the preventive. Plants already mature should be gathered and burned.

496. Other annual weeds that occur frequently in grain fields, and the seeds of which are found as impurities in grain, are lamb's quarters, false flax, spurrey, stickseed or bluebur, Pennsylvania smartweed, peppergrass, darnel, wild radish, hare's ear mustard, barnyard grass, ball mustard, black mustard, alligator's head or button weed, dragon head, fleabane or horse weed, marsh elder, yellow foxtail or pigeon grass, green foxtail, pigweed, prickly lettuce, shepherd's purse, morning glory, Indian pink, and tansy mustard. Some of these are of considerable importance locally and some are bad in certain seasons, but apparently no one of them causes great damage to grain the country over. No doubt there are still other annuals that are of purely local interest in grain fields.

497. Biennial weeds. — The seeds of biennial weeds germinate in the spring, and produce a tap root below the ground and only a rosette of leaves above ground the first year. The second year these plants start growth early from the stored food in the tap root, and send up stems that produce flowers and seeds, and then die. Examples are the bull thistle and common evening primrose. Biennials are rare in intertilled crops, as the young plants are destroyed in cultivation.

498. Bull thistle (*Cirsium lanceolatum*, Hill.). — The common thistle, because of its habits of growth, is not usually a serious crop weed, but it is often sufficiently abundant in winter grain to be very annoying in harvesting, and wasteful of time and labor. It is troublesome in the winter wheat of the middle Great Plains, and likely to be abundant on summer fallow not well cultivated.

The bull thistle grows 3 to 4 feet high, is branching, tomentose, becoming dark green and villous or hirsute with age, branchlets bearing large heads; leaves lanceolate, decurrent on the stems with prickly wings, deeply pinnatifid, the lobes having rigid prickly points, upper surface roughened with short hairs, lower surface with a cottony tomentum; heads $1\frac{3}{4}$ to 2 inches high, involucre bracts lanceolate, rigid when young, flexible with age, with long alternate prickly pointed spreading tips; flowers hermaphrodite; achenes bare, $1\frac{1}{2}$ inches long, pappus of numerous plumose bristles (Fig. 141 *j*).

In eradication, the important thing is to prevent seed from forming. Only a flattened mass of leaves is produced the first year. All plants that have escaped destruction that year should be cut off early the following spring. The flowers begin to appear early in August. In a good rotation the thistle cannot survive. Summer fallow should be cultivated until late in the fall.

A more common species in parts of the Great Plains and in Montana than the one here described is the field thistle (*Cirsium undulatum*, Spreng). In the western Great Plains still a third species (*Cirsium ochrocentrum*, Gray) is the most frequent.

499. Green tansy mustard (*Sisymbrium incisum* var. *filipes*, Gray). — This mustard is native, and occurs commonly in grain crops in the Prairie Provinces of Canada and in British Columbia.

The first season this weed appears as a flat rosette of finely divided leaves. The second year it produces stems 3 to 4 feet high, erect, widely branching at the top, and bearing an enormous number of narrow, bare, slightly curved pods from $\frac{1}{2}$ to $\frac{3}{4}$ inch long, on slender spreading pedicles; whole plant bright green and somewhat glandular; leaves twice pinnatifid; flowers yellow, $\frac{1}{8}$ inch across in an elongated raceme; seeds $\frac{1}{25}$ inch long, oblong, sometimes compressed at the scar end, reddish brown, minutely roughened with mucilaginous hairs (Fig. 142 *j*).

The seeds occur in poorly cleaned western grain. It is stated that the prevalence of the biennial mustard in grain fields of the Prairie Provinces of Canada "is largely due to the practice of raising cereal grains on stubble lands, with only surface cultivation in the fall or spring sufficient to produce a suitable tilth for a seed-bed, without first destroying the weed growth by plowing, thorough disking, or the use of the broad-sheared cultivator" (Clark, 1911, p. 48). Summer fallow should be clean cultivated all summer.

500. Evening primrose (*Œnothera biennis*, Linn.). — This biennial weed is native in this country, and found both in waste places and cultivated fields. It is occasionally abundant in winter grain. The flowers appear in June of the second year, and seeds mature near the end of September. The flowers are yellow and very attractive, opening in the evening and closing the next morning, but some of them remain open during the day. The fruit is a long, tapering, 4-celled capsule. On ripening, it breaks open and the small, dark, reddish brown, 4-angled seeds are shaken out by the wind (Fig. 141 *e*). The seeds are found usually in various clover and grass seeds.

The evening primrose in grain stubble may be destroyed by fall or spring cultivation. Only clean seed grain should be sown.

501. Other biennial weeds in grain that are of local interest are willow herb, golden fumitory, tower mustard, hairy tower mustard, cone flower, western wall flower, small wall flower, and biennial wormwood. Some or all of these would probably be of little or no importance except for the practice of growing grain on poorly cultivated summer fallow or on stubble ground not plowed.

502. Perennial weeds. — Weeds that are able to live from one year to another without reseeding are perennials. They are the worst kind of weeds to eradicate. In addition to seed propagation, perennial weeds are reproduced from underground parts. These are of two kinds, — running or horizontal roots and underground stems. The Canada thistle, milkweed, and horse nettle have the horizontal roots. Perennial sow thistle, quack grass, and Johnson grass produce underground stems.

503. Wild garlic (*Allium vineale*, Linn.) has been called the most injurious weed in the Middle Atlantic states. Garlic bulblets ground with wheat give the flour a very strong, disagreeable flavor, and cause the bread, cake, pastry, and all other products made from it to be unpalatable. There is the same effect on rye flour. In milling, the garlic bulblets also injure the rolls by forming a varnish-like coating on them. This may so interfere with the grinding as to make it necessary to shut down the mill until the rolls can be cleaned. Stone burs are also seriously affected, and require dressing afterward. On boards of trade, wheat containing much garlic is graded as "rejected," and sells at 20 per cent to 40 per cent lower than No. 2 Red. Garlic in wheat is worst in Maryland, Virginia, and Tennessee. The annual loss to wheat alone due to garlic is estimated to be $1\frac{1}{2}$ million dollars.

Wild garlic propagates almost exclusively by a form of underground stem, called a bulb, and by the aërial bulblets above mentioned. The form most abundant in this country rarely produces seeds. Where the tops of the plants are kept down, wild garlic reproduces by small secondary bulbs or "cloves" formed at the base of the old bulb. These are found in clusters at a depth of 3 to 10 inches below the surface of the ground (Fig. 143). After fall rains, they send up tufts of blue-green shoots which become more prominent later. These shoots remain green during the winter. In spring new bulbs are formed at the bases of the old ones. In grain fields where the tops are undisturbed, wild garlic propagates by aërial bulblets, like the "sets" of cultivated onions, as well as by the underground secondary bulbs (Fig. 142 *c*). Flower bearing stems 10 to 30 inches high are put forth in May or early June. Flowers greenish white to reddish purple, $\frac{1}{16}$ inch long, in simple umbels;

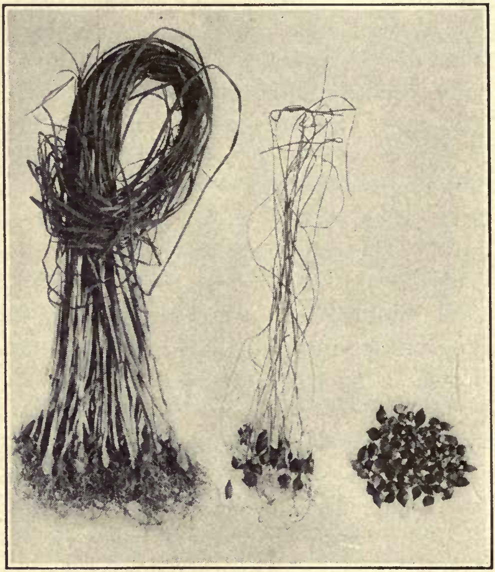


Fig. 143. — Wild garlic.

seeds when present black, flat, triangular, shriveled, $\frac{1}{16}$ inch long. Usually following the flowers, 40 to 120 aërial bulblets are produced on each plant.

Wild garlic is very difficult to eradicate. If infested land is plowed late in the fall, just deep enough to leave the most bulbs possible near the surface, many will die from exposure to alternate freezing and thawing. Any surviving shoots should be destroyed by early spring cultivation, and the land sown with oats or barley. This process, repeated, will be so effective that any remaining plants can be given special attention.

Shaving the soil near the surface as often as the green shoots appear is recommended, which method is expensive, but if persistently followed is likely to be effective. A tool similar to a broad scraper without a back may be used. Hogs confined on garlic patches will root out and destroy many bulbs. Crop rotations may be so arranged as to have good effect (Dewey, 1897).

Wild garlic bulblets mature just about when winter wheat and rye are harvested, and are gathered with the grain. They are so nearly the same size as wheat kernels that it is impossible to separate them by screening. However, Duvel (1906) has described a method of drying and then cleaning whereby the percentage of garlic in wheat may be reduced from over 2 per cent to $\frac{1}{20}$ per cent.

504. Canada thistle (*Cirsium arvense,* Scop.) occurs almost throughout the United States, but is common in the area from the Atlantic Coast to the meridian of 98° and south to the Ohio River, and also in the northwestern coast district. It is abundant in eastern Canada, Manitoba, and British Columbia, and spreading rapidly in Saskatchewan and Alberta. It is found frequently in grain fields, where it crowds out the cereal plants, and the seeds occur sometimes in the grain.

The Canada thistle grows from 1 to 3 feet high, and possesses deep running horizontal roots (Fig. 144). Leaves variable in shape, deeply pinnatifid, waved and crested, very prickly in some plants and less so in others, somewhat downy underneath; flower heads numerous, in a large loose corymb at the top of the stem; flowers varying in color from pale purple to pink and white; plants diœcious, the male flower heads globe-shaped, 1 inch across, female heads oblong and half as large. In large patches there may be found only male flowers, showing that all came from a single seed. Seeds $\frac{1}{8}$ inch long, light brown, elongated-oblong, glabrous, somewhat flat-

Fig. 144. — Canada thistle.

tened and curved, more or less bluntly angled, marked with faint longitudinal lines; the top nearly round, flat, having a narrow rim with a small cone-shaped point in the center; pappus copious, white. The pappus breaks off easily and is absent when the seeds are found in commercial grain (Fig. 141 *k*).

This thistle is very difficult to eradicate. First, no plants should be allowed to mature seeds. The scythe or mower may have to be used to cut out large patches in the grain field. Afterward, deep plowing, bringing roots to the surface to be exposed to winter freezing, and constant cutting back of the tops will greatly weaken the growth. A 3-years rotation of barley — clover — corn, following this preparatory treatment, will so nearly complete the eradication that a renewal of the growth can be prevented by careful watching. The thistle rust (*Puccinia suaveolens*) sometimes kills the plants to the ground, but rarely or never kills all the plants in a patch.

505. Bindweed or perennial morning glory (*Convolvulus spp.*). — This weed, including three species and one variety, occurs almost throughout the United States. Although widespread in Canada, and troublesome in restricted localities, it is said to be not yet a very common weed in that country. It is found most often on deep bottom lands and on rich prairie soils. It is therefore worst on the most valuable land.

East of the meridian of 100° the native hedge bindweed (*Convolvulus sepium*, Linn.) is the most common species (Fig. 145). West of that line the field bindweed (*C. arvensis*, Linn.) is probably the most common. A trailing form (*C. repens*, Linn.) with downy leaves has become a serious weed in wheat in central western Kansas. The fourth species of importance as a weed (*C. californicus*) is found in California.

The hedge bindweed has a long twining stem; leaves triangular, arrow-shaped, with basal lobes pointing outward; flowers funnelform, resembling those of the cultivated morning glory, but always white or rose colored; base of the flower inclosed in bracts $\frac{3}{4}$ inch long. The field bindweed is either trailing or twining; leaves ovate, with basal lobes pointed and projecting, smaller than those of hedge bindweed; flowers funnelform, white, or tinged with red, not nearly so large as those of hedge bindweed; bracts surrounding base of the flower small. The trailing bindweed is much like the hedge bindweed, but the stems are trailing and the stems and leaves more or less downy. The California bindweed has stems 1 to 15 inches long,

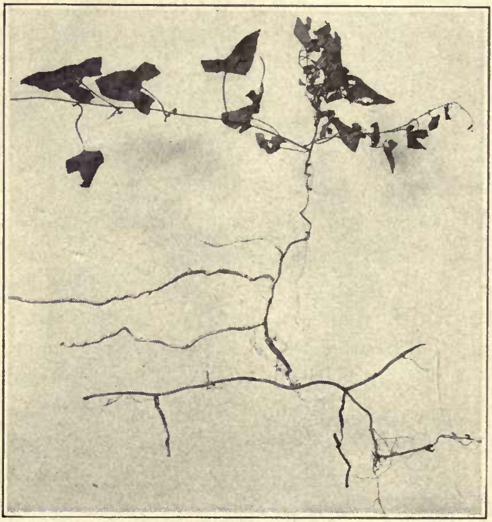


FIG. 145. — The hedge bindweed, showing its extensive formation of underground stems.

either short and erect or long and trailing; leaves oval to triangular, 1 inch long; flowers about the same size and shape as those of hedge bindweed, white or creamy, purplish outside; bracts of medium size; seeds $\frac{1}{6}$ inch long, dark brown, pear-shaped, one face convex, the other bluntly angled with flat sides; surface roughened with small tubercles, basal scar a roughly lined reddish depression at the lower point end. Seeds of field bindweed are shown in Fig. 142 *d*.

There are two different methods of underground propagation of the bindweed. In one method, represented by the hedge bindweed, the reproduction is from underground stems. The new shoots may start from new stems developed the preceding year, or from portions of old stems which retain their vitality 2 or more years. By the second method exhibited in the field bindweed new shoots arise from horizontal roots, lying from several inches to several feet below the surface.

506. Eradication of bindweed. — A number of methods of eradicating bindweed have been proposed, of which three appear to be the most practicable.

Clean cultivation, if thoroughly done, will destroy the weed usually in two years and occasionally in one year, if the underground parts do not lie too deep. The land must be cultivated every week or ten days throughout the growing season of the weed, or from spring frost to fall frost. The eradication may be effected in a bare fallow or in connection with an intertilled crop, the latter of course being the more profitable. After the crop is "laid by," the hoe must be used still, until every individual plant is cut off. On fallow land a large V-shaped knife is sometimes used. It runs 3 to 6 inches under the surface, and is attached to a frame like that of a 2-horse cultivator.

A second method is to seed the infested field with alfalfa. The frequent cutting, followed later by the smothering effect of the crop, will greatly lessen or entirely eliminate the bindweed. The cutting keeps down the tops about as effectively as clean cultivation. The alfalfa grows more rapidly after each cutting than the weed, which is shaded by the former.

Pasturing infested land with sheep or hogs has proven to be a good method of eradication. Three years of pasturing with sheep will nearly or entirely destroy the pest.

Hogs will root an infested field quickly, to get the roots and underground stems, of which they are very fond. For hog pasturing, the field should be plowed in late summer after removal of the crop, and hogs not ringed turned on until cold weather. They are again turned on in the spring until planting time, when an intertilled crop is planted, and its cultivation completes the eradication of the weed. The seeds of bindweed are not often found in grain.

507. Horse nettle (*Solanum carolinense,* Linn.). — This weed is common and troublesome from the Middle Atlantic states westward to the Great Plains, and is one of the bad weeds of Oklahoma. It propagates freely by slender roots which are often 3 feet long.

Stem 1 to 2 feet high, somewhat straggling, half shrubby at the base, hairy or merely roughish, with minute hairs which are star-shaped, also armed with stout subulate yellowish prickles which are usually numerous; leaves oblong or sometimes ovate, obtusely sinuate, toothed or lobed or deeply cut, 2 or 4 inches long; flowers in racemes, later becoming 1-sided, calyx consisting of slender lobes, corolla light blue or white, an inch or less in diameter; flowers followed by the yellow globose berries, $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter; seeds small, less than $\frac{1}{2}$ inch long, yellowish, minutely roughened. The flowers and berries resemble those of the potato, to which family of plants this weed belongs.

It is claimed by some that this weed is as difficult to eradicate as Canada thistle or the bindweed. Though troublesome in all crops and in all soils, it is worse in sandy or loose soils. There are two fairly effective methods of exterminating horse nettle. One is the use of an intertilled or hoed crop such as corn, a method almost always good. Before seeding, the ground should be kept well cultivated. After the crop appears above ground, both the cultivator and hand hoe must be used often. After it is impossible to longer use the cultivator, the use of the hand hoe should continue until the crop is removed and even afterward. It is of course understood that care has been taken previously to prevent the production of seed.

Another method of combating the weed is by smothering it with a vigorous thick standing crop such as rape. As in the other method, the ground should be cultivated until time for seeding, which for rape is in May or June. Seeding of rape at 2 pounds an acre in drills, or 3 pounds broadcast, is about right. When the crop attains rank growth, it may be pastured or removed and fed to stock. If the land is lacking in organic matter, the crop may be plowed under.

In the southwestern plains another species, blue top or blue nettle (*S. elæagnifolium*, Cav.), also perennial, becomes more common than the horse nettle. It is 15 inches high; stems and leaves ashy with scattered prickles; stems little branched; leaves wavy-margined; flowers usually purple; fruit the size of cherries, often turning dark colored late in the season; occurs in sandy loams. Still a third perennial species, bad in the Southwest, is Torrey's night-shade (*S. Torreyi*, Gray). This species has much larger fruit than the others, often reaching 1 inch in diameter, and remains yellow.

508. Perennial ragweed (*Ambrosia psilostachya*, DC.) was reported by many farmers some years ago to be the worst weed in Oklahoma. It is the most common ragweed in the western parts of other states of the Plains. It differs from the ordinary ragweed of the North and East (485) in having a perennial habit, thicker leaves, and a nearly smooth fruit.

The underground stems send up new shoots each spring, which are avoided by all stock, if possible. The weed is more common on upland soil. The stems are yielding to implements, and therefore often escape being cut. Implements having V-shaped knives or broad-edged cutting tools, around which the stems cannot glance, should be employed in eradication. Growing an intertilled crop will be of great advantage.

509. Perennial sow thistle (*Sonchus arvensis*, Linn.) is called one of the worst weeds in Minnesota. It is common in waste places, along roadsides, and in cultivated fields, from the Atlantic Coast to the Great Plains, both in this country and Canada. The seeds seldom occur in commercial grain.

The bright yellow flowers of perennial sow thistle are clustered in heads, from 1 to 2 inches across. The oblong dark brown seeds are longitudinally ribbed on the surface, and when mature, they have a dense tuft of hairs attached, which aids in their distribution by the wind (Fig. 142 *l*).

The first stray plants should be cut out individually. Badly infested fields may have to be fallowed, or be planted with an intertilled crop. A short rotation may well be practiced, such as (1) grain, (2) clover, and (3) a cultivated crop.

The common and prickly sow thistles (*S. oleraceus*, Linn., and *S. asper*, Hill), both annuals, are often bad weeds.

510. Wild rose (*Rosa spp.*). — There are several species of wild or prairie rose that are troublesome in grain fields, particularly in the Prairie states and the Prairie provinces of Canada. The seeds are often found in the thrashed grain of wheat and oats.

The wild rose flowers during nearly the entire summer, and matures seed early in the fall. The fruit is berry-like in appearance, and from orange to bright red in color; seeds hard and nut-like, varying in shape and color, but usually dark brown, about the same size as wheat kernels, from which they separate with some difficulty (Fig. 142 *a*).

As the wild rose propagates from deep underground stems as well as from seed, it is a very persistent weed.

FIG. 146. — Cutting milkweed from an oat field. A bad infestation.

It is particularly bad where grain is "stubbled in" without plowing. Deep plowing with a sharp plow, in hot weather, followed by double disking at frequent intervals, will be effective in eradication. Stubble cropping should be abandoned.

511. Other perennial weeds. — Two of the milk weeds (*Asclepias syriaca*, Linn., and *A. speciosa*, Torr.) are sometimes bad in grain fields (Fig. 146). Still other perennials that are troublesome in places are poverty weed, blue lettuce, skeleton weed, dwarf lupine, hedge nettle, quack-grass, and Johnson-grass.

512. Hand eradication. — In the preceding discussion practically every effective method of weed eradication is mentioned in some detail except two, eradication by hand and spraying. Hand work is practicable where a weed is just starting, or where eradication by other methods is nearly completed but a few scattering plants remain, or where the weed is in isolated patches, difficult to reach with a horse implement without destroying the crop badly. Prevention is better than eradication, and often a bad weed may be entirely prevented by constant watching and hand work. Annuals are hoed off or simply pulled. Biennials and perennials must be cut off rather deeply, for which purpose some form of hoe is usually employed. For certain weeds with single long roots, a hand implement called the spud is very effective. It is a chisel-like tool fastened to the end of a long handle. Dropping a little dry salt on the cut root will aid in the eradication.

513. Spraying to kill weeds. — When weeds are extremely bad, or when grain-growing is still done on so large a scale that the usual cultivation methods of eradication entail an enormous amount of work and consume much time, it has been found practicable to kill weeds by spraying them with solutions of chemicals. The basic principle is that such solutions may be made of sufficient strength to kill the weeds without killing the crop, the same principle that holds good in the treatment of grain for smut. Where the area to be covered is large, the solution is applied by large traction sprayers. Various chemicals have been used with success, such as common salt, iron sulfate, copper sulfate, and sodium arsenite, but iron sulfate is most commonly employed. A spraying machine is shown in Fig. 147.

The best time to spray is while the weeds and crop are still seedlings, and only 2 or 3 inches high, before the weeds even form flower buds. At that stage the weeds will be killed outright. If sprayed later, they are likely to produce more or less seed. Spraying should be done on a cloudy or "muggy" day, when rain is not expected for eighteen hours. If spraying is done on a hot, dry day, the spray will dry off too quickly. The wheat crop

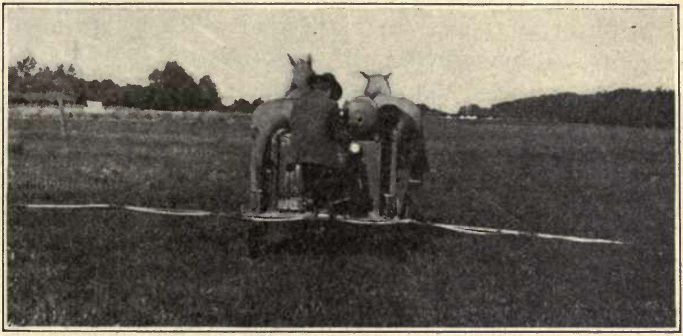


Fig. 147. — A weed-spraying outfit in North Dakota.

may be sprayed at any time before heading, but the younger it is the less harm is done. Barley will not stand as severe treatment as wheat.

514. Spraying in North Dakota. — Bolley (1908) reports considerable work in spraying to kill weeds at the North Dakota Experiment Station, and states that the following weeds may be eradicated or largely subdued thereby: false flax, wormseed mustard, tumbling mustard, wild mustard, shepherd's purse, pepper-grass, ball mustard, cockle, chickweed, dandelion, Canada thistle, bindweed, plantain, rough pigweed, kinghead, red river weed, ragweed, and cockle bur. The following other weeds are not effectively controlled by chemical sprays as now used: hare's ear mustard, French weed, pink cockle, perennial sow thistle, lamb's quarters, pigeon grass, wild oats, chess, quack-grass, sweet-grass, and wild barley.

Fifty-two gallons of solution to an acre were employed. In the 52-gallon solution, 75 to 100 pounds of iron sulfate were used, or 12 to 15 pounds of copper sulfate, or $\frac{1}{3}$ of a barrel of salt, or $1\frac{1}{2}$ pounds of sodium arsenite.

515. Results of other trials. — At the Rhode Island Experiment Station it was found that wild mustard may be controlled by spraying with iron sulfate, but wild radish could not be so controlled, as the method is practiced at present. The most satisfactory results were secured with a 20 per cent solution, applying the iron sulfate at the rate of 100 to 150 pounds an acre.

It is concluded from results at the Wisconsin Experiment Station that the eradication of Canada thistle and sow thistle by spraying is not practicable for the average farmer. A 20 per cent solution of iron sulfate was very effective, however, on wild mustard. Cockle bur, ragweed, dandelions, daisies, and wild lettuce were also partially eradicated at the same time that tests were made upon wild mustard.

Buckwheat is usually very free of weeds, and is one of the very best crops for cleaning the land of seedy annuals. It is planted late, allowing much early cultivation for germinating and then destroying weed seedlings. It grows rapidly, and soon forms a dense shade; the weeds, therefore, though having a good chance to start, are prevented growing later.

CHAPTER XVIII

CEREAL PESTS — INSECTS

THERE are two classes of insect pests of cereals, (1) those that are enemies of the growing crop, and (2) those which attack stored grain. In each class many insects can be enumerated, but the greater part of the damage is done by a few species.

INSECT ENEMIES OF THE GROWING CROP

Because of changing climatic conditions, and the greater abundance at certain times of their parasites, the principal insects of growing cereals, such as the chinch bug, Hessian fly, plant louse, and wheat midge, appear to recur periodically. Fortunately, it is rare that more than one of the very destructive insects occurs at one time.

516. The Hessian fly (*Mayetiola destructor*, Say). — This is one of the most destructive cereal pests. In 1908 the wheat loss in Kansas alone due to this pest was estimated to be nearly ten million bushels; while in Missouri it is reported that in 1914 there was a loss from the same cause of about six million bushels.

The Hessian fly has been known in this country since 1779, and was so named because of the fact that it did some damage that year on Long Island, New York, in the vicinity of a previous encampment of the army of Lord Howe, which included many Hessian soldiers.

The distribution of the Hessian fly in this country is from the Atlantic Ocean westward to about 100° longitude and southward to approximately 35° latitude, and in a narrow strip along the Pacific Coast from the same latitude 35° to Puget Sound. In Canada it is found from Prince Edward Island to some distance in Saskatchewan.

517. Description and food plants. — The Hessian fly is very small, about $\frac{1}{10}$ inch long, the body obscurely dark in color, and the form much like that of a very small mosquito.

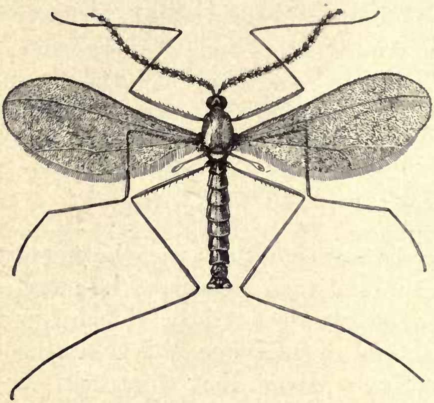


FIG. 148. — Adult male of the Hessian fly. Enlarged.

The abdomen of the female is red or yellowish when first hatched from the "flaxseed," the color varying with age, posterior segments terminating in a compressed cylindrical, very minutely hairy ovipositor, capable of great extension; the male smaller, more slender, and darker in color than the female, the abdomen terminating in a somewhat intricate organ composed of a set of outer and inner claspers (Fig. 148); the egg very minute, $\frac{1}{50}$ inch long, cylindrical, obtusely pointed at the ends, glossy, translucent, slightly reddish, color deepening with development; larva or maggot when newly hatched smaller than the egg, with a slightly reddish tinge, later, as size increases, at first white, then greenish white, clouded internally by flaky white. After reaching full growth, the larva acquires from its hardened skin a brown covering or puparium, and is then in the "flaxseed" stage (Fig. 149), so called because of the brown color and its more or less flattened shape. From the flaxseed it transforms first to a pupa and from that to an adult fly (Webster, 1915, pp. 2–3).

The chief food plant of the Hessian fly is wheat. It is found also on barley, but does not develop well on rye and does not attack oats at all. It is known also to breed in several species of wheat-grass (*Agropyron repens, A. tenerum,* and *A. Smithii*).

The eggs are generally placed in the grooves of the upper surface of the leaves, though occasionally found on the under side of the leaf. The young larva as soon as hatched makes its way down the leaf and inside the sheath. The fall generation of larvæ is found just above the roots of the seedling plant, except in cases where the latter has become disintegrated and separated at the place of attack in the fall, or the plants have been heaved out by the alternate freezing and thawing, in which case the larvæ may be scattered about on the ground. The larva occurs on the plant with its head downward, but later turns its head upward in the flaxseed.

Fig. 149. — Pupa of the Hessian fly, called the flaxseed stage.

518. Life-history of the Hessian fly. — There are two generations of the Hessian fly, probably in all parts of the United States, at least in favorable seasons. In the South the two generations are most widely separated, while in the spring wheat districts of the North, one apparently follows the other in quick succession.

In winter wheat districts the fly passes the winter in the young wheat, usually in the flaxseed stage; also, perhaps, in the South, as larvæ $\frac{2}{3}$ to full grown. In the spring the adult flies escape from the flaxseeds, in March in Georgia and South Carolina and in May in Michigan, and deposit their eggs on the wheat, the young from which develop to flaxseeds before harvest, and pass the summer in the stubble. From these arise the second generation of adults, which deposit their eggs on the new fall-sown wheat, when there is a repetition of what has just been described. Flies from the over-wintering larvæ appear later. These, with probable other adults resulting from eggs deposited earlier in the spring, form sometimes just before harvest what is called by some a supplementary second generation. In autumn the time of appearance of adults as between North and South is reversed from that in the spring. In the North they appear much sooner, — during the last of August and first of September in northern Michigan. In Georgia and South Carolina it may be the last of November or first of December before they all leave the stubble. Here again the earliest deposited eggs may be able, because of the long autumn, to produce adults before cold weather, which with the delayed individuals of the preceding generation form another so-called supplementary generation.

In the northern spring wheat districts the insect winters in the flaxseed stage in both stubble and volunteer wheat, but chiefly in stubble. Eggs are laid late in May, and in rainy seasons the second generation quickly follows, to which are added flies still continually emerging from the previous year's stubble. The breeding season extends from about May 20 to October 1, or practically the entire summer.

519. Effect of the larvæ on cereal plants. — Soon after the larvæ pass down from the leaf on to the straw inside the sheath, they produce a marked effect upon the plant. The uninfested wheat plant is of slender growth, has a light green color tinged slightly with yellow, the stems are usually visible, and the central unfolding leaf is present, the whole plant is drooping, and the tillers spread out and cover the ground. The infested plant is without stem, the leaves are broader and usually shorter, deep bluish green in color, and resembling those of oats. The plant stands more erect, and is a mass of short overgrown leaves that are usually killed by the first frost. Later the infested plants change to yellow and then brown. In summer the stems of both spring and winter wheat infested break over before harvest, and the plants are said to be "straw fallen."

There is no "fly proof" wheat. All wheats in the young stage are affected by the fly. By the time the attack of the second brood, however, the plants have reached a stage where there is apparently a considerable difference in the resistance of varieties. The ranker growing varieties with strong stiff straw are least affected. Tillering is important, in order that new tillers may possibly be sent out from the old roots of plants killed by the fly, which tillers should be able to withstand the winter. Durum wheats, in the later stages of growth, are little or not at all affected by the fly. In many cases common wheat plants mixed in the same field with durum wheat have been found badly infested, while the durum wheat plants were free.

520. Natural enemies of the Hessian fly. — There is no doubt that parasites take a most important part in the control of the Hessian fly. A considerable number of such parasites is known to occur in this country, among the most important of which is a black species (*Polygnotus hiemalis*, Forbes), with dark brown legs, banded with yellow, and yellow feet. As many as forty larvæ of this parasite have been found in a single flaxseed. It is believed by Webster (1915) that the serious ravages of the Hessian fly in 1914 were possible because of the absence of this parasite, which was greatly reduced in numbers by the severe winter of 1912–13. The parasite has been introduced into the state of Washington, where the Hessian fly was destructive, and the former has become since not only common but in some cases abundant, though it could not be found previous to this introduction.

521. Effect of climate on the Hessian fly. — The immunity of late-sown wheat from attacks of the fly is not due to frost, but to the fact that by the time severe frosts usually occur most of the flies have gone. The greatest climatic effect upon the fly is that caused by heat and drought, especially the two combined. In the South the two generations are widely separated by the long summer. Also emergence from the flaxseed is much delayed by dry weather. Humidity has greater influence in the development and distribution of the fly than either altitude or latitude. Migration of the fly westward from the meridian of 100° and eastward from the Cascade Mountains is no doubt prevented by heat and drought.

522. Preventive measures. — Any effective methods of combating the fly, it appears, must aim at the elimination of the pest from young wheat in the fall. Probably the most important of such methods is late seeding, or seeding after the second brood has gone. Experiments in this line have been made to a sufficient extent probably to justify the conclusion that in years of normal rainfall wheat may be sown in northern Michigan without danger from Hessian fly attack from September 1 to September 15; in southern Michigan to central Ohio from September 15 to September 25; in southern Ohio and Indiana and northern Kentucky from September 25 to October 10; in southern Kentucky and Virginia and northern Tennessee from October 10 to October 20; in Georgia and

South Carolina from October 25 to November 15; in extreme southern Kansas and northern Oklahoma from October 10 to October 20; in Maryland from October 1 to October 15, according to altitude.

Burning the stubble, the destruction of volunteer wheat, and crop rotations are other methods of prevention that are most important and can be made effective where farmers can be induced to coöperate. At the Kansas Experiment Station, Headlee and Parker (1913, pp. 119–121) found that plowing the infested stubble under deeply destroyed the fly much more thoroughly than the method of burning it, while there was the further advantage of the addition of organic matter to the soil. Naturally wheat should not be sown on stubble ground without plowing.

523. The chinch bug (*Blissus leucopterus*, Say). — In the middle Great Plains and eastward to Ohio and northward to Minnesota the worst insect pest of cereal crops is the chinch bug. It is distributed in less damaging numbers in other parts of eastern North America from Nova Scotia and Manitoba to the Gulf of Mexico and along the Pacific Coast. The chinch bug is native in this country, and attacks the small cereals, grasses, and corn, but not the legumes. It does its greatest damage periodically, and especially during a period of two or three dry years. It is thought that the damage to all cereals, including corn, in Kansas alone, may reach two million dollars in a single year, while occasionally the damage to these crops throughout the entire country probably reaches 50 or 60 million dollars. The loss from chinch bugs in Missouri was several million dollars in 1913. The chinch bug, both as young and adult, works at the base of the cereal plant, and does its damage by piercing the epidermis, sucking the sap, and killing the tissue around the wound.

524. Description and life history. — There are two broods of the chinch bug. During winter the mature winged insects of the last preceding brood hibernate in dead grass and under various kinds of rubbish. In the spring they leave winter quarters and locate in wheat and

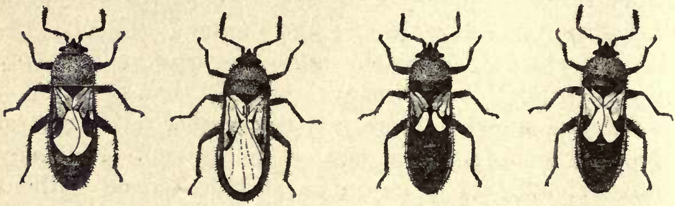


FIG. 150. — Several stages or instars in the life history of the chinch bug.

other small cereals. There the young are produced in May and June, and mature just after harvest. With the disappearance of their small-grain food supply, they migrate into the nearest corn or sorghum fields. There a new brood is produced that matures in the autumn.

There are 6 stages in the life history of the chinch bug. The egg is less than $\frac{3}{10}$ inch long, cylindrical, blunt at one end, pale or whitish at first, later showing color through the shell. The newly hatched larva is little larger than the egg, of a pale reddish color, and resembles the adult, except in having no wings. On molting there is a second larval stage or instar resembling the first, but larger and having the head and thoracic segments darkened and hardened. The third instar is still larger and the head and thorax still darker and more coriaceous. After a third molt, the fourth instar or the pupal stage is reached, resembling the adult almost entirely, but there are still mere pads instead of wings. Next there is the perfect insect which is black with white spots on the wings. The life cycle requires nearly two months (Fig. 150).

525. Control measures. — The chinch bug is most easily destroyed at two periods, (1) during hibernation in winter, and (2) at the time of migration of the first brood from small grain to corn or sorghum. All near-by grass lands and waste places should be burned over early in the winter, so that the bugs not killed by the fire may be exposed as long as possible to winter freezes. All rubbish in fence corners and in hedge-rows should be raked out and burned. These operations will prevent swarms of mature insects going into small grain in the spring.

In midsummer when the mature bugs of the first brood attempt to migrate from the small grain, dust barriers formed around the infested fields are very effective. These are strips of plowing 10 to 15 feet wide, which are thoroughly worked into a fine dust mulch. The heat destroys many bugs that attempt to pass over the barrier, and the hot, fine dust closes breathing pores and smothers those not killed by the heat. The surface must be kept constantly stirred into a fine condition. Also a ditch may be plowed, throwing the dirt both ways, and a log dragged through it back and forth, making a bed of fine dust in the bottom. Few bugs will cross the ditch.

In wet weather, when dust will not form, effective barriers of oil or tar may be made. First, a well-packed ridge should be made. Then, by using a sprinkling can with the sprinkler removed, or by attaching a hose to a barrel, a thin line of coal tar or thick road oil an inch or less wide is run along the ridge. The bugs will not pass over this line. It is kept fresh by adding more oil or tar once or twice a day, later once in 2 or 3 days. If post holes are made about every 20 feet on the side of the line next to the infested field, the bugs, repelled by the oil or tar, will run along the line and tumble into the holes, where they may be destroyed with kerosene.

Two species of fungi (*Entomopthora aphidis*, Hoffman, and *Sporotrichum globuliferum*, Speg.) are found parasitic on the chinch bug. It has been attempted to annihilate the insect by artificially propagating these fungi in quantity, and spreading them among the bugs in the field. The very conditions of continued wet weather favorable to the fungi, however, are very unfavorable to the chinch bug, so in such weather the former are scarcely needed, while in dry weather when the bugs are most active the fungi do not multiply.

526. The wheat midge (*Diplosis tritici*, Kby.) is a close relative of the Hessian fly, but unlike the latter works in the spikes of wheat, feeding on the soft developing kernels, causing imperfect filling, shriveled kernels, and blighted spikes. There are occasionally unusual outbreaks of this insect during which it causes great damage, but ordinarily it is much less serious than the chinch bug or Hessian fly.

The very minute oval eggs, pale red in color, are deposited singly or in clusters to the number of 10, in the crevices of the wheat spikes. These hatch in about a week and the orange-yellow larvæ or maggots find their way at once to the kernels. The full-grown larva is oval, about $\frac{2}{25}$ inch long when quiescent, somewhat longer in motion, and lives about three weeks. Many larvæ are still in the spikes when the grain is harvested, and are carried to the stack and to the thrasher, and are then often called "red weevils." The others pass from the wheat spikes to the ground, where they prepare cells in which to pass the winter.

Crop rotation and deep fall plowing of infested fields will readily control this pest. The deep plowing buries the larvæ so deeply that they cannot escape the following year.

527. Spring grain louse (*Toxoptera graminum,* Rond). — This insect is sometimes very destructive, but at periods widely separated. In Texas and Oklahoma where it has been a serious pest it is known as the "green bug." It appears on winter wheat in September in the form of wingless females, which are parthenogenetic, and go through several generations quickly (Figs. 151 and 152). They feed generally on the surfaces of the leaf, sometimes literally swarming down at the base of the unfolding leaves where they are in a measure protected. According to Webster, a mild winter followed by a cold wet spring is the sequence of meteorological conditions most likely to induce a serious outbreak of this pest. In the northern states the wingless females hatch from the eggs in April, passing through many generations until harvest. In the South there are no eggs, the insect reproducing viviparously during the entire year. The winged insect is shown in Fig. 153. There are many natural enemies of the grain louse, including predaceous beetles, flies, and internal parasites. The most important of the latter is *Lysiphlebus testaceipes,* Cress. These enemies and unfavorable weather conditions are usually sufficient to prevent excessive multiplication of the insect and much devastation. In the case of extensive infestations, there are no practicable remedies. Another species (*Macrosiphum granaria,* Buck-

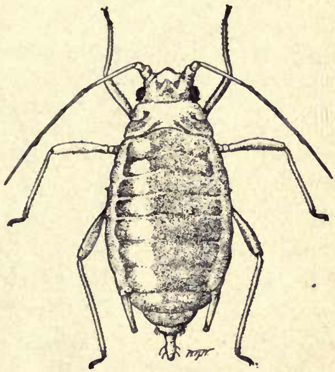


FIG. 151. — Wingless female of the spring grain louse.

ton) is present always, but only occasionally does very much damage.

528. The wheat straw-worms. — Two species of wasp-

FIG. 152. — Seedling winter wheat plant infested with the spring grain louse or "green bug."

like 4-winged flies are rather destructive to wheat, and one other attacks barley. The habits of all are similar, and result in similar injuries to the crop. They weaken and distort the culms causing them to break on thrashing, and decrease the yield by preventing or checking the development of the spikes.

The *wheat joint-worm* (*Isosoma tritici*, Fitch) is a true gall insect, producing swellings or enlargements in the walls of the wheat culms. The galls are usually at or near the joint, more commonly the second joint, but may occur near any one.

The adult insect is a minute black, 4-winged fly, $\frac{1}{8}$ to less than $\frac{1}{4}$ inch long, and resembles its own parasites and the parasites of the Hessian fly. The galls are in groups of three or four. Inside the galls are the larvæ, yellowish white with brownish-tipped mouth parts. The species is single-brooded.

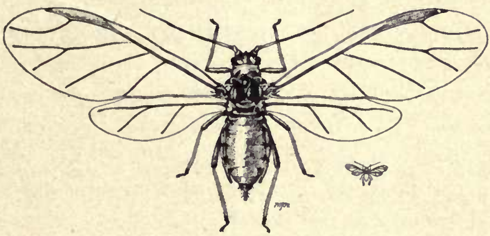


FIG. 153. — Winged adult of the spring grain louse.

The barley joint-worm (*Isosoma hordei*, Harris) possesses habits similar to those just described, but occurs on barley.

The *wheat straw-worm* (*Isosoma grande*, Riley) is closely allied to the joint-worm, but is distinguished by its habit of living free in the hollow culms of the wheat, and producing no gall. It also winters in the culm in the pupal stage instead of the larval stage, and has two broods.

The adults of the two broods are quite dissimilar in appearance. Those coming from the over-wintering pupæ are rather minute and the females are wingless or have wings greatly aborted. Eggs are deposited about May 1, near the beginning of the young wheat spike, not far above ground. The adults of the second brood are much larger, and consist entirely of winged females. They are therefore able to fly and are the migratory brood. Eggs are deposited in or near the joints of the culm, usually near the second joint from the spike. The worms reach the pupal stage within the straw in the fall, and emerge as adults the next spring.

These insects are attacked by several parasitic flies, which check their multiplication greatly. The remedy for the straw-worms is in burning the stubble which harbors the over-wintering stages and in crop rotation.

529. The bulb-worm (*Meromyza americana,* Fitch) in the adult stage is a minute yellowish-green 2-winged fly, quite different from the Hessian fly, and found on all the small cereals and other grasses. It is not nearly so destructive as the Hessian fly, but sometimes causes considerable loss. It occurs throughout eastern North America, from Canada to Texas. There are at least 3 broods in the latitude of Ohio, and maybe one or more additional broods in the South.

The fall brood passes the winter in the larval stage at the crown of the cereal plant. Adults emerge the next June, and deposit their eggs, often several in a row, near the edge of the sheath of the upper leaf. The resulting larvæ or maggots feed on the succulent portions of the culm, just above the last joint, and cause the upper portion of the straw to wither and die, and the spike to turn white. The adults of this second brood leave the straw in July and August, and breed in volunteer grain or grasses, and start a third brood in time to infest the winter grain in September and October as before.

Fortunately certain parasitic and predaceous insects are usually a good check to this insect. There is no very effective remedy, but burning the straw and stubble, and eradication of volunteer grain as soon as possible after harvest may destroy many of these pests.

530. The army worms. — Though these caterpillars probably cause some injury to cereal crops in some part of the country every year, severe injury usually occurs only at considerable intervals in any one district. The 3 principal species are the army worm proper (*Heliophila unipuncta*, How), the fall army worm (*Laphygma frugiperda*, S. and A.), and the wheat-head army worm (*Meliana albilinea*, Hbn.).

The true army worm confines its damage particularly to the region east of the Rocky Mountains. The adult is a pale or yellowish brown moth, with a white spot on the center of each fore wing. The minute white eggs are usually laid in strings beneath the sheaths of grass culms, also occasionally in other situations or beneath the sheaths of culms of other plants. The eggs hatch in 8 to 10 days, and the young caterpillars feed for a time in the fold of the leaf, but soon are able to consume entire leaves. Ordinarily the larvæ feed mainly at night or in damp cloudy weather, remaining hidden during bright days. They reach full growth in 3 or 4 weeks, attain a length of $1\frac{1}{4}$ inches, burrow into the ground and transform into brown chrysalids. In about 2 weeks the perfect moth results. Several generations are produced each season — 2 or 3 in the North, and 4 or more in the South. It has not been definitely determined in which stage this insect passes the winter in the various portions of its range. The moth is an exceedingly strong, swift flier, and may travel hundreds of miles under favorable conditions. The occasional notable swarms are the progeny of the first, second, or third summer broods. The larva is a naked, dark-colored caterpillar, with narrow pinkish or whitish longitudinal stripes.

The *fall army worm* resembles the true army worm so closely that even the entomologist is sometimes in doubt as to which species he has in hand. It has recently been determined that the fall army worm is native to southern Texas and Florida. In years of excessive abundance the swarms of moths migrate northward before depositing their eggs, the brood of moths resulting therefrom doing likewise. Thus the pest never reaches the northern states until the late summer or early autumn months. The injury to crops by this insect is confined chiefly to corn and alfalfa in the southern states, where it is known as the "grassworm," but in the northern states the young winter wheat sometimes suffers severely. The moth has bluish-gray fore wings, and cream-colored hind wings, and varies greatly in the markings of the former. As this insect pupates within an inch or two of the surface of the soil, it is easily destroyed by harrowing at this time. It is unable to survive the winter in regions visited by severe frosts.

The *wheat-head army worm* has been destructive in recent years in Iowa. The moth is about the size of the army worm moth, but is pale yellow or straw color. It flies only at night. The caterpillar varies in color, but resembles generally the cutworms and army worm, but differs in its habit of attacking spikes of wheat and timothy.

The moths lay eggs early in May. The caterpillars feed on the blades until the kernels are "in the milk," then attack the wheat spikes. When full grown they enter the ground, pupate, and produce the moths the middle of July. The second brood of caterpillars feed on grasses and other green crops in the fall, pupate in the soil, and pass the winter there.

Grass lands and waste places should be burned over, for prevention of these worms, and crop rotation is important. A good remedy is the one of plowing a furrow with the land side next to the field to be protected, and dragging a log through the furrow to keep the earth stirred and kill the worms which have accumulated in the ditch. Another remedy is to poison a strip of pasture or crop heavily with Paris green or London purple in advance of the traveling army of worms. A very effective poisoned bait is made as follows: 50 pounds wheat bran, 2 pounds paris green, 2 gallons sorghum or cattle molasses, 3 oranges or lemons. The paris green is thoroughly mixed with the bran while dry, the molasses is then added, together with the fruit juice, and the mass kneaded into a stiff dough. The small pieces of this, on crumbling, are then scattered thinly over the infested fields. It may be sown over large areas by means of the broadcast endgate seeder (351). The method can be followed where it is not advisable to spray with arsenicals. By disking infested fields late in the fall, winter, or early in the spring, many pupæ can be killed. There are natural enemies that keep the worm in check, such as the parasitic tachina flies. As many as 50 eggs of a species of tachina are attached sometimes to a single caterpillar.

531. The sawflies. — There are a number of 4-winged flies called sawflies found in grain fields, usually in wheat. They are so named because of the saw-like ovipositor of the adult female, with which incisions are made in the tissues of plants for the insertion of eggs. Most of the sawflies are of little economic importance, and only occasionally migrate from wild grasses to wheat. A few of them sometimes do considerable damage, and are of 2 classes, stem borers and leaf feeders.

The *European wheat sawfly* (*Cephus pygmæus*, Linn.), an important species, has caused little or no loss so far in this country, but is a recognized pest in Europe and particularly bad in France. The adult flies deposit eggs in the culms of the young wheat in April, and the resulting larvæ bore through the joints and work up and down the culm inside. When full grown they are $\frac{1}{2}$ inch long and milk-white in color. Near harvest they pass down to the bottom of the culm, and girdle the straw on the inside, nearly severing it. Beneath the girdle a cocoon is formed in which they pass the winter still as larvæ, but transform to pupæ, and then adult insects the following spring and summer. The object of the girdle is that the straw may break and allow the perfect insect to escape, and the chief damage done is in the lodging of the grain resulting from this weakening of the culm. The insect prefers wheat, but develops also in rye, and the females will oviposit in oats and other grasses (Marlatt, 1901, pp. 34–38).

The *western wheat sawfly* (*Cephus occidentalis*, Marlatt) is a native species but similar in habits to the European wheat sawfly, and resembles the latter closely in the adult form. It occurs in California and most of the extreme northwestern states, particularly in North Dakota, where it was reported as damaging as high as 25 per cent of the wheat in 1909. The larvæ work in the culms of grasses, but the insect may be expected any time to change its feeding habits from grasses to small grains.

Grass sawfly. — The larvæ of several leaf-feeding sawflies have been found on wheat. Probably the most important is the grass sawfly (*Pachynematus extensicornis*, Nort.). It is about the size of the common house fly, and occurs in the northern states east of the Rocky Mountains. The eggs are inserted in rows along the edge of the blades of wheat, or more commonly in grasses, and the larvæ feed on the leaves, more or less gregariously at first. When full grown, they separate and become practically solitary feeders. This species ordinarily causes no considerable damage, but may rarely sever the green portion of the culm just below the spike, thus causing some loss.

When any of the sawflies becomes a real pest, it can be largely controlled by turning all stubble land under deeply in the fall or winter, preventing the larvæ from escaping.

Insects Attacking Stored Grain

It is estimated that the annual damage by insects to all stored grain in the United States, including corn, is over 50 million dollars. Nearly all insects feeding on stored grain have been introduced, and are of world-wide distribution. They are largely indigenous to the tropics, and do not thrive in the northern states and Canada, but are acclimated in the South, and there do their greatest damage. Three species, the granary weevil, rice weevil, and Angoumois grain moth, live normally throughout their early stages in the cereal kernel. The other species live not only on grain in the kernel, but on manufactured flour, meal, and other cereal products.

532. The granary weevil (*Calandra granaria*, Linn.). — This weevil is one of the oldest of injurious insects. Becoming domesticated ages ago, it has long since lost the use of its wings, and is strictly an indoor species. The mature weevil is $\frac{1}{8}$ to $\frac{1}{6}$ inch long, chestnut-brown in color, thorax sparsely punctured longitudinally, head prolonged into a long snout or proboscis, with mandibles at the end, antennæ elbowed, attached to the snout; larva legless, considerably shorter than the adult, white, very robust and fleshy; pupa white, clear, transparent, and exhibiting the general characters of the future beetle (Fig. 154).

The female punctures the kernel with her snout, and then inserts an egg, the larva from which devours the mealy interior and transforms therein. A single larva inhabits a kernel of the small cereals, but several are found in a corn kernel. The time required for the life cycle varies with the climate and season, and the number of generations depends upon the temperature. In midsummer the period from the egg to the adult is about 6 weeks. Under favorable conditions there may be 4 or 5 broods in middle latitudes and 6 or even more in the South.

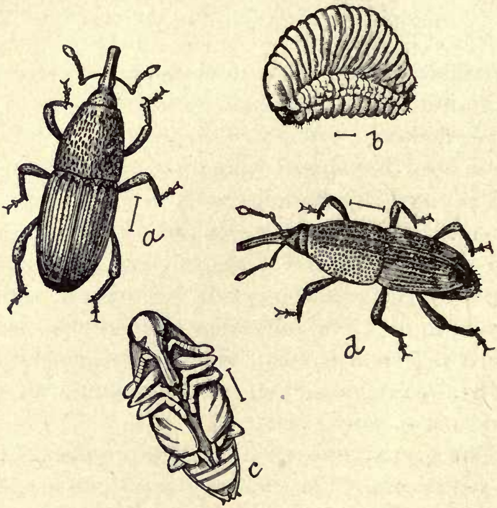


FIG. 154. — The granary weevil: *a*, beetle; *b*, larva; *c*, pupa; *d*, the rice weevil.

This species is injurious in wheat, corn, barley, oats, Kafir corn, and the chickpea. The adult weevils, as well as the larvæ, feed on the kernels, and obtain shelter within them. The species is very prolific. Egg laying continues a long time, and it is estimated that one pair, in the course of a year, will produce 6000 descendants (Chittenden, 1896, pp. 4–5).

533. The rice weevil (*Calandra oryzæ*, Linn.) probably originated in India, and was first found in rice, hence the name. It is a serious pest in the southern states, where it is commonly called black weevil. It is less important in the North, but is found in every state, and occasionally occurs in Canada and Alaska.

This species resembles the granary weevil in size and general appearance, but differs in being dull brown in color, the thorax densely pitted with round punctures, and the elytra ornamented with red spots. It has well-developed, usable wings (Fig. 154 *d*). The larvæ and pupæ are also similar to those of the granary weevil. In habits and life history the two species differ little, except that the rice weevil is found in the field, and lays eggs in the standing grain in the extreme South and in the latitude of Kansas on shocked and stacked grain, if the latter remains long without thrashing.

The rice weevil feeds on the kernels of rice, wheat, corn, barley, rye, hulless oats, buckwheat, chickpeas, and the grain sorghums. In storehouses and grocery stores the adult beetles are found in boxes of cakes, crackers, and other bread stuffs, in barrels of flour and bags of meal.

534. The saw-toothed grain beetle (*Silvanus surinamensis*, Linn.). — This insect is a common pest the world over. Both the beetle and larva of this species infest all kinds of grain, flour, meal, bran, breakfast foods, starch, miscellaneous seeds, nuts, and other stored foods. It will perforate paper bags and cardboard boxes, in which there is flour, meal, or breakfast food.

The larva is very active, yellowish white, slender, with 6 legs. It hatches shortly after the long slender egg is deposited, and begins feeding at once on the grain or grain products. When full grown, it fastens itself to some convenient object, and forms a covering of grain particles or small pieces of other infested material, held together by a sticky substance it secretes, and there passes the pupal stage. The pupæ are frequently in cracks or crevices of the bin, and may be overlooked. In 6 to 12 days the adult beetles emerge. These are very small, slender, flattened, dark brown, $\frac{1}{10}$ inch long, having the thorax armed on each side with 6 saw-like teeth. They are very active and run away quickly when disturbed. In middle latitudes there are 4 to 6 generations annually. The life cycle varies in length from 6 to 10 weeks in spring to only 24 to 30 days in midsummer.

This insect is common in cereal and feed mills, and in warehouses and grocery stores where there are cereals and mill products. Corn bran is often infested, and should not be used for bedding in railway cars (Dean, 1913, pp. 202–204).

535. The cadelle (*Tenebroides mauritanicus,* Linn.) is widely distributed over the world. Though there is only one generation each year, and the insect is predaceous, nevertheless, it is a serious pest. Both the adult and larva feed on grain, giving special attention to the embryo, and destroy the vitality of many kernels that are not consumed. They are sometimes beneficial by devouring other grain insects. This species is often found in elevators, granaries, and cereal mills.

The larva is a greasy, flattened, somewhat hairy worm, whitish, $\frac{3}{4}$ inch long, head and tail dark brown, tail ending in two horny points. The adult is a beetle, black, or nearly so, flattened, $\frac{1}{3}$ inch long, oblong, thorax and abdomen loosely joined. The adult and larva are easily distinguished from other stored grain and flour insects. The larva is much larger and more fleshy than other flour worms. The pupa is white.

In flour mills the adults are found in nearly all parts, and the larva in accumulations at the bottom of elevator boots and flour conveyors. The latter is a common pest in bags of flour. Dean states (1913, p. 206) that in the blending of flour in blending plants the larvæ are bolted out by thousands and cites one instance where 1460 worms were taken from one 140-pound bag of straight-grade flour.

536. Three other grain beetles are often found feeding on grain and mill products, but are not so important as those just described. The foreign grain beetle (*Cathartus advena*, Waltl.), though occurring in grain and cereal products, does not become a pest when these materials are stored in places dry, clean, and well aired. The square-necked grain beetle (*Cathartus gemellatus*, Duv.) is more common in the southern states, where it is particularly an outdoor species, but is found on grain in the middle Great Plains. The flat grain beetle (*Læmophlæus minutus*, Oliv.) is really more often found in flour than in grain, but does not usually occur in sufficient numbers to be a serious pest.

537. The yellow meal-worm (*Tenebrio molitor*, Linn.). — This insect is a native of the Old World, but is now common in this country, wherever grain is stored. It requires one year for its life cycle. The beetles are nocturnal, and breed in dark corners, in cracks, and under sacks. They prefer refuse, especially if damp or slightly soured, accumulated in corners, under machinery, in basements and other undisturbed places.

The white bean-shaped eggs are deposited in the spring singly or in groups in meal or grain, which serves as food for the larvæ. The larvæ are hatched in 2 to 3 weeks, are at first pure white, soon changing to waxen yellow, and are fully grown in 3 to 4 months, when they become long, slender, cylindrical, appearing waxen, and resemble wire-worms. They are then yellow, shading to yellowish-brown toward each end and at each articulation. The tail terminates in 2 spines. This form continues until the next spring, when it changes into a white pupa, in which condition it remains 2 to 3 weeks, and then changes to the adult insect.

The *dark meal-worm* (*Tenebrio obscurus*, Linn.) has the same habits and life history as those of the yellow meal-worm, and is found in the same places. The adult beetle is similar in size and shape, but is dull pitch black in color. The larva also resembles that of the yellow meal-worm in size and shape, but differs in color, having much darker brownish markings.

538. The confused flour beetle (*Tribolium confusum*, Duv.). — This insect is native in the Eastern Hemisphere, but since 1893 has become a serious pest in the United States and southern Canada. While primarily a flour pest, it also infests corn meal, cracked wheat, and many other dry foods. Of mill products, it prefers the low-grade flours, but is often found in large numbers in the best patents.

The eggs are very small, clear white in color, and are laid in cracks and corners of bins, and in seams and creases of sacks, and in cracks and on the sides of boxes, barrels, or anything containing cereal products. These hatch in summer in about 5 days, producing small white worms $\frac{1}{4}$ inch long, which, after about 24 days of feeding, change to naked white pupæ. The pupæ remain so only 5 or 6 days, when the adult insects emerge, making the total life cycle about 5 weeks, with a temperature above 85°. At lower temperatures the life cycle is from 14 to 15 weeks. The beetles are $\frac{1}{6}$ inch long, flattened, rust-red in color, and very common in flour. With favorable temperatures there are at least 5 broods annually.

This insect is found in mills in all stages, and is especially abundant in accumulations of flour in elevator boots and flour conveyors. It breeds in cracks in the floor and in mill machinery (Dean, 1913, pp. 210–212).

539. Other flour beetles. — There are 4 other flour beetles of less importance than the preceding. The rust-red flour beetle (*Tribolium ferrugineum*, Fab.) resembles the confused flour beetle in color, form, and size, but the head is not expanded beyond the eyes at the sides, and the antennæ terminate in a distinct 3-jointed club. It occurs in grain, meal, and flour, but is somewhat restricted to the southern states. The small-eyed flour beetle (*Palorus ratzeburgi*, Wissm.) was first found in

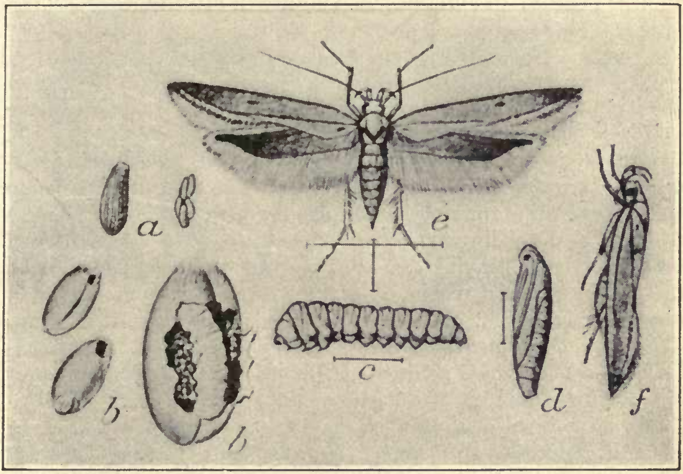


FIG. 155. — The Angoumois grain moth: *a*, eggs; *b*, infested wheat kernels; *c*, larva; *d*, pupa; *e*, mature moth; *f*, adult with wings closed.

this country in 1882 in a flour mill near Detroit, Michigan, and is one of the smallest of our flour beetles known to injure cereals. It shows a preference for ground products. The broad-horned flour beetle (*Echocerus cornutus*, Fab.) is injurious in about the same way as the small-eyed flour beetle, but not widely distributed, and is rarely found doing serious injury in this country. The latter, however, is a bakery pest in places in Europe.

540. The Angoumois grain moth (*Sitotroga cerealella*, Oliv.). — This insect is named from the province of Angoumois in France, where it existed in large numbers a long time ago, in granaries and grain fields. It is now distributed over the greater part of the United States, but is more common in the southern states. It attacks grain in the field, as well as in the bin, as far north as Pennsylvania. It infests all cereals, including buckwheat and the chickpea.

The eggs are laid 60 to 90 by each female, singly or in lots of about 20, on mature or immature standing corn, on grain in the shock or stack, and on thrashed grain in the bin or corn in the crib. They are minute, oval-shaped, white when laid, soon turning reddish, and are placed in longitudinal channels on the side of the grain and between the rows of kernels on ear corn. They hatch in 4 to 10 days, depending upon the temperature. The larvæ burrow into the kernels, leaving exceedingly small openings, and feed on the starchy material within. Usually a single larva infests a small cereal kernel, but 2 or 3 may be found in a kernel of corn. The caterpillar when full grown is $\frac{1}{5}$ inch long, white, with a yellowish head. It has 6 pointed legs in front, 4 pairs of fleshy prolegs along the middle, and 1 pair at the tip. It matures in 20 to 24 days, and spins a thin, silken cocoon within the kernel, in which it transforms to a pupa. In a few days the moth emerges. The adult moth is light grayish brown, small, measuring a little over $\frac{1}{2}$ inch across the expanded wings, the latter narrow, pointed, and bordered with a long fringe. In warm weather the life cycle is about 5 weeks (Fig. 155).

In the middle latitudes this insect, so far as known, hibernates in the larval stage in kernels of wheat, corn, rye, and barley, and there are 4 or 5 broods annually. In the South, and in warm buildings, 6 generations may be possible (Chittenden, 1896).

541. The Mediterranean flour moth (*Ephestia kuehniella*, Zell.). — This insect occurs throughout Europe.

It was first found in Canada in 1889, in California three years later, and by 1895 was reported as injurious in several eastern states. It has constantly spread, and is now a pest in every milling state of this country and a large part of Mexico. As it is very destructive in England and Canada, it appears to be well adapted for indoor existence in cool climates. It has no equal, it is stated,

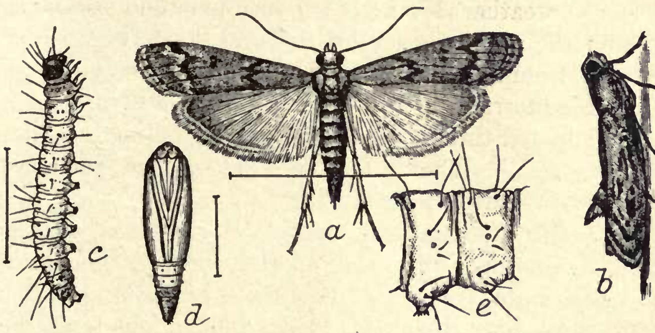


Fig. 156. — The Mediterranean flour moth: *a*, adult moth; *b*, adult in its characteristic resting position; *c*, larva; *d*, pupa; *e*, 2 segments of the abdomen.

as a flour pest, and may well be called "the scourge of the flour mill." In the absence of flour it will attack other cereal products and grain.

The small white eggs are laid in cracks and accumulations of flour along elevator legs, in spouts, around dust collectors, and in bolters and purifiers. At temperatures of 85° to 90°, they hatch in 3 days. The caterpillars are whitish or pinkish, ½ inch long, and slightly hairy. They begin at once to spin silken tubes wherever they travel and feed, and by this web-spinning make themselves a great nuisance. They are full grown in about 40 days, when, leaving their silken tubes, they search for proper places to construct their cocoons, and meantime spin a still greater amount of web. This mats the flour or meal together in lumps, clogs the machinery, and may necessitate a shutting down of the mill until it can be thoroughly cleaned. The pupal stage lasts 8 to 12 days. Under ordinary conditions the entire life cycle is about 9 weeks. The adult moth is small, tame, pale leaden-gray, measures less than 1 inch across the expanded wings, and when resting, assumes a characteristic slightly elevated position in front (Fig. 156). In well-heated mills there may be 6 or more generations in a year (Dean, 1913, pp. 223–228).

In cool weather this insect will be found more commonly around the warmer parts of the mill machinery. Dean believes from his observations that in a majority of cases "the Mediterranean flour-moth infestation of flour mills has originated through the practice of handling second or return sacks." When a mill becomes infested, the entire building should be fumigated.

542. The Indian-meal moth (*Plodia interpunctella*, Hbn.) is another introduced species which is now generally distributed over this country. It feeds on grain, flour, meal, bran, breakfast foods, and various foods and dried materials. It is especially fond of the wheat embryo, and one caterpillar will destroy dozens of kernels for seed purposes.

The eggs are minute, white, and are deposited singly or in groups of 3 to a dozen or more. They hatch in 4 or more days. The larva, when full grown, is $\frac{1}{2}$ inch long, and varies in color, being whitish with light rose, yellowish, or greenish tints. The pupa is light brown. The adult moth resembles in size and appearance the clothes moth, is almost $\frac{3}{4}$ inch across the expanded wings, the outer $\frac{2}{3}$ of the fore wings reddish brown, the inner $\frac{1}{3}$ whitish gray, frequently seen flying about mills, stores, and houses. There are 4 to 6 broods in a year, depending upon the temperature.

The caterpillar spins thin silken tubes through the material it feeds on, as does the Mediterranean flour moth. It also fastens together, by web-spinning, various seeds, kernels of grain, and excrement, and leaves flour and meal in a matted condition. The insect is common in cereal and peanut mills. In flour mills it prefers the middlings.

543. The meal snout-moth (*Pyralis farinalis*, Linn.) is generally distributed over the grain-growing regions. The caterpillar attacks all kinds of grain, ground products, and other dry vegetable material, but prefers meal and bran, especially where the latter are warm and slightly damp. The life cycle is about 8 weeks, and there are 3 or 4 generations annually.

The larvæ are slender, almost 1 inch long, whitish, shading to orange-yellow toward each end, the head brownish-red and rather shiny. The adult moth is light brown, with reddish reflections. The fore wings expanded measure from $\frac{3}{4}$ to $1\frac{1}{8}$ inches; are light brown in color, crossed with 2 wavy white lines, and have dark chocolate-brown spots on the base and tip of each. The female is always larger than the male. The moth is usually found near the food of the larva, but may be seen on ceilings of rooms and on bags of flour or bran, and when disturbed, will curve its tail up over its back.

The caterpillars form long tubes of silk and food particles, like the Indian-meal moth larva, and when mature, construct tough silken cocoons covered with food particles in which they transform to pupæ, causing in all these operations the same stringiness and lumpiness of the meal and bran already described.

544. The control of indoor cereal insects. — Mills and grain and flour warehouses should be kept scrupulously clean. All accumulations of flour and meal on the floors, in corners, and under machinery should be swept away and disposed of in a way to kill all life contained therein.

There are three chief means of eradication, (1) heating to a high temperature, (2) fumigation with hydrocyanic acid gas, and (3) fumigation with carbon bisulfid.

545. Heating to a high temperature. — Apparently the most efficient method yet known for completely eradicating all kinds of indoor cereal insects is the application of high temperatures, which method has been much developed in the last 4 or 5 years. Dean (1913, pp. 145–176) has thoroughly investigated the method and demonstrated its success. After determining the best way of applying the heat in 2 different series of experiments, a third series was conducted under conditions that could more nearly be produced in a mill or other large building. The insects employed were 15 specimens each of the larvæ, pupæ, and adults of the confused flour beetle, the adults of the saw-toothed grain beetle, and the adults of the Mediterranean flour moth. The specimens were placed in shell vials, so the actions of the insects under the slowly rising temperature could be observed, and the vials placed in a paraffin oven which was heated to higher temperatures gradually. The temperature at the beginning of the experiments was 87°, the same as that of the place from which the insects were taken. Heat was applied at 8 o'clock in the morning, and the temperature noted at intervals of a half hour. At 5.45 P.M., with a temperature of 122.5°, all insects in all stages were dead.

546. Demonstration in mills. — The heating of several mills, as a demonstration, proved that no stage of a mill insect, even in the most inaccessible places, could withstand the heat. Mills in Ohio, Illinois, Nebraska, Iowa, Indiana, and southern Canada confirmed the results secured in Kansas.

In one instance heat was applied from 6 A.M. until

6 A.M. the following day by the regular method of steam heating employed in the mill, but a water trap was attached to draw off the accumulated water in the steam pipes, and the steam was turned on directly with pressure, so as to heat the mill more rapidly. Four thermometers were placed on each of the 4 floors, both in the open and in the different depths of flour or other accumulations. At the beginning the average mill temperature was 90°, and that outside 77°. At 3 P.M. fatal temperatures were reached in several parts of the mill, and at 6 P.M. many insects had perished. At 9 P.M. fatal temperatures were shown by nearly all the thermometers except those on the first floor. By 6 A.M. the next day the heat had penetrated the innermost recesses of the mill, except on the first floor.

At the end of this demonstration there were no live insects on the 3 upper floors, even in the deepest accumulations and the most inaccessible parts, save in one corner of the fourth floor. In several places inaccessible to any gas the conveyor and bins were torn open, and not one live insect was seen, but thousands were found dead. Insects infesting samples in tin cans and sealed glass jars in a sample room, and inaccessible to gas, were all killed. Three weeks later a second examination of the mill revealed no live insects of any kind above the first floor.

547. The advantages of the heating method are several: (1) insects breed in places inaccessible to gas or vapor, but heat passes through all obstructions to the innermost recesses. (2) Many insects do not yield readily to hydrocyanic acid gas, but no stored grain or flour insect can withstand a temperature of 118° to 122°, for any length of time. (3) Fumigation with hydrocyanic acid gas requires 2 to 3 days, and the long shut-down of the mill and additional cost of the material is a considerable expense, besides the element of danger to the operator; while the heat can be applied from a Saturday evening to Monday morning with no loss of time, little expense, and no danger. (4) Any mill with sufficient radiation to heat it in winter to 70° can readily be heated in summer to a temperature of 118° to 122°. (5) With the heat method there is no injury to the floors, belts, or mill machinery, and no danger from fire.

548. Fumigation with hydrocyanic acid gas. — This method has been found very effective in eradicating the Mediterranean flour moth. All stages of this moth, if not covered with more than one inch of flour, yield to the gas. Therefore in mills or other buildings infested with this moth, where the heating system is not of a kind to furnish sufficient heat, the hydrocyanic acid gas treatment is to be recommended. The formula for preparing the gas is as follows: —

Sodium cyanid (129–130 per cent)	3 pounds
Sulfuric acid (best commercial grade)	$4\frac{1}{2}$ pints
Water	9 pints

Four-gallon stone jars are used in which to place the water and sulfuric acid. The 3 pounds of sodium cyanid are placed in a double manila paper sack, at the side of each jar, and at the proper time are to be dropped into the jar. Inside measurements should be made to determine accurately the number of cubic feet in each story of the building to be treated. A plan should be prepared for the guidance of the operator, showing the exact number of jars and the required quantity of chemicals for each floor. The quantity of sodium cyanid required for each floor is usually about as follows: —

Basement, 1 pound to each 1000 cubic feet
First floor, 1 pound to each 1200 cubic feet
Second floor, 1 pound to each 1300 cubic feet
Third floor, 1 pound to each 1500 cubic feet
Fourth and fifth floors, 1 pound to each 1600 cubic feet

The 4-gallon stone jars are placed in rows through the length of each floor of the building and the 9 pints of water poured into each one, the number of jars depending upon the number of cubic feet in each story. The sulfuric acid is added slowly after the water. When the building has been made tight, and all of the jars have been prepared, the cyanid is placed carefully but quickly in each jar, beginning at the top story at the end opposite the door, and going through each story regularly in the same manner down to the basement. It should be remembered in the application of this gas that it is extremely poisonous, and one full breath of the gas after liberation in an inclosure may prove fatal. The building fumigated should be thoroughly ventilated for an hour or more by drawing down a number of windows on each floor from the outside before human beings are allowed to enter. The windows may be fitted with strings reaching to the ground, and permitting the lowering of the top sash for this purpose. To produce good results the building should remain tightly closed for 8 hours or more after dropping the bags into the jars.

Baking tests have been made with the different grades of soft and hard winter wheat flour fumigated with hydrocyanic acid gas, and not fumigated, and the results showed absolutely no deleterious effect from the fumigation in any tests. The chief advantage of this method over the heating method is that it depends on no kind of heating apparatus, and can be used in any mill large or small.

549. Fumigation with carbon bisulfid. — This method is recommended as the simplest and least expensive remedy for all insects ordinarily infesting the farmer's grain and grain products stored in tight bins. In such cases this method is also fairly effective. It is not an effective method, however, in flour mills, and in its use in mills and in large grain elevators there is danger from fire.

In buildings reasonably tight, and with a temperature above 70°, 4 pounds of carbon bisulfid are about sufficient for each 1000 cubic feet of space, or 1 pound for each 35 bushels of grain. If the building or bins are not sufficiently tight for thorough fumigation, or if the insects are very abundant, the quantity of the liquid should be doubled or tripled.

Since the vapor is heavier than air, and settles downward, the liquid should be placed in shallow pans at the top of the building or bins, and should be well distributed, not more than a pound in a place. The fumigation should be allowed to continue 36 hours, or even 48 hours, if the grain is not to be germinated. It is a good plan to apply the liquid Saturday afternoon, and leave the building closed until the following Monday morning. The vapor of the liquid being highly inflammable, no fire or light of any kind should be allowed about the building during the fumigation.

CHAPTER XIX

CEREAL PESTS — PARASITIC FUNGI

North American farmers, without doubt, suffer an average loss of at least 50 million dollars annually from fungous diseases of small grains. Except for the rather common practice of seed treatment for prevention of smut, in recent years, the loss would be much greater.

The cereal diseases are included approximately in three main groups: (1) rust diseases, (2) smut diseases, and (3) miscellaneous diseases, or those caused usually by imperfect fungi.

Cereal Rust Diseases

Among the oldest known of all cereal diseases, and yet probably the least understood, are those caused by rust fungi. They are, moreover, exceedingly destructive. In 1904 it was estimated that the loss from these rusts to the three states of Minnesota, North Dakota, and South Dakota, alone, was fully 25 million dollars. Severe losses occurred in these same states again in 1914.

550. The orange leaf-rust (*Puccinia rubigo-vera,* DC.). — This is the most generally distributed of all cereal rusts, and is the earliest rust to appear in the spring. In this country it occurs on wheat, rye, and several other grasses. It is so named from the color of the uredosori, which occur chiefly on the leaves. Over twenty years ago

Eriksson and Henning (1894) and the author (Hitchcock and Carleton, 1894, pp. 2–4) began investigations, afterwards continued by others, which showed the existence of distinct physiological forms of this and other cereal and grass rusts. The separate forms of this rust on cereals in this country are the orange leaf-rust of wheat (*Puccinia rubigo-vera tritici,* Carleton) and the orange leaf-rust of rye (*P. rubigo-vera secalis,* Carleton). In Europe the name brown rust (*P. triticina,* Eriks. & Henn.) is given to this last-named species, though in this country the uredospore stage is not brown. The different physiologic forms will not be discussed here separately. They present no morphologic differences, but are important from the standpoint of propagation of the species. The form on rye will not infect wheat, and the form on wheat will not infect rye.

The fact that the rusts have four different stages, corresponding to the different stages of insects, probably needs no discussion in detail, except to call to mind that the different stages are not always on the same host plant, and that one or more of the stages are sometimes wanting. The æcidial stage of this leaf-rust occurs in Europe on species of the borage family of plants (*Anchusa arvensis* and other species). In this country no æcidial host has yet been found. The rust occurs by far the most abundantly in the uredo or summer rust stage, and is usually more abundant on wheat than on rye. It sometimes covers the leaves with bright orange sori. Toward harvest time the teleutospores appear in much smaller numbers on all parts of the plant, but particularly the leaves and sheath. The teleutosori show dimly underneath the epidermis, through which they burst sometimes only in a few places.

This is the rust that is always present, and is sometimes the only one occurring during the season in certain localities. When unusually abundant, it is likely to cause some damage, by preventing the complete functioning of the leaves in the elaboration of food material. It is rarely or never so destructive, however, as the black stem rust.

551. The dwarf rust (*Puccinia simplex*, Eriks. & Henn.) appears superficially much like the preceding, occurring chiefly on the leaves. It is not common, and is found only on barley. The uredosori are orange colored. The æcidial stage, if any, is unknown. The teleutosori are subepidermal, as in the preceding, and occur most abundantly on the leaves. The teleutospores are dwarfed and usually only 1-celled.

552. The black stem-rust (*Puccinia graminis*, Pers.). — This rust is apparently found in all countries, but is much less common and abundant than the orange leaf-rust, and is often absent the entire year in some localities. In some places in this country, it is seldom or never seen on certain hosts. In North America the species attacks wheat, oats, barley, rye, and many wild relatives of these cereals.

Inoculation experiments by the author (1889, pp. 52–65) indicated that there are at least 2 physiologic forms of this rust on cereals in the United States, one on oats, and one on wheat and barley, with probably a third form on rye. Eriksson (1896) determined that in Sweden there are 3 forms, one on oats, one on wheat, and a third on rye and barley. Later, Freeman and Johnson (1911, p. 27) decided that there are 4 forms, one on wheat and barley, a second on rye and barley, a third on wheat, rye, and barley, and a fourth on oats.

It is well known that the æcidial stage of this species occurs on the barberry. It is not of general occurrence in this country, however, but is occasionally fairly abundant in a particular locality. The uredosori are a dark brick-red or brown and occur on all portions of the plant, and, unlike those of the orange leaf-rust, are as abundant on the culm and leaf sheath as on the leaf-blade. The teleutosori soon become nearly as abundant as the uredosori, and burst through the epidermis, causing a rough or ragged as well as black appearance of the culm.

Black stem-rust is the most destructive cereal rust in this country, and sometimes ruins the crop completely. In such cases either the spikes or panicles do not fill or the kernels are so shriveled that the crop is not worth harvesting. As this rust appears later than the leaf-rusts, early varieties are likely to escape it. Rye and barley, because of ripening early, are not injured so often by stem-rust as wheat and oats.

553. The crown-rust (*Puccinia coronata,* Cda.) is the most common rust of oats, and corresponds to the orange leaf-rust of other cereals. It is not found on any other cereal. The crown-rust sometimes causes considerable damage to oats, chiefly in hindering the elaboration of plant-food in the leaves, but it is not nearly so destructive as black stem-rust of oats.

The æcidial stage of the crown-rust is found on different species of buckthorn. In this country one of the æcidial hosts is *Rhamnus lanceolata,* as demonstrated by inoculation experiments by the author (Carleton, 1900). The uredosori are light orange in color and are found chiefly on the leaves. The teleutosori are subepidermal and have about the same appearance superficially as those of the orange leaf-rust. The teleutospores are crown-shaped at the apex, hence the name of the rust.

The crown-rust is found on several wild grasses, and is often the only rust occurring on oats during the season. It is injurious to about the same degree as the other leaf-rusts.

Closely allied to the preceding is another oat rust (*P. coronifera*, Kleb.), also known by the common name crown-rust. It is as widely distributed as is *P. coronata,* and so closely does it resemble this species that it is distinguished from it only by minute differences and the fact that, with but few exceptions, it occurs on different hosts. The æcidial host of *P. coronifera* is *Rhamnus cathartica,* a European species of buckthorn widely planted as a hedge plant in the eastern United States, which in some localities has even become sparingly naturalized.

554. The yellow or stripe-rust (*Puccinia glumarum,* Eriks. & Henn.). — This rust has just been discovered in this country during the past year (June, 1915), and therefore little can be stated yet as to its distribution and damage in North America. Wherever it occurs in the other countries it is often the most serious rust. It was identified some years ago by Eriksson and Henning (1894) as a species distinct from the orange leaf-rust, with which it had been previously confused. The chief characters permitting it to be readily distinguished at sight from all other cereal rusts are (1) the bright yellow color of the uredo stage and (2) the peculiar arrangement of the sori in extremely long fine lines between the veins of the leaf. The rust attacks first and chiefly the leaves, but passes later to all parts of the plant, and is more common on the spikes than any other species.

The yellow rust attacks all the cereals, except oats, and many wild grasses. In this country it has been found so far on barley, wheat, rye, wild barley, species of Elymus, and *Bromus inermis.* It appears already to be very damaging to club wheat, and is quite prevalent in Oregon, Washington, and Idaho.

555. Control measures for rust diseases. — No means has yet been devised for the eradication of cereal rusts, and there are no effective remedies. The investigations of Galloway, Wütrich, and the author (Hitchcock and Carleton, 1894) have shown that certain fungicides will kill the spores in all cases where the rust has broken through the epidermis. It appears impossible, however, with any appliances yet available, to reach all affected portions of the plant with a fungicide spray, on a practical scale in large fields. Many sori occur on the under sides of the leaves, and often the leaves turn over. Driving through the fields, at the time the rust is worst, will also destroy much grain.

556. Prevention of rust. — Prevention of rust is possible to a considerable extent. Where wet seasons are usual, the crop should not be grown on low lands. A heavy stand in humid districts is favorable to rust. Under these conditions, it should be noted that the atmospheric humidity is the influencing factor, and not the moisture in the soil, except as the latter may affect the immediately overlying stratum of air. In fact, a soil over-wet may be inimical to the fungus if unfavorable to the host. Stakman (1914, pp. 34–36) investigated this subject and concluded that "the water relation in the soil which is most favorable for the host plant's development is also the most favorable for the development of the rust."

Well-balanced fertilization of the soil is important in this connection. Over-feeding with nitrogenous fertilizers, by causing greater vegetative growth and succulence of the host, is, in the same proportion, conducive to rust.

Earliness of the crop is a very important favorable factor in enabling it sometimes to escape rust. Either early seeding or the use of an early variety may accomplish this end.

557. Rust perpetuation without the æcidial stage. — It was demonstrated by the author (1894 and 1899) that the orange leaf-rust passes the winter in Kansas in the uredo stage, and, therefore, has no need of the æcidial stage. The latter stage, in fact, is not known to occur in this country. The uredo stage must also pass over the interval between harvest and fall seeding on volunteer wheat or wild grasses, which it is known to do. It would seem, therefore, that this rust might be in some measure controlled by the prevention of volunteer wheat and eradication of wild host plants. Such means, however, would require concerted action of farmers over a wide area of country, and even then might be found impracticable.

The over-wintering of the uredo stage of the black stem-rust has not been so well established, though it is thought to occur on a few wild grasses, especially wild barley, even as far north as southern Minnesota. Certain investigators believe the results of their experiments show that the black stem-rust and yellow rust may be carried over in the seed. These results of few experiments have not yet been confirmed by others. It is well known, however, that the black stem-rust continues its existence, in some instances, where there is no barberry bush within 100 to 1000 miles, and, as before stated, the yellow rust has no æcidial stage yet discovered.

558. Rust-resistance. — That certain varieties of cereals are affected with rust more quickly and severely than others is a fact well known to the cereal-grower. Careful trials of many varieties at several points have revealed striking differences in this respect. To make use of these varieties, or, if they are not otherwise good, to employ them in breeding, promises at present to be the best means of avoiding damage by rust. Just what this resistance is has not yet been satisfactorily determined, but Ward, Biffen (1907–08 b), and Stakman (1914)

b a

Fig. 157. — Resistance of durum wheat (*a*) to rust, compared with common wheat (*b*).

maintain that external morphologic characters have little or nothing to do with it. Biochemic investigations are needed in connection with this question.

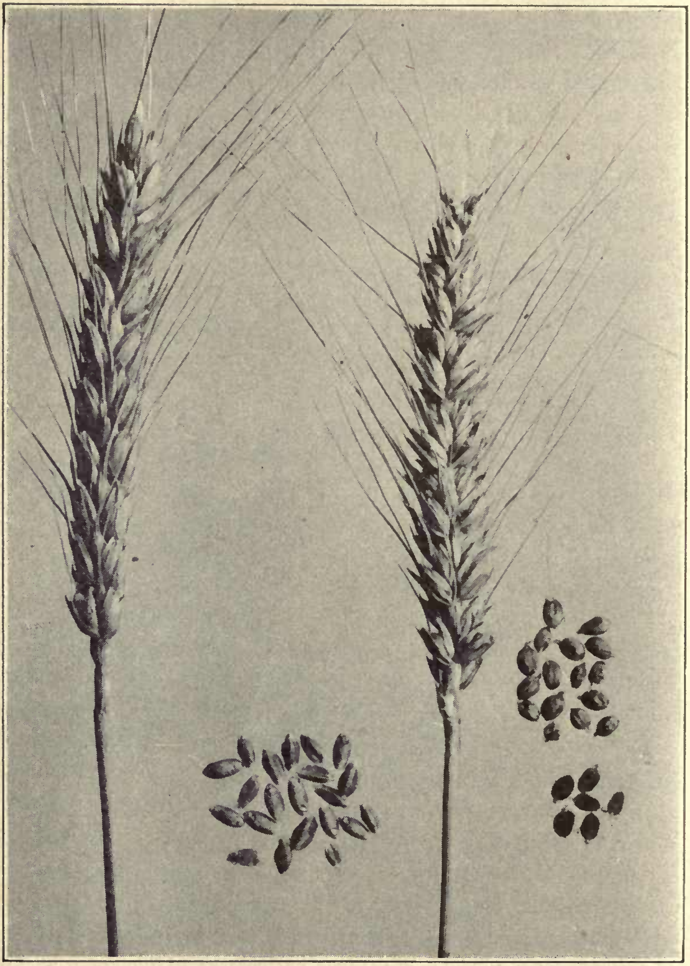
Some of the existing wheat varieties which already have been found to be strongly resistant to rust are Khapli and U. S. C. I. Nos. 1522, 1524, and 1526 emmers, Iumillo, Kubanka (C. I. No. 2094), and Arnautka durums, and a variety of einkorn (C. I. No. 2433) (Fig. 157). A few hybrids also have been produced of rust-resistant durums with varieties thought to be better milling wheats, which in the tests so far made appear very promising. Milling and baking tests with some of these show them to be of good quality.

Rust-resistance varies greatly geographically, and depends also upon the kind of rust. Varieties resistant in one locality may not be so in another. Varieties that escape rust by ripening early must not be confused with rust-resistant varieties.

Cereal Smut Diseases

For a long time no distinction was made between rusts and smuts, and both these, as well as some other parasitic fungi, were referred to as mildews or blights. Finally, Tull in 1733 pointed out specifically the bunt of wheat, saying, "Smuttiness is when the grains of wheat instead of flour are full of a black stinking powder." Tillet, over twenty years later, distinguished the two types of wheat smut, describing one under the name "la carie" and the other as "le charbon."

559. Bunt or stinking smut of wheat (*Tilletia tritici*, Wint., and *T. fœtens*, Trel.). — This is the most important economically of all the cereal smuts. Brefeld made the most exhaustive study of it. He grew it in his Nährlösung or artificial culture, and worked out the details of its morphology and development. The 2 species of bunt differ in the fact that the one (*Tilletia fœtens*) has smooth resting-spores and the other has reticulated spores.



a c b

FIG. 158. — Sound and smutted spikes of Preston (Minn. 188) wheat: *a*, sound spike; *b*, smutted spike; *c*, sound kernels; *d*, smutted kernels; *e*, smutted kernels cut in halves.

Infection of the host takes place during the seedling stage, some time before the seedling emerges above the ground, from spores attached to the seed or in the soil closely surrounding the seedling. The presence of the fungus is not manifest until the wheat spike emerges from the sheath, and even then may be overlooked by the ordinary observer. When the spikes are maturing, the glumes of those infected stand somewhat apart from the smutted ovaries. On removing the glumes the infected ovaries are found to be grayish black in color, swollen and more spherical in form than the normal kernel. These bodies crush easily between the fingers to a powder, which is a mass of fetid spores, the chlamydospores, and are the last stage in the life-history of the fungus (Fig. 158). The limit of viability of these spores is not known, but Humphrey has germinated them after a resting period of 12 years.

On germination a germ tube is formed which develops a promycelium. From this is produced the second stage of the fungus in the form of sickle-shaped primary sporidia, usually 8 in number from each promycelium. These fuse in pairs, back to back, forming H-shaped bodies which may become detached. They germinate and give rise to secondary sporidia which are able to infect a germinating wheat kernel when in contact with it. If no susceptible host kernel is present, a crop of tertiary sporidia will be produced.

Bunt of wheat has received more study than any other cereal smut, and has been the cause of greater financial loss. In occasional epidemics the infection runs as high as 40 to 70 per cent of the crop. Such losses are, however, in most places unnecessary, as the seed treatments for this smut are usually very effective. The annual loss from bunt of wheat in the United States is reckoned at ten to twenty million dollars. In 1902, in the state of Washington alone, it is estimated that wheat bunt caused a loss of two and one half million dollars.

560. Loose smut of oats (*Ustilago avenæ*, Jens.). — This smut occurs wherever oats is grown, and in this country was probably once the most serious pest of the oat crop. Now much loss is avoided by seed treatment.

FIG. 159. — Covered smut (*a*), and loose smut (*b*) of oats.

The presence of this smut in the field may be detected by the fact that infected plants are usually shorter than healthy plants, and the smutted panicles, instead of spreading and drooping, are considerably shortened, erect, and more or less constricted. Examining the infected panicle closely, it is seen that instead of each flower giving rise to a normal oat kernel, the entire flower and even glumes are converted into a mass of loose, easily distributed smut (Fig. 159 *b*). Usually all panicles of a stool are diseased. Occasionally the upper portions of certain panicles are sound while the lower portions are entirely destroyed by the fungus. The loose smut mass is found on microscopic examination to consist of myriads of brown resting-spores, which continue to be viable for at least 7 years. When the smutted grain is sown, if not treated with a good fungicide, the conditions which favor the germination of the seed also favor the development of the fungus. Infection takes place during the seedling stage of the host, and apparently at no other time, so in this respect the fungus is similar to wheat bunt.

On germination the spores produce a germ tube which divides into 3 or 4 cells, each of which develops a single conidium. These conidia germinate and produce narrow, elongated germ tubes, which, if near or lying upon the oat seedling, will infect it. Within the host the parasite attempts to grow in proportion to the vigor of the former. In vigorous plants the mycelium is perhaps most abundant at the nodes, and it appears that in some instances the rapidly growing tissue may actually grow away from the invading fungus. However, once established in the tissues of the growing point, it is hardly possible for the host to escape its enemy. A microscopic examination of the immature ovaries of an infected plant will show that instead of being filled with normal host tissue they contain a mass of fungus mycelium more or less knotted and of indefinitely appearing structure. Later they will be found filled with resting-spores.

a b

FIG. 160. — Sound spike (*a*) of common barley, and spike (*b*) affected with covered smut.

The damage from oat smut in Wisconsin was estimated to be four and one half million dollars annually. It is stated that in Ohio 6 per cent of the oat crop has been damaged by smut. All this loss can be prevented, and is being avoided more than formerly.

561. Covered smut of oats (*Ustilago levis,* Magn.). — In addition to the disease known as the loose or naked smut of oats, this cereal is more or less subject to epidemics of what is commonly known as the covered smut of oats caused by another species of the same genus. In recent years it has been observed that this type of oat smut is far more common and widespread than was formerly supposed. It is difficult to distinguish it by casual observation from the naked or loose smut, though, as a rule, the smut masses or balls are inclosed by the outer glumes of the florets, whereas in the case of the loose or naked smut, the whole spikelet is generally destroyed, including the outer glumes. The spores of the covered smut are smooth, whereas those of loose smut are minutely echinulate. The covered smut may be controlled by the same method of seed treatment recommended for the prevention of loose smut (Fig. 159 *a*).

562. Covered smut of barley (*Ustilago hordei*, Kell. & Sw.). — This smut, while it is very generally distributed throughout barley-growing districts, is not responsible for such great losses as is the loose smut of oats. Because of its manner of development, it is frequently overlooked even when present in considerable quantities. It resembles, in its life-history, the smuts of oats in many respects, and, like the latter, infects the seedling of the host. If the smut is present when barley is sown, and suitable conditions prevail, the spores will germinate and produce conidia, which will infect the young seedlings while they are still very small and beneath the soil. The parasite grows with the host, and finishes its development in the spikelets of the barley. These diseased ovaries remain closed and are not broken, as in the case of a loose smut, until thrashing time, or even later (Fig. 160).

563. Prevention of bunt, oat smut, and covered smut of barley. — The most effective methods of seed treatment for these smuts are those involving the use of the fungicides formalin and copper sulfate. In Europe and in parts of this country, the Jensen hot-water treatment is used to good effect.

These fungicides are applied in two ways — by steeping the grain in the solution or by sprinkling the solution over the grain. Before beginning any treatment, all smut balls must be removed, as they will not be permeated by the liquid and may afterward be broken and infect the treated seed. A fanning mill will blow them out.

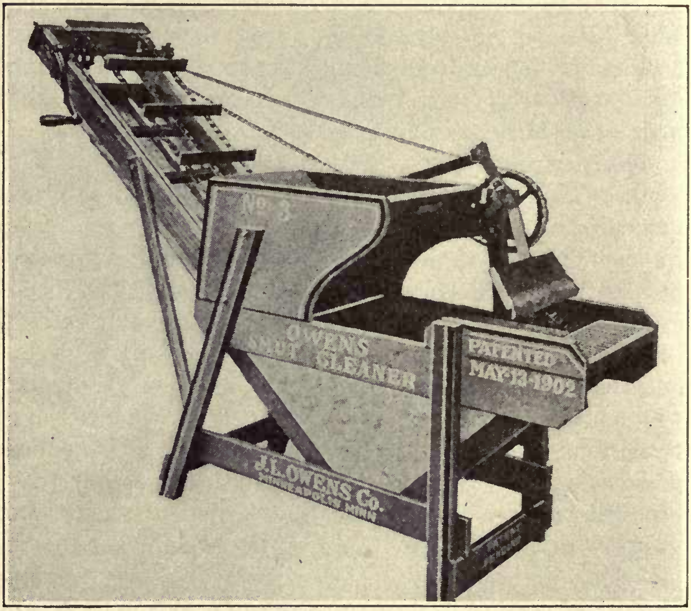


Fig. 161. — A smut-cleaning machine.

They will also rise to the surface of the fungicide solution and can be skimmed off, if time permits, during the steeping operation. Several smut-cleaning machines have been devised, which perform very well, and may be used before the steeping is done. One of these is shown in Fig. 161.

In Washington it is found that salt added to the copper sulfate solution increases its effectiveness. In both Oregon and Washington the viability of the treated seed is commonly observed to be much lower than that of untreated seed. For this effect a possible explanation is suggested in another place (434). It seems probable, however, that the condition more commonly favoring such injury is the cracking or other damage suffered by the grain in thrashing. At the Washington Experiment Station, experiments show that machine-thrashed grain is injured more as to germination than hand-thrashed grain. The kernels are cracked and broken by the machine, which allows the fungicide to injure them more than the sound kernels. The same difficulty as to treatment with copper sulfate is found in Germany.

564. Steeping in the fungicides. — The copper sulfate solution, for steeping, is prepared by dissolving 5 pounds of the sulfate crystals in 50 gallons of water. Time may be saved by tying the 5 pounds of crystals in a wide-meshed bag and suspending it overnight in 50 gallons of water. Hot water will dissolve the crystals more quickly than cold water. The formalin solution is prepared in the proportion of 1 pound of commercial formalin to 40 gallons of water.

When the solution is ready, 2 half barrels or vats are so placed as to permit one to drain into the other. The upper vat is then filled a little more than half full of the solution and the grain to be treated is poured into the vat or, what is better, a wire basket, and thoroughly stirred. This will insure the wetting of each kernel and will bring to the surface such smut balls as may not have been blown out by the fanning mill. The immersion period need not be longer than 10 minutes, following which the grain is piled in a heap and allowed to drain. It is then spread out and shoveled over frequently to facilitate drying. Steeping in the copper sulfate solution is done in the same manner, but the grain should not be allowed to remain in the solution longer than 10 minutes. A simple farm device for smut treatment is shown in Fig. 162.

Sometimes a copper sulfate solution of only 2 pounds to 50 gallons of water is employed, and the seed is soaked

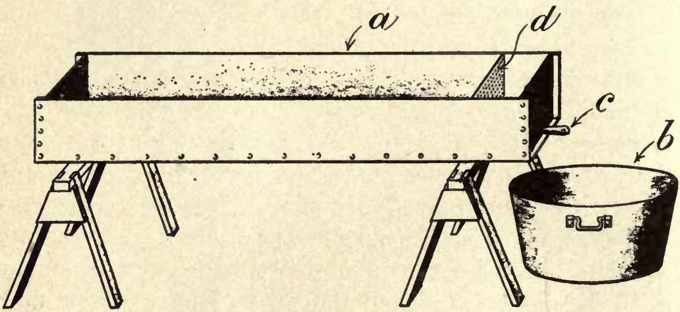


Fig. 162. — A simple farm device for seed treatment for smut.

for 12 hours, the solution being stirred occasionally, after which the grain is dipped for 5 to 10 minutes in limewater made in the proportion of 1 pound of quicklime to 10 gallons of water. The limewater treatment is applied to check the injurious effect of the copper sulfate upon the seed.

565. Sprinkling the seed with fungicides. — The sprinkling method involves much less labor than dipping, and is claimed to be just as effective. For this method the copper sulfate solution is prepared in the proportion of 1 pound of the crystals to 10 gallons of water, the whole quantity of grain is piled in a heap on a clean floor, and the solution is sprinkled on it with an ordinary sprinkling can. The grain is then shoveled over as quickly as possible, forming another heap, and back again, until every grain is evenly wetted. The grain should not be drenched but evenly moistened. It is afterward spread out to dry.

The solution of formalin for sprinkling is prepared in the same proportion as that for dipping. The sprinkling is done in the same manner as in the use of copper sulfate. The pile is left for 2 or 3 hours, covered with sacks, and then spread out to dry. Forty gallons of the solution will sprinkle about 40 bushels of grain.

566. Steeping in hot water. — The hot-water treatment is cheap and effective, but requires more care than the treatment with chemicals, and, therefore, with this method the careless farmer is likely to injure his grain. Nevertheless, it has one great advantage over the other methods in that no chemicals are necessary, and there is no risk of injury to the crop such as might follow the use of a chemical not of standard strength. Everything is under the farmer's control, but he must have a reliable thermometer.

All smut balls must be removed, as in other treatments. Two tubs or half barrels are used for holding the hot water, marked No. 1 and No. 2. The water in No. 1 is kept at a temperature of 125°–130°, but no higher; that in No. 2 at a temperature between 130° and 135°. No variation from these temperatures should be permitted. A supply of very hot water (or of steam) and of cold water must be always available. The temperature in the tub is raised by adding hot water or using a steam jet, and lowered by adding cold water. The water must be stirred, while adding either hot or cold water, in order to have all of the water at the same temperature. The temperature must not go above 135° nor below 125°.

The basket or sack of not more than a half bushel of grain is first dipped into tub No. 1 to bring the grain up to about the right temperature, so that when it is put into tub No. 2, the temperature in that tub will not be too much lowered. The basket is kept in No. 1 about a minute,

FIG. 163. — Increase of barley smut in two years, without seed treatment.

raising and lowering it, so the water will get quickly to all of the grain. It is then transferred to No. 2 and left there 10 to 15 minutes, but must not remain longer than 20 minutes. There again the basket must be raised and lowered frequently, so the water will permeate all the grain. After treating in No. 2, the basket is taken from the tub, allowed to drain a little while, and the grain is then spread out to dry on a clean floor or canvas (Freeman and Stakman, 1914, pp. 21–22). In Fig. 163 is shown the increase in smut that will occur in barley, in 2 years, without treatment.

After any treatment the seed must not be allowed to sprout or mold, and should not be exposed to a freezing temperature while still swollen. In sowing allowance must be made for the swelling of the seed by sowing more to an acre. All sacks and bins must be kept thoroughly disinfected. All new seed, after removal of weed seeds, should be treated for smut.

567. Smut in the soil. — Even for bunt the treatments above described are only of value where there is a smut-free soil. In the Columbia Basin district, where much of the harvesting is done with the header and combined harvester-thrasher, or even where the self-binder is used, it has been determined by actual count that as high as 34,800 smutted spikes to an acre have been left on the field. These spikes, on being broken by the disk harrow and other implements, are the direct means of distributing myriads of viable smut spores in the soil, ready to infect the new seed when germinated, without regard to seed treatment. As these machines cut high, and the smutted plants are short, it is easy to miss them in harvesting. To clear the soil of these spores, crop rotation must be substituted for continuous cropping and summer fallow.

568. Loose smut of wheat (*Ustilago tritici*, Rostr.). — One reason that progress in treatment for cereal smuts has not been more rapid is that we have not been in possession of the facts about their life histories. For many years it was supposed that this smut and the naked smut or barley were capable of infecting the host seedling or were able to infect the blossoms in such a way as to result at once in the formation of smutted ovaries. The thorough researches of Brefeld and Hecke revealed the true

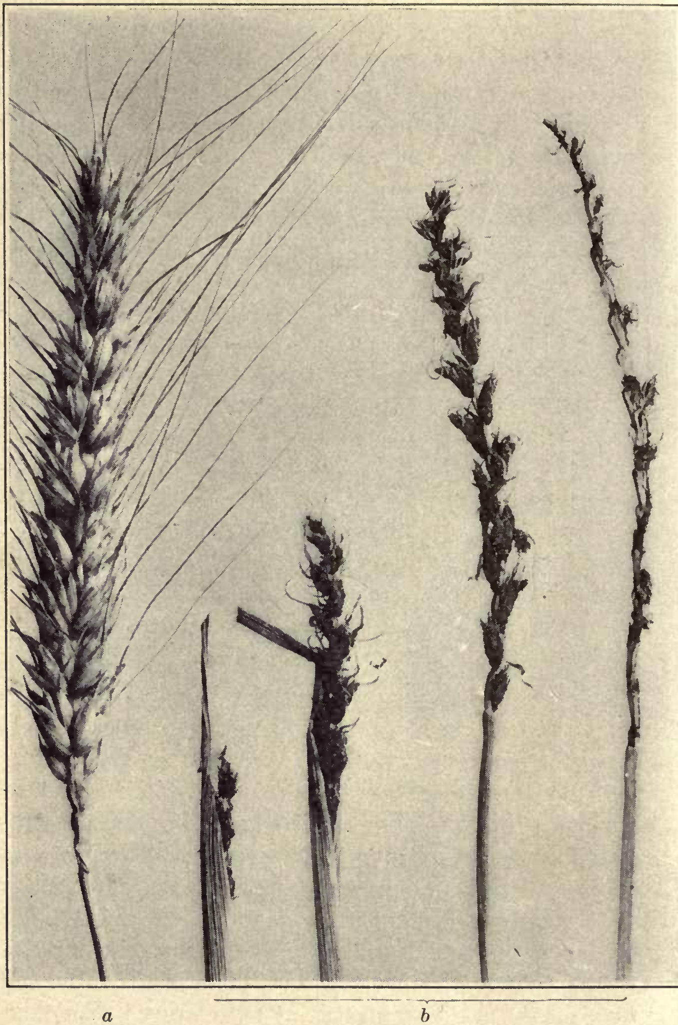


Fig. 164. — Pride of Genesee wheat: *a*, sound spike; *b*, spikes affected with loose smut.

conditions. It was shown that infection by these smuts takes place during the period of blossoming, the spores falling directly upon the stigmas, there germinating. Instead of producing primary and secondary conidia, these germinating spores directly infect the young ovary, but do not seem to interfere seriously with the completion of its development. The smut resulting from this infection, therefore, appears in the next year's crop. However, if the seed is microscopically examined latent hyphæ of the parasites will be seen. After planting the seed in the spring, these latent hyphæ resume their growth and infect the growing point of the young plant. Later the spores from the resulting diseased spikes are distributed just in time to fall on healthy wheat spikes when they are in blossom and again cause infection of the seed of the next crop. Stools of wheat infected with loose smut may be readily detected, as they are usually shorter than the healthy stools and have a purplish color (Fig. 164).

569. Naked smut of barley (*Ustilago nuda*, Kell. & Sw.). — As in the case of loose smut of wheat, this smut develops rapidly within the tissues of the host, and matures its spores at a time sufficiently early to insure infection of the blossoms of healthy plants. The spores lodging directly upon the stigma, germinate in a manner simulating that of the pollen grain, the germ tube entering the ovary directly without the previous development of conidia. As in the loose smut of wheat, the invading mycelium lies dormant in the tissues of the seed, but renews its growth the next spring after germination of the latter, and matures in that year's crop (Fig. 165).

570. Control measures. — Various methods of treatment for these last-described smuts of wheat and barley have been tried, usually without success. Chemical

FIG. 165. — Loose smut of barley: on left, sound spike; on right, two smutted spikes.

fungicides were regarded as particularly unsatisfactory, as they appeared to be incapable of penetrating the rather impervious layers of the grain tissue without seriously injuring the viability of the kernels themselves. Recently, however, some experiments involving the use of copper sulfate and formalin solution, conducted at the Wisconsin State Experiment Station, demonstrated the fact that these fungicides are effective in preventing the loose smut of barley, but apparently are much less so in preventing the loose smut of wheat. Jensen's modified hot water treatment, as improved by Kellerman and Swingle, Freeman and Johnson, and Appel and Riehm, seems best suited for the prevention of this type of smut. The essentials of the treatment are as follows: —

The seed is soaked in cold water in tubs, barrels, or vats for 4 or 5 hours. The soaking must not exceed 6 hours, nor be less than 4 hours. It is then removed, immediately drained, and treated in hot water. Wheat is treated for 10 minutes at 129° and barley for 13 minutes at 126°. If the temperature rises to 127° in treating barley, the time of treatment must be reduced to 10 minutes, and to 5 minutes if it rises to 129°. Otherwise the seed will be injured. In a similar manner, when treating wheat, if the temperature rises above or falls below 129°, the time of treatment must be diminished or increased accordingly. By previously soaking the grain in cold water, thereby causing it to swell slightly, and also causing activity of the latent fungous hyphæ, it becomes unnecessary to subject the seed to water of so high a temperature as when treated without the previous soaking, and there is, therefore, less danger of injuring its vitality.

Much time and labor may be saved by treating enough seed for a seed plat (191) and sowing the large field with seed taken only from the seed plat.

571. Effect of time of seeding. — The time of seeding of spring wheat and barley had no effect on loose smuts in experiments conducted at the Minnesota Experiment Station. Very late sowing of winter barley at Amarillo, Texas, however, resulted in almost no smut, while sowing at the ordinary time or earlier in the season resulted in a large amount of smut. This variation was probably due to a difference in optimum temperature for the internal smut and the seed germination.

572. Smut-resistance. — Varietal differences in susceptibility to loose smuts have been observed in both wheat and barley, but no immunity of particular value has been discovered, except that Manns reports his inability to infect Poole wheat with this smut because of "this variety's resistant qualities to the smut disease." The Burt and the Early Ripe oats are practically immune from loose smut of oats. In Australia, Medeah, Florence, and Genoa, wheat varieties are considered to be somewhat resistant to wheat bunt (206).

Miscellaneous Cereal Diseases

In recent years some other diseases of cereals have been found to be of considerable importance which were formerly little studied in this country. Still others are better known, but are of local or occasional interest. These are usually caused by those plant parasites known as imperfect fungi, because of the fact that in many cases their complete life histories are not known.

573. Wheat scab (*Gibberella saubinettii,* Sacc.). — This is the best known of the minor cereal diseases to the ordinary observer. It has usually been described heretofore under the name of its conidial stage (*Fusarium culmorum*, Sacc.). The work of Selby and Manns (1909) indicated the probable connection of this stage with the perithecial stage (*Gibberella saubinettii*), and showed by cultures that the forms found on wheat, oats, barley, rye, emmer, spelt, and clover are the same organism. In nature, the

a b c

FIG. 166. — Effect of artificial infection of oat seedlings with the scab fungus: *a*, inoculated with spores from wheat grass; *b*, check, not inoculated; *c*, inoculated with spores from oats.

scab is more common on wheat, but sometimes occurs to a serious extent on oats. It shows chiefly on the spike or panicle, and, when fruiting, becomes pinkish in color from the color of the conidiospores *en masse*.

Further studies of Selby and Manns show that the scab fungus survives as an internal infection in scab-infested kernels of wheat. On germination of these diseased kernels, the resulting young plants of the new crop become infected and many are killed before a month old. Considerable loss was caused in this manner to the wheat crop in Ohio in 1907. The flowering period is the time when the greatest infection takes place. The developing kernels are immediately injured from direct infection, and not from infection in the seedling reaching the spike through permeation of the stem, as in loose smut of wheat. It is found, however, that an abundance of conidia is produced on the dying roots of infected seedlings, and this is a source from which, no doubt, later spores are carried by the wind or insects and reach the spikes at flowering time. Johnson conducted inoculation experiments with this fungus on oats in sterilized soil, and was able to entirely destroy oat seedlings from artificially infected seed (Fig. 166).

Seed treatment for smut by the formalin method will also kill many adhering spores of scab. Thorough screening and cleaning with the fanning mill will not only eliminate small kernels, but will blow out the scab-infected kernels, which are always lighter.

574. Stripe disease of barley (*Helminthosporium gramineum,* Rabh.). — This disease was so called by Rostrup because of the long, discolored stripes produced on the leaves, leaf-sheaths, and culms. Prillieux has given the name helminthosporiosis to this and the other diseases caused by Helminthosporium. Inoculation experiments thus far have shown that *H. gramineum* affects barley only and will not transfer to other cereals. The disease caused by *H. gramineum* was studied by Pammel (1909), who called it the "yellow leaf disease" of barley and showed that the infection is transmitted through the germinating seed. Later Bakke (1912) reported the same manner of transmission of infection as a result of his investigations of another species (*H. teres*) which he calls "late blight" of barley. Johnson (1913) has studied *H. gramineum, H. teres,* and *H. sativum,* and found that

H. teres, on culture media, grows radially from the point of inoculation; while *H. sativum,* on culture media, grows in a rotary, counter clock-wise manner. The latter causes better defined and darker lesions on the leaves of the barley plant, and is now recognized as the cause of the "spot blotch" disease to distinguish it from *H. teres,* the cause of the "net blotch" disease.

Mortensen recommended, as a partial method of control, the Jensen hot-water treatment at a temperature of $124\frac{1}{2}°$, following an immersion of 3 to 10 hours in cold water. Störmer adopted the use of a solution of formalin $\frac{1}{10}$ per cent strength, and an immersion period of 15 minutes. Ravn, who made an exhaustive study of these fungi in Denmark, found that plants of barley seeded in the cool months of spring or autumn were much more affected than those seeded when the average temperature was higher, July and August seedlings being almost free of the disease. Soaking the seed in hot water or in a solution of potassium sulfid appeared to greatly reduce the disease. Appel and Riehm (1911) have found that certain fungicides used for preventing smuts, such as hot water and the mercuric salt of monochlorophenol, may be used to great advantage at the same time for preventing or controlling stripe disease and wheat scab.

575. Cereal anthracnose (*Colletotrichum cereale,* Selby and Manns). — This disease, fully described by Selby and Manns (1909), is found on wheat, rye, oats, emmer, redtop, timothy, and other grasses. Though rather widely distributed, and capable of doing considerable damage, this fungus has not until recently been recognized in this country. The injury is done in shriveling of the grain.

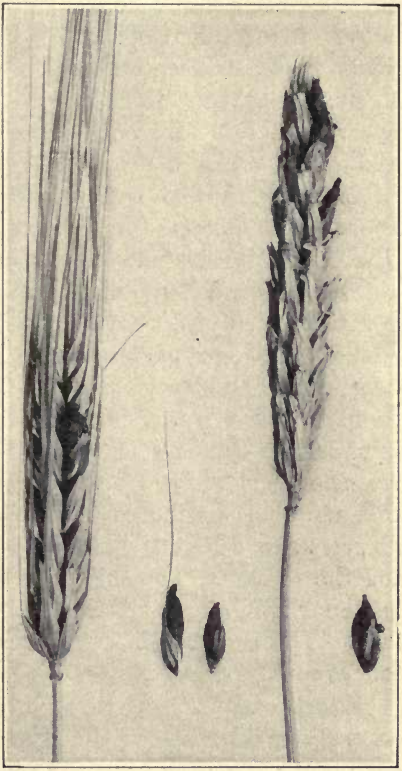
The mycelium consists of short septate hyphæ, dark brown in color, later forming acervuli varying from about 30 μ to 1 mm. in diameter. Upon these are developed the conidiospores, which in turn produce the ellipsoidal, hyaline, guttulate spores.

Fig. 167. — Ergot on rye: *a*, spike with ergot in place of some kernels; *b*, ergotized kernels; above *b*, sound kernels.

This fungus is particularly injurious to rye. Its presence is shown by the permanent dying of those portions of the spikes above the point of attack, resulting in almost total loss of grain in these dead portions. It also attacks the roots and basal portions of the rye culms, producing a blackened appearance of the affected parts. On wheat there is no special attack of the spike and less root attack, but there is a premature whitening and ripening of the plant.

The spores of this fungus are easily disseminated through seed grain. These will be readily destroyed by the formalin seed treatment. There are no doubt other sources of infection, however, because of the occurrence of the fungus on straw and on the culms of grasses.

576. Ergot (*Claviceps purpurea*, Tul.). — This fungus is rather frequent on rye and barley. It occasionally attacks wheat also, and rarely oats. It affects the spike or panicle only (Figs. 167, 168).



a b c

FIG. 168. — Ergot: *a*, *b*, on six-row barley; *c*, *d*, on hooded barley.

The season's growth of the fungus ends in the formation of hard, purplish sclerotia, taking the places of kernels, and which resume active growth in the spring. After a few days of warm, moist weather, stromata become visible, and subsequent growth is rapid. These stromata bear the perithecia which inclose the numerous asci or spore sacs. Infection takes place at flowering time, when the young ovaries of the host are most susceptible. The fungus then develops rapidly, producing what is known as the honey-dew or conidial stage. These conidia are probably largely distributed by flies, gnats, and other insects, which have a fondness for sugar. Later the young sclerotium forms rapidly, and is completed when the grain is mature.

Ergot causes no extensive damage to the crop, but in the sclerotia are produced poisonous compounds causing, when these are accidentally eaten in sufficient number, a disease known as ergotism. Abortion in stock may be caused if much of it is eaten.

577. Blade blight of oats. — For twenty-five or thirty years, there has been observed a leaf blight of oats in the Eastern area of the United States showing to some extent every year, but apparently more prevalent during a wet spring. There is a discoloration of the leaves, ranging from yellow, through red to brown, but no disturbance in the tissue to indicate the presence of any ordinary fungus. The only critical study of this blight, until very recent years, was made by Galloway and Southworth. In this study 200 cultures were made, in a dozen different media, and two bacteria were isolated, one of them being very abundant. The disease was produced, in 50 or more cases, by inoculation with the more abundant organism. After a long period of time, Manns (1909) reopened the subject, called the disease blade blight of oats, and attributed it to two species of bacteria. Experiments showed that aphides are means of carrying the disease. The chief weather conditions favorable to the blight are rains, excessive humidity, and cloudiness. The greatest loss to oats from the blade blight is a lowered vitality caused by injury to the blades and their final collapse. There is also a smaller loss resulting from direct blasting of the panicles due to the contact with them of sheath lesions. This occurs when the panicle is emerging. A similar bacterial disease is said to occur on barley.

578. Take-all or foot disease (*Ophiobolus graminis*, Sacc.). — This disease is not yet known to be prevalent in this country, but has recently been observed, and may soon become a serious trouble. It has been quite injurious in Australia for a long time, where it is universally known as "take-all." In England it is said to cause a loss ranging from $\frac{1}{50}$ to half of the crop. In France and Germany it is serious, and known as "foot disease." For some time the fungus could not be identified, as the fruiting stage usually is produced during the winter months on stubble, and, therefore, escaped observation. There are two distinct aspects of the disease, known as "take-all" and "white heads." The condition called "take-all" occurs at an early stage of growth of the host, causing the latter to become yellow and often die before a culm is formed. Infection occurs at the base of the plant, which appears blackened. The condition of "white heads" occurs when the host has attained full growth. The spikes are of normal size, but the grain either remains undeveloped or is very much shriveled. The spikes and straw appear to be bleached or prematurely ripened, the entire plant is found to be dry and dead, and for 2 or 3 inches at the base of the culm, is blackened as if charred.

The earlier varieties of wheat are said to be most susceptible, and red wheat least so, but none is immune. Land that has grown a diseased crop is certain to be infected, as the fungus is confined to the base of the culms, and is therefore left in the stubble. Crop rotation is important, where this fungus is bad.

579. Soil sickness. — There is no doubt that many of the imperfect fungi, long considered as injurious pests in the Old World, are recently becoming more prevalent in this country, and will be serious pests here. Naturally they are more common where there is continuous grain cropping. Bolley (1913) has considered a number of these fungi together as being largely responsible for diminished yields of grain in the Plains states, giving the name of " soil sickness " to the conditions of the land thus brought about. Just one thing, crop rotation, will be the chief means of overcoming these conditions, but there should be added, seed-treatment, seed selection, drainage (where needed), and the use of an intertilled crop.

CHAPTER XX

USES OF CEREALS

Cultivated cereals are used chiefly in two ways, either (1) as feed for live-stock or (2) as human food. There are a few miscellaneous uses.

Cereals as Feed for Live-stock

With the exception of oats the small cereals are not thought of as feed for live-stock; but the total value of bran, shorts, and other by-products of milling, malting, and distilling, disposed of in that way, in addition to cereal hay, amounts to a large sum annually. The miller's total profits are often governed largely by the market for by-products as feed.

580. Cereal crops for hay. — Considerable rye is used for hay in the New England and middle eastern states. In the southern states, a mixture of oats and vetch is employed for both pasture and hay. More grain is grown for hay in the western states, that is, west of the Great Plains, than in any other part of the country. Wheat, barley, and rye are especially handled in this manner. In the Columbia Basin of Washington, almost the only hay in many places is wheat. The farmer often gets his hay from the edges of his wheat fields. The wheat fields are "trimmed up" 10 days or 2 weeks before harvesting begins. This trimming is a cutting of 2 or 3 swaths around the field, while the straw is still green. Many wheat raisers secure their entire hay supply in this way. When bearded barley is grown for the grain, a strip of wheat is often sown on the outside of the field to be cut for hay. Wheat straw is largely used as a winter ration for cattle, and often they have no other feed. Rye is an important hay crop in the West, and is particularly adapted for sandy land. Hooded barley is, however, the most generally preferred cereal crop for hay (Griffiths, 1903).

581. Time of cutting. — In practice, cereals are cut for hay, in this country, when the grain is nearing the "dough" stage. In Australia, where there is proportionally more wheat used for hay than in any other country, it is cut, at earliest, sometime after flowering or when the grain is near the end of the milk stage or even in the early "soft dough" stage. The usual commercial standards for quality in wheaten hay in that country are (1) a bright green color and (2) shriveled grain. The highest quality will be secured when the kernels are full size, but still in the milk stage. At this stage the spikes, culms, and leaves will all be about equally nutritious. Investigations of this subject have been made by Perkins, Phillips, Spafford, and May (1912) at the Roseworthy Agricultural College, in South Australia. They determined that the heaviest yields of wheaten hay are secured if cut when the grain has fully reached the dough stage. However, in quality, it will be more or less indigestible and will not be equal as a feed, weight for weight, to hay cut at earlier stages, and will be dry and bleached and carry a large proportion of grain.

582. Grading of cereal hay. — Certain hay associations in this country have adopted rules governing inspection of hay and uniform grades of cereal hay, as follows, which are in use at about twenty-four important hay markets: —

No. 1. Straight rye straw. — Shall be in large bales, clean, bright, long rye straw, pressed in bundles, sound, and well baled.

No. 2. Straight rye straw. — Shall be in large bales, long rye straw, pressed in bundles, sound, and well baled, not good enough for No. 1.

No. 1. Tangled rye straw. — Shall be reasonably clean rye straw, good color, sound, and well baled.

No. 2. Tangled rye straw. — Shall be reasonably clean, may be some stained, but not good enough for No. 1.

No. 1. Wheat straw. — Shall be reasonably clean wheat straw, sound, and well baled.

No. 2. Wheat straw. — Shall be reasonably clean, may be some stained, but not good enough for No. 1.

No. 1. Oat straw. — Shall be reasonably clean oat straw, sound, and well baled.

No. 2. Oat straw. — Shall be reasonably clean, may be some stained, but not good enough for No. 1. (McClure, 1912, pp. 30–32.)

583. Varieties adapted for hay are, first, those that have broad leaves and succulent culms, and make the largest vegetative growth in proportion to weight of kernels. They should grow rapidly and tiller extensively, and should be awnless. Almost any awnless common or club wheat is suitable. Durum wheats are not suitable, though good for pasture. Of the barleys, the hooded varieties are best. Abruzzes rye is better than the more slender, narrow-leaved rye varieties. In Australia, it is common to distinguish between hay varieties and grain varieties of wheat. Examples of the former are Firbank, Baroota Wonder, Currell No. 7, Majestic, Thew, Triumph, and Zealand. The broad-leaved, heavy-strawed oat varieties are better for hay than such kinds as Sixty-Day and Burt.

584. Wheat for silage. — In the western states, during the dry summer months, there is great need of a succulent feed for stock before corn can be used. This need appears now to be met, at least partially, in the form of wheat as silage. Wheat has already been employed in this way successfully in eastern Washington. Jones Winter Fife is said to be the best variety, for the purpose, in that state. Usually vetch is sown with the wheat, and the two crops harvested together, while green, at the period when the wheat kernels are in the "milk" stage. If the wheat is grown alone, it may be cut and bound with the self-binder, but if it is grown with vetch, a mower must be used, as the vetch tangles the crop. The wheat is cut into half-inch lengths in preparation for the silo. It is spread evenly in the silo, thoroughly tramped, and is sometimes wet down with water during the filling, to exclude air.

585. Feeding the whole grain. — The practice of selling all the small grains, except a small quantity of oats reserved for the draft horses, and feeding corn, becomes so fixed a habit that the value of the former for stock feeding is usually not fully appreciated. In years of a large crop of wheat or other small grain and correspondingly low prices, the profits in feeding are made more manifest. Such a condition occurred in 1893–4 with respect to the wheat crop. In Kansas alone, over four million bushels of wheat were fed to farm animals in 1893, more than 16 per cent of the entire crop. From the experience of that and the following year it was concluded that (1) wheat is superior to corn, pound for pound, as a grain to produce healthful, well-balanced growth; (2) that mixed with corn, oats, or bran it is much superior to either alone for work horses; and that (3) corn is scarcely to be compared with it for feeding dairy cattle. It was found excellent also for hogs, but fed whole, without soaking, it is used at a disadvantage. If ground and made into slops, it is invaluable for suckling sows and for pigs before and after weaning (Coburn, 1894).

Chilcott (1894, pp. 4–5) decided that in South Dakota, wheat, at the price it was then bringing, could be profitably fed to hogs as an entire ration, but was better mixed with some other food. Later Chilcott and Thornber (1901) compared barley and emmer for fattening sheep and lambs, the whole grain being fed, and found that barley was worth 50 per cent more a bushel for fattening lambs, as a single grain ration, than emmer, and gave about twice the profit in fattening sheep, that resulted in feeding emmer.

Faville (1909), at the Wyoming Experiment Station, determined (1) that barley as a feed may be used to advantage as a corn substitute, and (2) that corn and Scotch barley, when fed with alfalfa, were nearly equal in value for mutton production, with barley a shade the better.

586. Feeding the ground products. — While feeding the whole grain of small cereals has given excellent results, it is probable that soaking or grinding the grain will give sufficient further profit to cover more than the cost of the operation. Experiments of Shaw and Norton (1906) showed that the animal derives no benefit from grain which passes through the digestive tract unmasticated, and that even its viability is not entirely destroyed, as 4.3 per cent of the corn and 10.6 per cent of the oats germinated after such passage. The swallowing of whole kernels is, therefore, a waste of both food value and energy in eating.

The different cereal products used in stock feeding are the various chops of oats and other small grains mixed with each other or with corn, bran, shorts, ground screenings, and rejected wheat, and maltster's and distiller's by-products.

Henry, in a compilation of results of experiments at several stations, showed that the weight of wheat meal required to produce 100 pounds gain, in hog feeding, is several pounds greater than that required of corn meal. Ground wheat has a tendency to form in a gummy mass, adhering to the teeth of the animal in a disagreeable way, which trouble can be avoided by feeding it mixed with some other grain, as corn, oats, or Kafir.

In experiments by Georgeson, Burtis, and Otis with ground wheat, corn, and red Kafir for fattening hogs, wheat was found to be most effective, followed closely by corn. Equal parts of corn meal and ground wheat were better for pigs than either corn or wheat fed separately.

587. Experiments in North Dakota. — Shepperd and Richards (1906) reported that the average daily gain of steers, fed on a ration of $\frac{2}{3}$ ground barley and $\frac{1}{3}$ bran, was as high as gains made in other trials of corn as the exclusive grain ration. They also concluded from another series of trials that it is unsatisfactory to finish steers on a ration of rejected wheat and bran, but that this feed is excellent when made part of a feeding period, completed with a corn and bran ration. The same men concluded from two other series of experiments (1909): (1) that it is profitable to feed barley to hogs if pork is selling at an average price; (2) that when mixed with shorts as a fifth part by weight it required 18 per cent more barley than corn to produce the same gain in feeding pigs; but (3) the carcasses of pigs fed barley and shorts showed a greater distribution of lean and firmer flesh than those of pigs fed corn and shorts; (4) that ground rejected wheat will produce good gains when fed to hogs in connection with shorts; (5) that it requires 8.9 per cent more rejected wheat than corn to produce the same gains; but (6) the quality of pork produced is better than that produced by corn.

588. Distiller's by-products. — In the manufacture of spirits or whisky from the different grains, corn, oats, rye, and barley, there is a residue in the form of distillery slop, which is dried and sold as distiller's dried grains of commerce. They consist of the hulls, the germs, the protein, and the less soluble carbohydrates of the original grains, and are somewhat sour to the taste and smell because of the fermentation. The larger the proportion of corn in distillery mashes the higher the grade of the grains produced. Rye whisky grains are the poorest. Armsby and Risser (1905) investigated the value of these dried grains as a feed for dairy cattle, in comparison with cottonseed meal. Five pounds of distiller's dried grains caused a slight increase in the milk yield over that produced by 3 pounds cottonseed meal and 2½ pounds corn meal. The distiller's grains also caused a marked increase in the fat content of the milk. The butter produced by distiller's grains was not quite as good as that produced by the cottonseed meal ration. The distiller's grain ration was more costly than the cottonseed meal ration.

589. Grain as poultry feed. — The grain of cereals is commonly fed to poultry. All the cereals are used, but wheat is commonly fed, of which usually the cheapest varieties are employed. Some years ago large quantities of durum wheat were shipped to the eastern states for poultry feed, no doubt chiefly because of its cheapness at that time, though it is of excellent quality for the purpose. To furnish poultry with green feed in winter, sprouted oats is prepared for them. The oats is sprouted in flats in a warm room or in a greenhouse. The rapidly growing roots soon form a tangled mat of the oats. The oats is fed when the sprouts are 4 to 6 inches high. The rate of feeding is a piece of the matted oats and attached green stalks 6 to 8 inches square for each 100 birds a day. Sprouted oats is fed purely as a digestive stimulant, in winter, when other green feed is lacking, and not because of its intrinsic food value.

Cereals as Human Food

The cereals are employed in human consumption chiefly in four ways: (1) as flour and meal for bread, (2) in the form of edible pastes, (3) as breakfast foods, and (4) in malting and distilling.

590. Development of milling. — Since the most ancient times some kind of bread has been made from one of the small cereals, and in the Western Hemisphere from maize. For a very long time the grain was ground on a flat stone, hollowed at the center, over which was rolled another stone of rounded oblong shape, tapering at each end. About the beginning of the Christian era the circular revolving mill stones were first used. The first stones were conical in shape, with a hole at the top into which the grain was poured. The stone was turned by slaves or a donkey. Later flat stones were employed, and finally the highly finished stone burrs, which prevailed until about 35 years ago.

In 1878 a small roller mill was established in Minneapolis, said to be the first complete roller mill in the United States. At the close of 1877 there were 197 runs of stone in the 21 Minneapolis mills. In a few years all plants in Minneapolis and all the principal mills elsewhere in this country were roller mills.

591. The modern roller mill. — Rolls cause a gradual crushing and flaking of the kernel, instead of pulverization, as with stone burrs, and thus allow a more perfect separation of particles afterwards. They were at first made of various materials, chiefly porcelain, but finally the present perfectly formed steel rolls were adopted. These rolls are usually 9 inches by 30 inches in size, and are set in pairs in a cast-iron frame. They revolve toward each other, from above, at a high speed but with a differential motion, that is, one roll revolves much faster than the other. The rolls handling the first stock of wheat and bran are corrugated with light furrows, slightly spiral in direction. This coarse stock goes through 5 processes, called "breaks," the corrugations increasing in number and diminishing in depth in each succeeding pair of rolls. The finer stock called "sharps," from each break, not used as flour, passes to smooth rolls called "crushes," for further reduction. There are usually 6 or 8 consecutive reductions on smooth rolls. After each reduction the stock falls into a sifter which separates the material, some to be re-ground, some to be sacked. There are many kinds of sifters. Where the stock is coarse, angular, and sharp, wire cloth is used; when it gets softer, silk cloths are preferred.

592. The milling process. — The entire milling process, in detail, is complicated, and entire books are written on the subject. It consists of the following steps: —

I. Preparatory process: —
- A. Cleaning
- B. Scouring
- C. Tempering

II. Milling proper: —
- A. Breaking
- B. Scalping
- C. Grading
- D. Purifying
- E. Reducing
- F. Dressing

A brief statement of these different steps has been made by L. A. Fitz, and kindly permitted by him to be inserted herein as follows: —

Cleaning. — The wheat is usually unloaded at the elevator and given a preliminary cleaning over the receiving separator. This machine is simply a large improved fanning mill which, by means of screens and air blast, removes the coarse material, such as sticks and straws, and also the fine material, consisting mostly of weed seeds and dirt particles. The final cleaning is given over an improved type of fanning mill, known as a "mill separator," and this removes practically all of the remaining foreign material.

Scouring. — However, there still remain fine dust particles clinging to the kernels, especially in the crease and the brush, and these are removed by "scouring." In this process the kernels of wheat are thrown with considerable force by sets of beaters against the slightly roughened sides of the scouring case and also against each other. The dust particles, fine hairs of the brush, and small bran particles are thus loosened and then removed by strong suction of air applied at the top of the machine. All fine material removed from the cleaning and scouring machinery by air suction currents is conveyed through spouts to dust collectors. This prevents such material from flying about in the mill and becoming mixed in the flour.

Tempering. — After the wheat has been cleaned and scoured it may be necessary, in order to prevent the branny coat from grinding up fine and going through the bolting cloth into the flour, to add to it a little moisture either as water or steam, or even both. This is called "tempering" the wheat. Tempering is especially necessary with the hard wheats because of their more brittle character.

Breaking. — After these preliminary steps in preparing the wheat for the rolls, the real milling process begins. This process is a gradual reduction of the endosperm and the elimination of the branny coat and the germ. The cleaned and tempered grain is passed through between pairs of chilled iron rolls, which gradually reduce the particles to smaller sizes. The first pairs of rolls used contain fine grooves on the surface and are called corrugated rolls. There are usually from 3 to 5 pairs of these, and they are referred to as the "break" rolls. One roll of each pair turns about two and one half times faster than the other, consequently this gives a sort of tearing motion instead of simply crushing or squeezing the particles.

Scalping and grading. — Each time after passing between a pair of rolls the "stock" (partially ground product) is sent through spouts to a sifter, where sieves of different meshes separate the particles according to size. This is called scalping and grading. The largest particles are "scalped off"; that is, do not go through the top sieve, but pass over the lower end to the next pair of rolls. After the coarser branny particles have passed through several pairs of corrugated rolls, usually from 3 to 5, the endosperm is practically all removed and the finished flakes of bran scalp off.

Purifying. — The smaller particles from the inner portion of the kernel are separated according to size by the other sieves, and those small enough to go through the fine silk bolting cloth are called flour, while those larger and granular, more closely resembling corn meal, are separated out and called "middlings." These are passed through machines, called purifiers, where light suction currents of air lift off the light branny particles and fluffy cellulose matter, until we have left "purified middlings."

Reducing. — Next comes the gradual reduction of these middlings until they become fine enough for flour. This is done by passing the stock between pairs of smooth rolls, each pair being set a little closer together so as to grind a little finer, and every time the stock is ground by a pair of rolls it is conveyed to a machine which separates out the fine flour. This may be done on what are called reels or flour dressers, hence the last step, "flour dressing."

593. Illustrating the process. — The accompanying diagram (Fig. 169) of a typical mill is inserted to make more clear, perhaps, the arrangement of apparatus and the passage of the grain from one machine to another through the different steps. Such a diagram, showing the movement of grain through the mill, is called a "flow sheet." The wheat cleaning processes are omitted for simplicity. The number of breaks and crushes and the number and arrangement of sifters, purifiers, reels, and dusters will vary in different mills. Following the diagram, in which the course of the grain is shown by continuous lines of arrows, it is seen that the grain is first crushed between the first break rolls (having in this case motions of 450

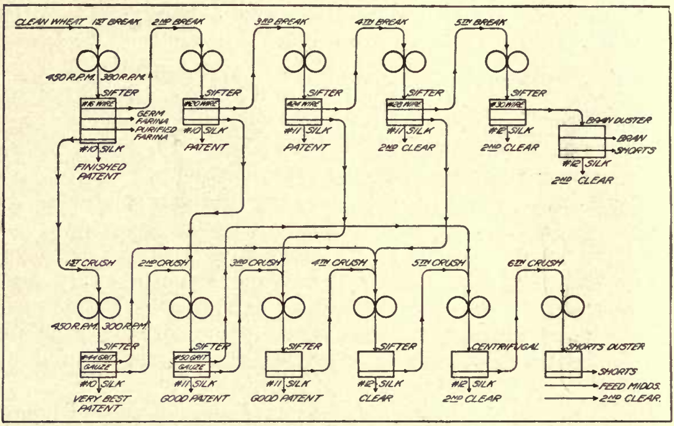


FIG. 169. — Sketch showing the principal steps in the gradual reduction of wheat to flour.

and 380 revolutions a minute), and then falls on a sifter with 3 sieves. The first sieve is of coarse wire No. 16. The material passing over this sieve goes to the second break. That which passes through falls on a finer wire, over which passes the germ and some other materials; while that which passes through falls on a No. 10 silk cloth, over which passes the "sharps" for regrinding in the first crush. That which passes through No. 10 is finished patent flour. With this explanation of the beginning, the remaining operations of the break rolls will be readily understood from the diagram.

The first crush rolls (in this case having 450 and 300 revolutions a minute) receive their stock from the first break, and, after crushing, drop it into a sifter with two sieves. The upper sieve is covered with No. 44 grits gauze silk. This takes out the coarser, poorer stuff, mainly bits of bran and germ, which is carried past the second and third to the fourth crush. That which passes through falls into a sieve of No. 10 silk, over which passes white middlings that go to the second crush; while that which passes through this sieve is the very best patent. The remaining operations of the crush rolls will be readily understood from the diagram (Davis, 1915).

594. Proportion and classification of products. — A good sample of Kansas Turkey wheat, properly milled, will yield products of approximately the following percentages: bran 12 per cent, shorts 14 per cent, total flour 72 per cent, which allows 2 per cent for loss in cleaning and scouring, and for evaporation of moisture and for elimination of dust particles in milling.

The total flour produced may be divided into different grades. The last 2 or 3 per cent of flour obtained at the tail of the mill is usually termed "low grade." If all the remainder of the flour is packed together, it is called "straight" flour.

On the other hand, if the flour made by the earlier reductions of the purified middlings is separated out, it is termed "patent" flour, and the remainder, made by the later reductions, is referred to as "clear" flour.

When made from the same lot of wheat, the "clear" flour will contain more gluten than the patent flour, but this gluten is not as good in quality.

In California, according to Davis (1915), 75 per cent of the total products consists of patent flour, clear and core (combined products of the fifth break and bran duster); 2 per cent is germ; and about 23 per cent consists of feed middlings, shorts, and bran.

595. Description of special products. — Since the milling process is not perfect, the stock at the end of the process, or "tail of the mill," contains a very large portion of fluffy, fibrous material and finely ground-up bran (bran-powder). A small percentage of poor or "low-grade" flour is separated from this, and the remainder, together with separations of somewhat similar character from nearer the beginning of the process, or "head of the mill," goes to make up what is termed shorts.

Graham flour is made by grinding the cleaned and scoured wheat without bolting or separating out any of the product. In other words it is unbolted wheat meal.

The whole wheat flour found on our markets differs from Graham flour in that the coarser particles of bran have been removed.

Wheat bran is the coarse outer coating of the wheat kernel as separated in the usual process of commercial milling from cleaned and scoured wheat.

Standard shorts, also known in some localities as "standard middlings," consists of fine particles of the outer bran, the inner bran particles, germ, and the offal or fibrous material obtained in the last reductions of the flour middlings. This material is frequently called "gray shorts." It may be subdivided into brown shorts (red shorts) and white shorts.

596. Flours of different wheats. — The chemical composition and physical condition of flours vary greatly in different wheats and in wheats from different districts.

The chief constituents of flour are starch and gluten, which are found in an average proportion of about 88 parts of starch and 12 of gluten. The gluten may run as low as 6 to 8 per cent in California Club wheat, and as high as 14 or 15 per cent in Kansas hard winter wheat, and even higher occasionally in durum wheats. Geographically considered, the wheats of the Great Plains and certain small parts of western intermountain districts have the highest gluten content, while those of the eastern, southern, and Pacific Coast states are lowest in percentage of gluten.

597. Essentials in the composition of flour. — In addition to starch and protein (forming the gluten), flour contains other carbohydrates and ash in small quantities which are of considerable value. The most important constituent is the gluten, both from the nutritive standpoint, as it is always present in limited quantity even when most abundant, and because of the necessary part it takes in the formation of the loaf of bread. Gluten is a complex substance, and, as previously stated (12) does not exist as such in the flour, but is formed from several proteins and the addition of water. The quantity of gluten is no more important in loaf construction than the quality, which is dependent upon the relative amounts present of its two main constituents, gliadin and glutenin. The normal proportion of these substances is about 65 per cent of gliadin to 35 per cent of glutenin. The former is the sticky element, and, if present in excessive quantity, causes the dough to become soft and "runny." If there is an excess of glutenin, the dough becomes too stiff and rises slowly. Guthrie (1896) demonstrated some time ago that it is the glutenin of the gluten that has the greater absorption of water. If, therefore, the gluten content of two flours is about the same, that one will be the stronger which contains the larger proportion of glutenin.

598. Blending. — In many mills flour is never made from one straight lot of wheat. In the locally grown wheat, some quality of the gluten is lacking or there is not a sufficient quantity of it, and some other wheat is mixed with it which will supply the lacking quality or add to the quantity. Sometimes as many as four or five different lots are mixed, or blended as usually stated, in order to secure a well-balanced product. Blending, though usually practiced by soft-wheat millers, is not always done solely to the advantage of the soft-wheat flour. It may improve the hard-wheat flour as well. Many millers who object to durum wheat flour alone for bread, agree that bread of the best quality is made from flour of blended durum and soft wheat, in which there is 50 per cent or more of the former. Blending of flours is practiced by the baker, particularly in seasons when the wheats are extremely variable.

599. Flours for special purposes. — No flour is the best for all purposes. While Kansas and Minneapolis flours are in the first rank for making loaf bread, Kentucky biscuits and pies from soft wheat flours will not soon be excelled in other districts. Different kinds of flour are required for biscuit and pastry from that which is best for loaf bread. The western white wheats are among the best for crackers and for certain breakfast foods. In making family flour, more attention is given to color than to expansion. Flour for bakers must have great strength, as their baking is a business matter, and strong flour carries more water in the dough than weaker flours, and water is cheaper than flour. For the same reason, a greater gluten content is required in bakers' flour, 13 per cent or more, while it may run from 10 to 12 per cent in family flour.

600. Increasing the protein content of wheat. — It is now rather generally agreed that a pure strain of wheat cannot be improved in protein content by selection alone, though such improvement is possible by the production of new strains through hybridization. Moreover, it is shown by Le Clerc, Thatcher, and others that protein content is not a heritable character, but an immediate effect of the environment. The greater effect is from climatic conditions, though a difference in soil structure affecting the water supply has much influence. Apparently the usual cause of an increase of protein is a shortening of the fruiting period. The matter may, therefore, sometimes be somewhat under the control of the grower. For example, late seeding of spring wheat, or, in California, practically spring seeding of winter wheat, will shorten the fruiting period by delaying the time of flowering, with much less corresponding delay of the time of ripening (289, 315–317).

601. "Yellow Berry" in wheat. — The same conditions just discussed should explain the presence of so-called "yellow berry," though there has been some differences in views expressed on this subject. The yellow kernels in a flinty wheat are mealy, like soft wheats, have a dull yellowish color, and contain less nitrogen. Such kernels may occur in spots in the same field with hard glutinous wheat. Headden (1915) believes the matter may be controlled in the use of fertilizers. Some condition possibly occurs lengthening the fruiting period, thereby decreasing the proportion of gluten to starch. It may be noted that the protein content of wheat is higher under dry-farming than on irrigated farms, and when a variety is transferred from irrigated land to arid land, its protein content increases.

602. Quality of different wheat varieties. — Of particular varieties of wheat, those usually having the highest protein content are Kharkov, Turkey, Kubanka, Fife, Arnautka, Preston, Velvet Bluestem, and a few others. Some of the most glutinous of the eastern semi-hard wheats are Dietz, Lancaster, Fulcaster, and Mediterranean. In Pennsylvania, Ohio, and Kentucky, the two best wheats apparently from all standpoints are Dawson's Golden Chaff and Fulcaster. Gardner (1910) reports that (1) Fulcaster contains one fifth to one fourth more protein than the Golden Chaff; (2) that the gluten of Fulcaster is relatively high in gliadin; (3) that bushel for bushel these two varieties give practically the same yield for flour; and (4) that the dough of Fulcaster flour is fairly tough and elastic, while that of the Golden Chaff flour is short and brittle.

Stewart and Greaves (1908) found that the protein content of Gold Coin wheat is less than that of other varieties grown on the arid farms. Ladd and Bailey (1910) concluded (1) that the hard wheats yield flours highest in baking strength; (2) that Turkey wheat grown in the Northwest did not yield flour of as good quality as the same wheat grown in sections of Kansas and Nebraska, although the flours of the former contained a higher average percentage of crude protein; and (3) that the quality of durum wheats is higher when grown in the drier sections.

603. The edible pastes (in France called pâtes alimentaires) made from wheat include macaroni, spaghetti, and vermicelli, all of which are simply different forms and sizes of the same product, and certain other pastes, including noodles, to which eggs are added. The manufacture of these pastes was originally an industry confined chiefly to Italy, where also the durum wheats from which the pastes are made were grown. Afterward, neglecting to grow these wheats, the Italians were forced to look elsewhere for raw material, and Marseilles imported durum wheat from Russia and Algeria and furnished the Italians with the necessary coarse flour or semolina for making the pastes. Later Marseilles began making the pastes themselves, and is now the chief point of manufacture of these products.

604. Varieties of wheat required. — The wheats that furnish the best semolina for macaroni and other pastes are the durum wheats. It is partly that fact that has caused these wheats to always sell in Russia at a higher price than any other wheats; as, until recent years, Russia was the only source of any considerable supply. Recently, because of the European war, both Italy and France have had to depend largely upon this country for durum wheat. Common wheats are never used in southern Europe for pastes. Metadine wheats, which are durum wheats grown on French soil, and said to deteriorate, are sometimes used when the better foreign material is scarce or high in price. At such times, however, there is a clear decrease in the demand for pastes, until the proper wheat can again be secured. The product of Metadine wheats, which is cheaper on the market, is consumed almost entirely in France.

605. The different forms of paste. — The chief form of edible pastes is macaroni, although there is a large amount of spaghetti consumed. Macaroni, the largest form, is made by forcing the dough through holes at the bottom of a cylinder under the slow, tremendous pressure of a piston, fitting closely within the cylinder. A little rod or wire passes through the center of each hole, without touching its sides, which causes a hole in the stick of macaroni. Spaghetti is smaller in diameter, without any hole through it, and vermicelli has a still smaller diameter. The name macaroni is applied often as a generic term to all forms.

606. Characteristics of good macaroni. — First, a good macaroni is never white, and that color is a sure indication either of bleaching or of poor quality. Though these products are called pastes, it is a fact that good macaroni must not be pasty, when cooked, but firm like rubber. A first-class product is extremely hard, vitreous in fracture, yellowish in color, and will bend considerably before breaking. It will hold its form firmly after cooking, and not become flabby or flatten out into a pasty mass.

607. Macaroni manufacture in this country. — Macaroni of the qualities just described cannot be made from the ordinary wheats of this country. Even the hard winter and hard spring wheats are not satisfactory. Many new macaroni factories have been built in this country in recent years, and a number of them already are using durum wheats. Using the proper wheat, American factories could have a large market for semolina, or perhaps even for the macaroni, in southern Europe.

608. Breakfast foods. — A few cereal foods of the breakfast food class, such as oatmeal, have been in use for a long time, particularly among the Scotch people. In recent years scores of new breakfast foods have been made from all of the cereals. There are three classes of breakfast foods at present on the market in North America: (1) the uncooked breakfast foods consisting of hulless cereals ground which must be prepared for the table before serving; (2) the prepared breakfast foods, which have been steamed or otherwise cooked and then rolled or ground; and (3) malted foods, in which a portion of the starch has been changed chemically by the action of malt.

609. Unprepared foods. — Twenty-five years ago practically the only cereal foods on our market were wheat flour, corn meal, and hominy, though oatmeal had been introduced but was not yet widely used. Barley, rye, and rice were used in a small way. Oatmeal is yet probably the most important unprepared breakfast food. It also contains the largest quantities of the important nutrients, with a fairly low proportion of crude fiber. Snyder concluded from experiments that the difficulty in digesting imperfectly cooked oatmeal is due to the large amounts of glutinous material which surround the starch grains and prevent their disintegration. When thoroughly cooked, the protecting action of this mucilaginous material is overcome, and the compound starch grains are sufficiently disintegrated to allow the digestive juices to act. Heat also has the direct effect of rupturing hard cell walls. Cereals differ very much in the amount of cooking required to make them as digestible as possible. It may always be remembered that over-cooking is unusual and harmless, while under-cooking is common and undesirable. Some cereals absorb much more water than others before they are sufficiently cooked. Oatmeal increases its water content from 70 per cent to 84 per cent in cooking. Puffed rice and puffed wheat are kernels expanded by heating them under pressure at a high temperature, and then suddenly releasing the pressure.

Barley water is an old-fashioned beverage made by boiling barley in water and straining the clear liquid from the undissolved barley. Oatmeal water is a similar preparation.

610. Prepared breakfast foods. — Among the first of the modern prepared foods were the rolled grains. These are prepared by cooking the hulless grain for some time by steam, and then, while still wet, running it between rollers, pressing it into thin flakes. After drying, it is ready for the market. These rolled foods are always supposed to be thoroughly recooked before serving. Some ready-to-eat brands are simply cooked in water and then dried and crushed. Some are a mixture of different grains. Some have sugar, molasses, or other carbohydrate material added to them, and some apparently contain caramel or other coloring matter. The shredded preparations are made with special machinery which tears the steam-cooked kernels into shreds, and deposits them in layers or bundles. Many prepared cereals are parched or toasted before packing.

611. Malted breakfast foods. — In the manufacture of certain breakfast foods, malt is added, the diastase of which changes some of the starch into soluble forms. These forms such as maltose and dextrin are more easily acted upon by the digestive juices than the original starch. It appears upon investigation that the amount of soluble carbohydrates thus produced is much less than is claimed by the manufacturers. The average amount in a number of samples analyzed was about 5 % of the total carbohydrates. In most of the malted cereals it appears that very little of the starch is converted into any soluble form other than dextrin, and a part of that change, even, is caused by the dry heat of cooking. The characteristic taste of malt is relished by many, and the malted cereals are often liked on that account.

612. Other cereal foods are common in foreign lands, but not known in this country. In Russia the kernels of emmer, proso, millet, and buckwheat have their hulls removed, are then little more than cracked, and are cooked and eaten as breakfast foods. On the other hand, buckwheat is not used for pancakes as in this country. In Tibet and Mongolia a food, called tsamba, is made by boiling barley in tea.

613. Distilling. — For the production of spirits or whisky, oats, rye, and corn are all ground together, mashed with water, and then mixed with a certain amount of barley malt, which converts the starch into sugar. The addition of yeast changes the sugar into alcohol, and the mixture is then ready to distill.

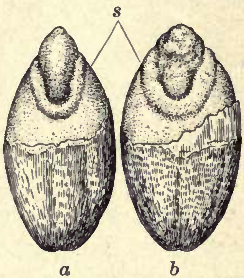


FIG. 170. — Variation in the size and shape of the scutellum (*s*) in different barleys: *a*, Manchuria; *b*, Goldthorpe.

614. Malting and brewing. — The use of barley in the production of malt for brewing beer is well known. In the course of the germination of the barley kernel, there is secreted from the epithelial layer of the scutellum a diastase which converts the starch into maltose, a form of sugar. Mann (1908) has shown the importance of the scutellum in malting, and pointed out the advantage of the broader and larger scutellum in the kernels of 2-row barley. There is also recently a full discussion by Mann and Harlan (1915) of the enzym-secreting areas of the barley kernel. It is stated that the conversion of the endosperm is effected by enzyms secreted by the epithelial layer of the scutellum, and that both cytase and diastase must proceed from the scutellum, and the proteolytic ferments most probably owe their origin to the same organ. The ideal grain of barley is one that is broadly oval with a scutellum extending well over the edges of the adjacent endosperm. Barley grains with pointed ends and a narrow scutellum are to be avoided (Fig. 170). Pedigree varieties are essential for securing barleys of superior morphologic and physiologic quality.

Other Uses of Cereals

615. Rye straw for drinking purposes. — There is produced a special kind of straw, utilized for drinking purposes, obtained from rye which is cultivated especially for the straw, and not for the grain.

After bleaching, the straws are assorted by hand, each individual stalk being examined, and the imperfect ones removed. They are then cut, the five lower joints only being utilized for drinking purposes. The sheaths are then removed, and the straw washed and bound into bundles ready for the market.

Drinking straws are, however, only a by-product, as the upper portion, which constitutes the larger part of the rye stalk, is utilized in the manufacture of straw braids. Drinking straw could not be produced profitably were it not for the utilization of the other portion of the straw, as the rye must be cut before the grain is developed, the straw being the only product of the land. In parts of Switzerland rye is grown wholly for these purposes.

616. Other uses of rye. — Rye straw has an extensive use for stuffing horse collars, for which purpose it must be given special care to bring a high price. The straw is also much used as bedding for live-stock, for packing trees, and in making paper.

CHAPTER XXI

CEREALS IN COMMERCE

CEREAL grains are of commanding importance in the trade relations of the world, but the full commercial discussion is not in place in this book. Only a brief statement of commercial transactions in cereals is given here, properly connecting production with consumption.

617. Bulk handling of grain. — It is the general practice in North America to handle grain in bulk. Grain transfers and transportation are, by this method, more quickly conducted, and without the cost of bags. It would be practically impossible to take proper care of all grain in any other way in the principal grain districts and markets. Bulk grain is also more easily and thoroughly inspected than grain in bags, and the expense of handling and transportation is less. When thrashing, the grain is commonly poured direct from the machine into a wagon box.

618. Handling in bags. — In the Pacific Coast region, and to some extent in the Great Basin, grain is handled in bags. This method is usually associated with the practice of harvesting and thrashing by means of the combined machine. In Australia, New Zealand, and Argentina, the bagging method is also generally employed. The bags are made to hold from 2 to 3 bushels. In the western United States they contain about 150 pounds of wheat, or 80 to 96 pounds of oats, while in

Australia they hold 186 pounds of wheat. Where handling in bags is practiced, both in this and foreign countries, there is a gradual but decided tendency toward bulk handling.

619. Immediate marketing. — When the condition and prices are good, the grain is often immediately marketed when thrashed. The trouble and cost of storage are thus avoided, and sometimes the advantage secured of an early rise in price. Often the grain is hauled directly from a header to the thrasher, when thrashing, or thrashed from the shock soon after harvest, and the thrashed grain then delivered at once to the grain dealer or mill; or, where the combined machines are employed, the bagged grain is taken direct from the field to the market. As previously noted (443), it is maintained by millers that thrashing without stacking does not permit the production of grain of the best quality.

620. Farm storage. — Whether wisely or not, it is the usual tendency for farmers to hold their grain for better prices. This necessitates either provision for farm storage of thrashed grain, or that it be delivered at the local elevator, if such exists, to be kept there pending a rise in price. The elevator exacts a small charge for storage. The farmer, in providing his own storage, should take care to prevent waste as far as possible. The bins must be made tight, and should either be metal-lined or the entire building be placed 2 feet above ground on piles, with caps of sheet tin over the top of each pile, having their edges extending downward and outward, to prevent the access of rats and mice. It may be necessary occasionally to fumigate the bins, as previously described (549), on account of insects.

In recent years, on large wheat farms, sheet metal tanks, like those at elevators, have been constructed in the fields, for storing grain near at hand.

621. Local markets are usually the small country railway stations. Sometimes the local buyer is acting as agent of a commission house or milling company at a terminal market. There may be a local elevator which does the business, or a mill may buy wheat for home

FIG. 171. — Interior of Farmers' Union Warehouse, Yuba City, California.

consumption, shipping the flour. Often the mill has an elevator attached, for storing its own wheat and for surplus grain to be shipped. There are now a considerable number of farmer's coöperative elevators, and, on the Pacific Coast, coöperative warehouses (Fig. 171).

622. Line elevators are a series of elevators constructed along a line of railway tributary to a large grain center, and under the control of a single grain commission firm or other corporation. Occasionally they are owned by the railway company, along whose line they are located. By calling on several or all of these elevators at one time, a firm may be able to fill large orders quickly, or secure a large quantity of one kind of grain.

623. Terminal elevators. — All the elevators so far mentioned transfer their grain later to other points. At the chief grain markets are terminal elevators where wheat is stored for consumption by large mills, and where grain is delivered in exchange transactions or held for export.

624. Floating elevators. — At the docks of lake and ocean ports, go-between elevators are employed for receiving grain from railroad cars to be transferred later to large steamers for export. Many of these are in use at New York City. As they are constructed on the water they are called floating elevators.

625. The modern elevators. — Formerly there was much loss of grain in elevators by fire. In later years they have been made more and more fire proof. At first this was done by stone construction. Now both the elevator and the large tanks are commonly made of steel (Fig. 172). There are at present 52 elevators in Minneapolis alone, having a storage capacity of 44,850,000 bushels. In 1912 there were 1315 elevators in the entire state of Minnesota, which shipped out that year 73,000,000 bushels. In the Canadian provinces, west of Winnipeg, there were 1763 elevators in 1911, with a storage capacity of 54,000,000 bushels. In other countries there are very few elevators. However, of the few that were seen in Russia by the author in 1900, those in North Caucasus were well built of stone.

The country elevator, when ready to ship, loads the grain originally received from the farmer, into a railroad car, either through spouts directly from the bins or by belt conveyors. At terminal elevators the car is unloaded by means of large scoops, pulled by machinery, but guided by hand. The grain is received into a large pit, at the bottom of which are large conveyors. From the pit the grain is carried to the top of the elevator,

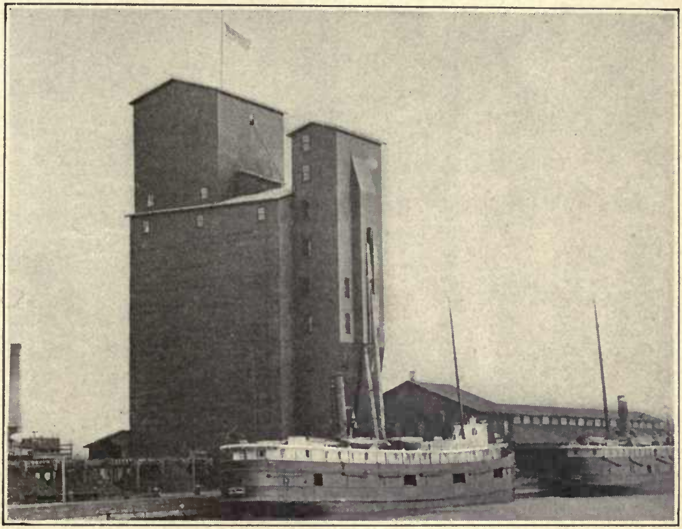


Fig. 172. — Grain elevator, Ludington, Michigan.

and weighed in scales holding as much as 500 bushels each. After weighing, it is transferred to bins below, from which it may again be taken by gravity or by moving belts to other parts of the elevator, or through chutes to cars or vessels (Fig. 173). Much cleaning of grain is done at the elevator, and mixing of different kinds and grades of grain, for the purpose of improving the total quantity.

626. Commercial classes of grains. — In commerce, the grains are valued according to the qualities fitting them for actual consumption, and to some extent, according to their appearance. Their classification by commercial men, therefore, is made independent of agronomic characters or botanic relations, though it

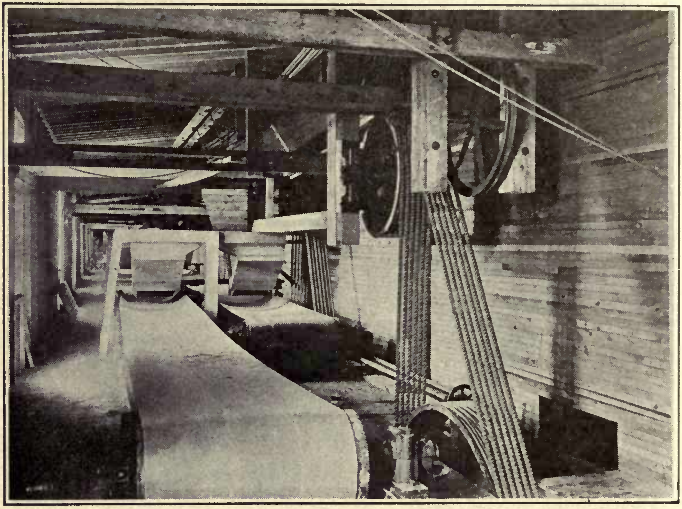


Fig. 173. — Interior of grain elevator at Portland, Maine. Discharging grain from elevator to belts.

will often be found that the commercial and agronomic groupings correspond. No doubt grain grading will become more perfect, the nearer becomes the correspondence between the commercial and agronomic classification.

The established commercial classes of grain vary somewhat at the different grain centers, but at present those most generally recognized in this country are about as follows: —

Wheat	Oats	Barley
White Winter	White	Common
Red Winter	Mixed	Bay Brewing
Hard Winter	Red (Rustproof)	Chevalier
Northern Spring (Hard Spring)	White clipped	Winter
Durum Common Spring	Mixed clipped	
Velvet Chaff (agronomically Preston)	Purified	
Pacific Coast White (Western White)		
Pacific Coast Red (Western Red)		**Rye**
		Common

White and Red Winter wheats are those of the eastern, southern, and central districts. Common and White Spring are spring wheats, other than northern, east of the Pacific Coast districts. Pacific Coast or western wheats are either winter or spring, and grown in Pacific Coast districts or in the Columbia River Basin and Montana. At Chicago there is a separate class of hard winter wheat, coming chiefly from Montana. There is a definite class of yellow oats, recognized even commercially, but it is simply stated that it "shall not be graded better than No. 3 white oats." Purified white oats is that which has been chemically treated. Mixed oats includes oats of various colors. Clipped oats differs from others only in having been run through a machine which clips off the sharp ends of the kernels and otherwise improves their appearance, making them weigh more and grade higher. Winter barley appears to include those varieties of common, nodding, six-row barley that are winter hardy, and which in other respects differ little or not at all, agronomically, from the class of common barley. Chevalier is the commercial term applied to two-row barley.

627. Difficulties of commercial classification. — In the older districts and as grain production increases, the number of varieties generally grown are reduced to a very few of each cereal, and commercial classification becomes simple. Where the question of best varieties is unsettled, and foreign sorts are being introduced, and particularly where many new hybrids are put on the market, much difficulty is encountered, and commercial classes are always changing. For example, at Portland, Oregon, the class of White Walla wheat includes at present white kerneled clubs, white kerneled hybrids, Sonora, and occasionally Gold Coin (Forty-fold). Gold Coin is also frequently accepted for Bluestem, while one can only be certain of delivery of real Bluestem by calling for Milling Bluestem. The class of Red Walla includes the varieties Red Russian, red kerneled hybrids, Jones Winter Fife (when mixed), and even Turkey. The last two are secured without question only on special orders, and when designating the pure product. At this market brewing barleys are divided into Blue Brewing and White Brewing.

628. Grading. — At the boards-of-trade and grain exchanges, each of the classes of grain is given usually four different grades. The principal requirements for grade No. 1 of each class are, that it shall have the proper color, shall be sound, dry, plump, clean, sometimes bright, sweet, sometimes shall contain at least a certain percentage of grain of the class, sometimes shall contain not more than a certain percentage of other grain or foreign matter or dirt, and usually shall weigh a certain designated number of pounds to the bushel. The lower grades must usually possess these requirements to a little less degree or amount, and weigh 1 or 2 pounds less to the bushel. Sometimes the difference is greater. Often a certain grade of each class is adopted as a contract grade, for example, No. 1 Northern Spring wheat, and all grain deliverable on contract, or in exchange operations, must be at least as good as this grade, or sometimes a lower grade will be admitted at a designated discount. For White oats, a separate grade of this kind, called Standard, is made. Rejected barley is a grade lower than either Brewing or Feed barley, with a test weight under 40 pounds to the bushel.

629. Standardizing grades. — It is often required that No. 1 wheat shall be dry, without stating the degree of dryness, though it is known that no grain is ever entirely dry. The term "hard wheat" also is in common use commercially, but as to the degree of hardness of kernel that is necessary for a wheat to be called hard, there is no agreement. In the United States Bureau of Plant Industry, investigations of the qualities forming the bases of different grades have been made for some time, with the aim of creating standards for as many of these qualities as possible, which would permit of more uniform grading. Considerable success has already followed the efforts, but particularly in the determination of standards of moisture content and the means for quickly ascertaining the percentage of moisture in samples. These moisture standards, and the means of testing moisture percentages, have been adopted for corn at the grain exchanges.

630. The moisture content. — While water is the most important factor in grain production, no quality of stored grain is so important as dryness. In addition to inferiority of the grain for milling, excessive moisture permits discoloration, molds, fermentation, and sprouting, and causes it to be more readily eaten by insects. The percentage of moisture that an average sample of grain should contain, however, varies greatly according to locality and season. There is also a considerable varietal difference.

Harris and Thomas (1914) studied the change in weight of grain during storage in Utah, which means really the change in percentage of moisture. They found that wheat and oats weigh most at thrashing time in that region, but gain weight in the winter, and lose weight in the summer. During the fall, just after harvest, there is a gain in weight of $2\frac{1}{2}$ to $4\frac{1}{2}$ per cent.

631. Testing the moisture. — Apparently the best method of determining moisture content of grain is that devised by Brown and Duvel (Duvel, 1910). The kernels of the sample are heated in a mineral oil having a flashing point much above the boiling point of water. The water in the sample therefore distills over, and on passing through a tube surrounded with cold water, is recondensed and collects in a suitable graduate, and the quantity in the sample is thus measured. An accurate thermometer is kept with its bulb immersed always to the same depth in the heated oil.

In testing wheat, 100 grams of grain are used with 150 cc. of oil, and the flame of the burner is extinguished when the thermometer registers 180° C. In testing rye and barley the same amount of grain and the same quantity of oil are used, and the flame is extinguished in the case of rye when the thermometer registers 175° C., and in the case of barley when it registers 190° C. In testing oats 50 grams of grain and 150 cc. of oil are used, and the flame is extinguished when the thermometer registers 195° C.

The apparatus has 6 compartments, so tests of 6 samples can be made at one time. One man and a helper, with the use of 3 machines of 6 compartments each, can readily make 200 or more tests in a day of 8 hours, — an average of a test every $2\frac{1}{2}$ minutes.

632. Inspection is made of all grain entering the large markets. When the grain is later transferred to another point, or exported, it is "inspected out." There are usually a chief inspector, one or more deputy inspectors, and a number of samplers. In Illinois, Minnesota, and Kansas, there is a state inspection service. At New York the inspection is in charge of the Produce Exchange. At Portland the inspection is effected by a committee of the Chamber of Commerce, of which the chairman is chief inspector. On the arrival of the grain the samples are taken from different parts of each car, and from different depths, both to get a fair average for the car and as a check upon the practice of "plugging." Sometimes a car is fraudulently filled or plugged at certain parts with poor grain or foreign material. The samples are then taken to the inspection rooms for examination. In many cases the inspector performs both duties, of taking the samples and determining the grades, at the same time. Certificates are issued by the inspector, showing the grade of each consignment of grain inspected and received into public elevators. These certificates are negotiable and are exchanged when there is a transfer of ownership of the grain. At Minneapolis and Duluth, the weighmasters are state officials. At some other points they are officials of the board-of-trade.

633. Exchange operations. — At every important grain market there is a board-of-trade or grain exchange, so organized as to render valuable service to both producer and consumer of grain. Inspection rooms are in the same building or near by. Samples of the different lots of grain of recent arrival are placed upon tables on the floor of the exchange and labeled with information as to the grade, origin, and ownership. Assistants write upon a large blackboard the constantly changing prices as received over the wires from different other markets. Buyers and sellers meet each other near the center of the floor, in a circular place, known as the "pit." On the floor of the Chicago board-of-trade there are separate pits for wheat, oats, and corn.

Grain exchanges exist in some of the grain centers of foreign countries also, but are not operated to the same degree of perfection as in this country. There is a well-organized board-of-trade (birzha) at each of the cities of Moscow, Odessa, Samara, Saratov, and Rostov-on-Don, in Russia. The pit feature is lacking at these places. Grain dealings are not so rapid, and are conducted more privately, often while sitting at tables drinking tea (chai).

634. Selling by sample for cash is a large part of the business at the Minneapolis exchange. The authoritative grade, however, may still enter into the transaction. In addition to state samplers, there are private samplers, who furnish samples from various cars, on authority of the Chamber of Commerce, to its members. All barley is sold by sample.

635. Sales for future delivery. — A very important feature of exchange operations is the sale of grain on contract for future delivery, or "dealing in futures," as is the common expression. It is the balance wheel of all grain business, and protects both buyer and seller from dangerous risks. For example, in January A sells to B 5000 bushels of wheat, which he contracts to deliver during the month of May at a certain price. B agrees to pay that price on any day in the month that the wheat is delivered, and, if at Minneapolis, he must accept No. 1 Northern Spring or No. 1 Hard Spring; or No. 2 Northern Spring at a discount of $3\frac{1}{2}$ cents a bushel under No. 1 Northern. The delivery is in the form of a warehouse receipt, which must represent actual wheat in a terminal elevator.

If B had agreed to pay 80 cents a bushel in May, and wheat is actually selling then at 75 cents, he loses 5 cents and A gains 5 cents a bushel. If in the meantime, B has sold the wheat to C at 78 cents, the warehouse receipt passes to C, and B receives no wheat, but gains 3 cents over C, and loses 5 cents to A, a net loss of 2 cents a bushel; while A gains 5 cents and C loses 3 cents a bushel.

Contract grades may differ somewhat at different exchanges. The contract grades for other cereals at Minneapolis are No. 3 corn, No. 3 white oats, and No. 1 flaxseed. At Chicago, St. Louis, and Kansas City, the contract wheat grade is No. 2 Red Winter, to which is now added No. 2 Hard Winter at the two last named markets. The usual months during which grain sold on contract is made deliverable, are May, July, September, and December.

636. Hedging. — It may not have happened that B lost in his entire business, even though his net loss in this deal was 2 cents a bushel. At the same time of his purchase from A, he may have wisely put a check on a possible loss, by contracting to sell to D the same amount of wheat the same month, that he purchased from A, and at the same price. This operation is called "hedging."

The practical advantage of hedging in regular business is great. A miller may make a sale of flour for delivery many months in advance, based upon the price of wheat at the time of sale, at perhaps only a slight profit. He is enabled still to maintain this profit, in spite of an advance in the price of wheat, by hedging against the flour sale with a purchase for future delivery of an equivalent amount of wheat. If wheat advances 5 cents a bushel, without a hedge, he loses, in his flour sale, that amount for every bushel of wheat required to produce the flour. However, the wheat he buys as a hedge must be delivered to him at 5 cents a bushel less than the future cash price, which cancels the 5 cents a bushel advance in price, and leaves him his profit in the flour sale undisturbed. The miller is thus able to do business on a low margin of profit between the cost of wheat and price of flour.

637. Bulls and bears. — When A sells 5000 bushels of wheat to B, the former is said to be "short" in wheat, while B is "long" in wheat. When there is a sharp advance in prices, the statement is sometimes made in commercial reports that "the shorts ran to cover," meaning that those who were short by selling, hastened to deliver before further advances in price could occur, as in every advance they are losing. Those who continue to buy and see high prices ahead, tend to rush the market, and are known as "bulls"; while those who prefer to sell, and therefore drag the market, are called "bears."

638. Corners in grain are effected when one man or a few men secure practically all the grain of a certain kind that is apparently available, and then attempt to dictate prices. In recent years efforts have been made so to regulate exchange operations as to prevent the possibility of corners. The natural condition of enormous production is likely in itself sooner or later to eliminate such occurrences.

639. Grain centers. — The principal grain markets of North America are Chicago, Minneapolis, Winnipeg, Duluth, Buffalo, New York, St. Louis, Kansas City, and Portland (Oregon). Chicago, centrally located and on the Great Lakes, has a general business. Minneapolis, the greatest milling city, has special interest in wheat, and its out-going trade is chiefly in the form of flour. Duluth and New York, connected with Europe by water, are great export points. Buffalo, also on the Lakes, is of importance in export, but mills a large percentage of its wheat. Winnipeg is chief headquarters for Canadian wheat. St. Louis, a central interior point, handles all classes of oats and corn and both soft and hard wheats. Kansas City, at the edge of the Great Plains cereal districts, has a large grain trade, and has export connections with Galveston and New Orleans. Portland is important as a Pacific export point.

640. Transportation. — As it is desirable to get large quantities of grain from one point to another promptly and with the least expense possible, the question of transportation is important, and it is of the greatest advantage that a grain center be also a railroad center. The availability of water transportation adds greatly to a city's advantages as a grain market, as water rates for carrying are so much lower than rail rates. The farther a farm is located from a railroad station, and the farther it is from a terminal market, the smaller is the net profit to the farmer, on deducting freight charges and cost of hauling to the railroad. Because of the latter, 5 to 15 cents a bushel may be lost. In addition to railroad charges, farmers in new settlements have sometimes been obliged to haul grain 50 to 100 miles to the railroad, increasing the cost.

641. The grain exports of this country exceed that of any other country, though Russia, Argentina, and Canada have a large export business. The ability of Argentina to export is not so much because of great production as it is because of the comparatively small needs of her own small population. Russia exports more wheat as a whole product than the United States, but the difference is much more than offset by the great flour export of this country. Recently the larger part of our export wheat is durum, sent to Mediterranean ports for making macaroni. A considerable quantity of barley and white wheat is now being exported from the Pacific Coast.

PART IV

BUCKWHEAT AND RICE

CHAPTER XXII

BUCKWHEAT

IN this country buckwheat is, in point of production, the least important of the grain crops. The grain is always in good demand, however, for human food, and it is an excellent crop in a rotation or for the renovation of land in poor condition. Its cultivation is at present limited practically to the territory north of Tennessee and east of the Mississippi river.

Buckwheat is not accurately a cereal, but belongs in the smartweed family of plants (Polygonaceæ). Nevertheless the grain is so commonly used as food that it is classed commercially among the grain crops.

642. The root system of buckwheat is of the kind known as a tap-root system. It consists of a central or primary root which extends downward to a considerable distance. This primary root is thicker and stouter than the lateral roots which arise from it. The lateral roots may be divided several times, but altogether the plant does not develop a large amount of root. This system is different from that of the true cereals in which no tap-root is found. In development the tap-root first penetrates the soil for some distance, forming no laterals. Later on laterals are formed, beginning at the upper portion of the main root. These lateral roots continue to develop until maturity, although the main root ceases development before this time.

643. The plant. — Buckwheat is a herbaceous, erect-growing annual, which under ordinary conditions attains a height of about 3 feet. A single stem only is produced from a seed, there being no tillering or branching at the crown such as occurs in the true cereals. The plant adjusts itself very efficiently to surroundings, such as fertility of soil and rate of seeding, by sending out branches from the main stem. The main stem varies in diameter from $\frac{1}{4}$ to $\frac{5}{8}$ inch. The stem and branches vary in color from green to purplish-red when growing, but change to brown when mature. The numerous joints of the stem are swollen, hence the family name Polygonaceæ (*polus* many, and *gonos* knee).

The leaves are arranged alternately on the stem and are triangular-heart-shaped, entire, 2 to 4 inches in length, slightly less in breadth, and are borne on a pedicel varying from nearly sessile to 4 inches in length.

644. The flowers of buckwheat are perfect and vary from nearly white to light red or pink in color. They are borne in many-flowered racemes either on the end of the stem or on short pedicels that arise from the axils of the leaves. These flower clusters are either erect or inclined to droop. The calyx is composed of 5 nearly equal sepals, resembling petals, the latter being absent. The calyx is not removed in thrashing, but remains attached to the base of the grain, the grain being about twice as long as the calyx. There are 8 stamens borne on thread-like, glabrous filaments. The ovary is 1-celled and 1-ovuled, but the style is 3-parted with knob-like stigmas. The flowers are produced in two forms, the stamens being long and styles short in one and the stamens short and styles long in the other. Only one kind of flower is produced by a plant, but the seeds from either form of plant give rise to both kinds, and the ratio is not influenced by fertility of the soil. Cross-pollination between plants is supposed to be facilitated by this provision.

Blossoming begins when the plant is still immature and continues uninterruptedly until the plant is killed by frost or is harvested. There may be then on the same plant both flowers and mature kernels. After the plants are cut many kernels may mature while in the swath or shock.

a b c

FIG. 174. — Form of kernel in 3 different varieties of buckwheat: *a*, Tatarian; *b*, Japanese; *c*, Silver Hull.

645. The buckwheat kernel is in the form of an achene, it being a single seed inclosed in an indehiscent pericarp that fits tightly around the seed. The achene is 3-angled, the angles being acute, and has the form of a pyramid with the base rounded (Fig. 174). The hull or pericarp varies from silver gray to brown or black in color and is hard and thick, with the surface polished and shining. It separates readily from the mealy endosperm. The grain varies usually from $\frac{3}{16}$ to $\frac{3}{8}$ inch in length and from $\frac{1}{8}$ to $\frac{3}{16}$ inch in width. The relatively large embryo is central, dividing the soft, white endosperm into two parts, the cotyledons being broad. The surrounding testa is membranous and light yellowish-green in color.

646. Classification. — Buckwheat belongs to the Polygonaceæ, or buckwheat family. Several of the common weeds, such as dock, smartweed, bindweed, and sorrel, knotweed, and the like, belong to this family, but not to the genus Fagopyrum, the name which has been given to the buckwheats. In this genus there are several species, but those of economic importance are *F. esculentum,* the common buckwheat, and *F. tataricum,* Tatary buckwheat or India-wheat (Fig. 174 *a*). The notch-seeded buckwheat is by some given the name *F. emarginatum,* but by others is considered merely as a form of the common buckwheat.

The name " buckwheat " is due to the similarity in the shape of the seed to that of the beechnut. The name for beech is in German, *Buche,* and for buckwheat, *Buchweizen.* The English name is derived from the German word. The scientific name devised by modern botanists, *Fagopyrum,* is from the Latin *fagus,* beech, and the Greek *puros,* wheat.

This grain probably originated in Asia and came into Europe in the Middle Ages through Tatary and Russia, reaching Germany early in the fifteenth century, and from Europe it was introduced into America. The Tatary buckwheat is a native of Tatary and Siberia, from whence it was introduced into Europe (later than the common) and into America.

647. Varieties of buckwheat. — There are three varieties of buckwheat commonly grown in the United States, the Japanese, Silver Hull, and Common Gray, all of which belong to the one species, *Fagopyrum esculentum.* The Tatary buckwheat, duckwheat, or India-wheat is grown to some extent in northern localities, as Canada, Maine, and northern Asia, where it is considered to be more hardy than the common forms. Of the common varieties the Japanese has the largest seed, while the Silver Hull has the smallest. In color the Japanese is darkest, the Common Gray is somewhat lighter, while the Silver Hull is of a glossy, silvery appearance. The margins or angles of the hull of the Japanese are inclined to extend into a wing, causing the sides of the grains to be somewhat concave in surface (see Fig. 174 *b*).

The plants of the different varieties are distinguishable by size and color characters. The plant of the Japanese variety grows the largest, is later-maturing, and the growing stem is green in color. The growing stem of the Silver Hull variety is red, and more branches are produced by this than by the other varieties. Its leaves also are the smallest. The flowers of the Japanese variety seem also to be less easily blasted by high temperature than the others. These differing characters have been taken advantage of in farm practice in some localities, where the Japanese and Silver Hull varieties are mixed and sown together. The idea in this is that the taller and hardier Japanese plants will protect the others from the sun, while the lower Silver Hull plants, with their many branches, will utilize to good advantage the available space beneath, thus resulting in higher yields.

648. Comparison of varieties. — The Japanese variety is considered as giving generally the best yields, although it seems probable that there are conditions to which the other varieties are better adapted. In tests made in New York in 1901 these varieties gave the following results: —

Table XVI. Comparative Yields of Three Varieties of Buckwheat in New York

Variety	Yield, Bushels to the Acre	
	Unfertilized plats: average 2 tests	Fertilized alike: average 11 tests each
Japanese	27.5	36.6
Common Gray	26.8	——
Silver Hull	19.5	23.1

Coöperative tests of two varieties made at fourteen different localities in ten different counties of the State of New York showed an average yield for Japanese of 21.29 bushels an acre, and for Silver Hull of 20.05 bushels an acre. In nine cases the Japanese led in yield, in four cases the latter, and once both were the same. The yields in this test varied from 8.3 to 41.5 bushels an acre.

In some localities the Japanese variety is preferred for milling purposes, while elsewhere the others are preferred. It seems, then, that the Japanese variety is at least equal in value to the others for flour making.

649. Minor varieties. — A variety known as rye buckwheat yielded best in Canada in a 7-year test of five varieties, those named above included, the average yield an acre being 31 bushels for this time.

The Tatary buckwheat mentioned above is more hardy in northern localities than are the common varieties. It is distinguished from these (1) by its smaller, greenish white flowers on shorter pedicels, and in smaller heads; (2) by its smaller leaves, which are arrow-shaped; (3) by the more slender nature of the plant; (4) by its smaller kernels, with wavy or slightly notched angles, and dull, roughish, furrowed surfaces.

650. Production and distribution. — Buckwheat is the least of the cereal crops in this country. The production in the United States amounted in 1909 (Census) to 14,849,332 bushels, produced on 878,048 acres. The average yield was, therefore, about 16.9 bushels an acre. The crop had a value of $9,330,592, or $10.63 an acre. About $\frac{2}{3}$ of this crop was produced in the states of New York and Pennsylvania, the acreage, production, and value being as follows: —

TABLE XVII. SHOWING ACREAGE, PRODUCTION, AND VALUE OF BUCKWHEAT IN NEW YORK AND PENNSYLVANIA IN 1909

	ACREAGE	PER-CENT-AGE[1]	PRODUCTION BU.	PER-CENT-AGE[1]	VALUE	PER-CENT-AGE[1]	YIELD TO THE ACRE BU.	VALUE TO THE ACRE
					$			$
New York	286,276	32.6	5,691,745	38.3	3,587,558	38.4	19.9	12.53
Penn'a	292,728	33.3	4,797,350	32.3	2,895,958	31.0	16.4	9.89

About $\frac{1}{4}$ of the crop was produced in this same year by these states, named in the order of yield from high to low: Michigan, West Virginia, Ohio, Virginia, Maine, Wisconsin, and New Jersey.

The largest crop of buckwheat ever produced in the United States, according to the estimates of the Department of Agriculture, was in 1886, when the crop amounted to more than twenty-two million bushels, but the production, as evidenced by the same figures, declined to less than half this amount a few years later, since which time there has been a slow, gradual increase.

651. Production in Europe. — Buckwheat is grown in Europe principally between the 48th and 57th parallels, the principal regions of production being Holland, Denmark, northwestern Germany, and northwestern, central, and east-central France. It is grown to some extent in nearly all of France, Prussia, Bulgaria, and Russia from Petrograd south to the Black Sea, and also in some parts of Austria. Buckwheat is not largely grown in Europe north of the latitude of Petrograd (60°), nor south of the latitude of the southern boundary of France. In Ufa Government, Russia, near the Ural Mountains, the crop is often unusually good in quality.

[1] Percentage of total for the United States.

The production in Europe is by far the greatest in Russia, next largest in France. Austria-Hungary, Scandinavia, and Denmark each produce about equal amounts, while the production in Germany is still less. All other countries not named produce no more than half as much as the German production.

Improvement

652. Introduction. — Several varieties of buckwheat have been introduced in recent years into the United States from foreign countries. Russian No. 1 and Orenburg No. 6 have given good results in North Dakota. Sando Soba, an introduced variety of the Japanese type, seems to be the best variety of 12 or more tested in Kansas. The Chinese buckwheats, as tested in Kansas, were hardier and more drought-resistant than were the other varieties and were generally longer in maturing. The Chinese varieties have smaller kernels of a peculiar shape, and are less attractive looking than the Japanese variety. The comparative milling value has not been reported.

653. Selection. — Buckwheat offers an excellent field of work for the plant breeder. Little has been done in the way of variety production or the isolation of pure strains. There is considerable variation observable between plants, and it should not be difficult to originate strains which will produce larger yields than the ordinary varieties. Some breeding work of this nature is under way at the Cornell Agricultural Experiment Station, in New York, where individual plant selections have been made and are being compared. Work is being done in Russia on the production of a 4-faced strain or variety, which is supposed to be more resistant to early spring frosts, and produces heavier seed.

654. Correlation of characters. — Love has studied the correlations of two varieties of buckwheat grown on two soils of different fertility. The correlation coefficients which he found are given herewith: —

TABLE XVIII. — CORRELATION OF CHARACTERS AS EXHIBITED IN 2 VARIETIES OF BUCKWHEAT, JAPANESE AND SILVER HULL

CHARACTERS CORRELATED	VARIETY			
	SILVER HULL		JAPANESE	
	Farm plat	Garden plat[1]	Farm plat	Garden plat
Height and yield	.503	.544	.593	.354
Height and yield, number of branches	.465	.448	.576	.396
Number of branches and yield	.432	.454	.635	.504
Length first internode and number of branches	−.169	.013	−.154	.029
Length first internode and yield	−.169	−.078	−.114	−.031

The correlation for the same characters of the varieties do not differ greatly in the main, although there are some large differences. The change in the amount of food supply exerts some influence on the correlations, the changes produced being generally larger in the Japanese variety. It was also found that as food supply is increased there is a tendency to more variation among the different characters. The correlations are generally somewhat higher on the poor soil.

[1] Richest soil.

It is seen in the table that as height or number of branches increases the yield also increases. There is some tendency for the yield and number of branches to increase as the length of the first internode decreases.

655. Soil relations. — In the matter of soils, buckwheat is not especially exacting, as it does well on various kinds of soil. On infertile, poorly tilled lands, it will produce a better crop than will any other kind of grain. It responds to better treatment, however, with increased yields. The rather light, well-drained soils, such as the sandy loams, seem best suited. It seems to prefer an acid soil, best results not being obtained where there is a large amount of lime present. Rich soils, especially those high in nitrogen, are not suited, as on these the crop usually lodges badly. When once the plants go down, they have no means of rising again, such as the true cereals have, and ruin to the crop may result. Although the growing period is short, root development is vigorous and of such a nature that relatively unavailable mineral foodstuffs in the soil can be utilized.

656. Climatic relations. — Buckwheat is very sensitive to cold, being quickly killed by frost or freezing temperature; nevertheless, it is grown far toward the north, even to 70° N. latitude. This is due to the short growing season of the plant, amounting to ten to twelve weeks, and to the small amount of heat units required to bring the crop to maturity. Haselhoff states that 1000° to 1200° C. are required for the buckwheat crop, while, in comparison, oats require from 2340° to 2730° C.

Buckwheat is also sensitive to high temperatures and dry weather, especially when both day and night are hot. In such conditions the flowers are blasted and produce no grain. In the hot, dry summer of 1913 the crop was an entire failure in many localities of New York on account of such blasting. Rather high temperatures are apparently not so destructive if the nights are cool. The time between flowering and formation of grain is a critical one in the life of the plant, dry weather or very hot weather at this time reducing the yield of grain very materially.

Pullman (1909) found that under the conditions of the experiment, temperatures of $-1°$ and $-2°$ C. did no harm to buckwheat seedlings, but at $-2.5°$ C. the tenderest leaves began to suffer; at $-4°$ nearly all the plants were damaged, while at $-6°$ they were killed. A type has been developed in Russia which resists $-4°$.

Cultivation

657. Seed cleaning and grading. — Large seeds of buckwheat will produce larger plants and more grain than small seeds. Cleaning and grading of the seed should result, then, in more vigorous plants, a more even stand, and better yields. The removal of foreign material, such as sticks and straw, from the seed will allow of more uniform seeding. Since there are no important fungous diseases, no special treatment of the seed is necessary for disease prevention.

Buckwheat grain can be used for seed immediately after harvesting. After the second, or at most the third year, it loses its power of germination, although retaining still its value for food.

658. Preparation of soil. — Buckwheat is most frequently sown on seed-beds hastily and carelessly prepared, due to its being used so often as a crop on left-over land or where other crops have failed. The land is plowed, then harrowed, and sown immediately afterwards, no time being allowed for settling of the plowed land or the decay of vegetation plowed under. Little reserve moisture is thus provided, and in dry years the crop may suffer. It is better to plow the land early in the spring and keep it in condition by occasional harrowing until the crop is sown. A reserve of moisture is thus provided which nearly insures the crop.

659. Fertilizers. — When the soil is very poor, it is often profitable to use fertilizers for the buckwheat crop. Nitrogenous fertilizers should be used sparingly, but good results are obtained from the use of phosphorus and potassium. On poor, sandy soils and on rough, stiff clays the addition of stable manure is advisable, but this is usually reserved for other crops. Experiments by Prianishnikov have shown that buckwheat utilizes undissolved mineral phosphates to better advantage than do wheat and oats. Pettit found that buckwheat in pot experiments absorbed from a loamy soil $3\frac{1}{2}$ times as much potassium oxid and twice as much phosphoric acid as barley. Low-grade fertilizers may then be used to advantage for this crop, and it would seem that rock phosphate and basic slag might be profitably applied. The buckwheat crop may serve as an excellent means of rendering these undissolved phosphates available.

Fertilizer tests with buckwheat made on soil of fair fertility in 1901 at the Cornell Experiment Station resulted in most cases in better yields of small grains following fertilization with acid rock, dried blood, and muriate of potash in different combinations. The results as a whole, however, were uncertain and somewhat contradictory.

660. Time of seeding. — In the three states of largest buckwheat production the sowing and harvesting dates according to Covert (1912) are as follows: —

TABLE XIX. — DATES OF SOWING AND HARVESTING BUCKWHEAT IN DIFFERENT STATES

STATE	SOWING			HARVESTING		
	Beginning	General	Ending	Beginning	General	Ending
New York	June 22	July 1	July 11	Sept. 9	Sept. 18	Sept. 28
Penn'a .	June 14	June 28	July 10	Sept. 6	Sept. 18	Sept. 30
Michigan .	June 16	June 24	July 3	Sept. 8	Sept. 16	Sept. 26

It is seen from these dates that the time of sowing buckwheat is well along in the season, after all danger of frost is past. This is necessary since the crop is greatly injured by the least frost. Also if sown early, the major part of the blossoming, which begins when the plant is small and continues for a long period, may take place during hot weather and blasting may result. Although the true cereals will germinate when the soil has a temperature of 4°–5° C., buckwheat will not germinate at a temperature below 8°–9° C. A temperature of about 15° C. should be awaited before seeding takes place.

As seen above, the growing period, or period from seeding to harvest, is about 80 to 85 days. An average of conditions in 20 states indicates that the period from general sowing to general harvesting is 84 days.

661. The rate of seeding buckwheat varies from 3 to 5 pecks to the acre, the usual amount, however, being 4 pecks. If for any reason the germination is low, the rate should be increased. The minimum amount may be used where the seed-bed is in good condition and weather conditions are favorable, and a drill is used for sowing.

Buckwheat may be sown with a grain drill or broadcasted and harrowed in. The latter method is probably the most common, but more satisfactory results are obtained by the use of a drill, where the nature of the ground permits. Less seed is required when a drill is used. It develops best when sown at a depth of $\frac{1}{5}$ to 2 inches, but will germinate fairly well when seeded even at a depth of 6 to 7 inches.

662. Harvesting. — The cutting of buckwheat should take place before the first frost kills the plants. It is often advisable to begin cutting as soon as the first lot of blossoms have matured their seed.

Most of the buckwheat crop in the United States is cut with the old-fashioned cradle. This is often necessary on account of the rough land used for the crop. A self-rake reaper is suitable for harvesting the crop. When these two methods are used, the bunches are left in the swath a few days and are then set up unbound, in small shocks, much as corn fodder. These shocks are not capped, but a few stems are twisted about their tops, holding them together and preventing the scattering of the shock. A self-binder may be used for cutting. The bundles are then set up in long narrow shocks and not capped. Cutting is usually done in the morning while the dew is on, or in damp weather, to prevent shattering of the grain. The pedicels which bear the seeds are slender, and these and the straw are very brittle when dry. This results in easy shattering and also allows of easy thrashing.

663. Thrashing. — The cut buckwheat is usually left in the field in the shocks until thrashing time. It is then either thrashed out with a flail or by machinery. If the former is used, the straw should be dry and the weather good, then the grain shells out easily. When a thrashing machine is used, the straw need not be so dry. The machine is modified by removal of the spiked concave, a smooth concave or a fitted plank being substituted. This is done to prevent cracking the grain and breaking up the straw more than is necessary. The grain is more easily thrashed than is that of the true cereals.

664. Rotations. — Buckwheat is often sown on land where early planted crops or meadows have failed, or where it has been impossible for some reason to put in another crop. It is often sown on land considered too poor for other crops. It is also sometimes sown year after year on the same land, when this is not suited to other crops. For these reasons buckwheat usually has no definite place in rotations. This rotation, however, is sometimes followed: clover, buckwheat, potatoes, oats, or wheat seeded to clover. The first crop of clover is removed early and the land plowed at once and seeded to buckwheat in preparation for potatoes. The use of buckwheat preceding the potato crop is very common. Buckwheat leaves the soil in a fine mellow condition that on heavy soils is of great benefit to potatoes, one result being smoother, better-appearing tubers. Buckwheat does not seem to be affected by preceding crops, but it is often claimed, though apparently without experimental proof, that oats and corn are unfavorably affected by a preceding buckwheat crop.

665. Buckwheat as a soil renovator has great value. On account of its rapid growth it is useful in clearing the land of weeds. Experiments indicate that it can utilize relatively insoluble mineral soil constituents to better advantage than can the true cereals, such as wheat and oats, and it is well known that it will flourish on poor soil. As a green-manure crop on poor land, therefore, it has value in rendering plant-food available and furnishing humus to the soil. A heavy growth plowed under will decay quickly and completely, leaving the residues soon available for the succeeding crop. A crop of buckwheat also leaves even hard soils in loose friable condition, doubtless due partly to its complete shading of the ground.

666. Weeds are seldom able to make headway in competition with a crop of buckwheat, owing to its rapid germination and growth. The ground is soon shaded and is covered so densely with the later growth that weeds are smothered out. This crop is therefore valuable as a means of cleaning the land of weeds (515).

667. Fungous and insect parasites. — Buckwheat is particularly free from destructive insect or fungous enemies. Since this is the case, losses do not often occur as a result of these causes. Wild and domestic birds when abundant may eat a considerable amount of the grain before it can be harvested. Blasting of the flowers often occurs as a result of unfavorable climatic conditions, but this does not seem to be due to disease. The flowers seem very sensitive to high temperature and dry weather, and often fail to develop grain because of such weather. Hot days followed by hot nights seem especially destructive, either when the soil is dry or wet. The Japanese variety seems to be least injured by such conditions.

Injury to buckwheat by Rhizoctonia is reported from western North Carolina, and attacks by the nematode, which causes the stalk disease of rye, are reported from Germany.

Uses of Buckwheat

668. Feeding value of buckwheat. — Buckwheat grain has a fair feeding value, but its total nutrients are somewhat lower than those of the leading cereals. The hulls have some feeding value, but many other better feeds are obtainable, so these should be used only when such other feeds are scarce. Buckwheat middlings, composed of that portion of the grain just beneath the hull, have a high feeding value, being high in protein, carbohydrates, and fat. Buckwheat bran is a mixture of the middlings and the hulls, and is much poorer as a feed than the middlings alone. Buckwheat middlings is high in nitrogen, phosphorus, and potassium, consequently the manure from stock fed with these has high fertilizing value.

The value of buckwheat by-products and fertilizing constituents as given by Henry is shown below.

TABLE XX. — BUCKWHEAT AND ITS BY-PRODUCTS, DIGESTIBLE NUTRIENTS, AND FERTILIZING CONSTITUENTS

NAME OF FEED	DRY MATTER IN 100 LBS.	DIGESTIBLE NUTRIENTS IN 100 LBS.			FERTILIZING CONSTITUENTS IN 1000 LBS.		
		Protein	Carbohydrates	Ether Extract	Nitrogen	Phosphoric Acid	Potash
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Buckwheat (grain) .	87.4	7.7	49.2	1.8	14.4	4.4	2.1
Buckwheat (hulls) .	86.8	2.1	27.9	0.6	4.9	0.7	5.2
Buckwheat (bran). .	89.5	7.4	30.4	1.9	36.4	17.8	12.8
Buckwheat (shorts) .	88.9	21.1	33.5	5.5	——	——	——
Buckwheat (middlings)	87.3	22.0	33.4	5.4	42.8	21.9	11.4
Buckwheat (straw) .	90.1	5.2	35.1	1.3	——	——	——

669. Buckwheat as a feed for live-stock. — The grain of buckwheat is used extensively as a feed for poultry, being popularly supposed to stimulate egg production, although this is not borne out by experiments. The ground grain is used as a feed for hogs, being valuable for this purpose. A kind of groats is made for human food by breaking and removing the hull. The flowers furnish a source of honey for bees, and buckwheat honey, although rather dark and having a distinctive flavor, is usually highly regarded.

When buckwheat is fed in too large amounts, it sometimes causes a rash to appear on the skin. This seems to be only in white-colored animals and has some connection with the light relations of the animal, such rash not occurring if the animals are not exposed to light. The substance that produces these effects is apparently located in the hulls of the grain, as it can be extracted from these by means of alcohol.

670. Buckwheat as human food. — The flour of buckwheat is used extensively in the United States, principally for making cakes. A batter is made of the flour and this is spread thinly on a smooth, hot, greased iron, where baking is completed within a few minutes, the cakes being turned in the process and browned on both sides. The cakes are eaten hot, with sirup of some kind. The cakes are usually somewhat dark in color, owing to the presence in the flour of portions of the hull of the grain.

The outer hulls of buckwheat, removed in milling, are used for fuel, and to some extent for mixing into stock feeds. They contain considerable carbohydrates and other nutrient materials, and are consequently of value for the latter purpose. The ground hulls are reported as an adulterant of black pepper.

The buckwheat middlings obtained in milling is composed of the inner hulls and the germ of the kernels. It is a very valuable feed for cattle, extensively used by dairymen, and contains a large amount of protein and carbohydrates.

671. Milling buckwheat. — In the process of milling the buckwheat grains are first passed to a separator, where all foreign material, such as sticks and stones, is removed by means of a series of sieves, and all dust is blown out by an air current. After this the grain is washed, scoured, and polished by special scouring machinery, and pieces of metal are removed by magnets. The excess water is removed by drying, and the dust again blown out. The grain then passes to the shelling rolls, where the greater part of the outer hull is removed by a machine known as the sieve scalper. The grain is then kiln-dried to about 10 per cent of water, to insure the keeping of the flour. After this it goes to the rolls, after which the process is practically the same as that used in milling wheat, there being a series of breaks and reductions with the usual bolting and grading, this being continued until the flour is separated almost completely from the middlings. Flour can be made as white as that from wheat by use of fine bolting cloth, but usually coarser cloths are used which allow particles of the hull to pass through and remain in the flour.

One hundred parts of buckwheat give, on milling, 66 parts of flour, 14 parts of middlings, 19 parts hulls, and 1 part loss.

The flour of the Tatary buckwheat is darker in color than that from the common, has a somewhat bitter taste, and is not so good for baking.

CHAPTER XXIII

RICE

THE chief dependable field crop in all warm countries is rice. It is the principal food in the countries that are most densely populated, such as China and India. Its importance in the United States is also great and will increase.

THE RICE PLANT

Rice belongs in the family of grasses (Poaceæ), and is a true cereal. It is further located in the tribe Oryzeæ, in which there are 1-flowered, perfect, or unisexual spikelets; glumes 2 or none; frequently 6 stamens; caryopsis with a small embryo and a linear hilum.

672. Description. — The genus Oryza, in which rice belongs, has the spikelets strongly compressed, laterally, 2 small glumes, and perfect flowers. There are several species of the genus, of which the one called *Oryza sativa*, Linn., includes the cultivated rices, as well as the weed known as red rice. The wild or Indian rices of this country belong in the separate genera Zizania and Zizaniopsis.

673. Roots. — The rice seedling has one seminal root. The permanent or coronal root system, like those of other cereals, is fibrous. The crown, from which the coronal roots spring, is formed from $\frac{1}{4}$ to 1 inch above the lower end of the culm. Many adventitious roots are produced from the first, second, or third nodes, and occasionally from the fourth node. Rice roots are usually less developed, in proportion to culms and leaves, than those of any other cereal.

674. Culms. — The height of the rice plant ranges from about 24 inches to 60 inches. The number of culms varies from 5–12, in some varieties, to 10–25 in the variety Shinriki. The culm is of medium strength; color of internodes light green to yellowish green, sometimes brown; color of nodes dark green to brown, rarely dark brown; culm wall, at base, usually thick, never very thin; just below the panicle, seldom thick but usually strong; foliage moderately abundant, panicles usually drooping.

675. Leaves. — The culm bears 5 to 7 leaves, including 1 or usually 2 basal leaves; sheath green or light green, 8–12 inches long, sheath node light green, conspicuous; ligule $\frac{1}{2}$ to $\frac{3}{4}$ inch long, white, sometimes light green, acute or obtuse, often split; auricle usually white or green, horny or membranous, usually prominent, hairy; blade 14 to 21 inches long, $\frac{1}{4}$ to $\frac{5}{8}$ inch wide, erect or ascending, glabrous or puberulent, often rough, particularly toward the apex, prominently veined, apex acute or acuminate.

676. Panicles and spikelets. — The length of the rice panicle is 8 to 11 inches, form medium; peduncle strong or medium, $14\frac{1}{2}$ to 18 inches long; axis of the panicle glabrous, sleek, slightly rough toward the apex; panicle branches somewhat rough, spirally arranged on the main axis; secondary branches in 2 ranks on the axes of the main branches; spikelets very strongly compressed laterally, obtusely keeled, each with 1 perfect flower. Half-whorls are not formed as in oat panicles.

The 2 glumes are lance-shaped, pointed, 1-nerved, rather flat, small, nearly $\frac{1}{2}$ the length of the lemma or still shorter, often with a sharp tooth on each side below the apex. Below the glumes are sometimes 2 rudiments of glumes. The axis of the spikelet is short and thick (Fig. 175).

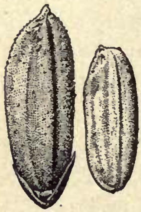


FIG. 175. — Spikelet (*a*) and caryopsis (*b*) of rice. ($\times 2\frac{1}{2}$.)

677. Flowers. — The lemma and palea are equally long, hard, parchment-like, strongly compressed laterally, deeply boat-shaped, obtusely keeled, obtusely pointed or lemma often awned, rough, pubescent, surface crossbarred with numerous fine longitudinal ridges crossed with rows of small elevations; lemma with 5 strong nerves, the margins bent inwards, catching hinge-like in the long furrows at the margins of the palea or closely appressed to the latter; palea narrower than the lemma, 3-nerved, with long furrows at the margin in which often hinges the bent margin of the lemma; lodicules small, grown together below, and to the other side of the palea at the lower margin, thick, fleshy, broad ovate, glabrous, with soft pointed apex; stamens 6; anthers long, crimped, 2-celled, opening the entire length, yellow, attached to the filaments at base of the middle band; pollen grains spherical, light yellow; styles 2, grown together at the base.

678. Kernels. — The caryopsis is firmly and completely inclosed by the lemma and palea, all together being known as the kernel; caryopsis oblong, elliptical or oval, glabrous, strongly compressed laterally, elliptical in cross-section, having on each flat side 2 obtuse-angled longitudinal ridges corresponding to the side nerves of the lemma (Fig. 175); hilum linear; endosperm flinty, sometimes mealy; the larger starch grains compound; aleurone cells in a single row, small; embryo scarcely $\frac{1}{3}$ as long as the caryopsis; the latter in ordinary rice translucent, sometimes dull, in which cases the outer circumference of the endosperm is mealy, the inner glossy, a condition very rare or lacking in other cereals; in glutinous rice, caryopsis always opaque, and starch grains colored yellowish brown instead of violet, in contact with iodine (684).

679. Origin of rice. — Dependent information on the origin of rice is about as scarce as that pertaining to the origin of the other common cereals. The earliest rice cultivation recorded is that referred to in the description by Julien of the ceremony instituted by the Chinese Emperor Chin-nung 2800 years B.C. (39). Two circumstances, however, appear greatly to reduce the value of this record: (1) Yokoi (1898) maintains that Julien's statement is incorrect, that the ceremony was instituted much later than the time of Chin-nung, and even then rice was not included in the five grains, but was included still later, and thinks rice is not indigenous in China. (2) It is not yet recorded that rice has been found outside of cultivation in that country. In Egypt where other cereals existed in ancient times, there is no record left of any early cultivation of rice.

Wild rice of the same genus (not Zizania) has been found in several places where there was no rice cultivation. According to Roxburgh, it grows on the shores of lakes in the country of the Circars in India, where it was called Newari by the Telingas. Nivara, an ancient Sanskrit name, apparently applies to the same plant. It has also been observed at Moradabad, in Delhi.

Wild rice was also discovered, abundant and widely distributed, in Khartum, central Africa, near the mouth of the Senegal River. The falling of the spikelets, observed in all these instances, shows the rice to be a wild form. When tested, the flavor was good. The oldest Sanskrit name for cultivated rice is vrihi, used in the Atharva-veda and Jadshur-veda (1000–800 B.C.). In the expeditions of Alexander the Great (400 B.C.) cultivated rice was observed in Babylonia and Susa. A thousand years later it was introduced into Syria, then into Egypt, and, later still, into Europe. Rice was introduced into Spain by the Arabs, and was first grown in Italy in 1468, near Pisa.

The bulk of the evidence appears to show that rice originated somewhere in the region from China to India inclusive.

680. Range. — Rice cultivation is limited in general by temperature and its water requirement. Ordinary rice will not succeed in higher latitudes than the warmest part of the temperate zone. Certain varieties, however, are grown in Manchuria and in some other cold temperate districts. Wild rice is a marsh plant, or grows along the banks of streams. In cultivation it usually requires irrigation, and must therefore be grown where there is a good supply of water, either by diversion from streams or by pumping. The so-called upland rice is only slightly or not at all different from ordinary rice, but appears to require less water, and is usually not irrigated. On the prairie land near Kissimee, Florida, and in northern Georgia near the mountains, it is grown without irrigation, but in the former locality the water table is near the surface. In these places the crop is not a large one and is grown chiefly for home consumption.

681. Classification. — Little study has been given to the classification of rice. The first need appears to be information that will establish more definite connection with wild forms. There are several from which to choose. Also in the numerous instances in which wild rice has been reported, it is not certain always whether or not it was rice escaped from cultivation. Watt (1891) believed that the surface structure of the lemma and palea (see 674) and of the facets of the receptacle bearing the spikelet are constant characters of importance, and that, on the basis of these, the two forms *Oryza granulata,* Nees, and *O. officinalis,* Wall., are distinct from any that are cultivated.

Subdivisions of cultivated rices have been made on several bases. The one feature common to all is the division into glutinous and non-glutinous rices. The characters of size, shape, and color of kernel are used variously by different writers. Some make red rice a main division of cultivated rices, but red rices exist having practically all the other chief characters of the species. The long-glumed rice is also sometimes made a separate main division, but is considered by most writers to be comparatively unimportant because of its rarity, and the probability that it has been developed abnormally in wet, ultra-tropical localities. Graham (1913) believes that the color of the leaf sheath is important in classification, and states that it is correlated with a similar color of the apiculus or tip of the spikelet. Others distinguish the scented rices (*O. moschata*) and the violet-colored rices (*O. violacea,* Mag.) as important divisions.

Based upon the little knowledge we have, the following provisional arrangement of wild and cultivated forms is presented, until we have something better, for those who desire a working basis for further investigation: —

Oryza
- granulata, Nees, wild rice.
- officinalis, Wall., wild rice.
- sativa, L, cultivated rice.
  - utilissima, Kcke.
    - communis, Kcke., large-kerneled rice.
    - minuta, Presl., small-kerneled rice.
  - glutinosa, Lour., glutinous rice.

O. coarctata, Griff., a brackish water species, *O. triticoides,* Griff., and perhaps one or two others, are wild species, but their relationships are not yet decided.

As in the case of club wheats, the large-kerneled and small-kerneled rices are here given specific rank agronomically, for convenience.

682. Common or large-kerneled rice. — A large part of the common rices are large-kerneled. In some varieties the kernels are large in both dimensions, in some others they are more than three times longer than broad, and called slender rices. In measuring the caryopsis of 372 varieties of Burma rice, Kikkawa found that 103 varieties belong to the group of medium sized, long-kerneled rices; that is, those having kernels more than twice and less than three times longer than broad, and whose length × breadth equals less than 19.5 sq. mm. and more than 15.0 sq. mm. The prevalent color of the caryopsis of common rices is a translucent waxy white, sometimes with a pale yellowish or grayish tint. Other colors are pale green, reddish brown, dark brown, and white with red or dark stripes.

The varieties Honduras, Carolina Gold, and Carolina White belong in this group. Some of the more important subdivisions and varieties are here given, following the classification of Koernicke, as in the other cereals, although with the small extent of material yet available any classification must be regarded as tentative. The very few varieties mentioned are nearly all foreign, and are given simply as examples of the groups. It is *Oryza communis*, Kcke.

Fig. 176. — Panicle of Honduras rice.

I. Awnless

(Oryza communis italica, Al.)

1. *Kernels yellowish red, caryopis white.* Bertone, the following from East Indies, — Gendjah-Marus, Molog, Tjempi Utri (very early), Lélé, Murbun, Benggala Bunturan, Gundil, Slowjur (early).

(Oryza communis javanica, Kcke.)

2. *Kernels dark red, caryopsis white.* Java.

(Oryza communis paraguayensis, Kcke.)

3. *Kernels dark, caryopsis large, white.* Paraguay.

(Oryza communis sundensis, Kcke.)

4. *Kernels yellowish red, caryopsis reddish brown.*

Sunda, Mataram, Tjempi Blulook (very early), Tjempi Kenanti (early).

II. Awned

A. Caryopsis White

(Oryza communis vulgaris, Kcke.)

5. *Kernels and awns yellowish red.*
   Carolina White, Carolina Gold, Ostiglione, Honduras (Fig. 176), Francone, Long-grain Carolina, Ebbas, and at least 25 other forms from East Indies.

(Oryza communis xanthoceros, Kcke.)

6. *Kernels yellowish red, awns dark violet brown.*
   Violet Bearded; a dozen forms from East Indies.

(Oryza communis melanoceros, Al.)

7. *Kernels yellowish red, awns black.*
   Black Bearded.

(Oryza communis leucoceros, Kcke.)

8. *Kernels dull brown, awns whitish.*
   White Bearded, Moscado de Valencia.

B. Caryopsis White, Red-streaked

(Oryza communis striata, Heuzé.)

9. *Kernels and awns yellowish red.*
   Red-streaked, Mantua.

C. Caryopsis Reddish Brown

(Oryza communis pyrocarpa, Al.)

10. *Kernels and awns yellowish red.*
    Yu-mi (China); a half dozen forms from East Indies.

683. Small-kerneled rice (*Oryza minuta*, Presl.). — There are great variations in shape and color of kernel and caryopsis, and presence or absence as well as color of awns, in the small-kerneled as in the large-kerneled rices. The number of varieties is much less than that of the large-kerneled group. Formerly only varieties of the latter group were grown in this country. Now 3 small-kerneled varieties are grown. The small rices are found chiefly in China, Burma, Siam, Philippine Islands, and East Indies. The Chinese in California prefer the small rices and import considerable quantities from Hong Kong. The small rices tiller more freely than the large rices. They can also be milled usually with less waste.

Fig. 177.— Panicle of Wataribune rice.

The varieties Shinriki, Wataribune, and Omachi belong in this group.

I. Caryopsis Rounded

A. Awnless

(Oryza minuta cyclina, Al.)

1. *Kernels yellowish red.*
Undallong (Sumatra), Sumbing (Java).

(Oryza minuta melanacra, Kcke.)

2. *Kernels grayish red, terminal spikelets with violet-brown awns.*
Sisirnaga (Java).

B. Awned

(Oryza minuta microcarpa, Kcke.)

3. *Kernels yellowish red, awns red.*
   Kitiran (Java), Shinriki, Wataribune (Fig. 177), Omachi.

II. Caryopsis Elongated, Kernels Awnless

(Oryza minuta longior, Al.)

4. *Kernels yellowish red.*
   Santong (Sumatra).

684. Glutinous rice (*Oryza glutinosa*, Lour.). — The caryopsis of glutinous rice is chalky white and opaque in cross section, when dry. On steaming, it becomes more transparent, and is more viscous than that of common rice. The iodine test gives a yellowish brown color to the starch, instead of violet. The zinc chloride solution of iodine colors the starch reddish brown, but colors that of common rice black. The explanation of this peculiarity is that there is present in the glutinous rice endosperm a considerable percentage of dextrine and maltose replacing the starch. The practical test for glutinous rice is in cooking it, when it runs together in a pasty mass. The kernels of common rice, if properly cooked, remain separate, keeping their shape. Glutinous rice has more tender stems and leaves than common rice, and, therefore, the straw is more valuable for feeding.

Glutinous rice is grown in India, China, Japan, Burma, Siam, and East Indies, but not at all in this country, and is rare or entirely absent in Europe. In no region is it a common food, but it is limited to use in desserts. Some of the chief subdivisions and varieties are as follows: —

I. Awnless

A. Caryopsis White

(Oryza glutinosa affinis, Kcke.)

1. *Kernels yellowish red.*
   Senggolan, Tjempa, Nangka, Bunsing, Djambang, Lombok, Ukel (all from East Indies).

(Oryza glutinosa Miqueliana, Kcke.)

2. *Kernels gray reddish brown.*
   Laron (Java).

B. Caryopsis Reddish Brown

(Oryza glutinosa dubia, Kcke.)

4. *Kernels yellowish red.*
   Tjaruluk (Java).

II. Awned

A. Caryopsis White

(Oryza glutinosa alba, Al.)

5. *Kernels and awns yellowish red.*
   Papah-Sogling, Lojar, Kuning, Lilin, Gendu, Adjas Suko (all from East Indies).

(Oryza glutinosa Heuzeana, Kcke.)

6. *Kernels yellowish red, awns dark violet brown.*
   Bussee, Djewineng, Krawang, Mulut, Mandalagiri, Surong (all from East Indies).

(Oryza glutinosa isochroa, Kcke.)

7. *Kernels and awns red.*
   Malele, Hurang (both from East Indies).

B. Caryopsis Reddish Brown

(Oryza glutinosa Eedeniana, Kcke.)

8. *Kernels yellowish red, awns dark violet brown.*
Gurunini (Java).

C. Caryopsis Dark Brown

(Oryza glutinosa melanocarpa, Al.)

9. *Kernels and awns yellowish red.*
Jtam (Java).

685. Special groups of rices. — There are certain groups of rice of special interest, though not of importance in classification. Scented rice includes those white kerneled non-glutinous varieties, which retain strongly the peculiar smell of the newly harvested rice grain and straw, which leaves the ordinary varieties after curing. The odor is said to be similar to the smell of mice. Nevertheless this rice is preferred by many oriental people. In deeply flooded places in tropical countries, rice sometimes grows very tall, to keep above the water. In deep lagoons the rice is gathered from boats, and sometimes the plants are 10 to 15 feet tall, and are called giant rice. Some varieties, called salt rice, appear to be rather resistant to the injurious action of salt water. The long-glumed rice (*O. grandiglumis*, Döll.) has been mentioned. This rice is thought by Japanese farmers to be more resistant to winds than other rices. The glumes equal or exceed the lemma in length. Some varieties are less than 2 feet tall, and may be called dwarf rices. A few of the violet-kerneled varieties have also violet-colored culms and leaves. They are rare, and usually grown only as curiosities. The color is caused by a coloring matter in the epidermis, which obscures the color of the chlorophyll. In a few rice varieties the spikelet is said to contain 2 or more ovaries (var. *plena*, Prain). A few varieties in the tropics are called cold weather rices; for example, Geemsal, a variety in the Sironcha tahsil of Chanda, in India, is sown in January and ripens in March.

686. World distribution of rice. — It is estimated that there are at least 5000 distinct varieties of rice in the world. Watt (1891, p. 529) expressed the opinion that there are close to 10,000 named varieties in India alone. Many of these may be synonyms or represent mere strains. A Chinese authority concludes there are over 3000 distinct varieties in China, and Kikkawa (1912) studied and classified 971 varieties from Burma. The Bureau of Agriculture of the Philippine Islands has studied over 1000 varieties, and has filed 3500 varietal names.

Rice is grown in practically all tropical and subtropical countries. The chief production is in India, China, Japan, Siam, Cochin China, Ceylon, Malay Peninsula, Burma, East Indies, and the Philippine Islands. It is grown to a less extent in the warm regions of North and South America, Africa, and southern Europe.

The most widely distributed rices are the large white and yellow kerneled varieties. The small rices are grown in oriental countries and the East Indies, particularly in China. Glutinous rices are grown in India, Burma, Siam, Java, China, and Japan. Scented rices are found in oriental tropical countries and Japan. Long-glumed rices are cultivated in Japan and China. The curious violet rices, having the entire plant colored, are found in various parts of the oriental tropics and in Japan and China.

687. Adaptation in the United States. — There are four rice districts in this country: (1) The Carolina rice district, (2) the Texas-Louisiana rice district, (3) the Arkansas rice district, and (4) the California rice district. In the Carolina district the varieties grown are Carolina White and Carolina Gold. The total production is small and is grown chiefly on the seacoast near Charleston,

Fig. 178. — A near view of a rice field ready for harvest. Ditch in center is used for irrigation and drainage. Creighton plantation near Jacksonboro, South Carolina, 1906.

in a narrow belt watered by the rivers Waccamaw to the Savannah, inclusive, extending slightly into Georgia, besides a very small acreage of upland rice in northern Georgia, near the mountains. The total acreage is 4600 acres. Old style methods and machines are still largely used, partly because of the size and character of the fields, and also because the farmers believe their methods produce better results (Fig. 178).

In the Texas-Louisiana rice district, irrigation is done by pumping either from bayous or deep wells. Here rice-growing is done on a large scale, similar to wheat-growing in the Great Plains. Immense pumping plants are established, which send the water through river-like canals, as in western irrigation, and the subfields are often near 100 acres in size. The soil is prairie land. The principal varieties grown are Honduras, Shinriki, and Blue Rose. During the last 25 years nearly all the rice

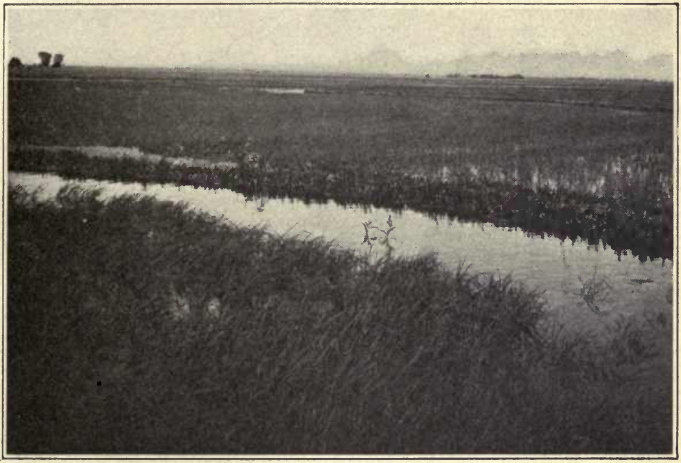


FIG. 179.—One hundred acres of rice in early stage of growth near Colusa, California.

of this country has been grown in this district. The rice acreage is 661,000 acres.

In Arkansas, the conditions are about the same as in the last described district, except that the average temperature is lower. The largest acreage is in Lonoke, Prairie, Monroe, Poinsett, and St. Francis counties. The total acreage is 100,000 acres.

In California, rice-growing is a recent industry, developed by the Sacramento Valley Grain Association, basing their efforts on experimental results of the Office of Cereal Investigations, United States Department of Agriculture. So far, the crop is grown chiefly in the Sacramento Valley, on the heavy adobe soil of that district, and watered mainly from the Sacramento and Feather Rivers. The present acreage is 34,000 acres (Fig. 179). The chief varieties grown are Wataribune and Shinriki. The small-kerneled rices seem better adapted to California conditions than the large-kerneled varieties. Outside these districts, there are about 2800 acres of rice grown in North Carolina, Florida, Mississippi, and Alabama. The largest part of this acreage is in Florida, where the upland or "gopher" rice is grown on prairie land.

688. Introductions of rice. — The first rice grown in this country is said to have been planted in the colony of Virginia in 1647. The $\frac{1}{2}$ bushel of seed, obtained from England, by Sir William Berkeley, Governor of the colony, produced 16 bushels of good rice. The beginning of the Carolina industry was made in 1694. Thomas Smith, Governor of the colony, obtained a small bag of rice from the Captain of an English or Dutch ship, which, driven by a storm, was forced to seek shelter in the Charleston harbor. The seed, which was apparently from a large-kerneled variety, was planted in a garden in Longitude Lane, Charleston, and from the resulting crop rice-growing was established. In 1718, lowland rice was introduced into Louisiana, and upland rice was started in South Carolina in 1772, coming, it is said, from Cochin China. When Honduras rice was first brought into this country is not known. It is supposed to have come originally from the country of the same name, but more recent importations have come from Mexico. It is still the

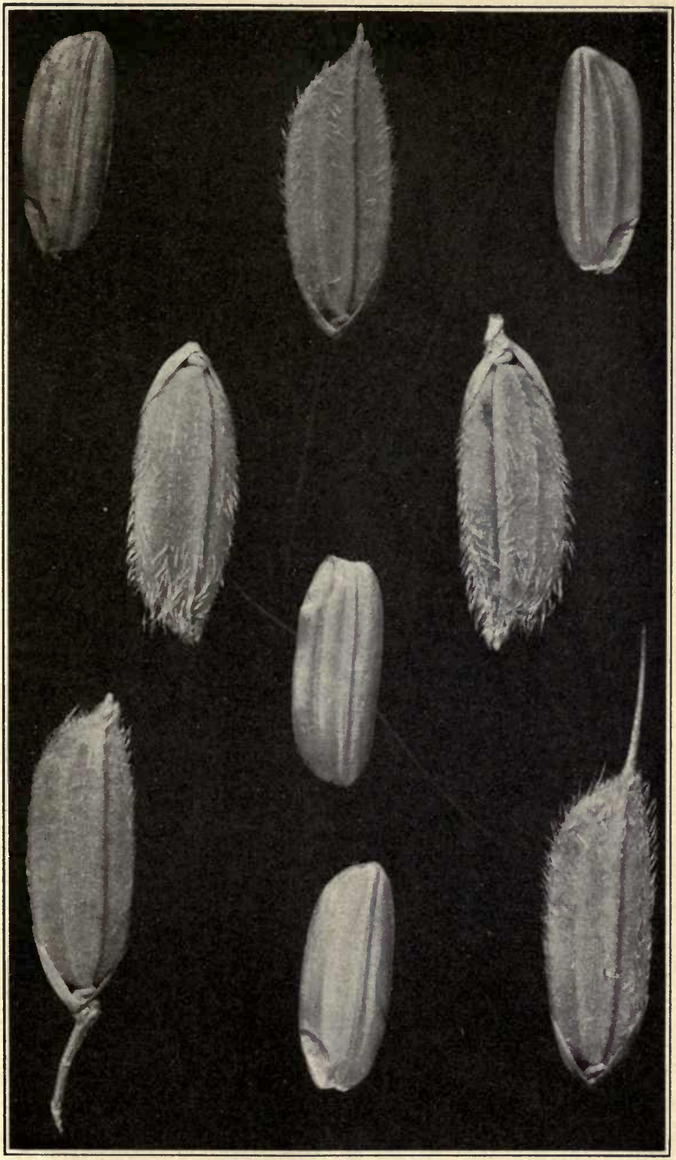


Fig. 180. — Honduras rice. Kernels × 5.

popular rice in the Texas-Louisiana rice district (Fig. 180).

Over 200 years after the introduction of Carolina rice, the Kiushiu rice was introduced from Japan by S. A. Knapp, for the United States Department of Agriculture. Ten tons of seed were secured, in the spring of 1899, and distributed for trial to coöperating planters, in the Texas-Louisiana rice belt. The variety was imported in response to a need for rice that would break less in milling than the long kernels of the Carolina and Honduras types, and thereby furnish a much larger proportion of head rice. Kiushiu rice has short kernels which are oblong oval, sometimes slightly obovate, white, and awned. It did so well, on first trial, that 100 tons more seed of it were imported by Louisiana planters for the season of 1900.

Out of the thousands of foreign varieties tested in more recent years by the United States Department of Agriculture, a few have given exceptionally good results. Two of these, Shinriki and Wataribune (Fig. 181), have done particularly well, and are now grown on the rice farms. The latter is already the popular variety in the Sacramento Valley. These are small-kerneled Japanese varieties. The Shinriki has white, awnless, oblong-oval kernels. The Wataribune has awned kernels darker in color, and more elongated. Omachi, another introduced small-kerneled Japanese variety, also gives promise of becoming established.

689. Seed cleaning and grading. — The treatment of this subject under discussion of the other cereals is quite applicable to rice. Ordinarily no seed of any cereal should be sown until well fanned and screened, usually with the fanning mill. Grading by means of the specific gravity method already described (181) may also be profitably employed with rice. Yokoi (1898) has made

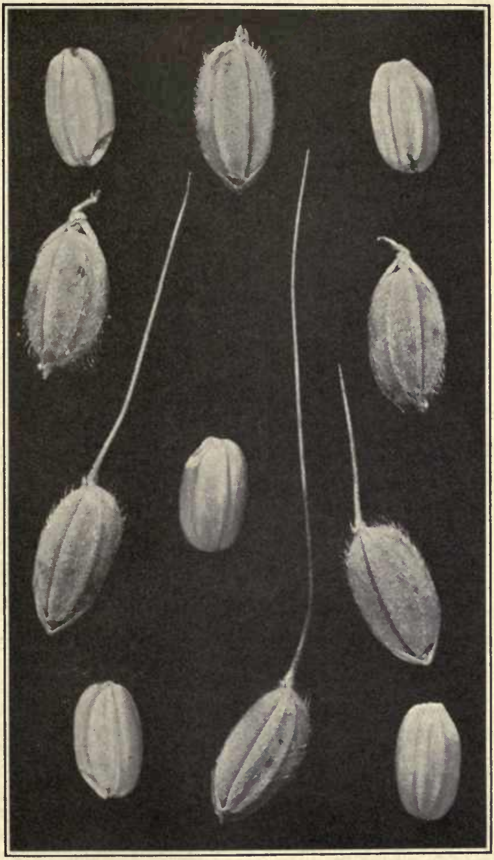


FIG. 181. — Wataribune rice. Kernels × 4.

important experiments in this line with affirmative results. It may be noted here that Andro (1898, pp. 477–481) has determined by experiments that rice kernels increase in specific gravity with the degree of ripening. The use of clean seed not only increases the yield, but is one good method of controlling weeds.

690. Selection. — Few or no results have yet been secured from experimental rice selection in this country, though a large number of selections are under trial at the federal and state rice experiment stations. Earliness is a quality generally needed. It is urgent in California, to enable the rice to escape the autumnal rains, and to flower and ripen at the proper time with reference to the occurrence of maximum temperatures. In the Texas-Louisiana rice district, about the greatest need is a variety resistant to the diseases rice blast and straight-head.

In Japan, a number of selections have been made and exhibited at the Panama-Pacific Exposition, and such work is undertaken in the central provinces of India. Ostiglione is a selection developed in Italy, from the Carolina rice, introduced into that country.

The importance of mass selection is just as great in rice-growing as in growing other cereals. The seed plat should, therefore, find a place on every rice farm (see 191).

691. Hybridization. — No valuable rice hybrids have yet been established in this country, but a considerable number are under trial by the United States Department of Agriculture. In some cases the effort is being made to fix new varieties that will resist the rice blast and straight-head. Other new varieties are being developed that have combined both the qualities of yield and adaptability for milling. A number of apparently valuable hybrids have been created in Japan.

Natural crossing is known to have occurred in rice, particularly the crossing of cultivated and red rices. At Dacca in India, natural cross-pollination is said to have occurred to the extent of 4 per cent of the flowers. On the other hand it has not yet been observed in the pure line cultures at Nagpur (Graham, 1913, p. 214). Two interesting correlations between length of stem and tillering, and between length of stem and weight of panicle, have been determined by Kikkawa (1912, pp. 18–19), which may be of use in hybridization work.

Cultivation

692. Soil adaptation. — Apparently the best soil for rice is a medium loam or clay loam having 50 per cent of clay and an impervious subsoil. The drift soils of the Texas-Louisiana gulf coast are well adapted. Extreme heaviness and stiffness of soil are always better than extreme lightness and porosity, partly because of the greater amount of plant-food usually in the former, and particularly because of its ability to retain water. The "buckshot clay" soils of southeastern Louisiana and the "adobe" soils of the Sacramento Valley, which are excellent rice soils, are so stiff that they are plowed with great difficulty before flooding, and are exceedingly tenacious and putty-like when wet. Rice will do well in soils that possess a considerable quantity of alkali, a fact no doubt largely accounted for by the flooding, which keeps the alkali in dilution, so it is never deposited at the surface at a time when it can injure the crop.

693. Fertilizers. — If the straw, chaff, and stubble of the rice crop are afterward plowed under, it does not greatly exhaust the soil, as the grain removes only about $\frac{3}{10}$ of the nitrogen, phosphorus, and potassium of the crop. If, in addition, the flooding is from rivers like the Mississippi, little if any fertility is lost. When the flooding is done with practically pure water, as is often the case, the soil can only be kept fertile by adding to the soil what the crop has removed. It is probable that the constituent most generally lacking is nitrogen. The particular soil amendments required will of course depend upon the conditions of the locality. Kelly (1914) concluded, after experimenting with fertilizers on rice soils of Hawaii: (1) that very little nitrification takes place in submerged soil, but ammonification goes on sufficiently to supply the nitrogen needs of rice, provided there is sufficient organic matter present; (2) ammonium sulfate should, therefore, be applied instead of a nitrate; (3) nitrates, under submergence, are reduced to nitrites, which are poisonous to the rice; (4) rice soils should not be plowed, unless immediately sown with a rotating crop, until it is time to sow rice again, as the aëration of the soil resulting will permit the formation of the poisonous nitrites. Further information on fertilizers for rice is needed.

694. Rotations. — Instead of the fallow or unplowed land preceding rice, it is far better, usually, to plant a legume to be plowed under as a green-manure, and as a part of a systematic rotation. This, in connection with the application of a locally adapted fertilizer, will complete a proper rice crop management.

In Japan and other oriental countries, rice land is often fertilized in the fall with straw, leaves, rice hulls, fish, and night soil. The field is then planted with vetch or sometimes wheat, for a winter crop, followed in the spring with rice without additional manure.

695. Irrigation. — The rice crop is generally irrigated. So-called upland rices, already mentioned, are ordinary irrigated varieties, grown on uplands, without watering, where there is considerable rainfall. By continued treatment of that kind, they become fairly well adapted to dry conditions. These varieties when subjected to irrigation again, always yield more than when not irrigated and often more than the other irrigated rices. Upland rices, in this country, are always grown on comparatively small areas, and for home use, where the farmer often has his own small mill, as in south central Florida. They are sometimes cultivated like corn.

In Japan, portions of China, the Malay Peninsula, and other oriental regions, water stands constantly on the ground until harvest time. The cultivation, of which there is sometimes little or none (see Pratt, 1911), is done in the water, and 12 to 18 inch seedling rice plants are transplanted in the water, from nurseries. In other places, and always in this country, the seed is sown in the field, the ground is prepared while unsubmerged, and the water is applied at regular intervals.

696. Sources of water. — In this country the sources of irrigation water are, in general, the following: (1) from the overflow of tide water streams on coast lands; (2) by gravity from rivers and their branches, and (3) by pumping from streams at a lower level, by pumping from wells, or by the water of artesian wells. The first mentioned condition exists in the Carolina district, the second in California and along the Mississippi River, and the third, with little help from artesian water, in the Texas-Louisiana and the Arkansas rice districts. The land along the Mississippi River is protected from overflow by levees, as it is often lower than the level of the river water. The water, at such times, is carried over the levees on to the rice fields, through siphons. At the lower stages of the river, it must be pumped into reservoirs built inside the levees and sufficiently higher than the fields, so the water will still flow through the siphon, over the levees.

697. The size of the subfields or cuts depends chiefly on the degree of slope. They range from 60 to 100 acres in the Texas-Louisiana rice district, to 1 or 2 acres near the Mississippi River. In the Carolina rice district a field is divided into rectangular cuts, of about 40 acres each. In oriental countries the cuts are often no larger than $\frac{1}{2}$ acre. The entire field must be practically level, so the water will stand all over it at about the same depth. The greater the slope, therefore, the smaller the fields must be made. The possibility of effective drainage must not be overlooked in laying off the fields.

698. Pumping. — In Texas, Louisiana, and Arkansas, which produce nearly all of the rice in this country, "all but 2.5 per cent of the irrigated land in rice is supplied with water by pumping, and wells afford a supply for about $\frac{1}{3}$ of this area" (Haskell, 1915, p. 3). Wells and their pumping equipment are usually owned by the individual farmers. In other instances the irrigation water is supplied from large canals, owned by companies or individuals, who furnish it to the rice-growers on a rental basis. The height to which the water is elevated varies from 10 to 80 feet. Some of the largest and best equipped pumping plants in the world are used in rice irrigation. Main canals, with a volume of water equal to that of some rivers, are employed, as in western irrigation (Fig. 182).

699. Levees. — The water, brought to the field through the main canal and laterals, is held there by a large levee 12 inches or more high, built around the field. Other levees are constructed, following contour lines, at every drop of a certain fraction of a foot in the slope. These should be just high enough to prevent overflow into the next cut or subfield below, and so broad that all kinds of machinery used in rice cultivation may pass over them easily without damaging them. They are therefore low and very broad, and should be planted with rice. These

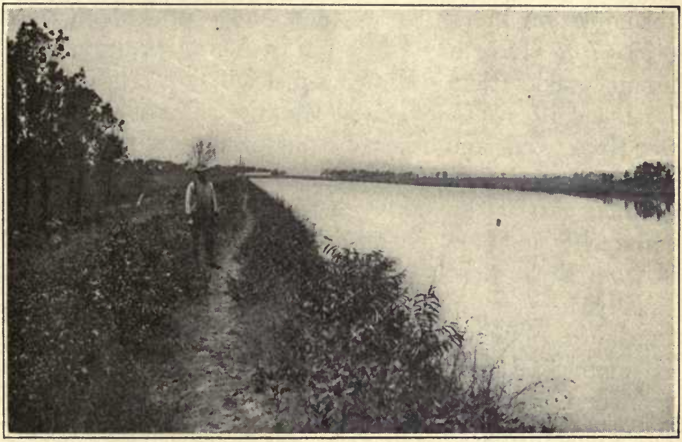


FIG. 182. — Neches Canal, Beaumont, Texas.

levees should be permanent and accurately located, with the help of a competent civil engineer. The cost of levee construction varies, but the average for field levees and laterals is about $1.50 an acre, the work including the running of contour lines, levee construction, and leveling. Levees of black adobe soil permit more seepage than those made of other types of clay. Levee construction and the prompt delivery of water are of the greatest importance. Payment for water should be based upon the volume delivered (Chambliss and Adams, 1915, pp. 7–9).

700. Drainage. — The necessity of good drainage is generally not sufficiently appreciated. The removal of the water is just as important as the flooding. Boggy fields delay harvesting, which results in reduced yields because of shattering. Poor drainage or lack of drainage causes under-production through waterlogging, and the accumulation in the surface soil of harmful alkali salts (472–476). It is an engineering problem, requiring community coöperation. Drainage districts should be created. Drainage ditches always need attention, and must be kept free from weeds and other obstructions.

701. Preparation of the soil. — Conditions in different districts vary so that a statement as to the time of plowing cannot be made for general application. The same thing is true of the depth of plowing. It is probably better usually to plow in the spring shortly before planting. In the Sacramento valley where there is winter instead of summer rainfall, deep plowing in late autumn appears to be best. Disking and harrowing are left to be done the following spring. Deep fall plowing permits any accumulations of alkali to be washed out by the winter rains. In the case of spring plowing, disking and harrowing should be performed at once if possible, otherwise the land will bake. The conclusion of Kelly, on the other hand, concerning the relation of early plowing to the formation of poisonous nitrites, has been mentioned (693).

702. Time of seeding. — Seeding may be done from March 15 to May 15. About April 15–20 appears to be a fair average time for best results outside of California, where April 1 is recommended. In dates of seeding tests at the Biggs (California) Rice Field Station, ranging from April 1 to May 15, the earlier seeding always gave the best results. It is not safe to sow Wataribune rice in California after May 1. Seeding should be done as soon as possible after spring plowing.

703. The rate of seeding varies in different districts with different methods of seeding, and with the variety of the rice grown. Soil fertility and the vitality of the seed are also factors of influence. The range is from 1 to 3 bushels an acre. On the black adobe soil of the Sacramento valley, 90 pounds an acre of Wataribune are sufficient. The long-kerneled varieties should be sown thicker than the short-kerneled rices, to which Wataribune belongs. The requirement of more seed in broadcasting than in drilling, on weedy land than on clean land, and on a poor seed-bed than on a good seed-bed, is as true of rice as of the other cereals (355).

704. Depth and method of seeding. — Always when at all possible, rice should be sown with a drill. In general, the same reasons for drilling apply as those for other spring sown cereals (357).

Ordinarily, rice should not be sown deeper than 2 inches. If the surface soil is well pulverized, even a less depth may be desirable. If irrigation is necessary to germinate the seed, seeding should not be done extremely shallow, as the water may float and scatter it.

705. Applications of water. — Remembering that rice may be successfully grown without any irrigation or with continuous irrigation from time of sowing to harvest time, the great possible range for variation in practice is seen.

If water is not necessary for germinating the seed, flooding is not begun until the rice is 6 to 8 inches high. Usually water is required for good germination, and is applied soon after seeding, remaining on from 1 to 6 days, depending on local conditions. The grain must be well sprouted, but in some localities the soil and air are at low temperatures at this season, and there is danger of rotting the seed if the water remains on very long. In California, the period of this irrigation should not be more than 2 days. As the soil also should not dry out, frequent irrigation is required until the plants come up (Chambliss and Adams, 1915). In South Carolina, the "sprout water," as this first application is called, remains on 4 to 6 days.

When the plants are 6 to 8 inches high, the long flooding begins, and the water then turned on remains at a depth of 3 to 6 inches, until the panicles are well filled and drooping. In California, this submergence should begin about 30 days after the plants come up, and the water should remain at a depth of 5 to 6 inches.

In South Carolina, there is a submergence of 10 to 12 inches, known as the "stretch water," when the plants have 2 leaves, which depth is gradually reduced to about 4 inches. This period continues 20 to 30 days. There is then a period of dry growth, when the crop is cleaned of weeds, including volunteer rice, by hoeing. When jointing begins, the final irrigation or "lay by flow" is given.

In the Texas-Louisiana rice district, and in Arkansas, the irrigation season extends from 70 to 120 days, or an average of about 90 days. Early-sown rice, as it matures later from the time of seeding, requires more days of irrigation.

706. Some general principles of rice irrigation are as follows: (1) The water should always stand at a uniform depth over all the field; (2) there should be a continuous inflow and outflow, to avoid stagnation; (3) continuous submergence for a long period is required for a paying crop; (4) for economy, the overflow or water loss need never be more than a mere film in depth; (5) increased tillering occurs directly, and root growth inversely, in proportion to the amount of irrigation; (6) irrigation water should not contain more than 0.3 per cent of salt, and even a little less than that may be injurious.

FIG. 183. — Twine binder used in rice harvest, Beaumont, Texas.

707. Harvesting and thrashing. — In the Carolina rice district the crop is cut with the sickle. The cut grain is laid on the stubble and cured before binding, and is also not bound while it is wet with dew or rain. The thrashing is done with modern machinery, in buildings called "thrashing mills," located on the bank of the river or a large canal, where the grain can be readily loaded on to boats for transport to market.

In all the other rice districts, the harvesting and thrashing are done with self-binders and steam thrashers, often on a large scale, in the same manner as other cereals are gathered in the north and west (Fig. 183).

Rice Pests

708. Weeds form one of the chief difficulties with which the rice-farmer must contend. Many grasses and some other plants are adapted to the same conditions that are favorable to the growth of rice. These weeds increase the cost of production, reduce the yield, and injure the grade of the grain, thus lowering the price.

As it is expensive to eradicate weeds, it is better to prevent their introduction. The irrigation water brings many foreign seeds. The community thrashing outfit also is a weed distributer. Weeding by hand should be done at once on the appearance of weeds, unless there are so many that the cost would be prohibitive. If the latter is true, clean culture must be practiced, and crop rotation, if a satisfactory crop to follow rice is available, as recommended in Chapter XVII. Planting the field levees with rice will reduce the area for weed growth.

709. Red rice (*Oryza sativa*, Linn., various varieties). — The worst weed of the rice fields of this country, except in California, is red rice, which is found in all rice countries of the world. The coat of the caryopsis is red, and the color does not refer to the hull. Red rice is introduced only through its occurrence in the seed. The importance of pure seed in rice seeding is, therefore, made evident. Red rice is readily distinguished from cultivated rice in the field, by its loose, open, drooping panicle, with few kernels on the branches. Even the individual kernels can be detected by the experienced rice-grower. The weed may be prevented from becoming established in a small field by pulling and removing the individual plants, at the beginning of infestation. The seed shatters greatly, and if care is not taken to remove these first plants, the crop each year will become infested. Where there is already a large percentage of red rice, the only recourse is crop rotation, which should, however, be practiced anyway, if possible. It has been demonstrated that, with crop rotation and rigid seed selection, the red rice problem is not nearly so difficult as is generally supposed.

There are numerous varieties of red rice belonging in different subspecies of Oryza, of which some are cultivated in foreign countries. It is not a deteriorated rice, but may be as good in food value as many cultivated rices. Its color injures the appearance of milled rice, and it is therefore rejected by the miller.

710. Barnyard-grass or water-grass (*Echinochloa crus-galli*, Beauv.). — This is the worst weed of rice fields in California, and gives considerable trouble also in Texas and Louisiana. It is coarse, awned, erect or spreading, and varies in height from 10 to 50 inches. It grows luxuriantly in irrigated fields, and produces a large number of seeds. On one plant there may be as many as 40,000 seeds. Therefore not a single plant should be allowed to mature seed in rice fields or near by. The seed is carried in irrigation water, and occasionally from field to field by winter floods.

As soon as water-grass first appears in the field, it should be removed by hand, before it produces seed. The seed germinates at the same time as the rice, but two weeks after coming up makes a more vigorous growth, and is lighter green in color than the rice plants. If not removed, it will mature seed before the rice crop is harvested. In removal, the plants are cut off below the crown and taken entirely away from the field. If cut at the soil surface they will grow again, and produce seed as often as cut, several times during a season. If the weed is allowed to seed in any quantity the first year of appearance, it will afterward be almost impossible to eradicate it. Complete eradication will be greatly aided by crop rotation, including a cultivated crop. Concerted community action is necessary to effect permanent eradication (Chambliss and Adams, 1915, pp. 16–18).

711. Rice water weevil (*Lissorhoptrus simplex*, Say). — The most injurious insect enemy of growing rice in the southern states is the rice water weevil. In its larval stage the insect is known to rice-growers as the "rice root maggot." The larvæ feed on the roots of rice plants, while the adults cause some injury by feeding on rice leaves. The insect breeds only where there is water, and feeds on plants growing in wet places. The eggs are laid on roots in water or on weeds, where the larvæ are hatched and transform into pupæ, and finally into adult insects. One generation in a season appears to be the rule, but two generations may sometimes be produced. The adults hibernate in the winter and invade the rice fields in the spring.

As the insect lives only in water, it is recommended as a means of control to drain the rice fields, causing them to dry sufficiently to exterminate the insect at the proper time before the larvæ have greatly weakened the plants. Alternate flooding and drying, if done properly, is effective. Very shallow flooding checks infestation, while fertilizers aid the plants to overcome injury.

712. Other rice insects are occasionally injurious. The rice grub is the larva of a large scarabæid beetle (*Chalepus* *trachypygus*, Burm.) which, contrary to the habits of the water weevil, attacks the rice fields when they are dry, feeding on the young roots of the rice, and laying its eggs there. Both larvæ and the adults perish at the last flooding of the rice. This insect may be controlled by crop rotation and destroying all volunteer rice.

The rice stalk borer is the larva of a moth (*Chilo plejadellus*, Zinck.) allied to the insect which attacks maize and sugar cane in a similar manner. It is 1 inch long when full grown, whitish, having longitudinal subdorsal stripes of reddish brown, and works throughout the culm from the base to the panicle. A second brood is developed on volunteer rice at edges of fields later in the season. The best means of control is to cut the stubble, volunteer rice, and weeds after harvest, as close to the ground as possible, and burn the material.

The rice weevil, destructive to stored rice, is described in another place (533).

713. The ricebird (*Dolichonyx oryzivorus*). — Several birds feed on rice at times, but the ricebird or reedbird or bobolink is the greatest bird enemy of the Carolina rice-planter. Hosts of these birds visit the rice fields at the time of planting in the spring, devouring the seed grain before the fields are flooded, and again at harvest time in the fall, when, if the maturing grain is "in the milk," they eat it to a ruinous extent. To prevent total destruction during these periods, thousands of men and boys with guns, are employed as "bird minders," to scare the birds away with blank cartridges. Still the number of birds arriving each year appears in no wise diminished. In some places it is estimated that the average loss due to this bird is 4 to $4\frac{1}{2}$ bushels to the acre.

714. Blackbirds. — In the Texas-Louisiana rice district, the ricebird is not important, but the blackbirds are the chief offenders. These birds, which are winter residents, are everywhere, in all rice fields, early in the spring. They begin their daily forage soon after sunrise, emerging from the wooded banks of bayous, and feeding in the old rice stubble, and also in the newly planted ricefields. They are found in particularly large numbers on the levees, where there is much shattered grain lying under the mat of fallen stalks of both white and red rice.

Other birds that feed on rice to some extent are the meadow lark, the mourning dove, the English sparrow, and the wild duck.

715. Straight-head. — Rice is affected by few diseases in this country. Two of these, the straight-head and rice blast, are sometimes very serious but do not occur in California. Probably the most destructive rice disease is the straight-head, so called because of the appearance of characteristic upright, unfilled panicles late in the season, when normal panicles are drooping from the weight of ripe grain. The affected plants are normal in color and foliage at time of heading, but the panicles remain erect and unfilled and the glumes are frequently distorted, or in extreme cases may be entirely absent. The cause of this disease is not yet known, and at present it is referred to as a physiological disease. No effective method is yet known for preventing straight-head.

716. Rice blast or rotten-neck (*Piricularia grisea*) occurs generally in the rice-growing districts of the South. It develops throughout the ripening season and exhibits two main types as follows: (1) a leaf spot, in the form of a large elongated brownish lesion, with a light center and dark border, fading to yellow at its outer edge; (2) a distinct brownish region on the peduncle or neck of the panicle, resulting in a very noticeable weakening at that place, thus causing the panicle to break over and become a total loss. No effective control measures have yet been discovered for this disease.

Uses of Rice

717. Rice as stock feed. — As a fodder for stock, it is stated that rice straw is about equal in value to good, southern prairie hay. It is composed of 4.72 per cent protein, 32.21 per cent carbohydrates, and 1.87 per cent fat. More care should be taken in disposing of the straw than is ordinarily done, in order that its flavor may be preserved.

Dalrymple (1910) concluded, from experiments with rough rice as feed for horses and mules, (1) that "ground rough rice may be found of considerable economic value as a feed for these animals, if intelligently and systematically used," and "when the prices of other cereal (feeding) grains are high, and other conditions warrant;" also (2) that, when "forming one of the ingredients of a mixed ration, [it] may be fed with safety and benefit."

Rice flour and rice meal are very valuable stock feeds, being rich in carbohydrates as well as albuminoids. According to an estimate by Stubbs, the by-products of rice compare in value as follows: rice polish $21.55 a ton; rice bran $20.80; rice straw $9.13; and rice hulls $8.34.

718. Primitive and oriental rice milling. — There were primitive methods of milling rice similar to those of milling other cereals. The old style pounder, and a crude fanning mill, are commonly used at present in oriental countries.

The pounder is a heavy wooden weight fixed to a horizontal beam 6 to 8 feet long, which rests on a fulcrum 4 to 5 feet from the former. The pounder rises and falls into a tub made of a short section of a hollow log, where the rice is placed, and is worked by a man stepping on and off the other end of the horizontal beam. With a woman at the fanning mill, it is stated that such an arrangement will clean a trifle over 3 barrels of paddy rice (thrashed rice with the hull on) a day, at a cost of 6 cents gold to the barrel. In places, there is an improvement over this method, in which water power (or steam power in the cities) is used to turn a long horizontal shaft, having rounded arms which at each revolution of the shaft, strike projections on the sides of vertical pounders, causing them to rise and then fall into tubs of rice as the arms slip by the projection. By this improved method, with 8 pounders, 96 bushels or 26⅔ barrels of paddy rice may be milled in a day, at a cost of 2 cents a barrel, which is said to be more than paid for by the value of the offal (Knapp, 1899, pp. 33–44).

719. The modern commercial milling process is somewhat complicated: —

After cleaning the paddy rice, the hulls are removed by rapidly revolving milling stones, set at distances apart of about ⅔ the length of a rice kernel. The products are separated by passing over horizontal screens and blowers. The naked grain (caryopsis) has a mixed yellow and white color. The outer coat (bran) is removed by placing it in large mortars holding 4 to 6 bushels and pounding it with pestles weighing 350 to 400 pounds. In recently erected mills, in place of the mortar and pestle, there is used a huller, a short cast iron horizontal tube, with interior ribs, and a funnel at one end for admitting the rice, similar in form to a sausage grinder. A corresponding shaft with external ribs revolves within the tube. The rice passes out at the end opposite the funnel. There are 6 hullers for each set of mill stones.

The contents from the mortars or the huller consist of flour, fine chaff, and clean rice of a dull, filmy, creamy color. The flour is sifted out through flour screens, and then the fine chaff is blown out with the fine-chaff fan and mixed with the flour. The rice then goes to cooling bins, made necessary by the frictional process through which it has passed. After 8 or 9 hours it passes to the brush screens, from whence the smallest rice and the little flour that is left passes down one side and the larger head rice down the other.

The clean rice is subjected to one more process, that of polishing, which gives it the pearly luster. This process is effected by friction of the rice against pieces of sheepskin or moose hide tanned and worked to a great degree of softness, loosely tacked around a double cylinder of wood and wire gauze. The rice then goes to the separating screens, composed of different sizes of gauze, and is divided into its grades, and then barreled for market (Knapp, 1899, p. 34).

Portable rice mills, for plantation use, have been devised, which clean 8100 pounds of paddy rice a day. These small mills do not give the finish required by the general market.

720. Grades of milled rice. — At the New Orleans Board-of-Trade, milled rice is handled under the following grades: (1) Screenings, the smallest product generally used for human food; (2) head rice, a collection of broken kernels of larger size, which may not contain any whole kernels; (3) fancy head, composed of whole and broken kernels; (4) extra fancy head, containing 75 per cent or more of whole kernels. These grades vary more or less according to the hardness of the rice. The lowest grade of rice sold is called brewers' rice, and is used chiefly in brewing. Milled rice is sold in the primary market on sample, and not on grades (634).

721. Rice as a food sustains more people than does any other one crop. In comparison with other cereals, it is poor in protein and fat, but rich in carbohydrates. In Japan and China, the lack of protein is offset by a very large use of beans and other legumes. In oriental countries, rice takes the place of potatoes, and is the principal food often at every meal. Even in this country, in the southern states, rice is often a dish in the heavy part of the meal, while in the northern states it is usually a dessert or breakfast food. Without question, this difference in the appreciation of rice as a heavy food is because of lack of information in the North on the best methods of serving it.

After cooking, rice should always come out unbroken and rather firm. If it is pasty, it is either not properly cooked, or of the glutinous kind. As previously stated (684), glutinous rice is used only in fancy dishes, pastries, and confectionery. In the Philippine Islands, rice is prepared by placing it, with cold water, in an unglazed pot, and cooking it until the water is absorbed and evaporated. It is then entirely unbroken.

Various fermented drinks are made from rice. Red rice is often thus employed, as the coloring matter of the cuticle imparts an attractive color to the drink. In the Philippine Islands, one of these is made, called tapuy. In Japan, a drink called "sake," similar to beer, is made from rice.

722. Polished and unpolished rice. — The same requirement of fashion or habit as to the appearance of the product, exists with respect to rice as in respect to other cereal food products. Whiteness and luster are demanded, resulting in the highly polished rice now furnished by the mills. The unpolished product is, however, more nutritious, since in polishing an average of .54 per cent of the protein is removed, as shown by analyses.

The chief constituents of polished head rice are present in the following proportions, on an average: water 10.82 per cent, protein 7.79 per cent, and carbohydrates 80.04 per cent. The nutritive ratio is 1 to 10.8 and 86.5 is the nutritive value.

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INDEX

The numbers refer to the page.

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