# THE EVOLUTION OF THE GENUS TRITICUM AS AN ECONOMIC CEREAL.

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The study of our cereals is a most fascinating subject, and, apart from the intense interest which necessarialy attaches to that cereal from whence comes our "staff of life", the study of the history and development of the grain and of the operations necessary for its successful cultivation, the subsequent treatment in mill and bake-house, provides us with a series of intellectual problems of the highest interest. The peculiarities of the growth of the plant, the characteristics of the different types, the creation of new varieties, the unique chemical nature of the grain, the problems connected with soil and climate, the question of storing and transport, together with a study of the diseases and insect enemies that attack plant and grain, one and all furnish material sufficient for the study of a life-time.

In treating such a broad subject I shall be able to touch in only the briefest possible manner the multitude of subjects herein presented for our study.

The principal cereal belonging to the genus _Triticum_ that we are especially interested in, and the one that will be most discussed here, is _Triticum sativum vulgare_, or wheat.

This cereal is the principal grain food of civilized communities, and next to rice, the principal grain food of mankind. Its cultivation is of the very greatest antiquity, it being cultivated even in prehistoric times, as were also rice and barley. Spelt, which is a small grained variety of wheat, has been found in the lake-dwellings of Switzerland, human habitations which have been traced back to the stone age . Grains and heads of wheat have been found in Egyptian monuments dating back to 3000 B. C. It is one of the grains known to have been cultivated in China nearly 3000 B. C., and was probably cultivated in the Euphrates valley some 2000 years before that. It was not only in general use in these remote periods, but its cultivation was of far greater economic importance among the older nations than it is at present and formed the principal industry and means of livlihood of mankind. It even played an important part in the religious ceremonies of some nations.

The native country of the cultivated wheat has generally been supposed to be the central part of Asia; it has been reported to have been seen growing wild in Mesopotamia, Kurdistan, and elsewhere, but the fact has not been proved. M. Fabre asserted after a series of experiments in 1838--46 that the AEgilops ovata, a grass near the regions of the Mediterranean and of the west of Asia, had under his superintendence been transformed into wheat, but it is suspected that his grasses were hybridized by wheat. It was commonly believed by many, however, that the cultivated varieties of wheat were derived from some species of the AEgilops.

Wheat being the most esteemed of all the cereals, particularly for the making of bread, the increase of its cultivation and use has marked the progress of agriculture and of wealth in many countries. It is only in comparatively recent times that bread made of wheat has become a common article of food among the lower laboring classes. Down to the end of the seventeenth century wheaten bread was the principal article of food only among the most wealthy, and under the old modes of cultivation was expected to produce only five fold as compared with - say fourteen fold now. During the period of the Revolution in England, 1689, the quantity of wheat grown in that country was estimated at 14,000,000 bushels while the crop of 1900 is estimated at about 54,400,000 bushels, or nearly four times as much. Coming down to the present day, the world's wheat harvest for 1900 amounted to a grand total of 2,532,567,000 bushels of which the United States produced 544,000,000 or more than one fifth of this enormous amount, Russia coming next with 312,000,000 bushels. More than half the total of two and one half billion bushels is produced in Europe but the United States is by far the largest producer of any one country. In 1889, which was the record year as far as yield is concerned, the production of nearly every country was in excess of that for 1900, and the total amounted to nearly three billion bushels.

The zone of the wheat producing countries is somewhat irregular. Wheat does very well in sub-tropical regions and in most regions outside of the sub-tropics, it being able to withstand considerable cold if covered with snow. Its northern limit of cultivation in Europe is 60°N. It does not thrive in the torrid zone except in elevated localities as it requires a mean temperature of about 55°F. for three or four months of the year. The yield is always low in dry regions but a very large proportion of the world's wheat is grown in semi-arid or arid regions.

In Southern Russia, for example, the area which includes the governments of Astrakhan, Samara and Orenburg, lying to the north of the Caspian Sea, and which is one of the principal wheat producing regions of Russia, contributing over forty-five million bushels yearly, the average annual rainfall is only thirteen inches; the yield of wheat is, however, only about six and one half bushels per acre. Over the whole district east of the Volga the rainfall is less than fifteen inches. In this area is grown the bulk of macaroni wheats and much of the celebrated red wheat such as Ghirka.

In order to show the correct relation of wheat to the genus Triticum and of this genus to the various other members of the Grass Family, I shall use the following tables adapted from bulletin No. 62 of the Minnesota Experiment Station. (Table I. Table II.)

Table I.

GRAMINEAE. (Family.)

Classification of the Grass Family, showing relation of Wheat to other Tribes.

| | |
|---|---|
| | 1. Maydear.-(Corn - Teasointe.) |
| | 2. Andropogoneae. (Sugar Cane - Sorghum.) |
| Spikelets 1 Flowered. | 3. Zoysieae. |
| | 4. Tristehineae. |
| | 5. Paniceae. (Millet - Hungarian.Grass.) |
| | 6. Oryzeae. (Indian Rice - Rice.) |

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|---|---|
| | 1. Phalarideae. (Canary and Sweet Vernal Grass.) |
| | 2. Agrostideae. (Timothy - Red Top.) |
| Spikelets Many Flowered. | 3. Aveneae. (Oats.) |
| | 4. Festuceae. (Blue Grass - Bromus - Orchard Grass - Fescues.) |
| | 5. Chlorideae. (Grama and Buffalo Grass.) |
| | 6. Hordeae. (Wheat - Barley - Rye - English Rye-grass.) |
| | 7. Bambuseae. (Bamboo.) |

TABLE II

# CLASSIFICATION OF WHEAT.

Hordeae. (Tribe.)

Nardeae (Sub-tribe.) /
Lolieae (Rye Grass.) - - / Agropyrum (Quack Grass.)
Leptureae - - - - - - - - / Haynaldia.
Triticeae - - - - - - - - + Secale (Rye.) /
/ AEgilops
Elymeae - - - - - - - - - / Triticum - - - - /
(Barley-Wild Rye.) / / Stiopyrus
/ Heteranthelium. /
Parinaeae /

AEgilops / Tr.Monococcum / Tr.sat.Spelta (Rice Spelt.) /
/(one-grained Wheat) / /Tr.sat.vulgare /(Common Wheat.)
/ Tr.sativum - - - - + Tr.sat.Dicoccum /
Sitopyrus / / Tr.sat.compactum /( Dwarf,Hedge-hog wheat.)
/ Tr.polonicum (Polish Wheat.) / Tr.sat.tenax / Tr.sat.turgidum /Egiptian,Miracle Wheat.)
/ Tr.sat.durum. /(Hard or Flint Wheat.)

The relation of wheat to other plants need not be entered upon extensively here. Table I simply shows the thirteen tribes of the great grass family while Table II shows (1) the six sub-tribes of the tribe, Hordeae, (2) the five genera of the sub-tribe, Triticum, (3) the two sections of the genus, Triticum, (4) the three species of the section, Sitopyrus; (5) the three racks of, Tr.Sativum, and (6) the four principal subraces of the race Tr.sativum tenax. This elaborate classification is necessitated by the numerous forms into which wheat has become differentiated since coming under the influence of man. When we look over the vast wheat areas of our country and take account of the millions of bushels that are produced and consumed every year, the question naturally arises in our mind - why the great popularity of this cereal? Why is it that the consumption of wheat is so universal? We find upon investigation that there are several reasons which combine to cause the greater popularity of wheat as a food compared with other grains. In the first place the grain can be readily separated from its chaff, that is, can be readily threshed, while barley, oats and rice adhere tenaciously to the chaff. In the second place the yield of flour and marketable products is very high. It can be ground entire as with the mill stones and the whole grain ground to meal, or, in the case of the modern steel roller mills, where the bran is entirely separated from the flour, the bran, poulard and the products other than flour have their value in the market and nothing is wasted in the process. Another cause of its value is that the nutritive ingredients are so proportioned as to render it a food by itself. It is almost as perfect a food as any one article can be except perhaps milk. The most important reason, however, for its universal use is that its nitrogenous material is in a form - gluten - which enables it to be made up and baked into a light, palatable bread. The gluten of wheat has the property of absorbing water and forming an elastic substance; consequently the dough, which is formed when water is added to wheat flour, possesses a considerable amount of coherence and elasticity, and this causes it to resist the passage through it of the carbonic acid gas produced by fermentation; so that when a lump of dough ferments it becomes spongy and aerated, and, on baking, a loaf results which is light and palatable.

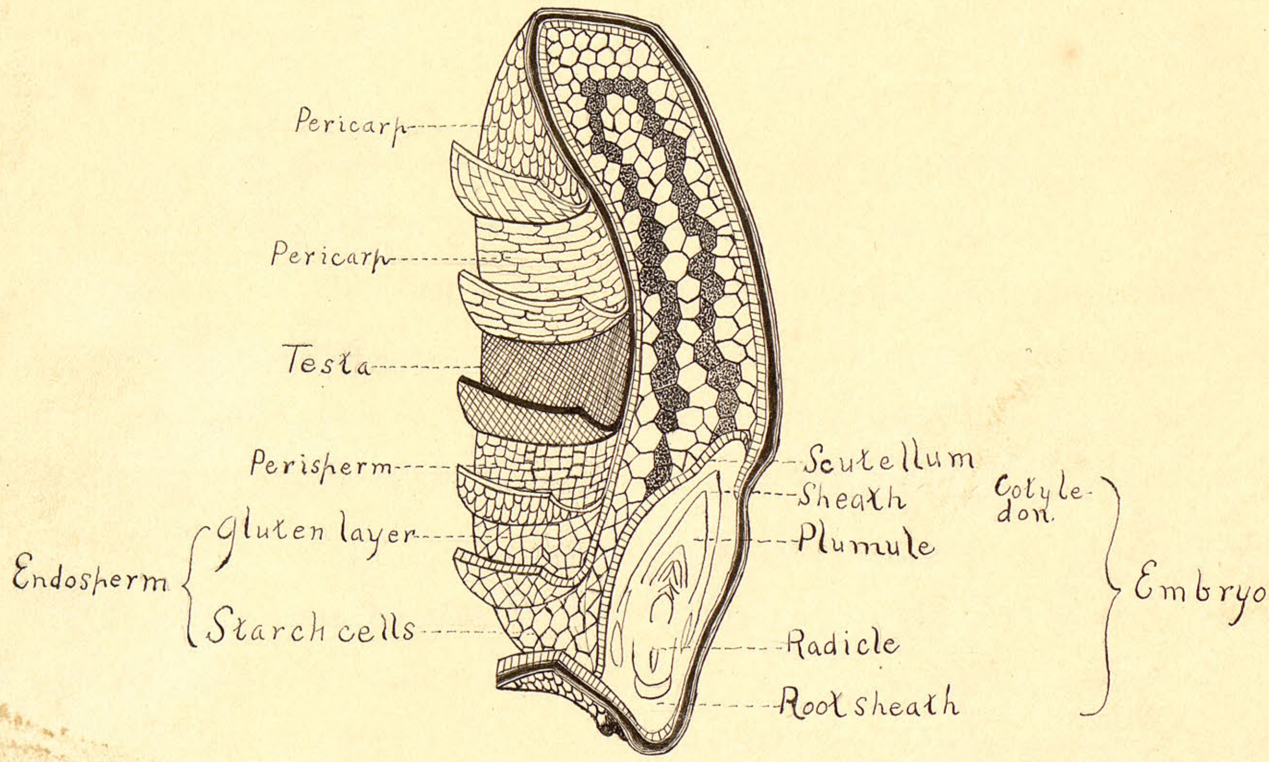
One is enabled to get a clearer idea of the value of this cereal as a food by study of the following table taken from the "Science and Art of Bread-Making," by W. Iago.

| | Wheat (mixture cleaned for milling) | Flour (straight grade) | Bran | Germ | Bread |
|---|---|---|---|---|---|
| Water | 12.0 | 12.0 | 12.0 | 11.5 | 38.3 |
| Soluble albuminoids | 1.0 | 1.5 | 1.5 | 11.5 | 7.0 |
| Gluten | 6.0 | 8.5 | 0.0 | 0.0 | |
| Starch | 72.0 | 74.5 | 56.0 | 41.5 | 50.0 |
| Sugar, Gum, etc. | 3.0 | 2.0 | 4.0 | 19.0 | 2.5 |
| Mineral matter | 1.5 | 0.5 | 7.0 | 4.0 | 1.0 |
| Fat | 1.5 | 0.5 | 1.5 | 9.0 | 0.7 |
| Cellulose | 3.0 | 0.5 | 18.0 | 3.5 | 0.5 |
| | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Nutrient value | 85-3/4 | 87-3/4 | 65-1/4 | 94-1/2 | 61-1/4 |
| Albumenoid ratio | 1 to 11-1/4 | 1 to 7-3/4 | 1 to 42-1/2 | 7-1/4 | 1 to 7-3/4 |

Required albumenoid ratio is 1 to 5.

This table shows the composition of the different products obtained on milling the wheat mixture referred to in column I.

Plate I.



Pericarp
Pericarp
Testa
Perisperm
Endosperm
Gluten layer
Starch cells
Scutellum
Sheath
Cotyle-don.
Plumule
Embryo
Radicle
Root sheath

The process of modern milling consists essentially in scraping off the bran and grinding the remainder into flour, separating out the germ and other impurities in the process. The result is that the flour obtained is weight for weight of higher nutritive value than the original grain, and is much more nitrogenous. This result is due principally to the removal of the bran, which contains a very large proportion of the indigestible cellulose. The complete removal of the bran by the modern system removes nearly the whole of this cellulose together with a large proportion of the starchy matter. The nitrogenous ingredients are thereby proportionally increased in the flour, since the bran contains no gluten and only a comparatively small proportion of the nitrogenous matter.

The removal of the germ is to be regretted for dietetic reasons since it is particularly rich in nutritive material and remarkably so in albumenoids and fat or oil. It is rendered necessary, however, owing to the fact that the flour containg the germ is always of a very dirty color and is found to deteriorate on keeping.

The composition of bread differs principally from that of flour in the amount of water added during the process of baking. It has, on this account, a lower nutrient value, but this is more than compensated for by the increased digestibility and palatability of its constituents.

A study of the morphology of the wheat grain is necessary in order that we may become familiar with the relative arrangement and structure of the different parts. We will first endeavor to get a general idea of the relative arrangement of the parts and then proceed to examine more closely the various components by means of the microscope. The accompanying drawing, Plate I, shows a longitudinal section through a grain of wheat, the different layers composing the outer portion being supposed to be cut through and folded back separately, so as to show more closely their structure and position.

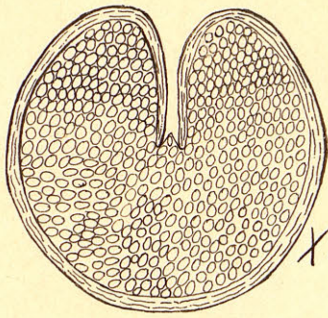
A grain of wheat consists essentially of two parts - the embryo and the endosperm, together with certain protective layers. The embryo is the future plant while the endosperm consists of starch and gluten and provides the nutritive material for the young plant before it is able to derive its food from air and soil. The interior of the grain consists mainly of large oblong or rectangular cells filled with starch granules of different sizes, through which runs a more or less irregular band of gluten cells. Outside this central mass of cells lies a layer of squarish cells containing gluten; this is called the aleurone - or gluten layer. The bulk of the gluten of the wheat if found in these cells; but the gluten which is distributed throughout the starch cells is of a better quality as far as breadmaking is concerned. The starch cells and the layer of gluten cells constitute the endosperm. The perisperm protects the gluten layer. Immediately above the gluten layer are the testa and pericarp, which constitute the skin of the grain. The testa is a fibrous band containing reddish or yellow coloring matter, and this coloring matter being visible through the thin, semi-transparent outer layers gives the grain its distinctive color, yellow or red.
Surrounding the testa lies the pericarp, which is the bran, and consists of two layers of fibrous material rich in cellulose. A peculiarity about these layers is that in the outer the one the cells are arranged vertically and in the lower one longitudinally. Dividing the endosperm from the embryo lies a circular membrane which is peculiar to all graminaceae, and is called the scutellum. This layer

contains certain ferments which dissolve the starch, gluten etc., of the endosperm, its function being to convert the material of the endosperm into forms which may be assimilated by the embryo in the early stages of its growth.

The embryo contains the cotyledon, a protective sheath enveloping the plumule (the rudimentary stems and leaves). The radical or rudimentary root lies in the embryo enveloped in its root sheath. In Plate II we have some of the parts as they appear under the microscope. It represents a cross section through the endosperm, showing the shape and disposition of the starch cells and of the cells of the gluten-layer. Fig.1 is a low power drawing of 165 diameter magnification and simply shows the outline while Fig. 2 is a high power drawing of 375 magnification and brings out in detail the structure of the different parts. Beginning at the outer edge we have the different layers of the pericarp, p.; then the testa, t.; lying next to the testa the squarish gluten-cells of the aleurone layer, a.; and on the interior, the flour cells, f., each surrounded by a thin wall. The contents of the flour cells are principally starch granules - very small, nearly globular masses of definite composition - and masses of glutenous compounds, together with small amounts of fats and ash. The proportion of gluten is slightly largest in those cells which lie nearest the aleurone layer, while those farthest from the bran in the middle of the kernel are somewhat more starchy, as is shown by the whiter appearance.

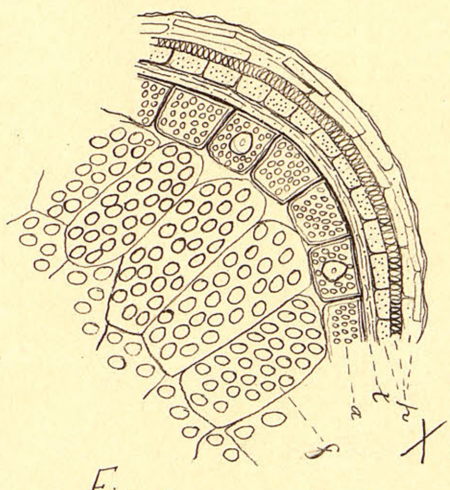
It has long been the custom to call the cells composing the interior of the wheat grain "starch-cells" from the fact that they are, as it has been customary to say, "packed" with starch grains. They certainly appear to be "packed" with starch grains, but investigations based on a series of biological analyses prove that they contain other very important substances, and among these latter is the substance

Plate II.



X165

Fig. 1.



X 375

Fig. 2.

Plate III.

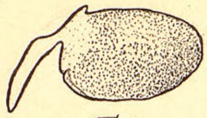


Fig. 1.

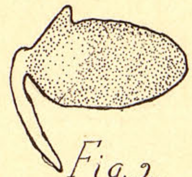


Fig. 2.

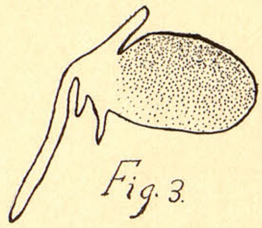


Fig. 3.

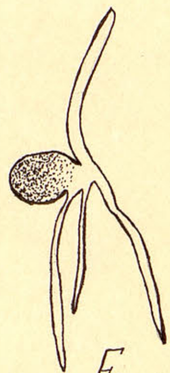


Fig. 4

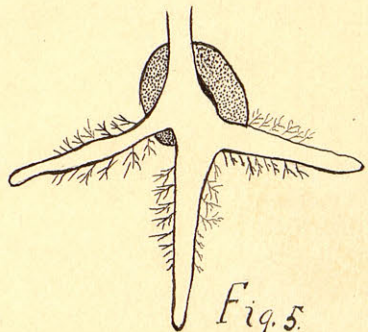
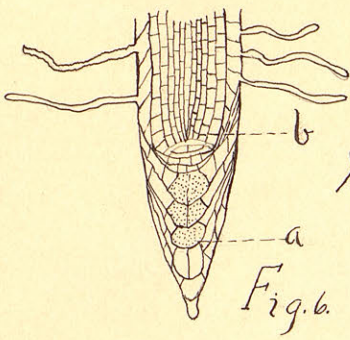


Fig. 5.




X 375

Fig. 6.

Plate IV.

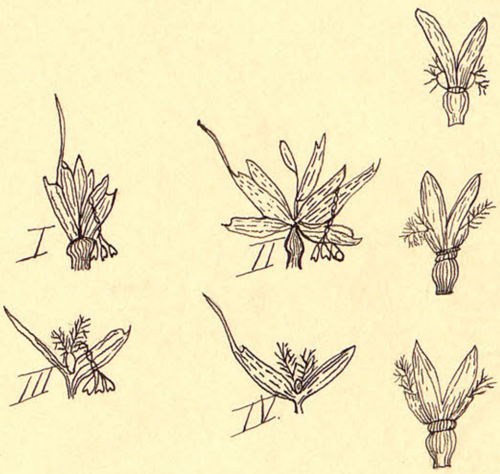
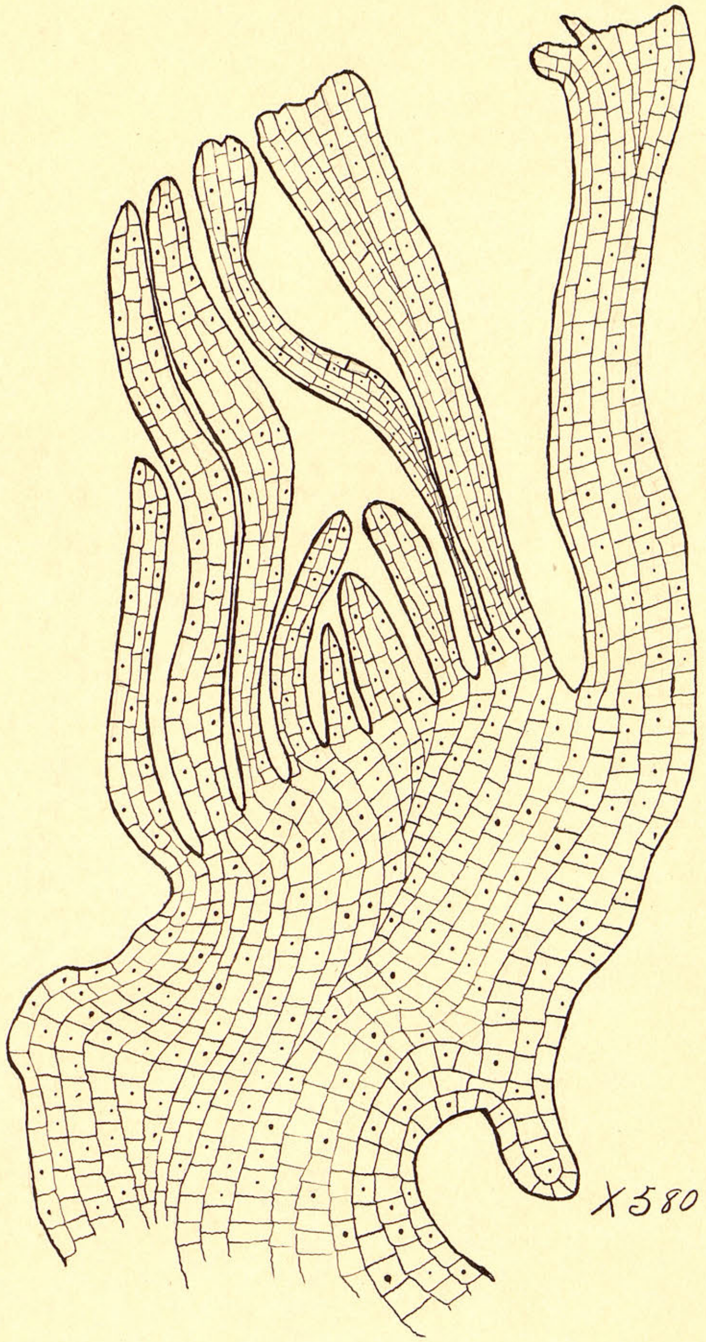
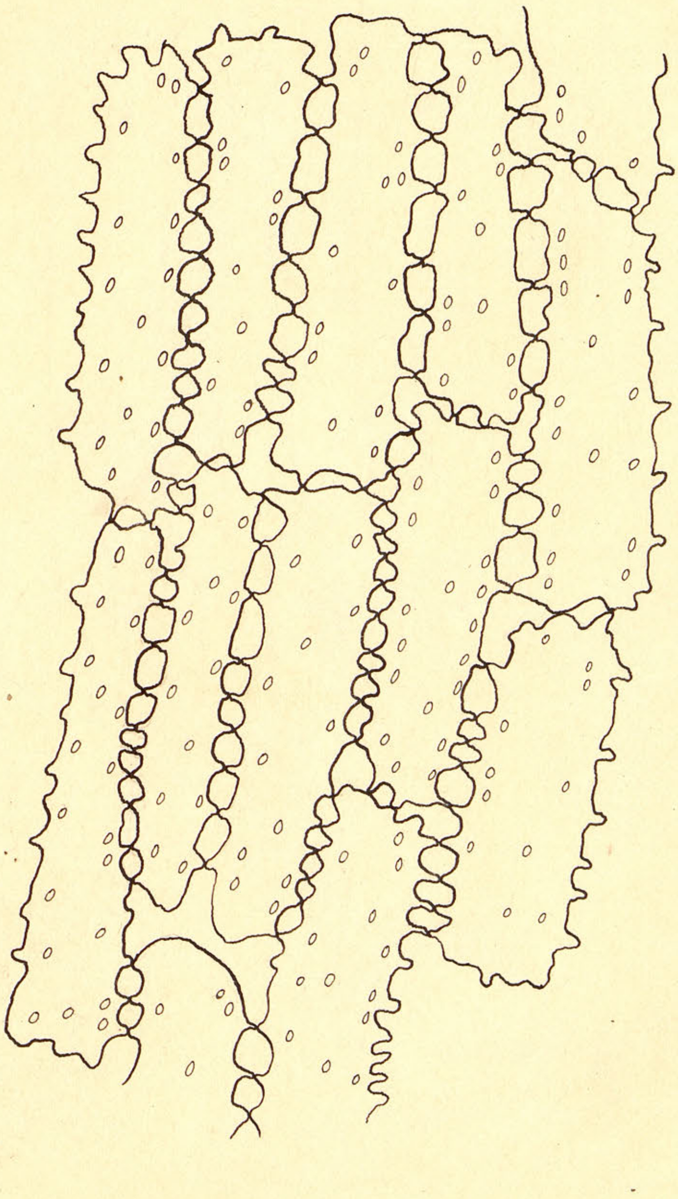


Plate V.

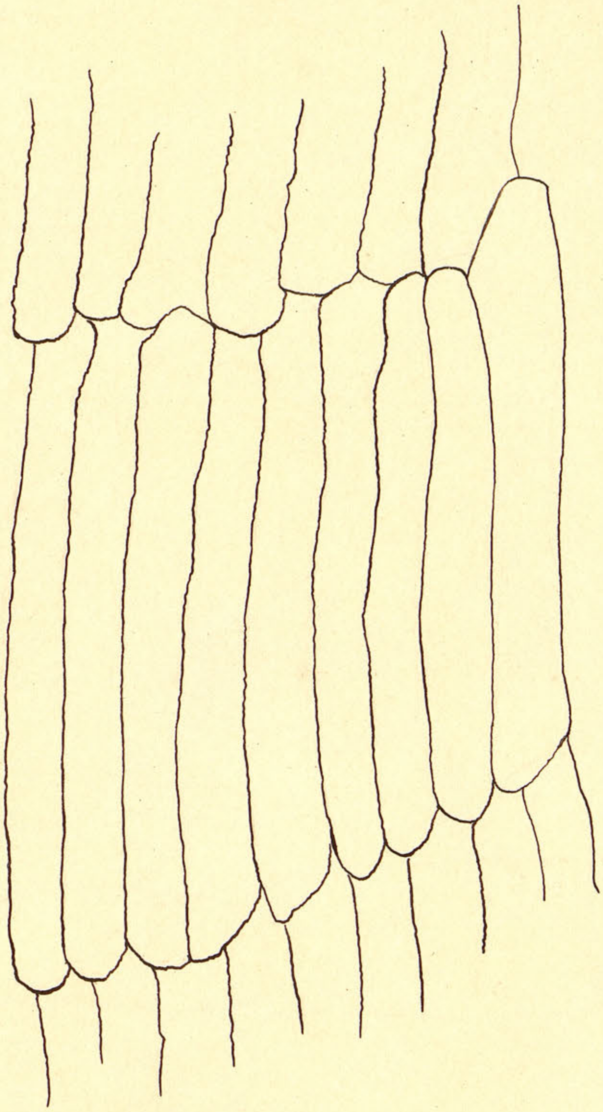


X 580

Plate VI.

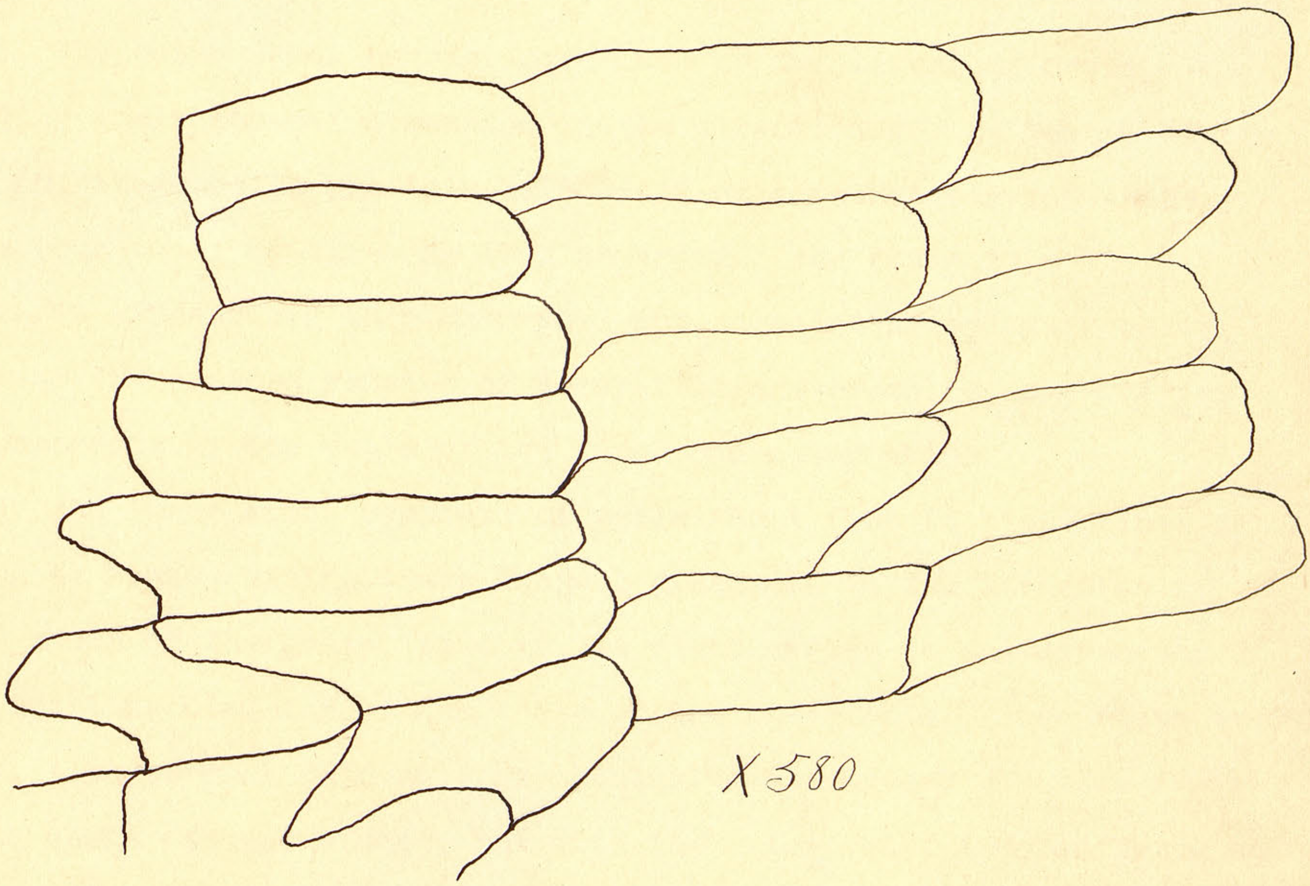


X 580



X580

Plate VIII



X 580

gluten. Although the bulk of the gluten comes from the cells composing the aleurone layer, enough gluten is found in the so-called " "starch-cells" to cause some authors to question the propriety of calling them starch-cells and the name "flour-cells" has been suggested instead. A careful study of the outer layers of the grain, and in particular of the one known as the aleurone layer will throw some light on the traits of the interior of the wheat grain. One would never suppose on looking at the seemingly smooth outside seed coat of a grain of wheat that there was anything complicated or interesting about it but when examined through a powerful microscope, the various layers present a very interesting and even striking appearance.

Beginning at the outside and peeling away one tissue after another we find:-

1. The outer skin, consisting of one or two layers of cells, having their longest dimension in the direction of the length of the grain; these cells are thin-walled and of somewhat varying shape, and four to eight times as long as broad. See Plate IV.

2. An exceedingly thin membrane, not composed of ordinary cells, but of the crushed remains of several layers of cells, and bearing impressions of the cells of the inner and outer skins.

3. The inner skin, composed of cells about four to eight times as long as broad, having their longest dimension in the direction of the width of the grain, that is, at right angles to the direction of the long diameter of the cells of the outer skin. See Plate VII.

4. A layer much thinner than the last and composed of cells of the same shape (except wider), but with their longest dimension lying at angle of 45° with that of the cells last mentioned. See Plate VIII.

5,6. Two thin colorless membranes.

7. The aleurone layer, composed of more or less hexagonal or rounded cells, which are about as deep as they are broad, each containing oil, granular-looking nitrogenous matter, and a large nuclear spot in the center of each cell. See Plate IX.

There is a wide difference in the appearance of the aleuron cells in different varieties of wheat, some having large polygonal cells with thick walls, the contents of the cells being of a peculiar texture; while others have smaller round cornered, thin-walled, cells and more closely packed with granules than usual. The morphology of these cells is a good indication of the quality of the wheat and character of the gluten.

The quantity and quality of gluten in a variety of wheat is one of the most important factor in determining the market value of the flour made from it. Wheat gluten is composed of two substances, viz.: gliadin and glutenin, in proportion of 60% to 70% of the former and 30% to 40% of the latter. The gliadin constitutes the binding material of the flour and enables the dough to retain the gas and become light when the bread is made. A flour that contains an excess of gliadin is soft and sticky, while one dificient in this material is lacking in power of expansion. The glutenin is the material to which the gliadin adheres and thus prevents the dough from becoming too soft and sticky. In hard wheat four the gluten is believed to be composed of gliadin and glutenin in the ratio of about 65% to 35%, while in the flours from the soft wheats the ratio is 70% to 30%. The gluten of flour, independent of ferment action, possesses, when baked, a power of expansion varying with the quality of the flour from which the gluten is obtained. As a general rule the better the baking qualities of the flour the greater the power of expansion. The quality of gluten determines very largely the quality of bread that is produced. Two samples of flour may contain about the same relative amounts of carbohydrates and proteid compounds and have the same amount of gas produced during fermentation, yet produce bread of entirely different physical properties because of the difference in the gluten of the two flours. In order to produce the best quality of bread the gliadin and glutenin must be present in the right proportion to form a balanced gluten. There are some features of the botany of wheat in relation to farming worthy of our attention. A farmer needs a knowledge of the roots, the leaves, and the kernel that he may understand the preparing of the land and better know how to sow, harvest and preserve the crop. The wheat breeder also needs to know the general anatomy and physiology of the wheat, and especially necessary is the knowledge of the structure and functions of the floral organs. Having gained some knowledge of the structure of the kernel, we are now in position to study more particularly the phenomena of germination.

Wheat, like all seeds, requires for germination moisture and warmth. The most favorable temperature is 84°F., while 104° F., is the maximum and 32° F., is the minimum temperature, though its germination is greatly retarded by the cold.

When a grain of wheat is placed in favorable conditions as to warmth and moisture, it begins to absorb water and to become turgid, that is, the cells become surcharged with water. The embryo swells and the root-sheath first makes its appearance, growing downward into the soil and protecting the radicle which subsequently pierces its way through. Soon the plumule appears, protected by the cotyledon growing upward; when about an inch the plumule pierces the apex of the cotyledon. The drawings in Plate III show the germination at different stages. The radical appears piercing its sheath and burrowing into the soil, Fig.1. Immediately after, the plumule makes its appearance and sends up its green shootlet to develop later into stem and leaves, Fig. 2. Soon the first pair of rootlets appear, followed by a second, Figs.3 and 4. The plant, which at first was entirely nourished by the material of the endosperm, can now obtain its nourishment from the air and soil. The rootlets force their way in and out among the interstices of the soil, obtaining food and moisture by means of the root hairs which secrete an acid fluid that attacks and gradually dissolves the material of which the soil is composed. Mere branching into innumerable thread-like branch roots does not give the roots sufficient contact with the soil so each root and root branch is covered with these fine root hairs which extend through the fine particles of soil and take up through their thin walls the hydroscopic moisture and plant food. The active hairs are born on a short zone just back of the root tip. These hairs are not distributed evenly about the root, being thin in places and at other points very thick, the density of the hairs doubtless depending much upon the local conditions of moisture and plant food. Roughly stated there are about fifty hair to the millimeter in length of root. Fig. 5.

The power roots have of penetrating hard soil is surprising. Fig. 6 shows a longitudinal section through the joint of a root. The wedge-shaped cap, a, is pushed beyween the soil particles, and by sub-division and growth of the cells in the middle of the root at b, the diameter of the root is enlarged and the joint is pressed still farther forward. A well developed system of roots is a necessity for a strong well developed plant. There is no direct way by which a breeder can select for this quality. He must choose vigorous yielders and the law of correlation of parts aids to select individuals with all the essential organs well developed. A breeder may pay little attention to the roots but the farmer in preparing the soil must know the root habits of the plant. The method of stooling is of interest in connection with the kind of soil, time and thickness of sowing, and harrowing or otherwise cultivating the soil after germination of the seed.

The roots grow rapidly and are long and numerous. In comparisosn to the area the leaves expose to the sun the plant presents a large root surface to the soil. A plant twenty-three days old with blades five inches long was found to possess roots twenty inches long. There is order in the attachment of roots and in the manner of branching. The first three roots that start from the chit are a temporary set and die before the plant is fully grown. The culms which soon develop send out roots from the bases of the leaves, the root buds presumably springing out in whorls from around the nodes under the bases of the leaves as in maize. It is interesting to note that if the ground be cool the roots grow in a horizontal direction while if the ground be warm their course is nearly downward. Each culm sends out roots and depends largely on these for support.

Besides a good root system the plant should have moderate height, sufficient stiffness of straw, and also a goodly proportion of leaves to serve as lungs, though an unnecessary proportion is undesirable as the plant should center its food material in its seed instead of using it to build up organs of less value. The culm or stem is made up of a series of hollow cylindrical internodes joined together by means of solid joints or nodes. When it starts from the soil the stem soon begins to branch, the first set of leaves sent up being a temporary set of organs designed to quickly reach above the soil that the plant may be supplied with chlorophyl cells in the sunlight. These leaves form the primary shoot of the plant and spring from the stem near the seed. They are found to be dead in the spring along with the germ whorl of roots in most of the winter wheats examined. At the same point where these first leaves arise another stem, apparently a rhizome, branches off from the primary stem. These rhizomes are known as tillers and it is a peculiarity of wheat and other cereals that they have this property of tillering or stooling. The original stem grows vertically upward but these other stem are produced at the crown which grow at first horizontally, in contact with the soil and send out roots. From these roots new shoots spring up until there is produced what is known as a stool of wheat.

Under favorable conditions with plenty of room to allow for free growth it is not uncommon to obtain as many as sixty grain-bearing stems from a single grain of wheat. Plants have been known to produce as many as one hundred twenty-five heads. The stems grow to various heights, depending upon the variety, soil, and season, and then the heads begin to form and swell through the surrounding leaves. Shortly after this the flowers appear. The flower of the wheat is a very inconspicuous one - so much so, in fact, that few people know where it is born. All that is visible to the naked eye is the extended pendulous anthers supported by the filaments, and these do not appear outside the glumes until after fertilization is complete.

The spike or head, of common wheat is made up of a central crooked stem called a "rachis". This rachis is jointed and at every joint it bears a group of flowers called a "spikelet". See Fig.1, Plate IV. The rachis bends in the opposite direction at each joint and thus the spikelets are arranged alternately in two rows on opposite sides of the rachis, giving nearly a rounded appearance to to the spike. The spikes are usually slightly smaller at the ends because there the spikelets are not so well developed or are farther apart. In some wheats, however, as in the club varieties, the internodes of the rachis are much shorter towards the top of the spike, resulting in the spikelets being much closer togather and in the spike being much broader at the top, or "club" shaped. This characteristic is sometimes shown by by cross-bred wheats where neither parent had this characteristic and may be the result of atavism or striking back to remote ancestors. Several of the Kansas bred hybrids growing in the experimental plats at Halstead this season exhibit striking cases of such atavism. The spikelet branches off at the angle of the central stem or radius of the spike. Its short stem, called rachilla, bears two or more flowers. Each flower is enclosed by two bracts or glumes. Below the lower floret the rachilla bears two flowerless glumes, a,a,II, while above the several flowering glumes are arranged alternately. The flower is by far the most interesting part of the wheat plant.

The perianth (that is the calyx and carolla) which constitutes the most striking part of many flowers, is only rudimentary here and is represented by two minute lodicules. The stamens are three in number, situated below the ovary, with long filaments. The anthers, oblong andnotched at the ends, as the lobes do not cohere throughout their whole surface, are pendulous and attached at the back to the filaments by a joint which enables them to swing as on a pivot. The pistil consists of a minute globular ovary, which is one-celled and contains only one ovule. The ovary is surmounted by two styles, branching out into feathery stigmas.

Fertilization if effected before the anthers are extruded. When the anthers are ripe they burst and discharge their pollen upon the feathery stigmas, and almost immediately after the bracts open and the anthers are extruded. And this is, as we have seen, the only outward sign of the flower.

Wheat is thus self-fertilizing and the amount of wind fertilization brought about by the scattering of the pollen grains still remaining in the extruded anthers is very small. It is owing to this fact that there is little or no cross fertilization of wheat, and different varieties can be grown side by side in the same field without losing their characteristics. This also makes it possible to form artificial cross-breeds.

There are two general methods of securing new and improved varieties of wheat. One is by selection, depending upon the variability of individual plants as a basis for breeding, and the other is by making artificial crosses followed by selection until the variety is reduced to a uniform type. In improving a variety by the method of selection, a few of the best plants, perhaps ten, are selected by inspection from the plat, attention being given to such intrinsic qualities as, manner of stooling; vigor of growth; manner of growth; nature of leaf; resistance to rust, smut and bunt; length; thickness and shape of head; number of grains in spikelet; size, color, shape, hardness and quality of the grain. The heads from these plants when ripe are harvested and these in turn planted in a plat to select from the coming year. This process is continued until an improved and more or less uniform type is secured.

In creating new varieties by artificial cross-breeding the wheat breeder exercises as much care in his selection of the parent of the parent stocks as does the stock breeder in selecting and mating the animals so as to improve a herd or to establish a new breed. In making his selection the breeder must give attention to intrinsic qualities rather than fancy points. Botanists and teachers have often given an undue proportion of their attention to the botanical characters, and too little to the intrinsic value or money-earning power of varieties. Some of our new varieties have very few or no botanical distinguishing marks by which they can be separated from the class of wheat to which they belong, but they yield more wheat per acre and are of much more value to the farmer.

To secure stocks for crossing the varieties should be subject to the same ridig selection as in the improvement by selection. From these stocks strong plants are taken as parents for the crosses thus the best is taken to begin with and no time is wasted on weak varieties or on weak plants of good varieties. When approaching the flowering time superior plants are chosen and from some of the best spikes the upper and lower spikelets are removed, leaving ten or a dozen of the largest, strongest ones near the center. The anthers of the flowers of these remaining spikelets are removed before they are ripe enough to burst open and cause self fertilization. This delicate operation must be performed in a careful manner or the floret may be so injured as to render fertilization impossible. Care must be taken to remove all the anthers without breaking any of them, if ripe, and causing the pollen to be dusted upon the stigma, thereby preventing successful emasculation.

Since the flowers naturally open in the morning, it is generally deemed best to emasculate in the afternoon and pollenate the next morning, but with a large number of crosses to make and the wheat blossoming rapidly this is often impracticable. The operations of emasculation and pollenation are usually performed with a small pair of tweezers and sometimes a pair of sharp pointed dissecting scissors are used to clip away the inferior florets. Some breeders advocate wrapping the head in tissue paper after emasculation to prevent any chance of entrance of foreign pollen, but many deem this unnecessary as there is so little cross-pollination among wheat. It certainly is much less work to allow the heads to stand without being wrapped and many crosses can be made in the same length of time by this manner. The greater the care with which the cross is made the more satisfactory the results, as a rule. From five to thirty percent of the flowers handled produce grains and oftentimes part of these do not prove to be true crosses as is shown by the strong resemblance to the mother-plant only.

Each kernel of wheat resulting from this artificial cross is planted in a small nursery plat the first year and the next year a hundred, more or less, of the seeds of each plant of the first generation are planted. Any stocks not appearing reasonably strong are at once discarded. There are different methods of procedure from this point on but the most logical way seems to be to take the same course as where varieties are improved by selection alone, which method has already been described.

Crossing produces greater variation among individual plants than is observed where selection alone is followed. The present indications are that the average yield of plants resulting from a cross between two distinct varieties is less, at least during the first few generations, than the average yields of the two parents. But there being more variation among the cross bred stocks, there is greater opportunity for the selection of the occasional good plant which will produce plants yielding better than either parental kind. It has been found by repeated experiments that the time required to reduce cross-bred wheats to a uniform type is about five or six years. If newly originated cross-bred wheats can be reduced to a type in so few years, the making of cross-bred varieties is not difficult from the standpoint of uniformity. In the effort to secure larger yields with superior quality, botanical appearance, it seems, will take care of itself. Experiments have also indicated that invividuals chosen for large yield and good quality will continue true to their type in these most important characteristics. The evidence seems conclusive that better varieties of wheat can be made at an expense which is indeed small when compared with the increased value of varieties which will raise the average yield per acre even only one bushel.

A few words now upon the merits of the several species and subspecies together with some of their varieties. The common bread wheats, Triticum vulgare, form of course the most valuable and widely distributed group of wheats in the world, and are represented by a greater number of varieties than all other species taken together. The species is usually divided into a number of botanical subspecies and varieties, based upon presence or absence of beards, nature and color of chaff, color and quality of grain, etc. These subdivisions are too numerous to mention, but we also have five great subdivisions based not upon botanical character, but upon characteristics induced by influence of invironment. These are:- (1) Soft Winter wheats, (2) Hard Winter wheat, (3) Hard Spring wheats, (4) White wheats, and (5) Early wheats. Their distribution throughout the world is approximately as follows: (1) the soft winter wheats, varying in color of grain from amber to white, are produced under the influences of considerable moisture and mild, even temperatures, and are distributed in the eastern United States, western and northern Europe, Japan, and in portions of China, India, Australia, and Argentina. (2) The hard winter wheats are red-grained, usually bearded, possess a relatively high gluten content, and are more limited in their distribution. They are grown usually on black soils and under the influences of a climate characterized by extremes of temperature and moisture, but especially by dry, hot summers. They are found chiefly in the states of Kansas, Nebraska, Iowa, Missouri, and Oklahoma in this country, in Hungary and Roumaina, in southern and southwestern Russia, and to some extent in India, asiatic Turkey, and Persia. (3) The hard spring wheats are also red grained and rich in gluten content, and are adapted to conditions of soil and climate identical with those just mentioned for hard winter wheats, with the exception that the growing season is shorter and the winter too severe for winter varieties. They are found in central and western Canada, our northern States of the Plains, east Russia and western and southern Siberia. (4) The white wheats are soft and very starchy, but possess grains a little harder and much drier than those of the soft winter wheats. They are either fall or spring sown and sometimes sown at both seasons in the same locality. They are grown chiefly in the Pacific Coast and Rocky Mountain States of this country, in Australia, in Chile, Turkestan, and the Caucasus. (5) The early wheats are soft or semi-hard and generally amber to red in color of grain, but are distinguished from other groups chiefly by their ability to ripen early. They are found in Australia and India, are represented by a very few varieties in the southern states of this country, and include some of the dwarf wheats of Japan.

We find in the varieties of this species the most diverse characters because of their cultivation under so many diverse conditions. Their greatest characteristic as a whole, however, if the well known and long established quality of their grain for the production of bread flour, hence the term "bread wheat" is aptly applied to them. We find in this group all grades from the best to the poorest. The hard, red-grained varieties are by far the best both in food content and for our present system of roller milling. They include the Fifes, Velvet Blue Stem, Turkey, Mediterranean, and Fulcaster, of this country and Canada; the Ghirkas, Ulka, Crimean, Buivola, of Russia; and the Theiss and Banat, of Hungary and Roumania. On the other hand the white wheats and soft winter wheats give the best success in the manufacture of crackers. Several of the most popular breakfast foods are also made from white wheats. In a few instances macaroni is made from the hard spring wheats and white wheats, but not extensively. No varieties of the bread-wheat group are well adapted for this purpose. The great bulk of the world's supply of macaroni wheat comes from the durum froup, _T.durum_, though a considerable amount of these macaroni pastes is made from poulard and Polish varieties. It has been found by repeated trials if some if not all these durum sorts used for macaroni can be successfully grown in this country, though they do not withstand the winters of this section and must be planted in the spring.

The special qualities to be obtained in this group are excellence of gluten content for making macaroni and other pastes, resistance to drought and to orange leaf rust. This wheat is peculiarly adapted to a very hot, dry climate and slightly alkaline soil and promises to be a valuable wheat in north-central Texas, and southern portions of Oklahoma and Kansas.

_Spelt_, _T. spelta_, _Emmer_, _T. dicoccum_, and _Einkorn_, _T. monococcum_, are in several respects very different from other wheats and are not widely cultivated. As an article of food they are not of much consequence here, but in the inter-crossing of wheat groups for the improvement of our bread wheats some very valuable qualities may be obtained from varieties of these species. These species do not hull out clean from the chaff like wheat but instead the grains cling tenaciously to the chaff and crosses secured between these species and out common bread wheat will render certain varieties valuable that are now almost worthless because they shatter so badly. The einkorns resist leaf rust completely and the emmers resist it to a high degree.

This discussion of the history and growth of our great industry is by no means complete, in fact no attempt has been made to give a complete discussion and that would require much time and many volumes, but a few of the salient points have been touched and it may serve to suggest something of the importance of the cultivation of that cereal which means so much to the people of Kansas.

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