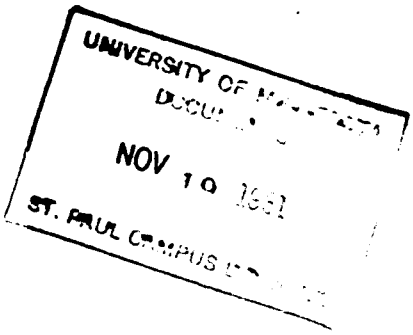
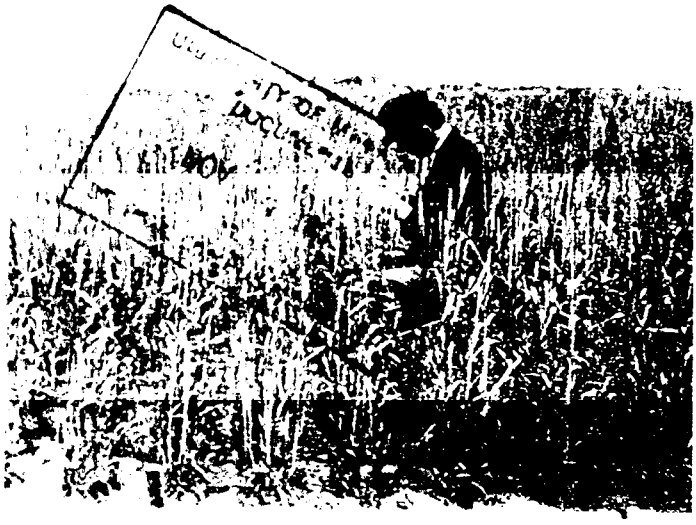


UNIVERSITY OF MINNESOTA.

Agricultural Experiment Station.

BULLETIN NO. 62.

DIVISION OF AGRICULTURE



MARCH, 1899.

WHEAT.

VARIETIES, BREEDING, CULTIVATION.

ST. ANTHONY PARK, RAMSEY CO., MINNESOTA.

UNIVERSITY OF MINNESOTA.

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☞ The bulletins of this station are mailed free to all residents of the state who make application for them.

WHEAT.

VARIETIES, BREEDING, CULTIVATION.

WILLET M. HAYS AND ANDREW BOSS.

Minnesota's large annual wheat sales; the superior quality of the wheat grown in the Northwest, early designated "No. 1 Hard;" the wonderful flour milling industry which has developed in the state; the business of wheat and flour transportation; and the growing of this cereal,—place this crop among our largest interests. Dairying and general stock farming should and will rapidly replace special wheat farming. But since the rotation and fertilizing of the fields which come with the keeping of domestic animals provides the best soil conditions for wheat, that crop is destined to continue as an important factor on most of our farms, and our wheat interest will doubtless increase rather than decline. The yields of wheat under continuous wheat cropping, when the rich character of our soils is considered, are ridiculously low. The experiment station has under way extensive experiments in rotating, pasturing, manuring, and cultivating fields to learn how best to prepare them for crops of grain. Many of these tests have already been under way for five years. While most of these experiments are not yet completed, but will be reported in later bulletins, results already reached warrant the statement that the average yields per acre of wheat can be increased 25 to 50 per cent. by so rotating the crops and manuring and cultivating the fields best to prepare the soil for this grain.

Next in importance to preparing the field for the crop of wheat is the choice of those varieties and strains which will yield the

greatest value per acre to the farmer, and will best uphold and improve the value of the flour made by our mills, and will best serve as human food. This bulletin is devoted mainly to the work of securing better varieties; the testing of varieties in the field and in the mill, in the bake-room and in the laboratory; and the improvement of wheats by breeding. Plant breeding is in its infancy, and plans for extensively and scientifically breeding this crop had to be devised rather than copied. It is believed that varieties materially improved in yield are evidence that the plans in use are so designed that increased yields of wheat will result from the new wheats being evolved and disseminated in the various counties throughout the state. The evidence certainly is such that better farming will add several bushels per acre to our yields of wheat, and that improved varieties will add in addition at least several pecks per acre.

COLLECTING AND TESTING VARIETIES OF WHEAT.

In 1888, the first year after the Minnesota Experiment Station was established, efforts were begun to find the varieties of wheat best adapted to this state. The chief points in mind were to secure kinds of wheat which would yield the largest profits per acre to the farmer, would supply our flour mills with wheat of superior quality, and would be the most nourishing and valuable as human food.

In 1888 and 1889 D. N. Harper and W. M. Hays collected from various sources about 200 varieties, or samples, of wheat. The best wheats grown in Minnesota were secured, and numerous varieties were obtained from other states. A large number were also secured through American consuls in Russia, Hungary and other European countries, experiment stations, grain merchants, and persons in Canada. Most of the varieties were spring wheats.

Chemical analyses were made of many of these samples by Prof. D. N. Harper, then station chemist, to determine the percentage of

the varieties were superior to our own." These analyses showed the Hungarian and many of the Russian wheats to be of great value, but none were more valuable than our Fife and Blue Stem.

Through the courtesy of Senator S. A. March, of Minneapolis, the larger number of these wheats were planted on the "March and Spalding Farm," in 1890, at Warren, in the Red River Valley, near the northwestern corner of the state. The small amounts available of most samples necessitated the use of plots so small that it was impracticable to make tests or even close estimates of the yields of the different wheats, though the planting and harvesting were carefully done, and notes were taken on each kind of wheat. Some proved to be winter wheats. A large number developed inferior plants, or grain of such poor quality that they were at once discarded. The general results proved that our own native varieties are superior to any of the foreign ones. Some of the Russian seeds yielded grain of apparently as good quality as our own, and these varieties were tested further. The Russian samples were mostly of mixed varieties of bearded and beardless wheats.

Sufficient seed was secured of 75 of the better varieties that a 1-40 acre plot of each was planted in 1891 in the southeastern part of the Red River Valley, at Glyndon. These wheats proved to be largely of the Fife type from Minnesota and Russian samples. At Glyndon, fair yields of grain of good quality were obtained of many of these wheats. The yields, however, were not fully comparable, and have not since been used in the summaries of comparative yields. In 1892 part of these wheats were grown at University Farm, St. Anthony Park, but the crop was so unsatisfactory that the yields were not recorded. In 1892 and 1893 a total of 110 varieties of wheat were grown at Fargo, N. D., the larger number of which were those originally collected by the Minnesota station. In the destruction by fire of the Minnesota station office building in the fall of 1890, the correspondence relating to these varieties of wheat and the laboratory book containing their source, names, analyses and other facts concerning them, were burned. The stakes marking each variety bore only the laboratory serial numbers, together with the numbers of the respective plots, and thus

a lot of wheats without names or records of source, kind or quality were in hand. While this was a serious misfortune, it led to the more careful inquiry into the real merits of each variety. In 1891, records of each variety were kept by using the name of the town, Glyndon, and our original laboratory entry number, e. g., Glyndon 811, and these numbers finally became our names for these wheats.

During the years 1892 to 1898, inclusive, various other varieties were collected from the states and countries above mentioned. Many new varieties were also secured from New South Wales, Australia, and a large number were originated at this station by selection, and also by crossing and selection. The total number of wheats having been under trial up to the present time is 552. Many of the collected wheats were discarded after a single trial in the crop garden. Not in all cases have the seasons and the soils been such as to give yields which it has seemed wise to use in tabulating and summarizing. Discarding the results of such years and places as gave yields which were not fairly comparable, we yet have about a dozen which can fairly be averaged for comparison.

The expense of all these trials has been large. It was not foreseen that so many trials, covering such a long period of years, and such a variety of soils, localities and climatic conditions, would be necessary. Looking backward, it can be seen that simple milling tests would have assisted early in the trials in throwing out some varieties of average yield, and of a quality too poor to be desirable. But on the whole this patient deliberation seems to have been the only safe method.

The immense financial considerations at stake certainly warrant that sufficient care and expense be incurred to enable the state to know which are its best varieties of wheat, and to find and distribute them to the farmers of the state.

WHERE THE TESTS FOR YIELD WERE MADE.

At the North Dakota Experiment Station most satisfactory comparisons were made of these varieties in 1892 and 1893.

A sufficient number of trials had then been made to warrant a comparison and many of those yielding poorly, and those of poor

quality were discarded. In 1895, 1896, 1897 and 1898 these wheats were planted at University Farm and at North Dakota Experiment Station, and from year to year the poorer varieties were discarded at each station. In 1897 and 1898 the best varieties remaining were also grown at Northwest Experiment Farm, Crookston, Minn., and at Northeast Experiment Farm, Grand Rapids, Minn. The trials at these stations will be specially reported upon in another bulletin. In 1898 the South Dakota and Iowa stations also grew a few of the best varieties.

METHOD OF MAKING THE FIELD TESTS.

The methods used in testing the varieties have been improved

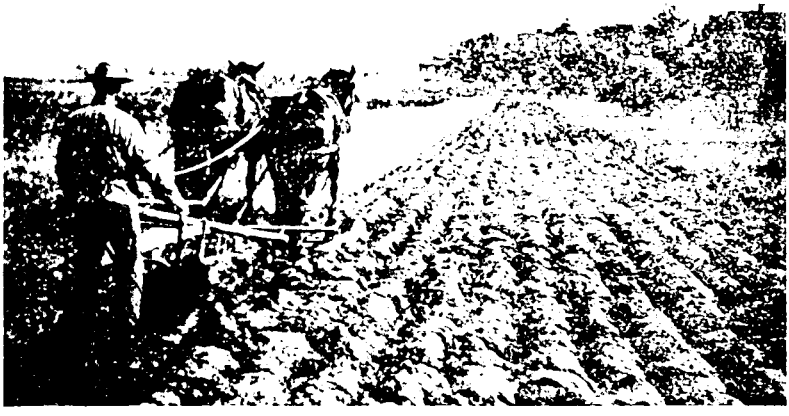

Fig. 2.—Plowing for Variety Tests of Wheat.

upon from year to year. Originally it cost about three dollars per plot to plant, harvest and thresh carefully each plot containing 1-20 or 1-10 of an acre. With the addition of specially chosen seeding and harvesting machinery, with specially constructed threshing machines and other handy arrangements, including a portable gas-[illegible] engine at University Farm, the cost has been re-

duced to one-half the former amount. An important factor in successfully carrying on these field trials has been the excellent character and the loyal interest of the workmen and students who have performed the manual labor.

THE PREPARATION OF THE LAND.

The land of the Minnesota experiment farms is platted into series eight rods wide and as long as the field is wide, usually about forty rods. The plots run across the series, and are one or two rods wide, and contain 1-20 or 1-10 of an acre. The rotation of crops for a few years previous is so managed as to prepare the land for the wheat. Light applications of rotted barnyard manure are made to some crops, as corn, roots or millet, one or two years previous to using the land for tests of small grains, but no concentrated fertilizers are used. The frequency of the manuring is determined by the needs of the land. The manure is not applied so frequently that when wheat is grown in a moist year it will lodge badly. The land is kept in that state of fertility which is practicable on all our better farms.

In preparing for variety tests of wheat, grass land is fall-plowed, or if following a cultivated crop, as corn or potatoes, the seed bed is made mellow by means of the disk harrow. The common drag or "Tower's Pulverizer" is used in making the surface fine and even.

THE SOIL.

The soil and subsoil at University Farm are medium in texture, with clay and sand mixed in such proportion that rainfall is absorbed rather freely and to a good depth, and is conserved quite well in seasons of drouth. At a depth of five to six feet the subsoil is gravel and sand, giving excellent underdrainage, but in times of drouth making the land less able to supply water to crops than if there were clay or mixed subsoil to a greater depth.

The soils used in the Red River Valley, at Glyndon, Euclid, Fargo and Crookston are the rich, peculiar clay soils characteristic of this noted wheat region. The soil used at Northeast Farm is a sandy loam, new, and sufficiently full of available fertility and

moisture to produce fair crops of wheat. At these farms the soils are far more uniform than at many experiment stations where the unevenness of the land makes variety testing very unsatisfactory or even impracticable.

THE METHOD OF PLANTING.

Sufficient thoroughly cleaned seed of each variety is weighed out to plant somewhat more than the respective plots. A shoe drill $8\frac{1}{4}$ ft. wide is used, thus sowing a rod in width each time the team passes twice over the plot. See Fig. 240. When the plot is sown the seeds remaining in the cups in the bottom of the drill are removed as cleanly as may be with the hands. The operator then blows out, by means of a rubber tube, every remaining seed. It is necessary to have sufficient seed in the drill box to prevent the force-feeding device from running so nearly empty that it will plant seeds thinly on the latter portion of the plot. An alley two feet wide is left between each two plots of grain. This places the varieties only two feet apart, but as wheat is nearly always close fertilized,—the pistil of a given flower being pollenized from anthers of the same flower,—there is but little cross breeding of varieties. The weeds are hoed out of these alleys a few times in the earlier growing season.

CARE OF GRAIN FROM SEED-TIME TO HARVEST.

Nothing is done with these plots before they ripen unless some occasional rank-growing or dangerous weeds need removing. In case of a newly secured variety the plot is gone over between the time the grain is headed and before it is fully ripened, and all plants not of that variety are removed. Many of the Russian wheats, both of the earlier and of recent importations, are very badly mixed. These wheats are the best samples of the commercial wheats of the foreign markets. Many of them were made up of two to four kinds of wheat, distinct as to color of chaff, length of beards, color and form of berry, etc. In some cases no one wheat has been in the majority, and a small plot has been utilized from which to select one or more prominent types for further trial.

Method of Harvesting Variety Test Plots.—Where the relative

earliness of the varieties has been learned by previous trials in the garden or field tests, the varieties are planted in order of earliness. This allows the self-binder to be started at one end of the series, and each plot is cut as it ripens. The cutting is all done in one direction. One or two men assist the driver and carefully clean the machine upon finishing each plot. They also carefully gather the bundles and any loose grain of each plot into shocks, beside which they place the labeled stake of the plot.

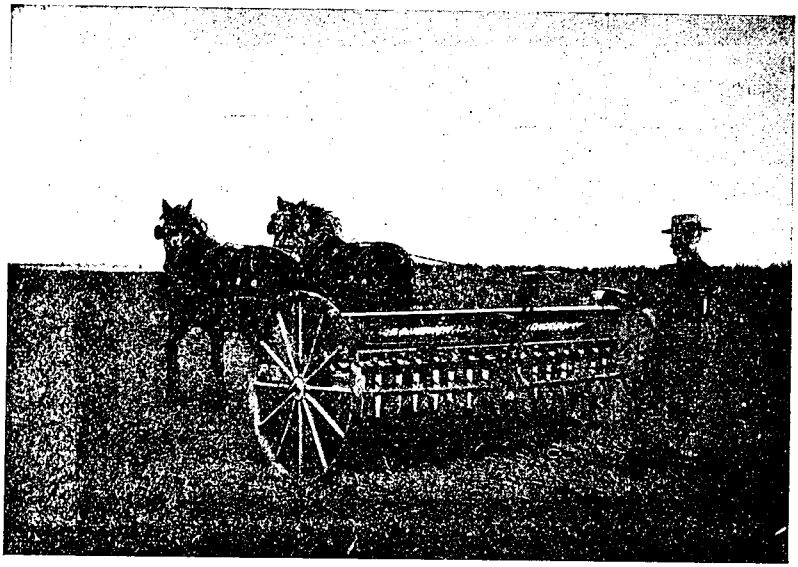

Fig. 240. Seeding the Variety Plots with Shoe-chain Drill.

The Method of Threshing Varieties of Wheat.—As soon as the grain has become well dried in the shock it is threshed. Much care is given to cleaning wagon racks between each load, handling the bundles at the threshing machine and caring for the threshed grain to prevent the mixture of the different varieties.

A Victory separator, which cleans itself so thoroughly that stopping between plots to sweep out the machine has not been necessary, was secured from the Minneapolis Threshing Machine Co. See Fig. 242. This make of machine was selected as being the

easiest of the numerous kinds examined to make over into a separator for this sort of work. The firm cheerfully made changes as suggested, so that the machine would shake out clean by running it two or three minutes after the last bundle was fed into the cylinder. After stopping the feeding of bundles, a pail is held under the discharge spout of the elevator which brings the tailings back to the cylinder, thus stopping the feeding of all grain into the machine that it may be shaken out clean.

A Trial of the Threshing Machine in Doing Clean Work.—In 1897 several beardless varieties known to be without admixture of bearded wheats were threshed, each one immediately after a bearded variety had been run through the machine. In 1898 these beardless varieties were sown, and notes were made at harvest time of the percentage of bearded heads showing in each. There were practically no bearded heads in any of the three plots of beardless wheats, thus proving that this threshing machine, when properly managed, separates the varieties perfectly.

Note:—*Numbers Used for Names.* The loss of the names of many of the varieties, some of which were similar to one another in appearance, led us to the adoption of numbers for all names. We were further led to this course by the fact that new varieties were constantly originating, many of which were in appearance exact counterparts of the varieties from which they had sprung. We therefore adopted in lieu of all names the words "Minnesota Number" and our Variety history Book number, commonly abbreviated and written "Minn. No. 149," "Minn. No. 66," etc. This plan contemplates using names of wheats only as names of classes or types. It is impossible to give a description of some of our new best yielding wheats by which farmers or even experts can identify them. Some differ only in their ability to yield better, others only in the superiority of their flour. These characters of intrinsic value are the qualities we are seeking. The profits of wheat raising do not depend upon the distinguishing botanical characters of the wheat. If our wheat crop can be increased one bushel per acre by seeking only for yield of crop and quality of flour, all names and peculiar botanical descriptions will appear relatively as exceedingly small factors. Systematists in botany, and herd book promoters in animal breeding, divert the attention of breeders too much from intrinsic quality to mere distinguishing marks. This system of naming with mere numbers has been used for several years with most satisfactory results. With such a system of names the effort is directed more to actually knowing that the seed came from the original stock which gained a reputation for superior merit in producing wealth, and it is believed there will be less temptation for dealers to substitute stocks and sell them under a popular name. This is especially true of varieties which have a published record of superior merit. The record and the number name must go together to represent value. Formerly we used the word "University" with the number of the variety, abbreviated thus: "Univ. No. 149." Hereafter we shall use the word Minnesota with the number, thus: "Minn. No. 149," "Minn. No. 169," etc. While the abbreviation "Univ. No." has been somewhat used in our publications, it has been extensively used in connection with only one variety of field crop which has been distributed from this station, viz.: Univ. No. 13 corn. Since this corn with further improvement, from longer selection, will ere long be sent out under a new number, no serious inconvenience will come from the change.

With the need for breeding field crops emphasized, and its importance more fully demonstrated, this matter of names will become an important subject.

SAVING, TESTING AND TREATING SEED WHEAT IN VARIETY TESTS.

To be doubly safe in threshing the varieties of wheat, the work proceeds as follows: As the grain from each plot comes from the machine the first half bushel or so is put into a large sack. Then a half bushel of grain is caught and saved in a small sack for planting the next year, thus avoiding the use for seed of that portion which comes from the separator immediately after the grain of the preceding plot, which might contain kernels of that variety. The balance of the grain is then put into the large sack with that which first came through the machine. See Fig. 243. Constant care is used that the interior of the machine is always in good repair and that there are no places where the grain can lodge. Care is taken at all points to keep the seed grain dry and strong in germinating power, that all varieties in the variety tests may have an equal number of plants per acre on the start.

That sufficient seed of each variety may be planted to insure a full stand, it is necessary to know the vitality of the seeds of each kind. This is of special importance when rains prior to threshing or slight dampness at the time of storing the grain have resulted in injury to the seeds. A germinating chamber adapted to testing seed wheat at the low temperatures prevailing in the soil at the season of sowing spring wheat is used for testing the vitality of wheats and other seeds. See Fig. 245.

Where necessary to treat the seed grain for smut, the blue stone, the formaldehyde, the corrosive sublimate, the hot water, or other suitable method, is used.

PROGRESS AND RESULTS OF TRIALS OF COLLECTED WHEATS.

Ending with Dec. 31, 1898, 552 varieties or samples of wheat have been entered in the Variety History Book of the Minnesota Experiment Station. The larger part of these samples came from foreign countries and states, a number from Minnesota farmers, and 49 varieties have been originated, 6 of which are cross bred wheats.

Prior to 1894 about 200 varieties of wheats had been collected by the Minnesota and North Dakota stations, and these have since been under co-operative experimentation. Only a portion of the

yields secured under the varying conditions can here be recorded, and only a portion of the data can be given room. Some of these data collected prior to 1897 may be found in bulletins 15, 31, 40,

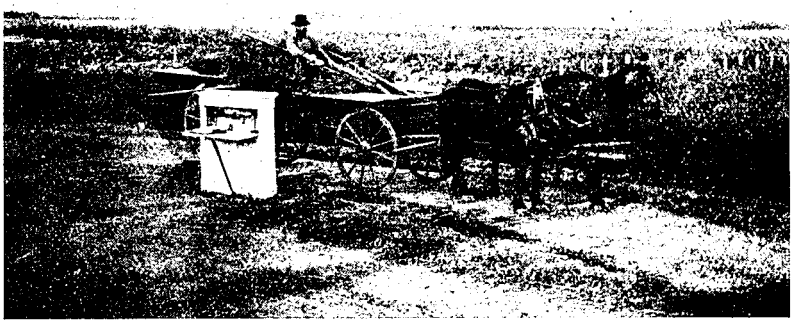

Fig. 241. Weighing the Bundles from a $\frac{1}{20}$ Acre Plot.

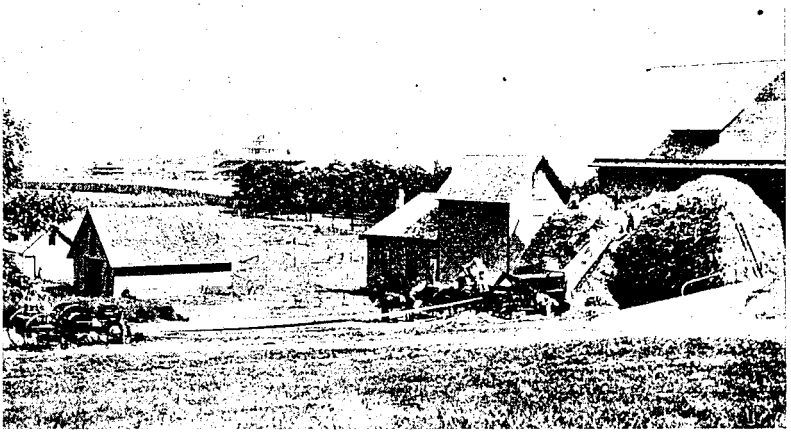

Fig. 242. Threshing the Variety Plots.

TABLE XXI.—Wheat, Yields for all Years and all Farms.

VARIETY.	Minnesota Number.	Fargo, 1892.	Fargo, 1893.	Fargo, 1894.	Coteau, 1894.	Euclid, 1894.	University F., 1894.	Coteau, 1895.	University F., 1895.	Fargo, 1896.	University F., 1896.	University F., 1897.	University F., 1898.	Northwest F., 1898.	Northeast F., 1898.	South Dakota, 1898.	North Dakota, 1898.	Iowa, 1898.
Blount's Hybrid No. 15	13	17.3	12.8	6.3	23.8	.....	.....	23.5	29.0	17.0	21.2	15.5	.....	.....	.....	.....	27.5	.....
White Russian..	19	17.7	11 9	.....	23.0	.....	.....	21.5	33 2	19.7	24.8	16.3	.....	.....	.....	.... ..	30.0	.....
Haynes' Blue Stem	51	16.7	12.9	15.0	.....	.....	.....	24.7	21.6	23.4	24.6	20.4	23.3	.....	23 0	20.2	33.5	8.8
Power's Fife	66	21.3	15.1	12 6	19.8	15.8	.....	22.8	26.3	22.5	21.4	17.4	24.0	18 8	20.7	17.4	32.0	7.0
Rio Grande	72	14.7	13.4	.....	13.6	13.5	.....	20.7	29.3	18.0	20.2	15.2	.....	.....	.....	.....	30.8	.....
Glyndon 711	105	23.3	10.0	9.7	21.4	16.0	.....	22.8	31.8	18.2	21.4	17.8	22.3	18.3	14.7	.....	32 0	.....
Glyndon 753	116	14.7	14.3	15.3	19.3	17.2	.....	20.6	31.5	17.0	21.0	19.7	.....	.....	.....	.....	33 1	.....
Bolton's Blue Stem	146	.....	17.8	12.3	21.4	15.3	.....	20.0	35.3	23.2	25.1	21.5	22.5	.....	19.3	17.3	35.3	6.3
Power's Fife	149	.....	. .....	..... .	.....	.....	11.4	.....	36.2	22.7	23.3	19.9	26.5	22.3	14.0	15.4	33.8	7.5

Glyndon 818	155						14.4		32 3	22.7	23.3	20.8	26.8	23.5	14.7		35.2	6.3
Glyndon 753	157						18.3		30.9	27.5	22.0	21.4	26.6	20.2	16.2		36.5	7.0
Haynes' Blue Stem	161						15.0		27.2		25.0	18.9	18.2	19 6				
Glyndon 811	163						33.0		42.7		23.0	19.9	25.0	20.3	14.7	15.4	37.2	8.0
Glyndon 761	167						11.7		35 0		24.9	19.7	27.0	26.2	15.7		34.7	
*Haynes' Blue Stem	169						15.4		37.8		25.0	24.3	26.3	*22.5	19.3	14.1	38.4	12.5
*Risting's Fife	171						26.2		35.4		21.7	19.8	26.3	*24.5	16.7	16.7	38.1	8.6
Wellman's Fife	172						11.3		33.3		22.2	19.5		26.8				
*McKendry's Fife	180						14.2		34.5			19.5	26.5	*21.5	17.3	13.3	35.5	
Lost Nation	183								32.8			16.8	24.0					
North Star	184								30.0			14.1	22.2					
Advance	185								45.4		18.7	18 3	23.0	16.0	16.5	13.8	33.0	9.6
Crown	186								36.2		18.7	18.8	18.0					

TABLE XXI.—Wheat, Yields for all Years and all Farms—Continued.

VARIETY.	Minnesota Number.	Fargo, 1892	Fargo, 1893.	Fargo, 1894.	Coteau, 1894.	Euclid, 1894.	University F., 1894.	Coteau, 1895.	University F., 1895.	Fargo, 1896.	University F., 1896.	University F., 1897.	University F., 1898.	Northwest F., 1898.	Northeast F., 1898.	South Dakota, 1898.	North Dakota, 1898.	Iowa, 1898.
Stanley	187								57.5		18.0	12.7	14.3					
Preston	188								44.0		27.0	20 6	26.3	19-3	15.2	17.2	36.5	9.6
Percey	189								29.7		19.7	12.9						
No. 1 Nicopol Girca	195											17.6	14.2					
No. 3 Nicopol Girca	196											15.4	9.7					
No. 4 Kocharka	197											19.8	18.3					
No. 6 Odessa	198											19.8	17.3					
No. 6 Odessa	199											15.4	23.2					
No. 2 Nicopol Girca	200											19.8						

No. 2 Nicopol Girca	201											15.9						
No. 5 Nicopol Girca	202											20.4						
No. 5 Nicopol Girca	203											16.5						
Square Headed / Dwarf of Sicily	274										18.0	14.7	12.6					
Red Bearded / May Wheat	275										17.3	14.3	12.8					
Power's Fife	276										29.3	18.3	18.3	20.8				
Glyndon 818	278										33.0	19.8	19.8	17.9				
Haynes' Blue Stem	283										33.0	20.3	20.2	17.6				
McKendry's Fife	284										19.7	14.8	16.6	16.8				
Glyndon 761	285										27.7	20.7	21.6	22.5				
Glyndon 811	286										28.1	19.9	22.6	20.5				
McKissick's Fife	287										22 0	15.7	25.0	18.0				
McKendry's Fife X / McKendry's Fife	288										29.0	14.4	31.3	21.3				

TABLE XXI.—Wheat, Yields for all Years and all Farms.—Concluded.

VARIETIES.	Minnesota Number.	Fargo, 1892.	Fargo, 1893.	Fargo, 1894.	Coteau, 1894.	Euclid, 1894.	University F., 1894.	Coteau, 1895.	University F., 1895.	Fargo, 1896.	University F., 1896.	University F., 1897.	University F., 1898.	Northwest F., 1898	Northeast F., 1898.	South Dakota, 1898.	North Dakota, 1898.	Iowa, 1898.
Haynes' Blue Stem X Glyndon 761	289	.....	.....	.....	.....	.....	.....	.....	.....	.....	25.0	20.4	26.0	17.6	.....	.....	.....	.....
Haynes' Blue Stem X Glyndon 811	290	.....	.....	.....	.....	.....	.....	.....	.....	.....	18.3	15.5	27.6	16.8	.....	.....	.....	.....
Haynes' Blue Stem X Glyndon 811	291	.....	.....	.....	.....	.....	.....	.....	.....	.....	24.3	19.3	27.0	20.0	.....	.....	.....	.....
Risting's Fife X Risting's Fife	292	.....	.....	.....	.....	.....	.....	.....	.....	.....	25.0	17.9	32.0	17.7	.....	.....	.....	.....
Risting's Fife X Risting's Fife	293	.....	.....	.....	.....	.....	.....	.....	.....	.....	24.2	18.0	21.3	20.0	.....	.....	.....	.....
Haynes' Blue Stem	294	.....	.....	.....	.....	.....	.....	.....	.....	.....	25.3	21.3	24.8	26.5	.....	.....	.....	.....
Improved Blue Stem	295	.....	.....	.....	.....	.....	.....	.....	.....	.....	21.3	22.0	26.6	27.8	.....	.....	.....	.....
Countess	451	.....	.....	.....	.....	.....	.....	.....	.....	.....	18.7	11.0	.....	.....	.....	.....	.....	.....
Ladoga	452	.....	.....	.....	.....	.....	.....	.....	.....	.....	19.2	12 0	.....	.....	.....	.....	.....	.....
Percy	453	.....	.....	.....	.....	.....	.....	.....	.....	.....	18.3	13.3	.....	.....	.....	.....	.....	.....

Dawn	454										19.2	17.3	17.6					
Alpha	455										17.4	16 3	20.5					
Progress	456										17.4	14.7						
Buchan	457										17.4	14.3		16.8				
Egyptian Fife	458										17.3	17.8		23.8				
McKissick's Fife	475										23.0	20.4	24.6					
Risting's Fife	476											20.9	26.6					
McKendry's Assinaboia Fife	477											18.2	23.8					
Glyndon 753	478											18.7						
Haynes' Blue Stem	479											22.0	27.5					
Haynes' Ped. Blue Stem	498											20.5	27.5	24.5				
Wellman's Fife	165												24.7	23.8				
Glyndon 811	168								42.2		19.0	16.3						

46 and 50, and in the annual reports of this station for 1893, 1894, 1895 and 1896; and in bulletins 10, 11, 23 and 37 of North Dakota Experiment Station.

In 1897 these 200 wheats had been so closely culled out that only the eight best yielding kinds were grown at University Farm. To still better decide among these, small amounts of each kind were made into flour, and the flours were subjected to careful tests by the methods known among milling experts as the "color test," the "gluten test" and the "baker's sponge test." Taking the re-

Fig. 243. Wheat as threshed from one plot. Small bag contains wheat saved for pure seed. The brass kettle at the left with its steelyard is used for testing the weight per bushel of the wheat.

sults of these tests of the flour in connection with the data on yields, grade, liability to lodge, etc., through the several years, the list of the eight best wheats out of the original collection of 200 varieties was reduced to four for planting at University Farm in 1898. Prof. Shepperd still retains others of these varieties at the North Dakota station.

In Table XXI. are collected all the yields of all the more prominent varieties for each year at the several experiment stations and farms. In a few cases the yields here entered have not been under

sufficiently uniform conditions to be comparable, and have not been used in the summarized tables following.

In Table XXII. are collected all the yields of the best eight varieties above mentioned for the years 1892 to 1897, inclusive, at the several stations and farms as heretofore noted.

In Table XXIII. are given the averages of the eight comparable yields, (column 3), of the best eight varieties out of 200, as given at the top of Table XXI. This table was made up in the winter of

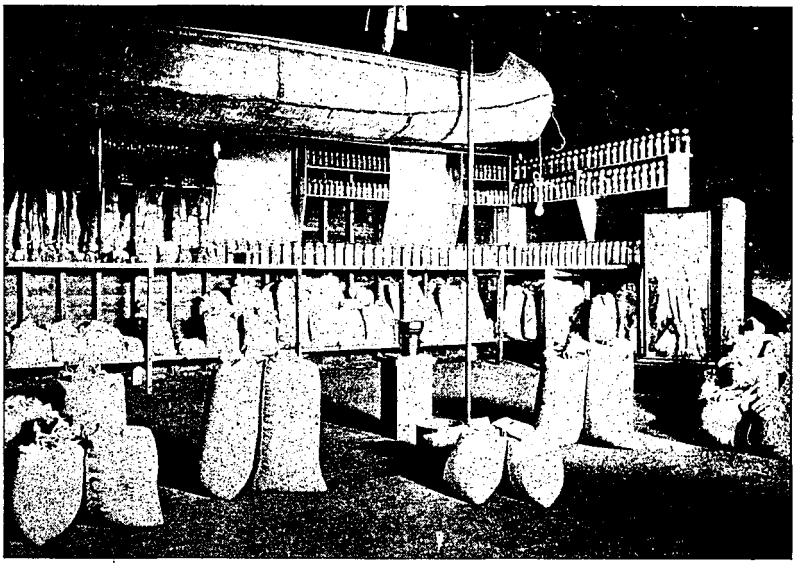

Fig. 244. The Seed House where are Stored the Samples of Varieties.

1897-8 that the list might be still further reduced by discarding those less desirable before seeding time in 1898. In a similar manner the data on grade, weight per bushel, per cent. rustiness and per cent. lodged of the several crops are here averaged and tabulated. Space will not permit the publication of all the tables, but the averages only as given in Table XXIII. are sufficient to illustrate their use in deciding the relative values of the several varieties. A careful inspection of this table will show why four of these wheats were discarded, retaining as the best four the following:

Minn. No. 51, Haynes' Blue Stem; Minn. No. 66, Power's Fife; Minn. No. 105, Glyndon 711; and Minn. No. 146, Bolton's Blue Stem.

Grading Wheat is the passing upon its commercial value for milling purpose. The grades (column 4) in Table XXIII. were determined for the first few years by professional grain inspectors from the State Grain Inspection force, who, from daily passing upon the grades of commercial grain, are expert judges. During later years the two who subscribe to this bulletin have done most of the grading. The public inspector's experience is nearly all with the two classes of wheat, Fife and Blue Stem. It was found that he passed judgment on other varieties by standards of color, hardness under the teeth, and of other characters, which were especially applicable in comparing the samples of the two varieties most common in our markets. When varieties from a foreign country, or varieties newly bred in Minnesota, which differed in appearance, came before the inspector, he would often place them too low, or too high, merely because of a lack of the amber color or of the flinty, transparent inside common to the standard wheats, which in his long daily experience had become his ideals of good wheats. The writers, knowing each wheat year after year, and having in mind the facts brought out by actually milling them, could better place the grade, though not so well trained in the empirical yet fairly satisfactory art of grading the two wheats commonly sent to our terminal markets. These

TABLE XXII.—Best Eight out of Two Hundred Collected Wheats.

Grown at \ Names.	Blount's Hybrid, No. 15. Minn. No. 13.	White Russian. Minn. No. 19.	Haynes' Blue Stem. Minn. No. 51.	Power's Fife. Minn. No. 66.	Rio Grande. Minn. No. 72.	Glyndon 711. Minn. No. 105	Glyndon 753. Minn. No. 116	Bolton's Blue Stem. Minn. No. 146
Fargo, 1892	17.3	17.7	16.7	21.3	14.7	23.3	14.7	*21.2
Fargo, 1893	12.8	11.9	12.9	15.1	13.4	10.0	14.3	17.8
Coteau, 1894	23.8	23.0	*20.8	19.8	13.6	21.4	19.3	21.4
Coteau, 1895	23.5	21.5	24.7	22.8	20.7	22.8	20.6	20 0
University Farm, 1895	29.0	33.2	21.6	26.3	29.3	31.8	31.5	35.3
Fargo, 1896	17.0	19.7	23.4	22.5	18.0	18.2	17.0	23.2
University Farm, 1896	21.2	24.8	24.6	21.4	20.2	21.4	21.0	25.1
University Farm, 1897	15.5	16.3	20.4	17.4	15.2	17.8	19.7	21.5
Averages of Eight trials	20.0	21.0	20.6	20.8	18.1	20.8	19.8	24.2

TABLE XXIII. Wheats. Best Eight of 200 Collected Prior to 1894—Yields, Grades, Quality of Flour, Etc.

Variety.	Minn. Number.	Yield per acre. Av. of eight trials.	Grade. Av. of seven trials.	Weight per Bushel. Av. of four trials.	Per cent. Rust. Av. of two trials.	Per cent. Lodged. Av. of two trials.	Gluten test, av. of two trials.			Baker's sponge test average of two trials.							Per cent. of Water absorbed by Flour.
										Time, Minutes.			Volume of Rise.				
															Rise for each gram of Gluten.		
							Quality.	Per cent. Dry.	Grams Water held by each gram Gluten.	First Rise.	Second Rise.	Total.	First Rise.	Second Rise.	Average of 1st and 2d Rise.	Second Rise.	
Blount's Hybrid No. 15.	13	20.0	84.0	55.4	15.0	15.0	75.0	17.3	1.94	122	63	165	1050	775	52 8	44.9	90.0
White Russian	19	21.0	77.1	55.0	16.0	18.5	77.5	14.5	2.03	90	72	162	725	550	53.3	46.4	82.5
Haynes' Blue Stem	51	20.6	85.0	54.0	12.5	7.5	82.5	15.7	2.04	98	68	166	1000	850	59.1	54.4	84.0
Power's Fife	66	20.8	89.9	55.4	12.0	15.0	87.5	16.5	2.21	101	53	154	1075	850	58.4	51.6	88.5
Rio Grande	72	18.1	81.4	56.6	20.0	12.5	72.5	17.2	2.08	107	92	199	1125	600	50.2	34.6	87.5
Glyndon 711	105	20.8	87.0	54.0	19.0	23.5	82.5	17.0	2.26	111	64	175	1175	800	57.9	47.1	90.5
Glyndon 753	116	19.8	85.4	54.5	15.0	24.0	82.5	16.7	2.16	115	86	201	1200	750	58.4	44.9	90.5
Bolton's Blue Stem	146	24.2	*88.6	†52.8	8.0	12.5	85.0	16.4	2.08	115	76	191	1163	800	59.9	40.7	87.5

* Average of five trials. † Three trials.

grades have a comparatively limited value in the tables because the gluten test and the baker's sponge test, described further on, tell in figures what the inspection attempts to estimate.

These grades have been here expressed in percentages rather than in commercial grades. These percentages are not convertible into commercial grades. In grading each wheat the quality of flour, as previously determined by milling it and subjecting it to the color test, the gluten test and the baker's sponge test, is taken into consideration. Thus the outward appearance of the particular sample of wheat is not taken as the sole measure of the quality of that particular kind of wheat. In case one wheat is poor in quality and quantity of its gluten, and if the sample is also poor in appearance, its grade is placed very low; or if the appearance of the sample is indeed very good it is given only a poor grade. An effort is made to let the grade represent the milling value of the wheat. With our present facilities, we are able to satisfactorily determine the quality and quantity of gluten in the wheats. The quantity of patent flour and the quantity of lower grade flours which the several grades of each variety of wheat will make should also be determined. For this purpose a four or six roll test mill is needed. With such an addition to our apparatus, we could determine more accurately the value of each variety of wheat, and its particular use as a mixer in combining it with other wheats to make flour of a given standard quality. Most of the factors which must be taken into consideration in grading wheat can be reduced to values expressed in figures. Among these factors are purity, weight, size of berry, color, plumpness, condition of bran; and where the wheat is of a known variety, and milling tests have been made, the percentage of gluten, the quality of gluten and the quantity of flour which a hundred pounds of the wheat will make may all be given their place in the estimate of value. By determining the relative importance of these several factors, grading wheat might be reduced to more nearly a mechanical basis, though the expense might be prohibitive in commercial dealings. In case of disputes simple

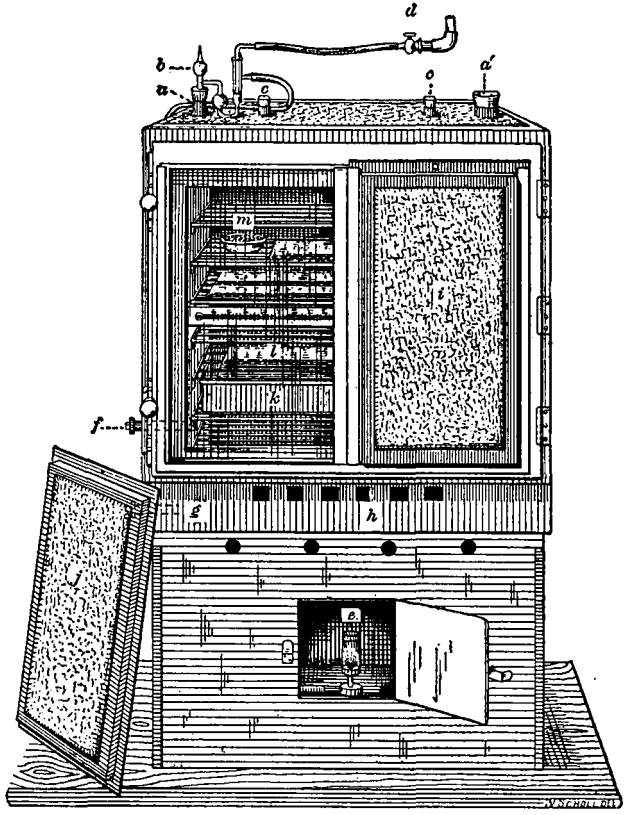

Fig. 245. Standard seed germinating chamber, used by the U. S. Department of Agriculture and American experiment stations (front view with one door slide removed); a a, openings into water jacket; b, thermoregulator; cc, openings into chamber; d, gas entrance tube; e, micro-bunsen burner; f, gas exit; h, ventilator; i, j, door slides; k, pan to hold porous saucers, etc.; l, blotter test; m, porous saucers with sand test.—[U. S. Dep. Ag. Circular No. 34.]

milling tests also might be employed to determine the value of wheats. The subject is one of large importance, and experimentation might lead to methods of inspection which are more accurate and yet inexpensive and practical.

The Weights Per Bushel have usually been taken as the grain came from the threshing machine, or where further cleaning was necessary, as it was cleaned sufficiently for market. The ordinary brass kettle used by official inspectors is used, duplicate weights being taken and averages made. These for the

several years have been averaged and appear in the several tables.

The Diseased or Rusted Condition, given in column 6, Table XXIII., is best noted before the grain is quite ripe, preferably one to two weeks before the maturity of the grain, and while the middle and lower leaves are yet full of active green cells. In taking these notes on rust some standard variety, as Blue Stem or Fife, is used, and all others compared with it. Table XXIII. does not show a very wide variation in the relative liability to rust of the best eight varieties. But some of the foreign wheats collected since 1894 show a much less power of resistance to this disease, as is shown in Table XXVIII. As a rule, the better yielding varieties are comparatively rust resistant. Or, it may be better to say that only varieties which have good rust-resisting power can yield well and have been able to hold a place in this list of eight best out of 200 kinds of wheat originally collected. Rust is always present and attacks all varieties, but some resist it with much greater power than others.

The Liability to Lodge has been noted during those years where the rainfall has been sufficient to cause more or less of the wheat to fall down. While yield and quality of grain are the main factors to be definitely measured in variety tests, the ability to stand up well and other peculiarities should be recorded. Farmers who have heavy, rich soils, especially need varieties of grain which have stiff straw. Here, also, one variety is used as a standard of comparison, and the proportion of the plants which have fallen down are expressed in percentages as in column 7 in Table XXIII.

TESTING THE QUALITY OF FLOUR FROM VARIETIES OF WHEAT.

The quality of wheat of new or unknown varieties cannot be fully determined by mere inspection. As between various samples of the same known variety, but grown under different conditions, the state inspectors and experienced grain dealers are able to judge closely the relative milling values. But there is no known empirical method of passing correct judgment upon varieties which are new to the inspector, nor of comparing their

milling value with our commonly grown Red Fife and Blue Stem varieties. This has been abundantly shown in our grading, where we have had judges of large experience undertake to grade many varieties.

If we should disseminate, and cause to be grown a new variety of wheat which would be different in appearance from our common kinds, the inspectors would need to know of its relative milling value, and they might need to make for it an entirely new class. Our Minn. No. 292, a Risting Fife in-cross, will be a case in point if its record for good yield is continued and it enters the list chosen to be disseminated to the farmers of the state. It is a pure Fife wheat in that both of its parents were pure Red Fife plants, yet this cross is very much lighter in color of berry than its parent variety. Any new wheat would have an additional value if combined with high milling qualities were the color, hardness, smoothness of bran and general appearance which would cause it to conform to the highest present market standards. But if the wheat has superior intrinsic worth it must stand upon its merit, and the standards or fashions of the market will need to change to suit the wheat. Fortunately, so far most of our best new wheats are Fife or Blue Stem in breeding, and in appearance and in quality are quite like their parents.

In seeking a knowledge of the real milling and food qualities of the numerous varieties under trial, the baking experts of the large mills were consulted, and also Prof. Harry Snyder, Professor of Agricultural Chemistry. Tests were decided upon for each variety, and for that purpose each was ground into flour. Mr. C. E. Foster, baking expert of the Consolidated Milling Company of Minneapolis, kindly offered assistance in milling and testing the wheats, and most freely advised and aided in devising plans which would be uniform and satisfactory. We were thus enabled to test the flours of the collected wheats in Table XXIII., in February, 1898, and also the other wheats that were then grown. In all, fifty-three varieties of wheat grown on University Farm were thus milled and tested, and of these thirty-

three duplicates which had been grown at Northwest Farm at Crookston in 1897 were milled and tested, making a total of 86 samples.

METHOD OF MILLING SAMPLES OF VARIETIES OF WHEAT.

The Consolidated Milling Company of Minneapolis kindly placed at our disposal their two small test roller mills in which to grind

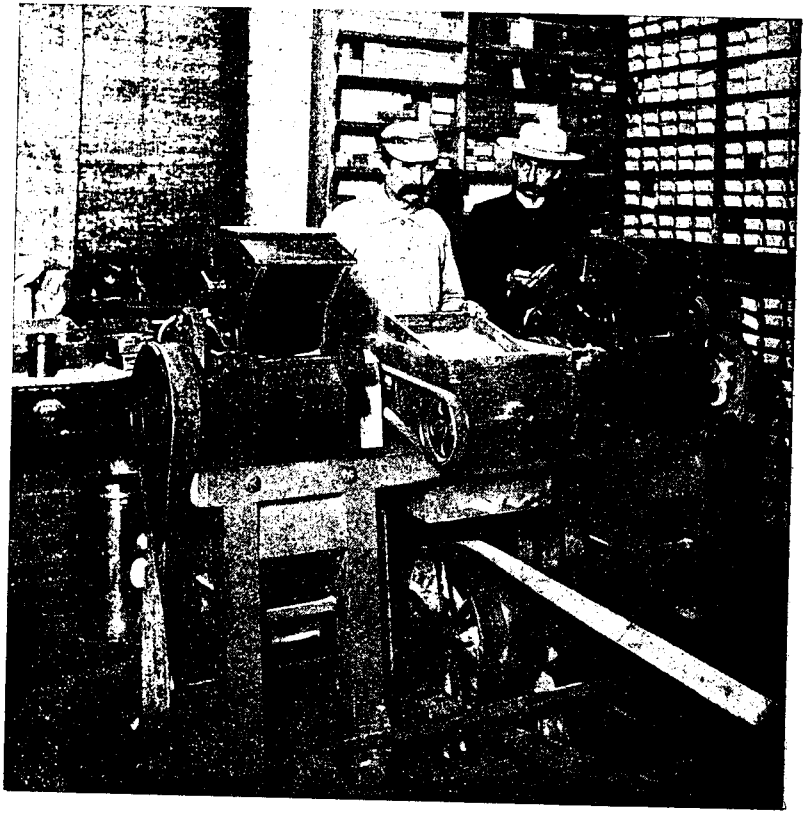

Fig. 246. Milling the Varieties of Wheat.

the samples of wheat. See Fig. 246. These mills are suited to grinding small quantities of grain. Each of the two mills has rolls six inches in diameter and six inches long. The first mill has corrugated rolls and the second smooth rolls. These miniature mills are very simple, consisting of little else than the

rolls. The ground wheat falls into a box. It is then poured into a sieve or simple plan-sifter which is shaken by machinery. Silk or wire sieves of such sized mesh that only the finer particles of flour will pass through are used, and the bran and coarser particles from the inside of the kernels are again passed through the rolls, further removing the floury particles from the bran, and making them sufficiently fine to pass through a fine silk cloth sieve.

The operator's judgment is used as to the closeness of removing the flour from the bran, since some varieties mill easier than

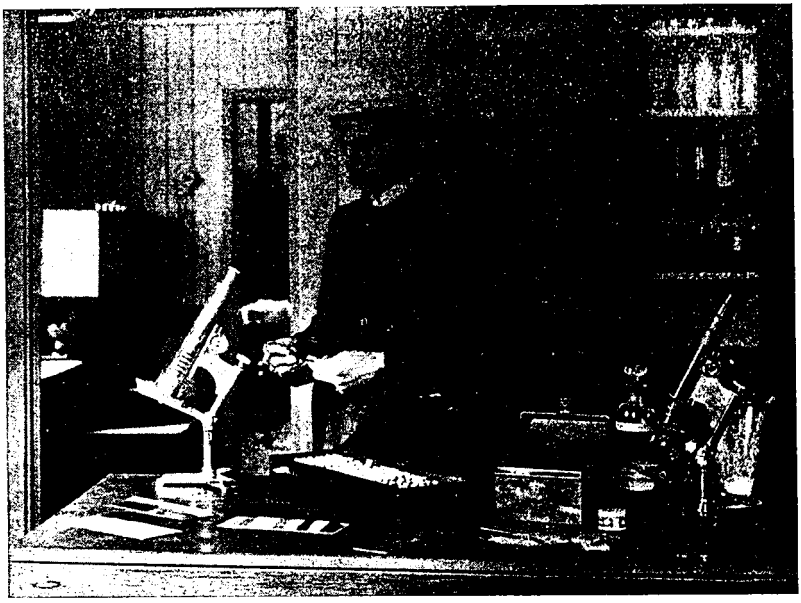

Fig. 247. Making the Color Test of the Flour from each Variety of Wheat.

others. No attempt is made in these tests to closely separate from the flour the finely broken particles of bran which injure its color. To do this effectually, it would be necessary to carry some of each variety through the complete process of the modern roller mill with its extensive system of "rolls" and reels or shaking sieves.

Since comparisons of flour of each new wheat with the flour of our common Fife and Blue Stem varieties were the objects sought, rather than making perfect flour from each, it was found that this could be done by milling small amounts and making the tests with comparatively small quantities of flour.

Milling the Test Samples.—A quart or more of each kind of wheat having been cleaned, it was run through the test mill. An ounce of this flour was weighed out for the gluten test, and 100 grams for the baker's sponge test. In the gluten test the

Fig. 248. Making the Gluten Test.

essential facts sought were the amount of gluten and its strength, while incidentally its color and other qualities were noted. In the baker's sponge test the flour was subjected to a practical trial of its ability to rise in a dough when worked down and required to again rise in the loaf.

The Gluten Test was carried on as follows: An ounce of the flour was weighed out. Water was added and the flour kneaded into a stiff dough. This was worked considerably so as to bring

all the gluten into active contact. Then the mass of dough was held under a stream of water and gently pulled and kneaded. The dough was thus manipulated until all the parts had been turned out and exposed to the running water, and all the starch grains had been disentangled from the fibrous mass of gluten, and washed away, as shown by the wash water no longer containing a sediment of starch.

To avoid the loss of small portions of gluten, which might break loose, a hair sieve was kept under the stream of water, and any detached portions of gluten were gathered up and again placed with the general mass.

When this gluten had been washed clean of starch it was dried to a standard dryness. This was done by continuously pulling and kneading it in the hands, frequently drying the hands on a towel, until the free portions of water had been removed. This mass of moist gluten was then weighed, that the difference might be found between the wet weight and the dry, water-free substance, weighed later on, thus finding the power of the gluten to hold water. Notes were made on this wet gluten as to its color, and especially as to the strength of the gluten. It was stretched out into threads, the better gluten stretching out into longer and finer threads than the poorer, which breaks off more squarely. It was then laid in a round mass upon a stiff card. The stiffer the gluten the higher it lies in a more nearly globular mass; and the poorer the gluten, the more it "runs," or spreads out on the card. This method, while somewhat empirical, is reasonably accurate, and an expert operator can tell by it much regarding the quality of the gluten of a given variety of wheat. The varieties with stiffer, tougher gluten will rise high in the loaf, and as a rule will retain their power of rising after the dough has been worked down one or more times. And the varieties with gluten which runs freely, and easily breaks upon being stretched, make a loaf which will not rise high, rises poorly after it has been "worked down," and makes withal a "runny" dough that creeps out over the edges of the pan rather than rises into a well formed loaf. Tables XXIII. and XXIV. bear out these

general statements, though the various tables giving gluten and baker's sponge tests do not in quite all cases show a uniformity of results from these two methods as to the quality of the gluten.

The moist gluten was dried in a temperature of 212 deg. F. until its moisture had been all driven off. It was then weighed (col. 9 in Table XXIII.), and the difference between the dry and the wet weights was taken as the amount of water held by the gluten (col. 10 in Table XXXIII.), and from this was figured the amount of water held by each gram of gluten. See Fig. 248.

The Color Test is made as follows: The samples of flour are placed in adjacent masses on a rectangular plate of glass about three by ten inches in size. Each mass is smoothed down with a steel spatula so as to present a smooth surface. An extensive series of colored glass slabs is used. The colors of these glasses are delicately graded from light to gray, and to brown, each color being marked with a certain percentage or scale. The flours are then matched with the glasses and the color of that glass recorded which corresponds with the color of the flour. See Fig. 247.

The Baker's Sponge Test was performed as follows: One hundred grams of flour were weighed out in a wide porcelain dish or an earthenware bowl holding a pint or more. See Fig. 249. Part of the water needed to make the flour into a dough (usually about 65 cc.) was then measured out from a burette. Into this was dissolved five grams of sugar and five grams of compressed yeast. The flour was stirred into this water with a steel spatula, and more water was added until the whole was kneaded into a dough of standard consistency or "stiffness". The cubic centimeters of water required by a given sample of flour were then expressed in percentages of water taken up by each one hundred grams of flour. (See column 8, Table XXIII.)

The dough was then placed in tubes about four inches in diameter, which were graduated into cubic centimeters. These tubes were then set in water at 90 deg. F., and the dough allowed to rise. It was constantly watched until it reached its full height and fell, when the time required to rise and its volume expressed

in cubic centimeters were recorded. The tube was left in the water bath until the dough again rose to the full height its remaining strength was capable of, when the time required and the volume were again recorded. These facts are noted in Table XXIII., under columns 12-16 inclusive.

By dividing the volume of loaf to which 100 grams of flour would rise by the percentage of gluten in the flour, the volume of loaf produced by each gram or percentage of gluten was found. Since 100 grams of flour were used and the specific grav-

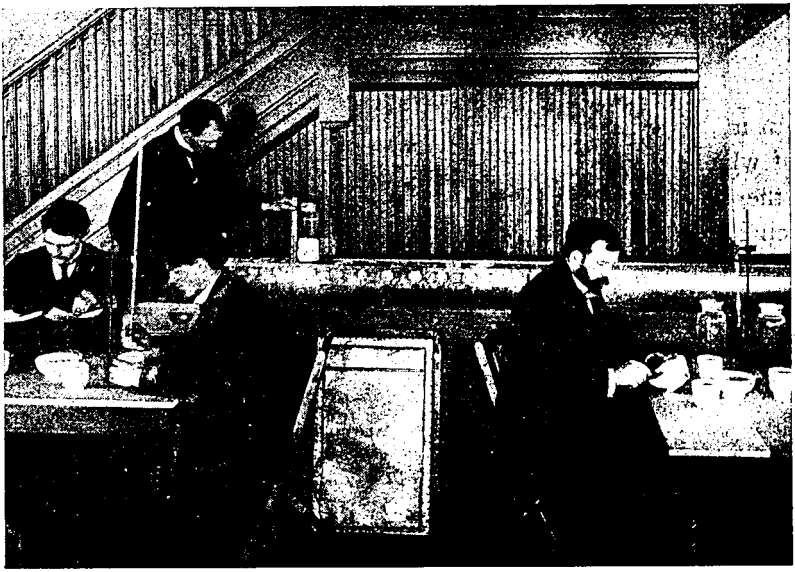

Fig. 249. Making the Baker's Sponge Test of Varieties of Wheat.

ity of the gluten is not far from unity, it may be said that these figures represent the number of times a gram of gluten from each of the several kinds of wheat will expand. Thus, flour from Bolton's Blue Stem wheat contained only 16.4 per cent. of gluten, yet dough from a hundred grams of flour rose the first time to a volume of 1163 cc., and each gram of gluten produced sixty times its volume of loaf. During the second rise

it rose to a volume of 800 cc., each gram of gluten producing forty-nine times its volume of loaf.

Rio Grande wheat, on the other hand, had a larger percentage of gluten, 17.3 per cent. But this was of poorer quality. The loaf rose nearly as high the first time as that from flour of Bolton's Blue Stem wheat, but there being a larger amount of gluten present, each gram of gluten produced only fifty times its volume of loaf, while in the case of Blue Stem wheat each gram produced sixty times its volume. In the second rise, the gluten from the Rio Grande flour did not show good "staying" qualities, and produced only thirty-five times its volume of risen loaf. The volume of rise produced by each gram of gluten is shown in columns 17 and 18 of Table XXIII.

The gluten test and the baker's sponge test were each carried out in duplicate with each variety of our best wheats, one sample of which was grown at University Farm near St. Paul, and the other at Northwest Farm at Crookston, nearly three hundred miles to the northwestward, and under very different conditions of soil and climate, giving four tests to each variety, the results of which have given satisfactory comparisons. The results of the gluten tests and the baker's sponge tests, taken in connection with the average of eight yields (col. 3, Table XXIII.), give facts which were used in further reducing the list of the wheats retained from the two hundred varieties collected prior to 1894.

RELIABILITY OF MILLING TESTS.

The milling tests to which these varieties of wheats were subjected are not new nor experimental in their principal features. Expressing the amount of rise from each gram of gluten, as in columns 17 and 18, Table XXIII., is a new way of indicating the quality of the gluten present in a given sample of wheat. This method of expressing the strength of the gluten is especially useful for the second rise. It shows whether the gluten has the ability to endure and will repeatedly rise when the loaf is kneaded down. In Table XXIV. are grouped the principal results from Table XXIII., giving the facts relative to the eight best yielding varieties of two hundred wheats collected prior to 1894. It so

happens that these varieties give considerable range in quantity of gluten present and in the quality of the gluten, thus giving opportunity to compare the two methods of determining the strength of the gluten. In column 5 is given the quality of the gluten as determined by Mr. Foster in the gluten test described on pages 348-349, using a percentage comparison. The eight varieties are here arranged in the order in which Mr. Foster placed them, the range being from 87.5 per cent. for the best, down to 72.5 per cent. for the poorest, flour. In column 6 are given the coefficients of expansion as determined by the averages between the

TABLE XXIV.—Comparing the Gluten Tests and Baker's Sponge Test

Minn Number.	Variety.	Yield per Acre Average of 7 trials.	Per cent. of Gluten Av. of 2 trials.	Quality of Gluten Av. of 2 trials.	Av. of 1st and 2d Rise for 1 gram of gluten, 2 trials.	Av. of 2d Rise for 1 gram of gluten, 2 trials.	Average of Best four and Poorest four wheats compared.		
							Quality of Gluten.	First and Second Rise.	Second Rise.
1	2	3	4	5	6	7	8	9	10
66	Power's Fife	20.8	16.5	87.5	58.4	51.6	.....	.....	.....
146	Bolton's Blue Stem	24.2	16.4	85.	59.9	48.7	.....	.....	.....
51	Haynes' Blue Stem	20 6	15.7	82.5	59.1	54.4	.....	.....	.....
105	Glyndon 711	20.8	17.0	82 5	57.9	47.1	84.4	58.8	50.5
116	Glyndon 753	19.8	16.7	82.5	58.4	44.9	.....	.....	.....
19	White Russian	21.0	14.5	77.5	53.3	46.4	.....	.....	.....
13	Blount's Hybrid, No. 15	20.0	17.3	75.0	52.8	44.9	.....	.....	.....
72	Rio Grande	18.1	17.2	72 5	50.2	34.6	76.9	53 7	42.7

volumes of rise the first and second times, divided by the amount of dry gluten as found present by Mr. Foster.

It will be seen that, with the exception of the first and third, which are reversed, the flours stand in their power of rising, as shown in this test, in the same order of superiority in which they were placed by Mr. Foster. Taking the second rise alone, there is nearly the same relation shown. In other words, these two methods correspond closely, and it is fair to presume that each, in a general way, is nearly accurate. These tests do not by any means make a complete test of the milling qualities of the wheats. Numerous actual baking trials, milling the wheats in

quantity, alone and in mixture, will be necessary before we have a full knowledge of the quality of any wheat. These simpler tests, however, seem practical in aiding to throw out the less desirable varieties of wheats, that our limited time and means may be spent on the comparatively few which are most promising.

By means of the comparisons we were at once enabled to discard one-half of the best eight wheats of our earlier collections. (See Tables XXIII., XXIV. and XXV.) Minn. No. 72 Rio Grande, easily goes to the foot of the list, being the poorest of the eight in yield and poorest in quality of gluten, and especially poorest in the ability of its dough to rise a second time.

Blount's Hybrid, No. 15, may rightfully be placed next to the lowest on account of the poor quality of its gluten, though it averaged slightly better in yield than Glyndon 763, and as much as Haynes' Blue Stem, one of the four wheats chosen to remain in our preferred list of varieties.

It will be observed that both Rio Grande and Blount's Hybrid No. 15 have an unusually large percentage of gluten, being the richest in these most valuable food substances of any of the eight varieties given in Tables XXIII. and XXIV. But they are without that quality of gluten which enables the baker to make a light loaf; consequently the nutrients cannot be well utilized, and the miller cannot afford to pay a good price for the wheat.

White Russian is excelled in yield only by Minn. No. 146, yet for two reasons it should have the place assigned to it by Mr. Foster's estimate. It lacks both in the quantity and quality of its gluten, being poorest in amount of gluten of any of the eight wheats; i. e., 14.3 per cent.

Glyndon 753 stands highest in the list of the four discarded wheats, and is nearly equal to Minn. No. 105 and Minn. No. 51.

THE BEST FOUR WHEATS OF 200 COLLECTED PRIOR TO 1894.

Of the best four wheats, Minn. No. 146 easily stood at the head. It yielded for the several years an average of 3.4 to 3.6 bushels more than each of the other best four wheats; the per cent. of gluten it contained was excelled in the two trials by Minn. No. 105; its quality of gluten, as shown by the gluten test

TABLE XXV.—Yields of Best Four of 200 Wheats Collected Prior to 1894.

	VARIETY.	Fargo, 1892.	Fargo, 1893	Coteau, 1895.	University Farm, 1895.	Fargo, 1896.	University Farm, 1896.	University Farm, 1897.	University Farm, 1898.	Northeast Farm, 1898.	North Dakota, 1898.	Footings.	Average of 10 Yields.	Average of all kinds and all yields.
Column in Book 108.....	....	2	3	8	10	11	12	14	17	19	22			
Minn. Number 51..........	Haynes' Blue Stem......	16.7	12.9	24.7	21.6	23.4	24.6	20.4	23.3	23.0	33.5	224.1	22.4	....
Minn. Number 66..........	Power's Fife.................	21.3	15.1	19.8	26.3	22.5	21.4	17.4	24.0	20.7	32.0	220.5	22.0	....
Minn. Number 105.........	Glyndon 711...............	23.3	10.0	22.8	31.8	18.2	21.4	17.8	22.3	14.7	32.0	214.3	21.4	....
Minn. Number 146.........	Bolton's Blue Stem......	21.2	17.8	20 0	35.3	23.2	25.1	21.5	22.5	19.3	35.3	241.2	24.1	22.5

and by the second rise in the sponge test, was poorer than that of Minn. No. 66, while its strength of gluten in the first rise excelled that shown by any other wheat. Among the other three wheats there is not much choice, as shown by TableXXIV. While the gluten test placed Minn. No. 66, Power's Fife, highest in quality of gluten, Minn. No. 51, Haynes' Blue Stem, showed gluten of greater staying quality in the second rise of the dough. Minn. 105 had a higher percentage of gluten than either 51 or 66, but its gluten showed a lack of endurance in rising a second time.

We have been surprised that from so many wheats collected as the best from countries which are our competitors in spring wheat sections of the world we have found nothing so good as our best samples of home-grown Blue Stem and Fife wheats. These experiments have greatly added to our respect for these two hardy classes of wheat, and to our faith in their continued usefulness in Minnesota and surrounding states. That these wheats have so successfully met all newcomers under the varying conditions of these trials, is good proof that our hard wheats are not "running out," and that new seed need not be procured from somewhere sufficiently "far off" to mystify.

We have thus secured a standard of yields with which to compare our best wheats on experiment station lands, not especially rich nor manured with special fertilizers, but simply well farmed. The four wheats thus used for standards of comparison averaged about 22.5 bushels per acre, as shown in Table XXV. It is the ambition of the experiment station to procure, or to create by breeding, varieties which will increase this yield on these soils to an average of 28 bushels per acre, other conditions remaining as now, and to disseminate such seed throughout the state, that the yields for farmers may be proportionately increased. That this can be done there seems no reason for doubt, though the time required to accomplish this important result may be long.

Twenty-three bushels per acre is a larger average by several bushels than is secured by farmers of the state from seed similar to these best varieties. With a better system of field management, providing for crops preceding the wheat which will

prepare the soil for the wheat, with live stock to make more manure, and with better methods of tillage, farmers can approach or even surpass on good farms the average yields secured on the experiment farms. No doubt a greater increase over our present average yields, of which no one is proud, can be secured by better tillage and a proper rotation of crops than will come from the introduction of new or improved varieties. Our farmers can bring average yields of common Fife and Blue Stem wheat up from 15 to 22 bushels by good farming just as well as the station has done. If the station can then furnish them with Fife or Blue Stem or cross-bred varieties so improved as to raise these average yields five bushels higher, profits will be very greatly increased. It is not expected that such results will come at once. But that patient experimenting, and patient, extensive educating will eventually win, seems possible.

BEST BLUE STEM AND BEST FIFE VARIETY OF 200.

The question yearly arises in our experiment work as to which varieties shall be retained for use and increased for dissemination. In connection with the breeding of wheat, it is necessary also to know which are the best kinds of wheat to use as foundation stocks in the attempt to make new varieties. Table XXV. gives the ten most fairly comparable yields of the four best yielding wheats yet collected. The average yields, grades, weights per bushel and milling tests of these four wheats to date afford useful comparisons. In yield, Minn. No. 146, Bolton's Blue Stem, is still in the lead, 1.7 bushels; Minn. No. 51, Haynes' Blue Stem, stands second; and Minn. No. 66, Power's Fife, third; while Minn. No. 105, Glyndon 711, stands last in yield.

Bolton's Blue Stem, Minn. No. 146, also ranks best in grade. Power's Fife, Minn. No. 66, ranks best in weight per bushel. Haynes' Blue Stem showed the greatest ability to resist rust and lodged least of all varieties. Minn. No. 105, Glyndon 711, showed a bad tendency to lodge. Minn. No. 66 and Minn. No. 105, Fife wheats, have half of 1 per cent. more of gluten than the two Blue Stem varieties. The quality of the

gluten in Power's Fife, Minn. No. 66, was estimated as superior in the gluten test, but this was not sustained by the baker's sponge test, where it stood lowest of the four wheats in the amount of rise of dough from each gram of gluten. In total value per acre, Minn. No. 146, Bolton's Blue Stem, stands out as the best for use, and it is being extensively used for a foundation stock in the production of new varieties of wheats.

RUSSIAN WHEATS COLLECTED IN 1893-4.

In 1893 and 1894, a number of wheats were collected through our American consuls and from seed dealers in Russia. These were grown in small plots in 1894. In all cases there was a mixture of varieties, and hand sorting was resorted to, the several

TABLE XXVI.—Yields of Russian Wheats Collected in 1893-4.

Russian Names	Nicopol Girca No. 1	Nicopol Girca No. 3	Kocharka No. 4	Odessa No. 6	Odessa No. 6	Standard Wheats			
Minn Nos.	195	196	197	198	199	66	146	163	169
Yields at									
University Farm, 1897	17.6	15.4	19 8	19.8	15.4	17.4	21.5	19 9	24.3
University Farm, 1898	14.2	9.7	18.3	17.3	23.2	24.0	22.5	25.0	26.3
Average Yields	15.9	12.5	19.1	18.6	19.3	20.7	22.0	22.5	25.3

types being picked out of the bundles of harvested grain. Nine of the most promising of these wheats were selected for field variety tests. In 1898, four of these were discarded. In Table XXVI. are given the yields per acre of field trials of the remaining five varieties at University Farm in 1897 and 1898.

Minn. Nos. 195 and 196 have since been discarded without further test, because of their inferior yield.

In Table XXVII. are given the yields, grades, weights per bushel and the quality of the grain for milling purposes of the remaining three Russian varieties. Bolton's Blue Stem and Power's Fife are placed in the table, with their yields, etc., compiled, to serve as standards for comparison.

It is plainly shown that no varieties of especial promise have been gained from these later importations, and again we have failed to find North European varieties of hard wheat which are equal to our commonly used varieties.

WHEATS COLLECTED IN 1895 AND 1896.

In Table XXVIII. are tabulated the results of trials of wheats collected in 1895 and 1896. In some instances they are original stocks of wheat from which we have bred new varieties, and they are again planted, that their newly originated progeny may be directly compared with the foundation stocks. Such parent varieties are Nos. 165, 168, 172, 294, 475, 476, 477, 479. Nos. 183,

TABLE XXVII.—Russian Wheats, Results of Tests at Univ. Farm in 1898.

Minn. No.	Names of Russian Varieties.	Yields per Acre.	Weight per Bushel.	Per cent. Gluten.	Quality of Gluten.	Baker's Sponge Test.						
						Time. M		Water absorbed by flour	Volume of Rise.			
						Av. of 1st and 2d Rise	2d Rise.		1st Rise.	2d Rise.	From one Gram Gluten. Av. of 1st and 2d Rise.	From one Gram Gluten. 2d Rise.
197	No. 4 Kocharka	18.3	60.5	10.4	75	86	40	69	950	600	74.5	57.7
198	No. 6 Odessa	17.3	57.5	8.1	65	88	64	72	750	650	86.4	80.2
199	No. 6 Odessa	23.2	59.5	10.2	65	74	28	74	1000	550	73.5	49 0
	Standard Varieties											
66	Power's Fife	24.0	59.0	12.8	98	111	104	72	950	625	60.8	47.5
146	Bolton's Blue Stem	22.5	59.5	11.2	85	127	125	74	1075	600	79.5	53.6
163	Glyndon 811	25.0	56.5	14.4	98	97	73	73	1050	725	61.1	50.3
169	Haynes' Blue Stem	26.3	57.5	11.9	95	75	27	75	1100	600	68.9	53.8

184, 274, 275, 497, 457 and 458 are varieties which have been brought to our attention by parties interested in them.

SAUNDERS' CROSS-BRED WHEATS, RECEIVED IN 1895.

In 1895, Dr. Wm. Saunders, Director of the Dominion Experiment Farms, Ottawa, Can., sent the station five of his new cross-bred wheats. These were tried in comparison with our standard wheats. The results of these trials are collected in Table XXIX., and all but Minn. Nos. 185 and 188 are discarded from further trial. Minn. No. 188, Preston, gives promise of large yield with fair quality, exceeding in yields most of our best collected varieties. Minn. No. 185, Advance, also yielded well, and proved to

TABLE XXVIII.—Wheats Collected in 1895 and 1896.

Minn. No.	Names of Varieties.	Yield			1897	1898 Grade	Weight per Bushel		Per Cent. Lodged		Per Cent. Rust		Gluten 1898		Baker's Sponge Test						
															Time		Volume of Rise				
		1897	1898	Average			1897	1898	1897	1898	1897	1898	Quality	Amount	First Rise	Second Rise	First Rise	Second Rise	Av. of 1st and 2d Rise	From each gr'm gluten 2d Rise	Water Absorbed.
165	Wellman's Fife	.....	24.7	.....	....	92	.....	59.5	.....	0	....	7	95	12.6	145	94	1125	675	69.4	55.5	73
168	Glyndon 811	16.3	.....	.....	78	....	56	.....	20	0	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
183	Lost Nation	16.75	24.0	20.4	78	89	55	59	20	0	12	.....	80	10.0	111	13	800	650	72.5	65	72
184	North Star	14.12	22.2	18.2	80	86	55.5	59	20	0	12	.....	80	9.7	114	15	900	650	79.9	67	72
274	Sq. Headed Dwarf of Sicily	14.66	12.6	13.6	73	70	51	56	20	0	.....	14	75	12.4	126	27	1100	550	66.5	44.3	69
275	Red Bearded May Wheat	14.33	12.8	13.6	78	65	52	56.5	40	0	.....	23	65	10.3	117	59	950	600	75.2	58.2	75
294	Haynes' Blue Stem	21.25	24.8	23.0	84	90	54.5	59	17	0	9	6	80	11.2	125	85	950	750	75.8	66.9	74
295	Improved Blue Stem	22.0	26.6	24.3	84	92	54	58	20	0	12	7	95	13.9	132	76	1000	750	62.9	53.9	72
475	McKissick's Fife	20.35	24.6	22.5	....	88	.....	58	15	0	10	22	95	13.2	121	87	950	750	64.3	56.8	73
476	Risting's Fife	20.9	26.6	23.7	....	90	.....	60	15	0	10	15	85	13.0	135	68	1050	700	69.1	57.6	71
477	McKendry's Assa. Fife	18.15	23.8	21.0	....	85	.....	60	10	0	11	10	95	12.9	125	65	950	750	65.8	58.1	72
478	Glyndon 753	18.7	.....	.....	....	..	.....	.....	13	0	10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
479	Haynes' Blue Stem	22.0	27.5	23.7	....	86	.....	60	8	0	10	3	95	12.5	136	89	950	750	68.0	60.0	73
497	Gehum	12.65	.....	.....	....	..	.....	.....	15	0	12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
498	Haynes' Ped. Blue Stem	20.5	27.5	24.0	81	86	52	60.5	13	0	10	2	95	12.4	148	80	1100	700	72.5	56.4	75
457	Buchan	14.33	.....	.....	78	....	54	.....	10	0	12	15	.....	.....	.....	.....	.....	.....	.....	.....	.....
458	Egyptian Fife	17.83	.....	.....	80	....	54	.....	25	0	11	6	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Standard Collected Wheats																				
66	Power's Fife	17.4	24.0	20.7	83	93	55	59	15	0	12	10	98	12.8	118	104	950	625	60.8	47.5	72
146	Bolton's Blue Stem	21.5	22.5	22.0	83	94	53.5	59.5	10	0	9	12	85	11.2	132	125	1075	600	66.1	53.5	74
	Standard New Wheats																				
163	Glyndon 811	19.87	25.0	22.4	87	93	56	56.5	10	0	11	8	98	14.4	127	72	1050	725	61.5	50.3	73
169	Haynes' Blue Stem	24.3	26.3	25.3	85	87	54.5	57.5	8	0	8	7	95	11.9	123	27	1100	600	71.4	58.8	75

TABLE XXIX.—Saunders' Cross-Bred Varieties. Received in 1895.

Minn. Nos.	Names of Saunders' Varieties.	Yield per Acre.	Grade.	Weight per Bushel.	Rust, Per Cent.	Lodged, Per Cent.	Gluten Test.			Baker's Sponge Test.							Per Cent. Water held by Flour.
										Time.			Vol. of Rise.				
							Quality.	Per Cent. Dry.	Grams Water per Gram Gluten.	1st Rise.	2d Rise.	Total.	1st Rise	2d Rise.	Av. of 1st and 2d Rise.	2d Rise.	
185	Advance	20.6	85	57	13	7	80	13.1	2.07	125	56	181	1175	650	83.7	50.5	84.
186	Crown	18.4	86	57	15	5	87	14.4	2.11	118	56	174	1225	1000	73.3	60.	84.
187	Stanley	13.5	82	56	17	12	78	13 4	2.1	127	52	179	1225	675	72.1	50.6	82.
188	Preston	23.3	85	56	22	7	75	13.1	2.35	125	50	175	1150	725	71.8	54.0	82.
	Standard Varieties																
51	Haynes' Blue Stem	21.9	90	56	8	5	85	14.4	2.0	117	73	190	1050	675	69.2	51.1	79.
66	Power's Fife	20.7	90	57	11	7	94	15.3	2.7	110	89	199	1025	738	57.8	47.6	81.
146	Bolton's Blue Stem	22.0	88	57	10	5	83	13.9	2.35	121	98	219	1065	750	66.7	54.0	80.5

Yield of 1897 and 1898 at University Farm.

be a fairly good milling wheat. The three discarded varieties made flour of good quality, especially Minn. No. 186, Crown.

In Table XXX., seven yields of the two wheats still retained are given in comparison with our best two collected wheats and the best two wheats originated in our field crop nursery. Preston is the most interesting and promising variety of wheat procured outside the state, and it bids fair to be a strong rival of our best Fife and Blue Stem wheats. It is being subjected to rigid selection in our field crop nursery, that new varieties may be produced from it, and it is employed as a parent of cross-bred varieties.

TABLE XXX.—Saunders' Cross-Bred Wheats Received in 1895.

Names of Varieties	Advance	Preston	Standard Wheats. Collected: Power's Fife	Collected: Bolton's Blue Stem	New	
Minn. Nos	185	188	66	146	163	169
Grown at						
University Farm, 1896	18.7	27.0	21.4	25.1	23.0	25.0
University Farm 1897	18.3	20.6	17.4	21.5	19.9	24.3
University Farm 1898	23 0	26.3	24.0	22.5	25.0	26.3
N. W. Farm, 1898	16.0	19.3	18.8		20.3	22.5
N. E. Farm, 1898	16.5	15.2	20.7	19.3	14.7	19.3
South Dakota, 1898	13.8	17.2	17.4	17.3	15.4	14.1
North Dakota, 1898	33.0	36.5	32.0	35 3	37.2	38.4
Averages	19.9	23.1	21.7		22.2	24.3

Advance, Minn. No. 185, having failed to keep its average yield up to the best standard varieties, would be discarded but for the fact that stocks of it are being bred in the field crop nursery, and it is desirable to retain the original stock for the purpose of future comparisons with its progeny.

SAUNDERS' CROSS-BRED WHEATS RECEIVED IN 1896.

In 1896 the station received from Dr. Saunders six other cross-bred varieties, which were grown in small plots in that year and given field trials in 1897 and 1898. Four varieties which had yielded poorly in 1897, and were not especially promising at harvest time in 1898, were not threshed separately in the latter year,

TABLE XXXI.—Wheats. Saunders' Cross-Bred Varieties Received 1896.

Minn. No.	Name of Varieties.	Yield per Acre, 1 Trial.	Grade, 1 Trial.	Wt. per Bush., 1 Trial.	Lodged, 1 Trial.	Gluten Test.			Baker's Sponge Test.							
									Time.			Vol. of Rise.				
														Of 1 Gram Gluten.		
						Quality.	Per Cent. Dry.	Grams Water held by 1 Gram Gluten	1st Rise.	2d Rise.	Total.	1st Rise.	2d Rise.	Av. of 1st and 2d Rise.	2d Rise.	Per Cent. Water Held by Flour.
451	Countess	11.0	80	55.5	35	85	15.2	2.20	85	150	235	950	750	5[illegible].6	48.6	93
452	Ladoga	12.0	60	49.5	30	65	15.2	2.80	100	85	185	1050	800	60.8	52.6	87
453	Percey	13.3	78	54.0	25	70	17.2	2.13	110	92	202	1300	900	63.9	52.3	92
454	Dawn	17.2	76	53.5	25	70	15.2	2.08	95	90	185	900	700	52.6	46.0	92
455	Alpha	16.2	78	54.0	20	70	16.2	2.11	93	96	189	950	600	48.1	37.0	82
456	Progress	14.6	78	54.0	25	75	17.1	2.06	109	75	184	1150	800	57.0	46.8	91
	Standard Varieties.															
51	Haynes' Blue Stem	20.4	82	53.5	10	75	15.0	1.98	96	75	171	1000	800	51.8	48.7	84
66	Power's Fife	17.4	83	55.0	15	85	15.4	2.13	102	75	177	1100	850	55.1	44.0	90
146	Bloton's Blue Stem	21.5	83	53.5	10	80	16.2	2.03	110	70	180	1050	900	58.7	54.2	87

Table is made from results at University Farm for 1897.

and were discarded. In Table XXXI. are given the results of 1897, together with the results of one milling test.

Minn. No. 454, Dawn, and Minn. No. 455, Alpha, were harvested in 1898, and the results of the three years' trials of these two wheats are shown in Table XXXII. in comparison with the yields of four of our best wheats. Since we have so many varieties of greater promise, it does not seem wise to retain either of these varieties in the tests.

ORIGINAL FIFE AND BLUE STEM VARIETIES VS. BEST NEW WHEATS.

When the comparison of varieties of wheat had continued for some years, and it had become evident that Fife and Blue Stem varieties were better adapted to our conditions than any other

TABLE XXXII.—Best of Saunders' Cross-Bred Wheats Received in 1896.

			Standard Wheats			
			Collected		New	
	Dawn	Alpha	Power's Fife	Bolton's Blue Stem	Glyndon 811	Haynes' Blue Stem
Minn. Nos.....	514	455	66	146	163	169
Grown at						
Univ. Farm 1896	19.2	17.4	21.4	25.1	23.0	25 0
Univ. Farm 1897	17.3	16.3	17.4	21.5	19.9	24.3
Univ. Farm 1898	17.6	20.5	24.0	22.5	25.0	26.3
Averages.....	18.0	18.1	20.9	22.0	22.6	25.2

wheats we had obtained, it seemed best to try to determine which of these two classes of wheat is superior.

In Table XXXIII. are summarized the yields for 1897 and 1898 of six original stocks of Fife and six of Blue Stem, and with them are placed also, for comparison, three of the most promising new wheats originated in our field crop nursery.

MISCELLANEOUS WHEATS.

Goose Wheat is a variety or class of wheat which the station was urged to test by persons who had taken a casual interest in it. It has been variously named in the current literature as goose wheat, rice wheat, kubanka, ironutka, etc. Statements have been circulated that it would yield 30 to 50 bushels per acre, and that it is a superior crop for stock food. After thorough trials, we deem it unfit for flour, and too poor a yielder for a stock food.

TABLE XXXIII.—Original Fife vs. Blue Stem Varieties vs. New Wheats.

Name / Grown at	Fife Varieties.						Blue Stem Varieties.						Best New Varieties.		
	Power's Fife.	Wellman's Fife.	Wellman's Fife.	McKissick's Fife.	Risting's Fife.	McKendry's Assa. Fife.	Haynes', Crop of 1891.	Bolton's.	Haynes', Crop of 1895.	Jackson's Improved.	Haynes', Crop of 1891.	Haynes', Crop of 1896.	Power's Fife, Selected in 1892.	Glyndon 811, Selected in 1892.	Haynes' Blue Stem, Selected in 1892.
Minn. Nos....	66	165	172	475	476	477	51	146	294	295	479	498	149	163	169
Univ. Farm, 1897....	17.4		19.5	20.4	20.9	18.2	20.4	21.5	21 3	22.0	22.0	20.5	19.9	19.9	24.3
Univ. Farm, 1898....	24.0	24.7		24.6	26.6	23.8	23.3	22.5	24.8	26.6	27.5	27.5	26.5	25.0	26.3
Average.....	20.7	21.2		22.5	23.8	21.0	21.8	22.0	23.1	24.3	24.8	24.0	23.2	22.4	25.3
General Average.....						22.0						23.3			23.6

The gluten in its flour has very little strength, and it yields less than our hard wheats.

Ladoga Wheat received much attention a decade ago, especially in the Canadian Northwest. This wheat was used with good results by Dr. Wm. Saunders, director of the Canadian experiment farms, as one of two parent varieties in producing cross-bred wheats. His effort was to produce early varieties suited to the short seasons along the northern borders of the spring wheat belt. Minn. No. 188, Preston, and Minn. No. 185, Advance, (see Tables XXIX and XXX), were thus produced by crossing Ladoga with Fife wheat, and they both show the Ladoga parentage by their bearded character. While these wheats are not especially early, they have proven to be good yielders. (See Table XXI.)

Several trials of Ladoga wheat in Minnesota resulted in poor yields of very poor wheat, and this variety was discarded without even a milling test.

Winter Wheat has been grown but little in Minnesota. During recent years several counties in the southeastern part of the state have produced considerable winter wheat of a variety which has generally proven hardy and has yielded about fifty per cent. more than the standard varieties of spring wheat. Minnesota is credited with producing larger yields of winter rye per acre than any other state. If winter wheats could be secured or produced sufficiently hardy to endure the winter and extend the winter wheat belt one or two hundred miles further to the northward, we could expect our average yields of wheat to be materially increased. We have already collected a few varieties, and have commenced breeding some of the most promising ones with a view of obtaining still greater hardiness, as well as the increased yields. Dr. Otto Lugger, entomologist of this station, and Dr. L. O. Howard, chief entomologist of the National Department of Agriculture, question the wisdom of bringing winter wheat northward. They express the belief that the Hessian fly will follow the winter wheat and spread to the fields of spring wheat, and will there cause enough damage to more than offset the value of the increased yields of the winter wheat. This

phase of the question will be watched with great interest, and the facts may warrant the restriction of winter wheat from certain districts where spring varieties mainly are grown.

NEWLY ORIGINATED VARIETIES OF WHEAT.

In 1892, the breeding of eight of the best varieties of wheat which had been collected by the Minnesota experiment station was begun by W. M. Hays, then at the North Dakota experiment station. Four hundred selected kernels of each of the eight varieties, which had been grown at Glyndon, Clay county, the previous year, were planted at Fargo, N. Dak., and a like number on the farm belonging to J. B. Power & Son, Power, Richland Co., N. Dak. The conditions being better at Power, and the plants more uniform in size, the selection of plants for "mothers" of varieties was made from the plots at that place. Besides choosing plants from which to originate varieties by selection, numerous crosses were made both at Fargo and at Power.

THIRTY-ONE NEW WHEATS FROM SELECTED MOTHER PLANTS.

The method of planting and selecting wheat in the field crop nursery, when first begun in 1892, was crude in many ways. The important feature of dealing with the individual plant in selection was, however, fully recognized, and not only the yield, but the quality, of the grain, and other characteristics, were taken into account in selecting plants to become the mothers of varieties.

Four hundred plants of each of eight kinds were placed on very uniform soil, with the surface nicely pulverized. The seeds were carefully chosen from bulk grain,—heavy, "hard" kernels of rather large size being selected. The seeds were planted in hills twelve by eighteen inches apart, making the plots twelve by fifty feet in size. One kernel was placed in a hill. This distance apart of hills has since been found too great for the best results in wheat breeding,—four by four inches being preferred.

The plants were all cultivated until in flower, when strong plants were chosen for male and female parents of crosses between several of the varieties. When the grain was ripe the plants used in crosses were harvested, so as to obtain the yields

of the parents of the various cross-bred kernels which had resulted from the cross-pollenated flowers. After the removal of the plants which had been used for parents of crosses, each plot was carefully inspected, and the best ten plants chosen and the spikes from each plant harvested separately. The seeds of each plant were shelled out, and the net weight of the clean grain was determined for each plant. From the eighty plants thus secured, the thirty-one having the largest yields, and of superior quality, were chosen to plant the next season. In 1893, one hundred to four hundred kernels from each of these thirty-one plants were planted at Fargo in a manner similar to the method of planting in 1892. When this wheat was ripe the best ten plants were chosen from each plot, and from these the best plant was selected, after weighing the clean grain as in 1892. Thus the best plant was secured for the mother of a plot in 1894, each plot of which traced back through a single plant to one of the thirty-one plants chosen in 1892. The breeding of these thirty-one stocks of wheat was started, and in case of each of those proving most promising has been annually continued to this date. The best plant of one generation thus becomes the mother of all of the one or more hundred plants of the next generation. Since wheat is practically self-fertilized, the "blood" of one plant is kept pure for several generations, and the best one of the progeny of each generation is chosen to become the double parent of the succeeding generation. This more than incestuous breeding seems natural to wheat plants. In a manner similar to that described under the next heading new varieties are produced by increasing the wheat from the mother plant chosen every fifth generation in this line of continuous annual selection.

BEST EIGHT VARIETIES FROM MOTHER PLANTS OF 1892.

In 1893, the best plant was first chosen from each of the thirty-one stocks as above mentioned. Then the poorest one-fourth of the remaining plants was discarded, and the seed from the remaining plants of each stock was saved in bulk. This sample of seed was given a variety name, as Minn. No. 163, Minn. No. 169,

TABLE XXXIV.—Best Eight Out of Thirty-One Selected Varieties from 1892.

Names of Mother Varieties	Power's Fife	Glyndon 818	Glyndon 753	Glyndon 811	Glyndon 761	Haynes' Blue Stem	Risting's Fife	McKendry's Fife	Standard Varieties			
Names of New Varieties	Minn. No. 149	Minn. No. 155	Minn. No. 157	Minn. No. 163	Minn. No. 167	Minn. No. 169	Minn. No. 171	Minn. No 181	51—Haynes' Blue Stem	66—Power's Fife	105—Glyndon 711	146—Bolton's Blue Stem
Grown at												
University Farm, 1895	36.2	32.3	30.9	42.7	35.0	37.8	35 0	34.5	21.6	26 3	31.8	35.3
University Farm, 1896	23.3	23 3	22 0	23.0	21.7	25.0	21.7	.....	24.6	21.4	21.4	25.1
University Farm, 1897	19.9	20.8	21.4	19 9	19.8	24.3	19.8	19.5	20.4	17.4	17.8	21.5
University Farm 1898	26 5	26.8	26.6	25.0	26.3	26.3	26.3	26.5	23.3	24.0	22.3	22.5
Northwest Farm, 1898	22.3	23 5	20.2	20 3	24.5	22.5	24.5	21.5	.....	18.8	18.3	.....
Northeast Farm, 1898	14.0	14.7	16.2	14.7	16.7	19.3	16 7	17.3	23.0	20.7	14.7	19.3
North Dakota Experiment Station, 1898	33 8	35.2	36.5	37.2	38.1	38.4	38.1	35.5	33.5	32.0	32.0	35.3
Averages	25.1	25.5	24.8	26 1	26.0	27.7	27 4	*27.8	*24.4	22.9	22.6	*26.5

*Averages of only six yields.

TABLE XXXV.—Wheats. Eight Best of Thirty-one Selected from 1892 Mother Plants.

Names of Mother Varieties	Names of New Varieties	Mother Plants in 1892.	Yield of Plant, Grams.	Century Number in 1893.	Yield per acre, Average of six trials.	Grade, Average of six trials.	Weight per Bushel, Average of five trials.	Rust, Average of four trials.	Gluten Test, Average of four trials.			Baker's Sponge Test, Av. of 4 trials						
												Time		Volume of Rise				
									Quality.	Per cent. Dry.	Grams of Water held by Each Gram Gluten.	First Rise.	Second Rise.	First Rise.	Second Rise.	Rise from each Gr. Gluten		cc. Water Absorbed by each 100 Grams Flour
																Ave. 1 & 2 Rise.	2d Rise.	
Power's Fife	Minn. No. 149	108	9.0	601	25.6	91 3	58.8	13	90	13.5	2.13	122	102	1065	738	66.8	54.5	84
Glyndon 818	Minn. No. 155	2540	15.5	3501	25.5	90.0	58.7	11.5	88	13.5	2.04	114	98	1075	663	75.1	70.0	87
Glyndon 753	Minn. No. 157	1277	11.0	4401	25.6	83.6	58.7	11.5	88	13.9	2.08	105	90	1013	688	61.9	49.8	81
Glyndon 811	Minn. No. 163	2001	15.0	14201	27.1	87.3	57.7	11	87	13.8	2.0	113	70	1075	719	65.6	52.	83
Glyndon 761	Minn. No. 167	1701	16.0	12601	26.2	70.0	58.4	10	81	12.7	2.13	105	86	988	713	68.6	58.4	82
Haynes' Blue Stem	Minn. No. 169	476	19.1	6901	28.5	86.3	57.8	6	80	12.5	2.03	120	50	988	688	68.5	59.1	84
Risting's Fife	Minn. No. 171	4944	9.5	13201	26.3	86.1	57.9	10	80	13.1	2.04	103	57	1045	723	71.8	56.9	82
McKendry's Fife	Minn. No. 181	802	13.0	8701	25.9	86.6	57.7	11	91	12.5	2.07	99	62	963	750	71.2	62.0	79
Standard Varieties.																		
Haynes' Blue Stem 51					24.6	87.0	57.8	6.2	85	13.4	2.4	114	82	925	731	59 5	54.7	79
Power's Fife					23.6	86.0	58 5	12.2	86	14.0	2.12	108	69	938	706	58.9	50 2	81
Bolton's Blue Stem					26.5	90.0	58.0	9.5	84	13.2	2.16	126	103	1063	700	69.3	54.9	81

etc., and a pint, more or less, of seed of each variety was planted at University Farm in 1894, in a small plot, to increase the quantity of seed to a sufficient amount for field variety tests. In 1895 and 1896, the thirty-one new varieties were tested at University Farm in twentieth acre plots. Averages of these two yields were made, and only the best yielding variety from each original kind was retained. In 1897 and 1898, these eight varieties thus chosen as the best were again tested at University Farm, and in 1898 all of them were tested at the Northeast Station, the Northwest Station and at the North Dakota Station, and a few of them were grown by the South Dakota and Iowa Experiment Stations. The yields of these varieties for all years and stations are shown in Table XXI. under Minn. Nos. 149, 155, 157, 163, 167, 169, 171 and 181, and in Table XXXIV. all the yields which are comparable are collected.

Table XXXV. gives the average yields per acre, grades, weights per bushel, ability to resist rust, amount and quality of gluten, results of baker's sponge test of flour, and other facts concerning these eight new wheats. Beside these figures similar facts for comparison are given, concerning the best three wheats the station has collected from the spring wheat growing countries of the world.

It is worthy of mention that the North Dakota Experiment Station has continued the work started there in 1892 and 1893, in making new varieties from the selected and the cross-bred stocks above mentioned. That station has about fifty of the best selected and cross-bred stocks, each of which has been selected to the best mother plant since 1892, 1893 or 1894. A number of the choicest stocks were harvested in bulk in 1898, with a view of increasing the seed in 1899 and making varieties which are to be tested in comparison with the standard wheats found to have yielded best at that station. Those found superior are to be distributed to the farmers of North Dakota. These stocks of wheat appeared very promising when nearly ripe in 1898, and since several valuable varieties have been branched off from the same stocks, there is good reason to hope that valuable

TABLE XXXVI.—Best Four Collected vs. Best Eight New Varieties. Yields at University Farm.

Varieties. / Grown at	Haynes' Blue Stem.	Power's Fife.	Glyndon 711.	Bolton's Blue Stem.		Minn. No. 149.	Minn. No. 155.	Minn. No. 157.	Minn. No. 163.	Minn. No. 167.	Minn. No. 169.	Minn. No. 171.	Minn. No. 181.
Minnesota Nos.	51	66	105	146									
University Farm, 1895	21.6	26.3	31.8	35.3		36.2	32.3	30.9	42.7	35.0	37.8	35.0	34.5
University Farm, 1896	24.6	21.4	21.4	25.1		23.3	23.3	22.0	23.0	24.9	25.0	21.7	
University Farm, 1897	20.4	17.4	17.8	21.5		19.9	20.8	21.4	19.9	19.7	24.3	19.8	19.5
University Farm, 1898	23.3	24.0	22.3	22.5		26.5	26.8	26.6	25.0	27.0	26.3	26.3	26.5
Averages	22.5	22.3	23.3	26.1		26.5	25.8	25.2	27.7	26.7	28.4	25.7	

wheats for the Red River Valley will result. It will be of interest also to compare stocks of wheat from the same mother plant of 1892 selected for several years at the widely separated stations of Minnesota and North Dakota.

BEST EIGHT VARIETIES OF NEW WHEATS AT UNIVERSITY FARM.

In Table XXXVI. are summarized the yields at University Farm only of these best eight new wheats in comparison with the best four out of 200 collected varieties.

It will be observed that some of the new wheats are superior in yield to all of the old wheats, as shown by the averages in Tables XXXIV., XXXV. and XXXVI. In grades, weights per bushel and in ability to resist rust and other characteristics, the new varieties compare favorably with the best old kinds. Some of them are comparatively low in the quantity and the quality of gluten. As a rule, they rank high in milling quality, as shown by the results of the baker's sponge test given in Table XXXV. Some of these wheats give especial promise, and all of them are good varieties. While Minn. No. 163, Minn. No. 169, and Minn. No. 149 show especial promise, others of these eight wheats may prove valuable for at least some portion of the state or of surrounding states. The fact that each of these wheats yields more than Power's Fife and Haynes' Blue Stem, and that only four of them, and they Fife varieties, are exceeded by our best yielding old variety,—Bolton's Blue Stem,—is most encouraging. Here is certainly positive evidence that superior varieties have resulted from this effort at the systematic breeding of wheat by selection.

SEVEN VARIETIES FROM MOTHER PLANTS OF 1892-3-4.

In Table XXXVII. are tabulated the yields of seven wheats which were selected in the nursery during 1892, 1893 and 1894. The best Fife and the best Blue Stem collected prior to 1894, and the best new Fife and the best new Blue Stem variety mentioned in Table XXXIV., are also placed in this table as standards with which to compare these new wheats. None of these

TABLE XXXVII.—Wheats Selected in Nursery in 1892, 1893 and 1894.

Names of Parent Varieties.....	Power's Fife 66	Glyndon 818 480	Haynes' Blue Stem 51	McKendry's Fife 477	Glyndon 761 481	Glyndon 811 168	McKissick's Fife 475	Standard Old Varieties		Standard New Varieties	
Names of New Varieties.....	Minn. No 276	Minn. No. 278	Minn. No. 283	Minn. No. 284	Minn. No. 285	Minn. No. 286	Minn. No. 287	Power's Fife 66	Bolton s Blue Stem 146	Glyndon 811 163	Haynes' Blue Stem 169
Grown at											
University Farm, 1896.....	29.3	33 0	33.0	19.7	27.7	28.0	22.0	21.4	23.3	23.0	25.0
University Farm, 1897.	18.3	19.8	20.3	14.8	20.7	19.9	15.7	17.4	19.9	19 9	24 3
University Farm, 1898.....	18.3	19.8	20.2	16.6	21.6	22.6	25.0	24 0	26 5	25.0	26.3
N. W. Farm, 1898	20.8	17.9	17.6	16.8	22.5	20.5	18.0	18.8	22.3	20 3	22.5
Averages	21.7	22.6	22.8	17.0	23.1	22.8	20.2	20.4	23.0	22.0	24 5

seven wheats as yet give promise of especially good yields, though most of them are worthy of further trial.

In Table XXXVIII. are given the summarized facts regarding the yields, grades, milling tests, etc., of these seven new wheats in comparison with several of the stocks of wheat from which they came.

OUT-CROSSED AND IN-CROSSED VARIETIES.

In 1892, many of the strongest plants in the field crop nursery were artificially cross-pollenated. Out-crosses were thus made between plants of different varieties and in-crosses between plants of the same variety. Each of the 101 seeds thus produced in 1892 was planted by itself in the field crop nursery in 1893, and a number given the resulting plant. Through an accident, about two-thirds of the resulting plants were destroyed. Those remaining were harvested separately, and full notes were recorded of each. Only a part of the out-crosses proved to be true crosses. A Blue Stem variety with hairy chaff had been used for the male parents in all the out-crosses, and all the female parents were smooth-chaffed varieties. Where the resulting plants were marked by the hairy chaff of the male parent, the proof of a true cross has been regarded as certain. Where the chaff remained smooth, not showing the character of hairy chaff from the male parent within two years fecundation has been regarded as having resulted from self-pollenation, and the varieties have been discarded from further trial, or if especially promising have been classed with the new varieties by selection alone.

From each cross-bred plant grown in 1893, one hundred or more seeds were planted in 1894. The best plant was chosen in each of a number of cases, and from these one or more hundreds of seeds were planted in 1895. After selecting the best plants with which to continue the breeding, and discarding the poorer ones, the remainder of the plants of each stock were harvested in bulk and planted in a small field plot in 1896. From these plots sufficient seed was produced so that in 1897 a twentieth acre plot of each was grown at University Farm. In 1898, these varieties were again

TABLE XXXVIII.—Wheats, Seven Selected Varieties from 1894 Mother Plants.

Minn. No. / Names of New Varieties.	Names of Parent Varieties.	Parent Plant in 1892.	Yield of Parent Plant.	Parent Plant in 1893.	Yield of Parent Plant.	Parent Plant in 1894.	Yield of Parent Plant.	Century Number in 1895.	Yield per Acre, Four Trials.	Grade, Av. of Two Trials.	Weight per bush., Av. of Three Trials.	Per cent. Rust, Av. of Three Trials.	Gluten Test.			Baker's Sponge Test.						
																Time.		Volume of Rise.				
																				Rise from each Gr. Gluten.		
													Quality, Two Trials.	Per Cent. Dry Gluten.	Grams Water held in One Gr. Gluten.	1st Rise.	2d Rise.	1st Rise.	2d Rise.	1st Rise.	2d Rise.	Water Absorbed by Flr.
276	Power's Fife	103	13.8	806	11.8	2222	6.1	23201	21.7	86	55.8	11	92	14.7	2.26	105	74	950	775	60.0	54.5	82
278	Glyndon 818	2476	15.0	3018	14.3	3130	4.9	23601	22.6	86	55.9	10	94	14.2	2.14	105	75	900	650	56.5	47.4	76
283	Haynes' Blue Stem	551	19 3	995	17.2	7621	7 0	27701	22.8	88	56.	8	88	14.0	2.10	110	70	950	662	59.7	49.2	79
284	McKendry's Fife	953	.....	6623	6.3	173	7.3	101	17.0	86	57.	11	88	13.3	2.10	105	78	850	625	57.9	49.3	79
285	Glyndon 761	1731	.....	6650	2.4	311	4.9	1601	23.1	83	55.2	8	95	14.5	2.55	.....	83	875	700	55.2	49.0	79
286	Glyndon 811	2174	.....	6661	10.8	804	9.9	4301	22.8	85	55.6	11	90	12.9	2.15	154	49	925	675	71.0	59.5	81
287	McKissick's Fife	4791	.....	6682	4.2	1379	7.7	7101	20.2	87	56.	12	83	15.7	2.05	136	62	950	750	55.1	48 5	77
Parent Varieties.																						
51	Haynes' Blue Stem	.....	.....	.....	.....	.....	.....	.....	22.8	88	56.2	7	88	14.5	2 04	139	73	1050	738	62.6	51.1	79
66	Power's Fife	.....	.....	.....	.....	.....	.....	.....	20.9	88	56.6	11	92	15.3	2.12	111	90	1225	738	68 2	52.8	81
168	*Glyndon 811	.....	.....	.....	.....	.....	.....	.....	16.3	78	§57.	11	85	16.6	2.12	92	101	1000	600	48 2	56.1	83
475	†McKissick's Fife	.....	.....	.....	.....	.....	.....	.....	†22.5	88	58.	10	95	13.2	2.20	121	87	950	750	64 4	56 8	73
477	‡McKendry's Assa. Fife	.....	.....	.....	.....	.....	.....	.....	‡21.0	85	60.	11	95	12.9	1.7	125	65	950	750	65.9	58.1	72

*1897 crop only. †Average 1897 and 1898 yields only. §Average 1896 and 1897 only. ‡1898 crop only.

TABLE XXXIX.—Yields of Crosses of 1892. Out-crosses vs. In-crosses.

	Out-crosses			In-crosses			Standard and Parent Varieties					
Name of Mother Varieties.....	H. B S. / G. 761	H. R. S. / G. 811	H. B. S. / G. 811	McKend F. / McKend F.	Rist. Fife / Rist. Fife	Rist. Fife / Rist. Fife	Power's Fife	Power's Fife	Glyndon 811	Haynes' Blue Stem	Risting's Fife	McKendry's Assinaboia Fife
Name of New Varieties.....	Minn. No. 289	Minn. No. 290	Minn. No. 291	Minn. No. 288	Minn. No. 292	Minn. No. 293						
Grown at							66	149	163	169	476	477
University Farm, 1897.....	20.4	15.5	19.3	14.4	17.9	18.0	17.4	19.9	19.9	24.3	20.9	18.2
University Farm, 1898.....	26.0	27.6	27.0	31.3	32.0	21.3	24.0	26.5	25.0	26.3	26.6	23.8
N. W. Farm, 1898.....	17.6	16.8	20.0	21.3	17.7	20.0	18.8	22.3	20.3	22.5	.....	.....
Averages.....	21.3	20.0	22.1	22.3	22.5	19.8	20.1	22.9	21.7	24.4	.....	.....

tested at University Farm and at Northwest Farm. In Table XXXIX. the yields of three out-crosses and three in-crosses are tabulated. With them are placed the best parent Fife variety, Minn. No. 66, and the best two new Fife varieties, Nos. 149 and 163, also the best new Blue Stem variety, No. 169.

It will be observed that some of the in-crosses and also some of the out-crosses have made very creditable yields in comparison with our best varieties. These results indicate that useful varieties of wheat may be originated from single carefully selected mother plants one generation from the cross. It by no means follows that it is the wiser course to start at once new varieties, rather than to continue the selection of newly crossed stocks to a single best plant out of one or more hundreds for each of several generations before using a single plant as a mother of a new variety, or to first grow the cross-bred wheats in the field for a few years, and then subject them to extensive nursery selection before increasing into a variety. It must be said, however, that while these new out-crossed wheats are known to be true crosses, they have shown very little tendency to vary or revert to types other than the type of the 1894 mother plant, of the second generation after the cross, from which they originated.

In only one of the in-crossed wheats have we evidence of there being a true cross. Minn. No. 292, Risting's Fife X Risting's Fife, (Minn. No. 476 X Minn. No. 476), is a much lighter colored wheat than the parent variety, and presumably the changed color is a variation resulting from the cross between two plants of the same variety.

It is not to be expected that even under a most rigid selection of plants in the nursery that all resulting cross-bred varieties will prove valuable when subjected to field trials. That a majority of the six thus far tried give promise of being among our best wheats gives a basis for the hope that by systematic cross-breeding followed by rigid selection varieties may be originated which will prove superior not only to the best parent wheats collected, but superior also to the best wheats originated by selection alone. Experiments mentioned elsewhere demonstrate that greater varia-

TABLE XL.—Wheats. Six new Cross-bred Varieties, Crossed 1892, Mother Plants of 1894, Compared with Various other Wheats.

New Names / Minn. No.	Varieties Used in Crossing.	Mother Plant 1892.	Mother Plant 1893.	Yield of Mother Plant 1893.	Mother Plant 1894.	Yield of Mother Plant 1894.	Yield per Acre, Av Three Trials.	Grade, Two Trials.	Weight per Bushel, Av. of Three Trials.	Rust.	Gluten Test			Baker's Sponge Test.						Water Absorbed by Flour.
														Time		Volume of Rise				
																		From Each Gr. of Gluten		
											Quality.	Per cent. Dry.	Grams Water per Gram Gluten.	First Rise.	Second Rise.	First Rise.	Second Rise.	Av. First and Second Rise.	Last Rise.	
	Cro-ses.													Min.						CC.
289	H. B. S. X G. 761	753/1339	6652	5.1	563	6.7	23.8	89	56.5	8	95	14.5	2.08	111	82	900	750	57.3	50.9	81
290	H. B. S. X G. 811	631/2376	6659	7.6	640	6.7	20.7	86	58.0	10	94	15.0	2.22	109	88	950	725	56.1	48.6	82
291	H. B. S. X G. 811	631/2376	6660	3.5	719	8.0	23.5	81	54.8	11	92	15.4	2.11	87	114	1050	800	65.3	52.1	82
288	McKendry's Fife X McKendry's Fife	884/982	6632	4.7	219	5.5	24.9	89	57.5	10	83	15.1	2.06	135	79	1050	750	55.6	49.8	81
292	Risting's Fife X Risting's Fife	4910/4941	6670	6.5	1153	11.0	25 0	83	57.0	9	90	15.3	2.16	110	93	925	740	55.1	48.9	77
293	Risting's Fife X Risting's Fife	5008/4942	6669	8 0	1201	8.0	21.2	89	57.7	10	95	15.4	2.14	118	79	875	725	53.2	48.3	78
	A Parent Variety.																			
51	Haynes' Blue Stem	.....	.....	.....	.....	.....	22.8	88	56.0	7	85	14.5	2.06	118	73	1050	738	62.7	51.2	79
	New Selected Varieties.																			
167	Glyndon 761	.....	.....	.....	.....	.....	23 5	85	57.0	10	83	14.3	2.08	109	89	1100	725	66.3	52.9	82
171	Risting's Fife	.....	.....	.....	.....	.....	22.6	86	56.0	9	93	14.1	2 15	107	68	1125	72	66.5	52.1	79
181	McKendry's Fife	.....	.....	.....	.....	.....	22.7	88	56.5	10	93	13.6	2.10	106	66	1100	750	68.8	55.6	79
286	Glyndon 811	.....	.....	.....	.....	.....	23.4	85	55.7	11	90	12.9	2.15	154	49	925	675	71.0	59.5	81
	Standard Varieties.																			
66	Power's Fife	.....	.....	.....	.....	.....	20.9	88	57.0	11	92	15.3	2.12	111	90	1025	713	58.0	47.8	81
146	Bolton's Blue Stem	.....	.....	.....	.....	.....	20.0	88	56.3	9	83	13 9	2.22	121	98	1063	750	66.8	53.9	80

tion is produced by crossing than occurs in wheat permitted to self-fertilize.

Rigid selection of these cross-bred stocks through a series of years will doubtless result in finding those plants which are adapted to becoming the progenitors of heavy yielding varieties of good quality. This selection includes (1) the choice of the best yielding plants bearing good grain in the nursery, (2) the varieties yielding best in the variety field trials, and (3) those proving to have high quality in the milling tests. In Table XL. are given the summarized facts relative to yield, grade, milling, and baking qualities, etc., of these six cross-bred wheats.

NEW WHEATS COMPARED WITH PARENT VARIETIES.

In Tables XLI. to L., inclusive, the yields of several new wheats are tabulated beside the yields of the varieties from which they came. Some of the new varieties do not appear here because the parent variety has been discarded from the variety tests.

In Table XLI., Minn. No. 161 is shown to yield slightly less than its parent variety. This new variety was originated from a

TABLE XLI.—Minn. No. 161 Compared with its Parent Variety, Haynes' Blue Stem.

Grown at \ Varieties.	Haynes' Blue Stem.	Minn. No. 161.
University Farm, 1895	21.6	27.2
University Farm, 1896	24.6	25.0
University Farm, 1897	20.4	18.9
University Farm, 1898	23.3	18.2
Average	22.5	22.3
Loss	.....	0.2

single plant of Haynes' Blue Stem grown in 1892, in a similar manner as the eight varieties given in Table XXXIV. were origin-

ated. It has been discarded from further trial because of its poor yielding qualities.

In Table XLII., another variety, Minn. No. 169, originated at the same time and from the same parent variety as Minn. No. 161, mentioned above, but from a different mother plant, is compared with the parent variety. In columns two and three are given yields at University Farm, Northeast Farm, South Dakota Experiment Station and at the Iowa Experiment Station, with the

TABLE XLII.–Minn. No. 169 Compared with its Parent, Haynes' Blue Stem.

Grown at / Variety	Haynes' Blue Stem—Minn. No. 51	Minnesota No. 169	Haynes' Blue Stem—Minn. No 51	Minnesota No. 169
University Farm, 1895	21 6	37.8	21.6	37.8
Uuiversity Farm, 1896	24.6	25.0	24.6	25.0
University Farm, 1897	20.4	24.3	20.4	24.3
University Farm, 1898	23.3	26.3	23 3	26.3
N. E. Farm, 1898	23.0	19.3		
So. Dakota, 1898	20.2	14.1		
Nor. Dakota, 1898	33.5	38.4		
Iowa, 1898	8.8	12.5		
Averages	21.9	24.7	22.5	28.3
Gain		2.8		5 8

TABLE XLIII.—Minn. No. 149, Compared with Its Parent Variety, Power's Fife.

Grown at / Variety	Power's Fife No. 66.	Minnesota No. 149.	Power's Fife No. 66.	Minnesota No. 149.
University Farm, 1895	26.3	36 2	26.3	36.2
University Farm, 1896	21.4	23.3	21.4	23.3
North Dakota, 1896	22.5	22 7		
University Farm, 1897	17.4	19.9	17.4	19.9
University Farm, 1898	24.0	26 5	24.0	26.5
N. W. Farm, 1898	18.8	22.3		
N. E. Farm, 1898	20.7	14.0		
South Dakota, 1898	17.4	15.4		
North Dakota 1898	32.0	33.8		
Iowa, 1898	7.0	7.5		
Averages	20.7	22 1	22 3	26 5
Gain		1.4		4.2

average for eight yields. Here the increased yield of the new wheat over its parent is 2.8 bushels per acre. In columns four and

five, four yields are given at University Farm only. Here the average shows an increased yield in the new wheat of 5.8 bushels per acre over its parent.

This is the most promising of all the newly originated wheats. Being a Blue Stem variety, it will doubtless become popular in the southern two-thirds of the state.

In Table XLIII., in like manner Minn. No. 149 is compared with No. 66, Power's Fife, the variety from which it was originated. Averaging the eight yields, at the several farms, the increased productiveness of the new variety over the parent is shown to be 1.4 bushels per acre, and averaging the four yields at University Farm, the increased yield is 4.2 bushels.

In Table XLIV., Minn. No. 477, McKendry's Fife, is compared with three of its progeny. Only the two yields for 1897 and 1898 at University Farm are available for the comparison.

TABLE XLIV.—Minn. Nos. 181, 284 and 288 Compared with their Parent Variety, McKendry's Fife.

Grown at \ Variety.	McKendry's Fife.			
	Foundation Stock.	Parent Plant, Selected 1892.	Parent Plant, Selected 1892-1894.	Parent Plant, In-cross Selected 1892-1894.
	Minn. No. 477	Minn. No. 181	Minn. No. 284	Minn. No. 288
University Farm, 1897...	18.2	19.5	14.8	14.4
University Farm, 1898...	23.8	26.5	16.6	31.3
Averages.....	21.0	23.0	15.7	22.8
Gain or Loss.....	.....	+2.0	−5.3	+1.8

Minn. No. 181 was originated from a mother plant grown in the nursery in 1892. It shows an increased yield of two bushels per acre.

Minn. No. 284 was selected in the nursery in 1892, 1893 and 1894, being multiplied from the single mother plant grown in 1894. Here we have the remarkable decrease in yield of 5.3 bushels per acre.

Minn. No. 288 is from a flower pollenated with pollen from a plant of the same variety in 1892. The cross-bred plant was

grown in 1893, and from it in 1894, 100 plants were grown. From among these the best plant was chosen as the mother plant of this variety. The average increased yield here is shown to be 1.8 bushels per acre.

TABLE XLV.—Minn. No. 276 Compared With Its Parent Variety, Power's Fife.

Variety	Power's Fife	Sel. Mother Plant 1894
Minnesota Number	66	276
Grown at		
University Farm, 1897	17.4	18.3
University Farm, 1898	24.0	18.3
Northwest Farm, 1898	18.8	20.8
Averages	20.1	19.1
Loss		1.0

In Table XLV., Minn. No. 66, Power's Fife, is compared with Minn. No. 276, which was originated from the Power's Fife in the nursery. It was selected in 1892, 1893 and 1894, the best plant being retained in 1894 for a mother plant. A decrease in yield of one bushel per acre is shown.

TABLE XLVI.—Minn. No. 283 Compared with its Parent Variety, Haynes' Blue Stem.

Variety	Haynes' Blue Stem.	Selected from 1894 Mother Plant.
Minnesota No.	51	283
Grown at		
University Farm, 1897	20.4	20.3
University Farm, 1898	20.3	20.2
Averages	20.4	20.3
Loss		0.1

In Table XLVI., Minn. No. 283 is compared with its parent variety, Minn. No. 51, Haynes' Blue Stem. This new variety was subjected to nursery selection in 1892-4, inclusive, originating from a best plant grown in 1894. The decreased yield here shown is .1 bushel per acre.

In Table XLVII., Minn. No. 476, Risting's Fife, is compared with three varieties which have sprung from it. Minn. No. 171 was originated by selecting the best plant of Risting's Fife in the

TABLE XLVII.—Minn. Nos. 171, 292 and 293 Compared with the Parent Variety, Risting's Fife.

Grown at \ Variety.	Risting's Fife.			
	Foundation Stock.	Selected from 1892 Mother Plant.	In-cross of 1892, 1894 Mother Plant.	In-cross of 1892, 1894 Mother Plant.
	Minn. No. 476	Minn. No. 171	Minn. No. 292	Minn. No. 293
Univ. Farm, 1897	20.9	19.8	17.9	18.0
Univ. Farm, 1898	26 6	26.3	32.0	21.3
Averages	23 8	23.1	25.0	19.7
Gain or Loss		—.7	+1.2	—4.1

nursery in 1892 for a mother plant. A decreased average yield of seven-tenths of a bushel per acre is here shown.

Minn. No. 292 is the result of an in-cross made in 1892 between two plants of Risting's Fife. The plant resulting from this cross was grown in 1893, and from it 100 plants were grown in

TABLE XLVIII.—Minn. No. 287 Compared With Its Parent Variety McKissick's Fife.

Grown at \ Variety	McKissick's Fife	
	Foundation Stock	Selected from 1892-1894 Mother Plant
	Minn. No. 475	Minn. No. 287
University Farm, 1897	20.4	15.7
University Farm, 1898	24.6	25.0
Averages	22.5	20.4
Loss		2.1

1894. From the best plant of this 100, some 900 plants were grown in 1895, and of these the best 300 were selected and the grain from them planted as a variety in 1896. This variety is

doubtless the result of a true in-cross, since the berry is of a much lighter color than the parent wheat. The averages show an increased yield of 1.2 bushels per acre.

Minn. No. 293 had its origin in the same manner as 292, excepting that its 1893 cross-bred parent plant originated from crossing two other Risting's Fife plants than those used in producing the parent plant of No. 292. A marked decrease in yield of 4.1 bushels per acre, as compared with the parent variety, is shown in the averages. In this case there is no satisfactory evidence that this variety is the result of a true cross.

In Table XLVIII., Minn. No. 475, McKissick's Fife, is compared with Minn. No. 287, which was originated from a single plant of McKissick's Fife in 1894. This mother plant was from a nursery stock which had been selected to the best plant in 1892 and 1893. A decreased yield of 2.1 bushels per acre is here shown.

TABLE XLIX.—Minn. No. 163 Compared with the Parent Variety, Glyndon 811.

Variety	Glyndon 811. Minn. No. 168.	Minn. No. 163.
Grown at		
University Farm, 1895	42.2	42.7
University Farm, 1896	19.0	23.0
University Farm, 1897	16.3	19.9
Averages	25.8	28.5
Gain		+2.7

In Table XLIX., the promising new wheat, Minn. No. 163, is compared with its parent variety, Minn. No. 168, Glyndon 811. This parent variety was one of the wheats grown at Glyndon, Minn., in 1891. It has every appearance of a Fife wheat, and probably was originally collected in this country, though its name was lost by fire. The average of three yields shows an increase of 2.7 bushels per acre. Arrangements were made with numerous farmers and seedsmen to grow this wheat in 1899 and sell it for seed to the farmers of the state.

TABLE L.—New Varieties Compared with their Parents: +Gains; —Losses.

Minn. Nos. of Parents	Minnesota Nos. of New Varieties	Minn. No. 161	Minn. No. 169	Minn. No. 283	Minn. No. 149	Minn. No. 276	Minn. No 171	Minn. No 292	Minn. No. 293	Minn. No. 287	Minn. No. 163	Minn. No. 181	Minn. No. 284	Minn. No. 288
	No. of Trials Averaged.....	4	8	2	10	3	2	2	2	2	3	2	2	2
	Parents													
51	Haynes' Blue Stem.....	—.2	+2.8	- 0.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
66	Power's Fife.....	.....	.....	.....	+1.4	—1.0	.....	.....	.....	.....	.....	.....	.....	.....
476	Risting's Fife.....	.....	.....	.....	.....	.....	—.7	+1.2	—4.1	.....	.....	.....	.....	.....
475	McKissick's Fife.....	.....	.....	.....	.....	.....	.....	.....	.....	—2.1	.....	.....	.....	.....
168	Glyndon 811.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	+2.7	.....	.....	.....
477	McKendry's Fife..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	+2.0	—5.3	+1.8
	Gains at University Farm Only.....	.....	+5.8	.....	+4.2	.....	.....	.....	.....	.....	.....	.....	.....	.....

In Table L., is given a summary of the increase or decrease of the new varieties over the parent kinds as shown in Tables XLI. to XLIX. Out of the thirteen wheats thus compared six give promise of increased yield, while with seven a decrease of yields has resulted. The average increased yield of the six improved wheats is 1.98 bushels per acre. The average decreased yield of the poorer new wheats is 1.92 bushels. Minn. No. 293 shows the most marked variation in yield, and that a retrograde variation. Minn. No. 169 shows the most pronounced increase in yield. This table gives the most positive evidence that marked variation occurs, both towards better and towards poorer yields. *Where variation occurs improvements may be effected.* A comprehensive detailed plan of operations diligently and accurately carried out for a long series of years cannot fail to very materially increase the productiveness and the quality of wheat or any other crop.

METHODS OF DISSEMINATING NEW VARIETIES.

The work of originating new varieties of seeds after plans mentioned above brings out a new element in seed distribution. There is needed a method of retaining the identity of varieties which resemble their parent varieties in appearance, differing only in yield and quality of grain. Since their identity cannot be retained by botanical description, it must be done historically. The seller or purchaser of the seeds of a given variety needs a means of tracing the seed back to its source.

In sending out kinds of plants which have not been broken up into varieties or sub-varieties similar in appearance, as timothy or orchard grass, the seeds may quite properly be sent out under their specific names. With our new Fife and Blue Stem wheats, or with most of our newly-originated varieties of bromus or timothy, this would lead to a confusion of names and stocks of the seed. The original variety might easily be passed off for the new and better yielding kinds.

In case of open fertilized plants like corn, timothy, brome grass or millet, small samples sent from the station would often be

planted beside fields of common stocks of the same kind of plants. This would result in cross-breeding, and the improved characters of the new varieties would be modified by the more prepotent race characters of the common kinds, and the improved characters would thus be nearly destroyed.

The plan we have devised for the distribution of our promising varieties is outlined as follows: Several men in each county, preferably graduates of the School of Agriculture, are encouraged to become growers of certified seeds of field crops. Men are chosen who have good land, and who rotate their crops in a manner to give the best possible conditions for seed growing. Those who keep live stock that they may grow a goodly proportion of crops which enrich the farm and clean the land of weeds, who are business-like in their dealings, and who have the confidence of their neighbors, are desirable seed growers.

Arrangements are made with these farmers to grow seeds of varieties which the state experiment station has tested until it is assured that they will succeed in the counties to which they are sent. It seems wise to send out comparatively few varieties, and to do all the preliminary testing at University Farm and at the substation farms. The seeds are to be sold in some quantity, usually in bushel or bag lots, that each seed grower or farmer may grow them in fields rather than in small patches, and the station desires that modest but remunerative prices be asked and given for these certified seeds.

It is believed that under this plan each new variety will be more rapidly multiplied, if it proves valuable, than if the station were to break the first lot of seeds up into small packages and send them out free of cost. Paying a reasonable price for a new variety of grain, thus well vouched for, would cause the new owner to take an interest in it. A small profit, say twenty-five cents per bushel on seed wheat, would repay the seed grower for his extra work in growing, caring for and cleaning seeds for sale to the other farmers in the county. The farmers securing these new varieties from our seed growers could make a small margin of profit by selling these certified seeds to still other neighbors. It seems practicable

for the station to supply blank certificates with descriptions which growers could sign and give with each quantity of seed sold, thus "certifying" it to be the variety described on the certificate. To avoid errors, seed growers could occasionally submit specimens of the plants and seeds to the experiment station for comparison with the original sample. Those purchasing direct from the experiment station might be required to send samples to the station to be filed as a record of the fact of their having received the variety intended for them. Seed firms within the state should be aided to secure stocks of the new varieties that they might also propagate them for sale. We have no other agency so efficiently organized for distributing useful seeds, and their full co-operation is desirable. Their facilities for advertising a new stock of seeds are superior to any other medium, and the financial interest of the seed companies would cause them to procure these well-tested varieties and advertise them for sale. Seedsmen and nurserymen properly argue that each firm cannot afford to test all the new varieties. Instead of so many experimental grounds, the experiment station, with its better equipment, can do the larger part of the work. Likewise the station can best originate or secure and thoroughly test, and finally certify to the value of seeds of field crops, and thus insure good stocks for the farmers and a more satisfactory business to the seed merchant.

TABLE LI.—Minn. No. 163 Compared with Best Fife and Blue Stem Wheats.

Minnesota No.	Name of Variety.	University Farm, 1895	University Farm, 1896	University Farm, 1897	University Farm, 1898	North Dakota, 1898	South Dakota, 1898	N. E. Farm, 1898	Iowa, 1898	Total	Average
66	Power's Fife	26.3	21.4	17.4	24.0	32.0	17.4	20.7	7.0	166.2	20.8
146	Bolton's Blue Stem	35.3	25.1	21.5	22.5	35.3	17.3	19.3	6.3	182.6	22 8
163	A New Variety	42.7	23.0	19.9	25.0	37.2	15.4	14.7	8.0	185.9	23.2
66	Power's Fife	26.3	21.4	17.4	24 0	Yields at University Farm only.				89.1	22.3
146	Bolton's Blue Stem	35.3	25.1	21.5	22.5					104.4	26.1
163	A New Variety	42.7	23.0	19.9	25.0					110.6	27.7

A blank certificate is used by the station in selling seeds to its list of recommended farmers who have been chosen to assist in the introduction of new varieties. It is designed to supply these men with a number of these blank certificates, which they in like manner may fill out to go with the wheat to farmers to whom they in turn sell the seed of varieties supplied to them by the station. The circular briefly states whatever is known of the origin, the method of breeding, the general character of the plant, the comparative yield, the grade, the milling qualities and other facts which may be known about the variety. A circular prepared to accompany Minn. No. 163 wheat, a few hundred bushels of which is being distributed for planting in 1899, contains the Table LI., comparing the yields of that wheat with our best collected Fife and best collected Blue Stem wheats. The following form of blank certificate is also attached to this circular, and is properly filled out for those purchasing this wheat:

CERTIFICATE OF MINNESOTA NO. 163 WHEAT.

I hereby certify that the seed wheat sold by me and marked order No.....on this.....day of the month of.....in the year.....to..... , ...County, Minnesota, was originated and raised by the State Experiment Station, and is being disseminated under the name of Minnesota No. 163, *as described in the circular attached hereto; and that this sample has been kept free from admixture with other varieties of wheat.*

.....

Agriculturist.

St. Anthony Park, Minn.

....., 1899.

SOME BOTANICAL CHARACTERISTICS OF WHEAT.

There are some features of the botany of wheat in relation to farming which are worthy of attention. The farmer needs a knowledge of the roots, the leaves and the kernel of the wheat, that he may understand preparing the land for this cereal, 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 he especially needs a knowledge of the structure and functions of the floral organs.

BOTANICAL RELATIONS OF WHEAT.

The relation of wheat to other classes of plants will not be entered upon extensively here. Mr. Warren W. Pendergast, when a student, adapted from Haeckel's "The True Grasses" Table LII, showing the thirteen tribes of the great grass family. From the same book he also adapted Table LIII, showing (1) the six sub-tribes of the tribe Hordeæ; (2) the five genera of the sub-tribe Triticeæ; (3) the two sections of the genus, *Triticum;* (4) the three species of the section, *Sitopyrus;* (5) the three races of *Tr. Sativum* and (6) the four principal sub-races of the race, *Tr. sativum tenax.*

This elaborate classification of the genus Triticum is necessitated by the numerous forms into which wheat has become differentiated, in part, since coming under the influence of man.

The species first mentioned, *Triticum monococcum,* is, as the name implies, one seeded, and is so different from the common species of wheat, *Tr. sativum,* that the two have not been successfully cross-fertilized.

The third species, *Tr. Polonicum,* is evidently not so distant in its relationship, and an occasional fertile flower may be secured

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

- GRAMINEÆ.
  - Spikelets 1 Flowered.
    - Maydeæ—[Corn-Teosointe.] (Tribes,)
    - Andropogoneæ—[Suga Cane—Sorghum.]
    - Zoysieæ.
    - Tristegineæ.
    - Paniceæ—[Millet—Hungarian Grass.]
    - Oryzeæ—[Indian Rice—Rice.]
  - Spikelets Many Flowered.
    - Phalarideæ—[Canary and Sweet Vernal Grass.]
    - Agrostideæ—[Timothy—Red Top.]
    - Aveneæ—[Oats.]
    - Festuceæ—[Blue Grass—Bromus—Orchard-Grass-Fescues.]
    - Chlorideæ—[Grama and Buffalo Grass.]
    - Hordeæ—[Wheat—Barley—Rye—English Rye-Grass.]
    - Bambuseæ—[Bamboo.]

TABLE LIII.—Classification of Wheat.

- HORDEÆ..... (Tribe)
  - Nardeæ. (Sub-tribe)
  - Lolieæ. [Rye Grass.]
  - Lepture æ.
  - Triticeæ.....
    - Agropyrum. (Genus) [Quack Grass.]
    - Haynaldia.
    - Secale. [Rye.]
    - Triticum.....
      - Ægilops. (Section)
      - Sitopyrus.
        - Tr. monococcum. (Species) [One-Grained Wheat.]
        - Tr. sativum.....
          - Tr. sat. Spelta. (Race) [Rice spelt.]
          - Tr. sat. Dicoccum.
          - Tr. sat. tenax.....
            - Tr. sat. vulgare. (Sub-race) [Common Wheat]
            - Tr. sat. compactum. [Dwarf and Hedgehog Wheat.]
            - Tr. sat. turgidum [Eng. Wheat, Egyptian or Miracle Wheat.]
            - Tr. sat. durum. [Hard or Flint Wheat.]
        - Tr. polonicum. [Polish Wheat.]
    - Heteranthelium.
  - Elymeæ. [Barley, Wild Rye.]
  - Parinaeæ.

by cross-pollenating it with *Tr. sativum*, our common species. Our energies so far have been directed to making crosses between the less widely differing varieties, and even there the variation is considerable and seems to be more often backward or downward than toward useful forms. Since the Polish wheats have not shown an adaptability to our climate and soils the chance of securing useful crosses between them and our best wheats is very remote.

The races of spelt wheat, *Tr. sat. spelta*, have not shown an ability to yield well either at University Farm or at Northeast Farm, where Mr. Pendergast tried one of them, thinking it might prove useful on light soils, such as these wheats are grown on in northern Spain. At University Farm it has been much worse affected by rust than our common Blue Stem and Fife varieties.

The sub-races of the sub-species or race, *Tr. sat. tenax*, are not all equally well adapted to our conditions.

Our common bearded and smooth wheats, both winter and spring varieties, belong to the race first named in the last column of the chart, *Tr. sat. vulgare*. Haeckel remarks that the characters of these four sub-races overlap. Each of these sub-races is broken up into many varieties, some of which are probably the result of crosses between the sub-races. Common wheat, *Tr. sat. vulgare*, has been known since ancient times, grains having been discovered in the Egyptian Pyramids, and the assumption is safe that this sub-race has been very much modified by man.

Tr. sat. compactum, "Dwarf wheat," or "Hedgebog wheat," Haeckel says, was found in the ruins of the old lake dwellings of Robenhausen.

Neither of the sub-races, *Tr. sat. turgidum*, English wheat, nor *Tr. sat. durum*, Flint wheat, have made any progress toward general cultivation in the middle Northwest. Mr. M. A. Carlton, special agent of the Department of Agriculture, Washington, D. C., has expressed the hope that *durum* wheats might be a good source of rust-resistant blood to use in crosses with the common wheats of some sections of this country.

Our experiments have demonstrated the superiority for our conditions of the Blue Stem and Fife wheats, which are varieties of

Tr. sat vulgare. These varieties yield the most wheat of the best quality, and are the most rust resistent of all which we have tried. Doubtless this power of rust resistance is the main reason why these wheats have proven themselves best on our experiment farms, and among our farmers. The rust is an ever-present disease, and varieties which have rusted badly have always given poor yields and wheat of poor quality. Blue Stem is more rust resistant at University Farm than is Fife wheat, and no doubt its better yields here and among the farmers of Minnesota are in large part due to this characteristic. While other varieties are being used in the effort to find or make better kinds, our variety testing and breeding is centering more closely in these two wheats. In many respects these wheats are similar, yet in their relationships they are quite distant, as is clearly shown by the great variation of their cross-bred progeny, and also by the fact that Blue Stem has hairy chaff, while the chaff of the Fife is smooth.

An era of producing new varieties of wheat by crossing has evidently set in, one man, Mr. Wm. Farrar, having sent us fifty new cross-bred wheats at one time from Australia. The selection or "roguing" to which we subject newly received varieties, to reduce them to type changes them somewhat, and a description we might publish would not apply to the stock of wheat in the hands of other parties. No attempt can be made in this bulletin to publish descriptions of our many wheats, and their value if published would not be great.

The nomenclature of wheat in our grain markets is comparatively easy when we have little else than Fife and Blue Stem, but with the multiplication of varieties the confusion of names will be great. Botanists and teachers often give 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 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 much more valuable to the farmer. With records, we must keep them true to the

original, as live stock breeders must record their animals, and in selling them give certificates of genuineness.

While the experiment station is disposed to investigate all new varieties and races of wheat, and to give garden or even field trials to new wheats of promise, we have learned by wide experience that our work should mainly be directed to making better wheats of the best varieties already in hand, and to devote considerable attention to a new wheat only as it is shown to be very promising of usefulness. There is ample opportunity among the wheats which are successfully grown to make crosses, some of which are even too radical for practical breeding. The attempt has not been made to produce botanical wonders, but to add to the yield of the acre of wheat. Now that a fairly good method of improving practical varieties has been devised and successfully used, it seems wise to put more time on those theoretical questions the solution of which will enable us to still further perfect the methods of breeding this grain from which is made the "staff of life."

Many questions of interest from the standpoint of systematic botany are constantly arising where so many notes are yearly accumulating on numerous selected and cross-bred stocks of wheat. But of greatest interest are the questions which yearly arise regarding heredity, variation, and the practical theories of plant and animal breeding.

WHEAT IS USEFUL IN STUDYING PLANT AND ANIMAL BREEDING.

Hugo de Vries, of the University of Amsterdam, has recently stated that most of the theories for correct practice in breeding animals, as well as plants, can best be worked out with plants, in part because they may be used in such large numbers. With animals, the small numbers produced at a birth and the great expense of keeping all under similar conditions and of making records, makes their use unsatisfactory and so costly as to be almost prohibitive.

The wheat plant is one of the very best of all plants for the solution of many of these problems. We have been able to devise a

thoroughly feasible plan of dealing with the individual whereby each plant has practically an equal chance with each other plant. The notes of yield of seeds per plant, of quality of grain, of strength of straw, of rust resistance, of height, of character of spikes, etc., are easily and accurately recorded. If need be, the seeds may be kept for a number of years, and from seeds thus preserved plants may be grown in comparison with progeny which have been modified by breeding or environment. Of great importance in this connection is the fact that wheat is nearly close fertilized. Another important consideration is the fact that cross-bred stocks of this close-fertilized plant may be selected to a uniform type in a few years, the time required depending upon the variable nature of the particular cross. We now have in store seeds of unselected stocks, of stocks selected for shorter and longer periods to single mother plants, of cross-bred wheats from mating plants of different degrees of relationship, and of different types of cross-bred wheats not as yet selected to uniform types, and those selected until they are partially uniform, others where uniformity has been secured by being longer subjected to selection to a type. These, with new wheats the station is constantly acquiring, are highly valued for use in many experiments, under way or soon to be started, in studying numerous questions in breeding.

THE WHEAT PLANT.

In Minnesota the plants of those varieties of spring wheat commonly sown reach a height of from thirty-five to forty inches. In some cases on moist rich land, the height mentioned is exceeded; while in dry seasons on poor land, the wheat sometimes ripens at a height of two feet or even less. The modern self-binder can successfully cut and bind into bundles straw which does not stand two feet high, but for best results it is desirable to have the wheat stand thirty to forty inches high. Wheat much higher than forty inches is likely to lodge in wet seasons and on rich, moist soils, and in breeding wheat only moderate height with great stiffness of straw, is sought. A goodly proportion of leaves is necessary, that the wheat may be well supplied with these organs, which serve both as

lungs and stomach to the plant. But a disposition to produce an unnecessary proportion of leaves is undesirable. The plant should center its food material in its seeds, and not lay it aside in other organs of less value.

Fig. 250. Washing out Wheat Roots and Making Drawings.

A well developed system of roots is a necessity to the plant. There is no direct way by which the breeder can select for this quality. But by choosing vigorous yielders, the law of correlation of parts aids to select individuals with all the essential organs well

developed. While the breeder may pay no attention to the roots, the farmer in preparing the soil for this crop needs to know the habits of the plant in sending its roots throughout the soil. The method of stooling, also, is of interest in connection with the soil, with the time and thickness of sowing the seed, and especially in connection with the harrowing or otherwise cultivating the soil after the grain has germinated.

THE ROOTS AND STEMS OF WHEAT.

In 1898, a dozen wheat plants were grown in a plat of land where water from a hydrant could be used to wash out the roots that

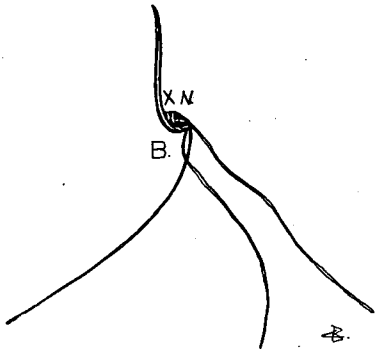

Fig. 251. The entire wheat plant five days old, natural size. The roots are more than twice as long as the stem. No matter in what position the germ of the seed lies, the stem end at once seeks an upward direction, and the roots go outward and downward.

drawings might be made showing the root development at different stages of growth. Individual plants were grown several feet apart, and at stated intervals a plant was washed out and a drawing made of its root system. Messrs. Carl S. Scofield and Coates P. Bull, students, did the work on these plants, the latter doing most of the drawing. Each root springing from the culms was carefully followed out and measured, records being taken of its depth, the distance of the point from the plant and the general direction or curvature of the root. The various stem-roots were thus faithfully grouped on the charts so as to represent a view of them as though one were looking at them in a horizontal direction

with the soil removed and the roots left in position where they grew. These drawings are shown in Figs. 251-9. A diagram showing the character of the soil in which these plants were grown for washing out is given at E in Fig. 252.

Figure 251 shows the young plantlet of spring wheat at five days old. The direction of the three roots is more nearly downward than usual, as the seed was planted somewhat late. In cool weather they take a more nearly horizontal position. Close in-

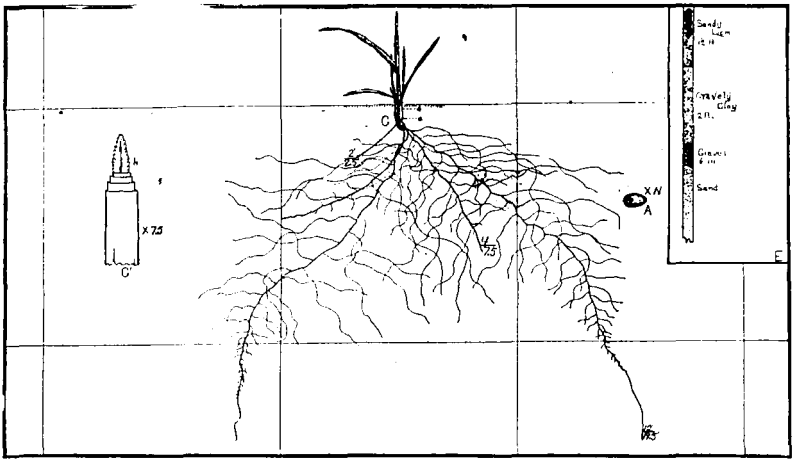

Fig. 252. *A*—The kernel of wheat. *E*—Diagram of the soil in which wheat plants were grown for washing out roots. *C*—Wheat plant at 23 days old, longest roots four or five times as long as the plant is tall. The squares represent feet, the longest root is 19.5 inches long and about 16 inches deep. *c*—The joint of the stem dissected out from *c* at *a-b*; *h*—the minature spike.

spection of a germinating kernel of wheat will show that the stem and the first whorl of roots, usually three in number, have their origin in the chit or germ. See C, 15, and C, *s* and *r*, 16, Plate XXV., page 412. Until somewhat further developed than the plant shown in Fig. 251, the kernel is the sole source of food for the young plant. Not until it has green leaves in the sunlight does the young plant have green chlorophyll cells with which to digest the plant food from the soil and by combining it with water and carbonic acid of the air elaborate substances which the plant tis-

sues can use. The reason for using well matured, plump, heavy seeds, is that such a kernel has more food for the young plant, and the food is of good quality. As shown in Fig. 16, Plate XXV, the chit or minute plantlet is but a small portion of the seed. The main body of the kernel is the starchy and glutenous contents. During germination these substances are changed into soluble forms and passing through the juices of the plant are used in developing the cell walls and the protoplasmic cell contents of the small roots and leaves and the tiny axis or stem.

THE ROOTS GROW RAPIDLY.

The wheat plant passes rapidly from the germinating stage, and

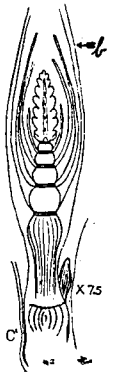

Fig. 253. A diagramatic section through the stem of wheat about 25 days after planting, magnified 7½ times, as from *a* to *b* in C, Fig. 252. The first bud designed to form a tiller is just starting. One blade starts from each joint.

with favorable conditions soon has green leaves absorbing the sun's rays and a spreading mat of roots absorbing water and plant food from the soil. In Fig. 252 a plant twenty-three days after planting is shown. The blades are only five inches high, while the earliest roots which sprang from the chit are twenty inches long. The roots are long and numerous, and in comparison with the area the leaves expose to the sun they present a large area of root surface to the soil. Upon dissecting out the stem from among the mass of leaf sheaths, a very small point is found extending from the lower joint at *a* to *b* in C. This miniature primary culm

is shown enlarged several diameters at C. Even at this stage the spike is discernable, as at *h* in C.

Fig. 253 shows the branching culm still more elaborately figured in diagram. The attachment of the leaves at the nodes will be observed, also the fact that the internodes are as yet short, having the nodes or joints very close together. The first secondary culm or tiller at x indicates that "stooling" has already begun.

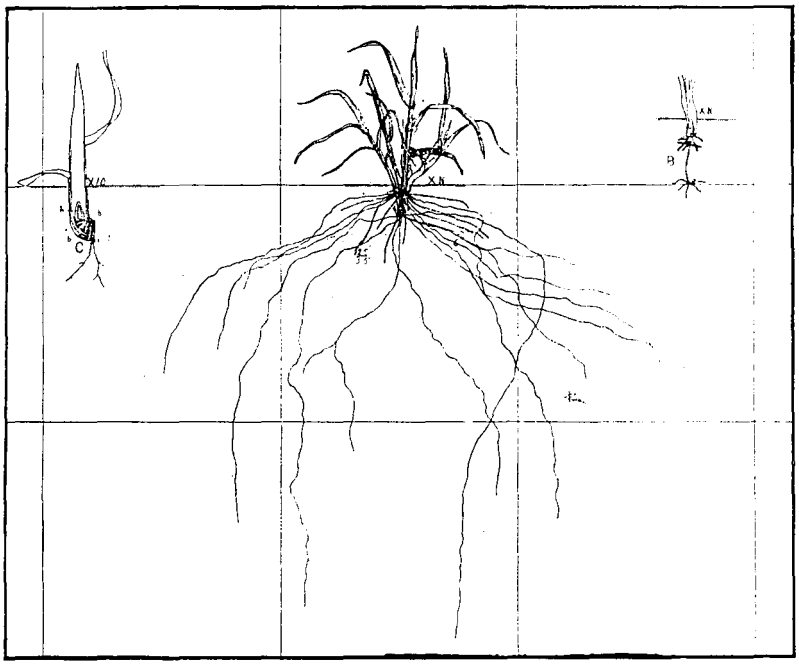

Fig. 254. Wheat plant 43 days old. Blades eight inches high and roots two feet. Branching roots are not shown. *B*—the kernel with its three or four roots; culms and roots branching out half way from the kernel to the surface of the soil, where roots and leaves spring from the stem or rhizome. *C*—The branching culm. *b*, *b*—buds which will become tillers. *h*—minature spike.

In Fig. 254 a plant 43 days old is shown. Here three or four whorls of roots have developed, and the culm has produced several stools or tillers. No attempt is made to show the many branching roots, only the roots originating from joints of the culm being drawn.

In Fig. 255 is shown a plant 63 days old; the roots emanating from the culms and seed, in all enumerating about fifty; also, one of the dozen or more culms. At this stage the wheat was about

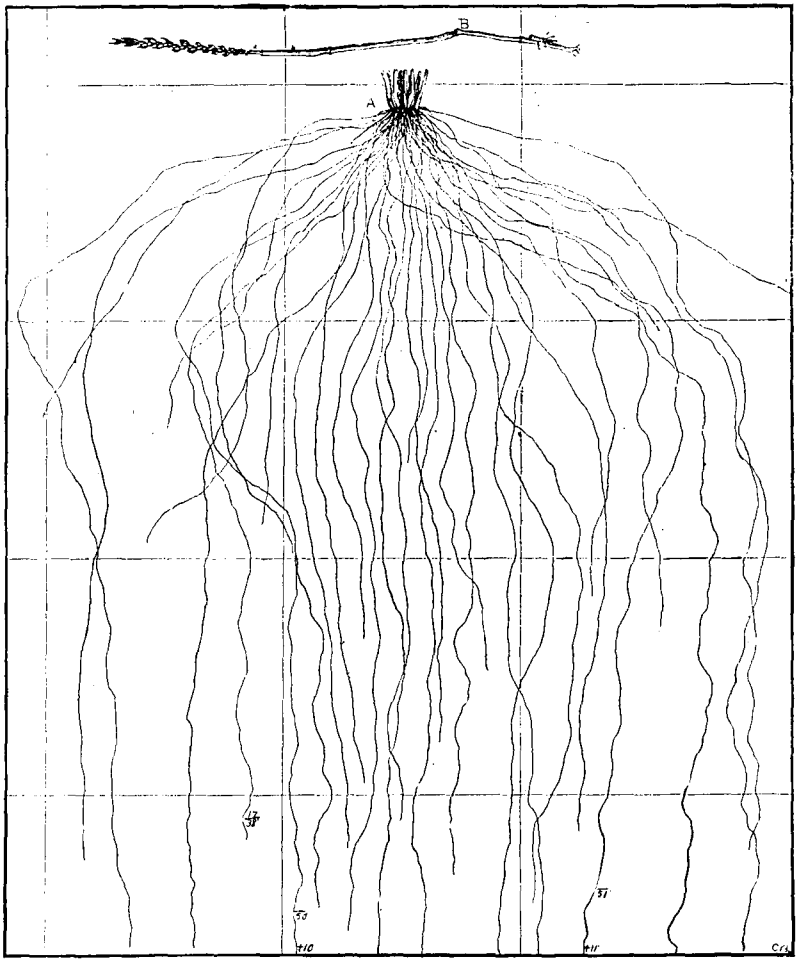

Fig. 255. *A*—"Crown" and stem-roots of a plant 63 days old, branching roots not shown. (Figures near the bottom of the plate show spread and depth of the respective roots.) *B*—Culm nearly ready for the head to appear from leaf sheath.

two feet high and ready to head out, and some of the roots had penetrated to the depth of more than four feet.

In Fig. 256, the roots are shown from a plant which was nearing maturity. Here there were sixteen culms and nearly one hun-

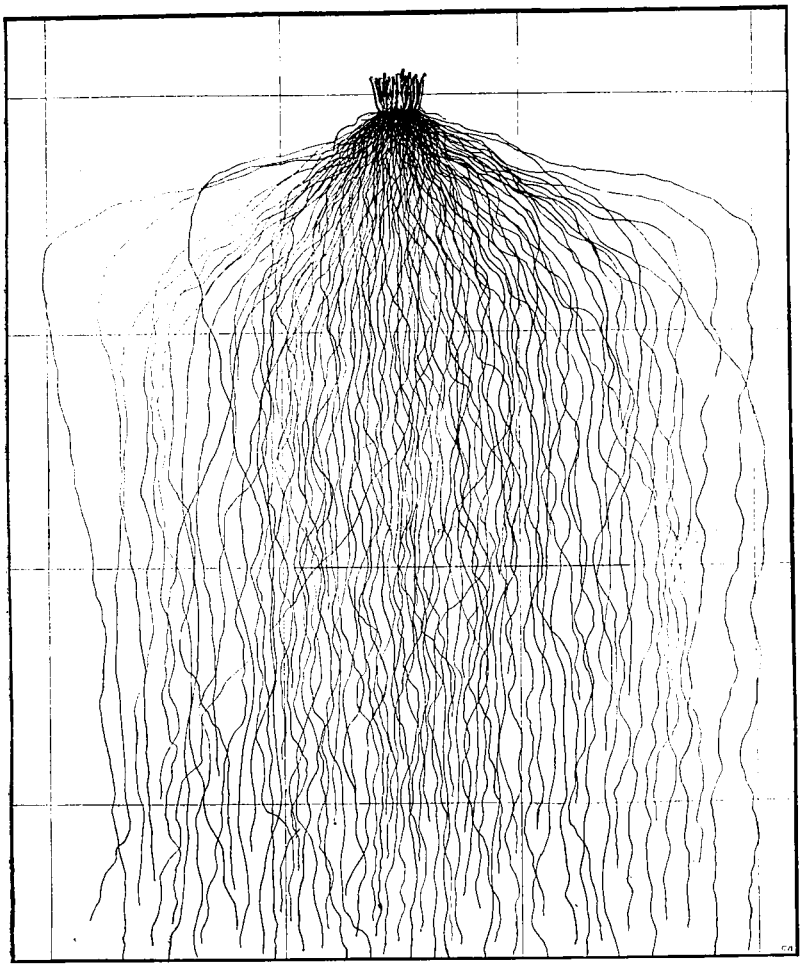

Fig. 256. Crown and stem roots of a mature wheat plant, from one seed. There are about 100 stem roots, each of which had for some distance on an average about eight branch roots to the inch, making a wonderful mat of roots in the soil.

dred roots springing from the culms. Where crowded in the field each seed gives rise to only a few culms. The roots had not gone much deeper than those shown in Fig. 255, owing in part to the

coarse character of the soil, though many of them went deeper than the three feet eight inches shown by the drawing.

THE PLAN OF THE ROOT SYSTEM.

There is order in the attachment of the roots to the seed and culms and in the manner of branching. Three roots start from the chit at the same time that the stem starts upward. These are

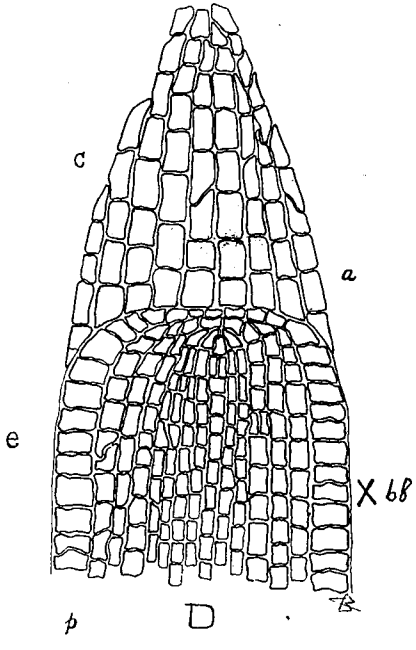

Fig. 257. Point of the wheat root. *c*—the root cap; *e*—periderm; *a*—apical area; *p*—corticle.

a temporary set of roots which usually die before the plant is fully grown; in case of winter wheat they were all found dead in the spring in several varieties which were examined. As the culms develop they send out roots from the bases of their leaves. Presumably the root buds spring out in whorls from around the nodes under the bases of the leaves, as is the case in Indian corn. See bulletin 5, page 10. Those roots which spring out first when the plants are as yet young are small in diameter and much

branched. In the cool autumn or in cool weather early in spring these first roots go out more nearly in a horizontal direction than in warm weather, as in early autumn or late spring planting. When these roots are several inches long, branches begin to show, and they soon have many branches. Each culm sends out from the few joints at its lower end a number of roots for its separate support, and each culm soon depends largely upon its own roots. Those first coming out reach the greatest length, while some of the uppermost roots start out so late as to not have time to grow long, though these later roots springing from higher up on the stem usually have a greater diameter than the threadlike roots which first started. The roots throw out many branches in the upper eighteen inches of earth, and these branches again branch. Those roots which penetrate deeper go nearly straight downward and have few or no branches below eighteen or twenty-four inches. Since the branches, as well as the stem roots, radiate outward from the plant, there are few roots immediately beneath a plant which stands alone, while in the field this space is occupied by the roots of neighboring plants. Since there are about eight branch roots to the inch for eighteen to twenty inches down each stem root and each of these branches is from one-tenth of an inch to twenty-four inches in length, it can be seen what an immense number of roots each plant has.

THE ROOT HAIRS AND THE ROOT CAP.

Mere branching into innumerable thread-like branch roots does not give the roots sufficient contact with the soil, and each root and branch root is covered with hairs which extend among the fine particles of soil. These root hairs have been appropriately called "feeding cells" or "sucking sells," and through their thin walls the plant gets the larger part of its water and plant food. Beginning near the tip of the root, these hairs are very short. Proceeding upward toward the stem, they are longer. Within a few inches the hairs which are observed are shriveled, showing that there is a short zone near the end of the root on which active hairs are born, but that each hair has a short period of activity. Back of this the

outer covering of the root has become hard and the root serves merely as an avenue for the passage of water and plant food taken in by the active zones bearing fresh hairs. Here branching roots, in case of the stem roots, take the place of the hairs, and they in turn bear hairs on zones near their freshly developed points.

Fig. 258. A small section of a wheat root showing the root hairs, enlarged two diameters.

In Fig. 259 is a cross-section of a root showing three root hairs. These hairs are not distributed evenly along the root, they 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 hairs to the millimeter in length of root.

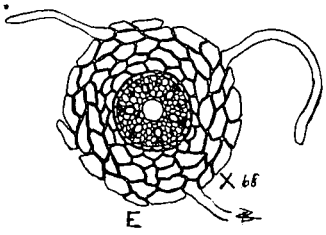

Fig. 259. Cross-section of a wheat root near the tip showing three root hairs and the manner of their development.

The power roots have of pentrating hard earth is surprising. Fig. 257 shows a cross-section through the point of a root. The wedge-shaped cap, C, is pushed in between the soil particles, and by the subdivision and growth of the cells in the middle of the root at *a* the diameter of the root is enlarged and the point is pressed still farther forward. Many of the roots were found distorted in pass-

ing through the subsoil just below the furrow-slice where repeated treading of the plow team and the pressure of the plow had made the earth compact.

These drawings show what a power this crop has of spreading into the soil far and deep for its food. It was not practical to show the immense number of branch roots on Figs. 255 and 256, since they were so numerous that the paper would have been black throughout the center of the drawing.

THE BRANCHING OF THE CULM.

The culm or stem of the wheat plant is made up of a series of hollow cylindrical internodes joined together by means of solid joints or nodes.

In starting from the seed the stem soon begins to branch. The first leaves which are sent up seem to be a temporary set of organs designed to quickly reach above the soil, that the plant may be supplied with green cells in the sunlight. These leaves form what appears to be 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 case of several varieties of winter wheat. At the same point where these first leaves arise another stem, apparently a rhizome, branches off from the primary stem. This rhizome has an internode quite unlike all the other lower internodes, not even covered by the sheath of a leaf, and extending about half way to the surface of the soil. In case the seed is planted two inches deep this rhizome is about one inch long. See B in Fig. 254. At the top of this internode a joint bears a leaf, and a few other joints follow at very short intervals, each having a bud in the axil of its leaf. At C, Fig. 254, is shown a longitudinal section of one of these buds after it has grown into a tiller or stool. The minute spike is shown at *h*, and two branches appear at *b*, *b*. Roots also have made their appearance. Each branch may subdivide, and plants from single kernels of wheat have been known to develop several dozens of culms. These branches only occur from the few lower nodes, but the branches

may again produce branches from their lower nodes. When the wheat is in the stooling stage, at several inches high, the base of the stems appears compact and bulbous, especially if cool, moist weather and a rich soil have favored the development of numerous strong tillers.

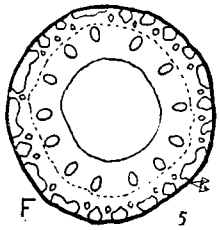

Fig. 260. Cross-section of internode—the stem between the joints.

By observing Fig. 254, it will be seen that the bulbous crown of the wheat is near the surface. The roots branch off from the several culms, not at the point where the seed was placed, but much nearer the surface. When planted deeply the wheat plant lifts the bottoms of its stems nearly or quite to the surface by means

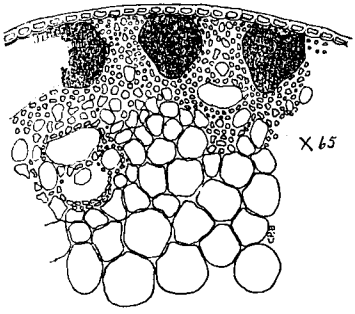

Fig. 261. A portion of a cross-section of the stem of wheat, in detail.

of the long internode of its rhizome, which develops shorter or longer according to the depth to which the seed has been planted. See Fig. 254 B. It will be seen that wheat plants thus set in the surface of the soil, with their roots extending outward at an angle of less than forty-five degrees from horizontal, can easily be injured by harrowing the wheat field after the plants are up, and es-

pecially after they have "stooled out." This certainly is what has occurred in a number of experiments where dragging the growing wheat has lessened the yield of grain.

A partially developed culm is shown in 255 at B. Fig. 260 shows a cross-section of an internode, and Fig. 261 a much magnified portion of the same.

When the tiny shoot is sent out of the germinating seed it is mostly a mass of leaves. It rises above the soil, where the leaves expand into the air to receive a large number of the rays of the sun. These rays, by the aid of the green chlorophyll cells, are changed from rays of light to active force, and then again changed by the plant into latent energy and stored up in such chemical compounds as sugar, starch, fat, cellulose and gluten. During the first few weeks the stems are very short, branching organs, whose chief functions at this time seem to be to produce leaves and roots. Not until the field is covered with a thick mat of blades nearly a foot high do the stems change their habit and extend upward. The plant up to this time has been expending its energies in the production of a wide expanse of leaf and in sending innumerable roots far and wide into the soil. The working parts of the plant having been developed, it sends up its shoots very rapidly, and when the culms have reached their full height the work of growing the fruit for the harvest is begun in earnest.

In the crowded field, however, the branches from branches rarely develop, as the field becomes crowded so that the leaves of these stools have no room in which to develop. The plant is partial to those branches which start earliest, and is loath to start new tillers. If a tiller cannot quickly send out its own leaves for air and sunshine, and soon reach into the soil and there compete with other roots for food, it must give up the race and leave the field to those that started early. If the conditions are favorable, many buds will succeed in getting enough roots started to enable them to compete in the effort to run up culms, and the stand of wheat will be good; while if the conditions are unfavorable, few culms will result and the wheat will stand thinly on the field.

When the plant has an abundance of blades and roots, the culms

begin to lengthen. This is accomplished by the lengthening first of the joints near the ground, as shown at B in Fig. 255. The upper culms, b and a, soon follow, however, and the ear of wheat rises above the leaves. As the culm lengthens, the blades from the upper joints also develop and become active leaves of the plant; while those which rose from near the roots and did service earlier, pass their period of activity and wither, leaving the work to the upper leaves, which are better situated to gather sunlight and food from the air. The leaf sheath completely surrounds the stem, and the edges overlap each other.

The development of the spike from the first tiny rudiments of an ear, as shown at *h* in C, Fig. 252, to the mature head of wheat, may be followed with interest. All that is needed is a sharp pointed knife and patient work in dissecting away the leaves at the various stages of growth of the plant. A small magnifying glass for ordinary work and a dissecting and compound microscope for reaching the greater minutia, are very useful for successful studies in these processes.

THE SPIKE AND THE FLOWER.

The spike 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 2, Plate XXV. 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. This gives a nearly rounded appearance 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 together and in the spike being broad at the top, or "club" shaped. This characteristic is sometimes shown by cross-bred wheats where neither parent had this characteristic, and may be the result of atavism or striking back to remote ancestors.

In Fig. 262 are shown the spikes of three varieties of wheats.

At 18 is a spike of Blue Stem, 19 a spike of Red Fife wheat, and 20 is a spike of Preston, one of the best new wheats we have yet

18 20 19

Fig. 262. 18 Blue Stem, 19 Red Fife, 20 Preston.

received. It is a strongly bearded wheat which originated from a cross made by Dr. Wm. Saunders, of the Canadian experimental farm, Ottawa, Can. The Blue Stem is awnless, but its white chaff is covered with a coat of fine velvety hairs. Red Fife, also, is awnless, and its white chaff is free from hairs.

The spikelet branches off at the angle of the central stem or rachis

of the spike. Its short stem, called rachilla, bears two or more florets. A spikelet is shown at 2, Plate XXV. If the conditions are favorable, each spikelet may produce several mature seeds, but very frequently only two or three reach maturity, thus materially reducing the yield of grain. Below the lower floret the rachilla bears two flowerless glumes, f and g, 2, also 7, Plate XXV, which closely resemble the flowering glumes. Above these the several flowering glumes are arranged alternately on the rachilla. In Plate XXV, 2, *k, k, k, k,* represent flowers bearing seeds and *r, r,* represent rudimentary flowers.

The Floret is by far the most interesting part of the wheat plant. The flowering glume is the outer and larger of the two portions of the chaff which enclose the floral organs, and later the seed, while the smaller or inner portion of chaff is called the palea. The palea is on the ventral, or creased side of the kernel and its two sides are folded inside the keel-shaped flowering glume, and are shorter and thinner than the latter. The floret is shown at 3, Plate XXV, the flowering glume at 6 and the palea at 8. A third portion of the floral envelope is shown at 9, four times its natural size. This small organ is called the lodicule. It is at the base of the flowering glume and palea, and is so placed between them that by swelling it pushes them apart. It is believed that this little organ absorbs water and swells up when the flower is ready to be fertilized

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Plate XXV. shows the spikes, flowers and seed of wheat.

The smaller spike is Fife and at its left is shown a Blue Stem spike. In the lower right hand corner is a spike from which small late flowers have been removed preparatory to crossing.

At 2, spikelet, natural size, with a few joints of the rachis; *f* and *g* are flowerless glumes; *k*, florets bearing seeds; *r*, rudimentary florets.

3, a single flower closed just after flowering, X4.

4A, longitudinal diagram before flowering, X3; anthers marked *a*; ovary, *o*; stigma, *s*; filament, *f*.

4B, diagram of floret just after flowering, X4, showing how anthers are held within the envelope.

5, transverse diagramatic section, or floral plan, as is made by cutting across 4A at X, X7; *fg*, flowering glume; *p*, palea; *a*, anthers; *s*, stigma.

6, flowerless glume; 7, flowering glume; 8, palea; all natural size.

9, lodicule, X4, shown also at L in 4B.

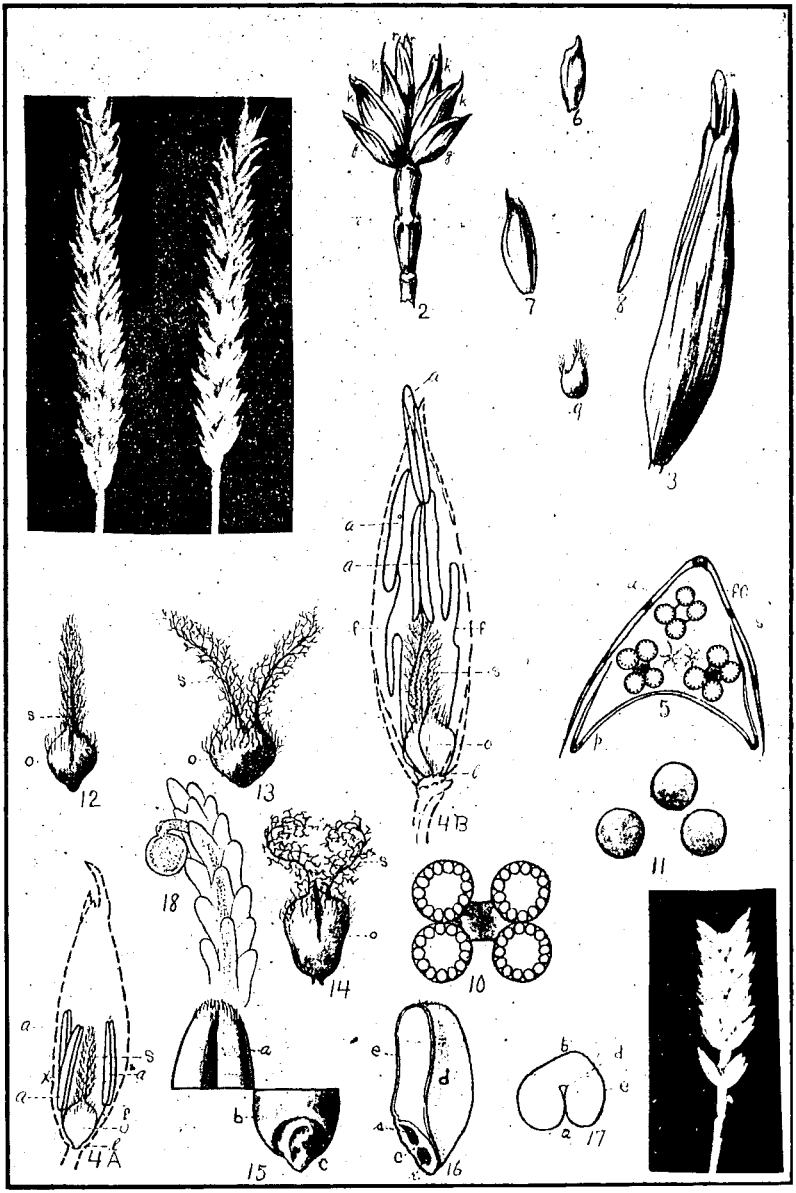
10, cross-section of anther, X30; showing the pollen sacs and the central mass of tissue to which they are attached.

11, pollen grains, round and smooth, 55 micro millimeters in diameter.

12, ovary and stigma just prior to flowering; 13, at the time of flowering; and 14, shortly after flowering.

15, 16 and 17, the mature seed; *a*, the ventral side; *b*, the dorsal side; *c*, the germ or chit; *s*, the stem end of the germs; *r*, the root end; *e*, outer layers or bran; *d*, the incurved surface of bran on the ventral side of the seed. The white portions of 16 and 17 are the floury interior consisting of cells containing the gluten and starch from which white flour is made.

Plate XXV. The Reproductive Organs of Wheat



and thus assists in opening the chaff, as will be seen later in connection with the flowers shown in Plate XXVI. Its position is shown at l in 4B, Plate XXV. When not filled with water it is a flat, almost leaf-shaped organ, but when full of water it is rounded out like a minute sack. Being so near the point of attachment of the two parts of the chaff, it needs to swell only slightly to press their outer points some distance apart.

The male and female organs of the immature flower are closely packed within the lower part of the compartment enclosed by the chaff, as shown in the diagram 4A, Plate XXV. The three stamens are shown at a; the filaments which bear the stamens at f; the stigma at s, and the ovary at o. The floral plan is shown by the cross-section at 5, where the flowering glume, *f, g,* and the palea *p,* are folded about the three anthers, *a,* and the stigma *s.* 4B shows a longitudinal section of the floret at the time of flowering. The anthers, *a,* have been pushed upward by the rapid elongation of the filaments at *f;* and because the glume and palea did not fully open, the anthers were caught and the filaments were bent upon themselves in their endeavor to lift the anthers out of the floret. The stigma remains folded up as shown in 12, Plate XXV, while the flower is yet immature, and it expands, as in 13, when the floret is in the fertilizing stage, as in 4B.

When the anthers are being pushed upward by the filaments they break open, as in 2, 3, 4, 12, 13 and 14, in Plate XXVI, and allow pollen grains to fall on the stigma of the same floret, and often scatter other pollen grains outside the floret.

A cross-section of the anthers is shown at 10, Plate XXV. It is made up of four round sacs, the two pairs being supported by a central mass of tissue, as shown in the engraving. The inner wall of each sack is lined with a single layer of the minute globular pollen grains. The pollen grains are shown at 11, Plate XXV.

At the flowering time the stigma is spread out, as in 13, Plate XXV, is moist and in a condition to receive the pollen grain and cause it to germinate. In 18, Plate XXV., a pollen grain is shown germinating and sending its pollen tube into a branch of

the stigma. The protoplasmic contents of the pollen grain in this manner grows downward through the stigma and style, and passes into the ovary, *o*, 13. In the center of the ovary is the minute female cell, called the "ovule." The pollen tube reaches this, when the two coalesce, completing the fertilization of the seed. The stigma, having done its duty, soon becomes shriveled, as shown in 14, Plate XXV.; while the ovary begins a rapid development and soon reaches the full size of the mature berry.

HOW THE FLOWERS AND ANTHERS OPEN.

There is a general belief that since wheat does not often cross in nature its floral covering does not open. Having observed that some of the anthers escape, and that their filaments are caught between the glume and palea at a point below their center, it was decided to make observations through the day, and if necessary at night, to see when and how much the floral envelop spreads. It was found that the flowers open very early in the morning, just as day is dawning. A flower was sketched at intervals during its opening and closing, and these sketches, together with the exact time of making each, are presented in Plate XXVI, at 1 to 8 inclusive. The flower began opening at forty minutes past four, and closed at eighteen minutes past five. Other flowers observed required from thirty-five to fifty-five minutes to open and close again, or, generally speaking, three-fourths of an hour for the entire operation.

By observing the progressive stages in figures 1 to 8, it will be seen that the anthers move upward as the flower opens, and before it has closed many of them have been pushed upward and have fallen out, the upper end now hanging downward. Not all, however, are raised sufficiently high to escape. In 9, Plate XXVI, the diagramatic section shows the flower as closed, only one anther having escaped; and in 10 none of the anthers succeeded in passing out of the enveloping chaff.

The figures in the lower column, 11 to 16, inclusive, show the opening of the pollen sacs. When the flower begins to open, as in

1, the anther is not open, as in 11, as a rule. But as the opening of the flower proceeds, as in 2, the anther splits open, as in 12 and 13. The anthers in a flower nearly open, as in 4, are ready to pass out of the floral envelope, and at this time they are freely shedding their pollen into the floret on the stigma. When the anther drops over and hangs downward, as in 4 to 8, inclusive; or when it is re-inclosed in the envelope, as in 9 and 10, it soon splits open through-

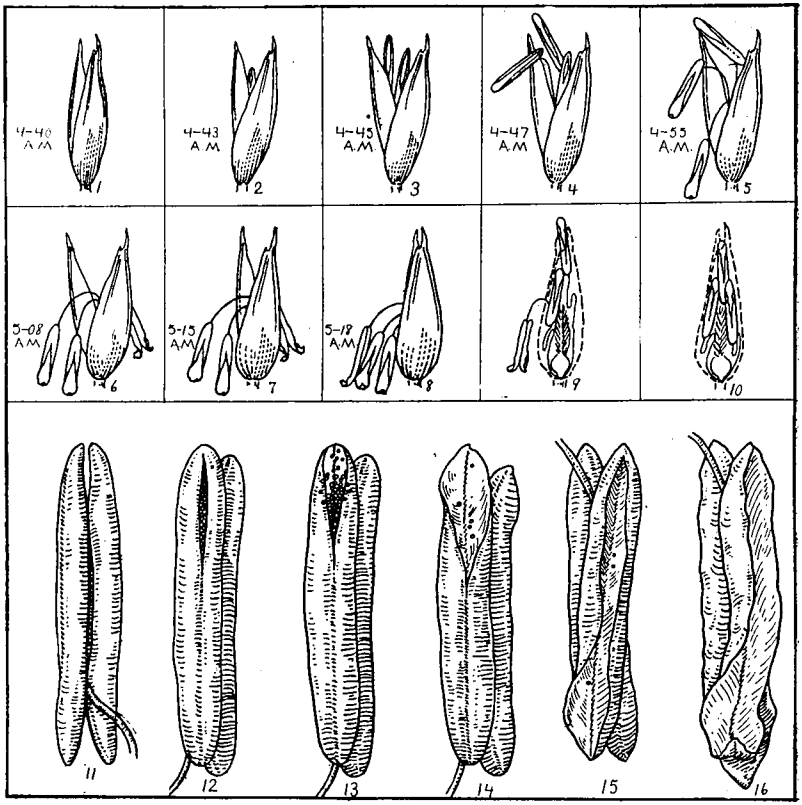


Plate XXVI. The Opening of Wheat Flowers and Anthers.

Note.—The opening of the wheat flower at early dawn is shown in 1 to 5, inclusive; and its closing in 6 to 8, inclusive; the time of making each sketch being given on the plate. In 9 only one anther passes out of the envelope and in 10 none escaped before the flower closed. In 11 is shown the anther with its attachment to the filament, in 12 to 16, inclusive, are shown the progressive changes in the opening of the pollen sacs and in 15 and 16 they are shown as having fallen out from the flower, thus inverting their position and allowing the remaining pollen to fall out.

out its entire length, and becomes shriveled and brown, as in 15 and 16. A large amount of the pollen is lost by anthers which pass out of the envelope after they drop over and hang downward.

The fact that the glumes and palea spread so widely, and that much pollen is scattered outside the florets, makes it probable that there is more crossing in wheat than has been generally supposed. An experiment is in progress to test this question. Plants of some of the varieties which have been successfuly crossed were grown side by side in rows three inches apart last season. Seeds of these are to be planted and the proportion of cross-bred plants which result will be determined. General observation in the field indicates that these varieties, though mixed, very rarely cross. Blue Stem and Fife wheats, for example, of which we have made numerous crosses, are often found mixed in fields, but none of the variable forms produced by artificial crossing have been observed.

THE KERNEL OF WHEAT.

Wheat has the first place among the farinaceous grains as food for man, because of that quality of its gluten which allows the yeast to expand the dough into a beautiful sponge, soft, palatable, and snowy white. Having that proportion of nitrogenous to carbonaceous food elements best suited to man's needs, its use balances food rations too poor in nitrogen and too bulky. And when used freely by persons who eat too much meat it makes their ration less rich and more healthful. The more abundant and the cheaper this cereal can be grown the better for all classes of consumers.

The work of raising wheat, of breeding better varieties, and of storing the ripened grain all centers around the berry, which should be brought to the complex processes of milling in a perfect form that good flour may finally be the result. The kernel of wheat, though small and apparently simple, has a wonderful history, and its structure is of interest. Several of the parts of the grain are shown in Plate XXV at 15, 16 and 17. See notes ac-

companying description. Fig. 264 shows a highly magnified section of a grain of wheat through the bran and including a few layers of the farinaceous cells inside the covering of bran.

The bran is composed of several layers. Two layers, a, b, are made up of strong cells overlapping in such a way as to make a tough integument covering the berry of wheat. A third fairly strong layer, c, lies inside these outer ones and against the inner, colored layer of the bran. This latter is called the "aleurone," layer, since its nearly cubical cells are partly filled with aleurone grains. These cells lie against the floury interior of the kernel.

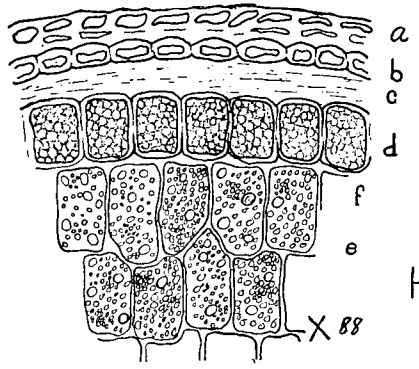


Fig. 264. Highly magnified section of portion of grain of wheat, as at X in Fig. 263; a, b, and c, outer coats or bran of the grain; d, aleurone layer; e and f, floury interior starch cells of the grain.

Fig. 263. Transverse section of a grain of wheat.

They contain fermenting substances which during the germination of the seed act on the floury cells making their contents soluble and ready for the use of the germinating plantlet.

Though this layer of cells is rich in materials suitable for human food, the effort in the roller mill is to crumble the floury cells off the inside of the bran, leaving the aleurone cells attached to the tough part of the bran. These aleurone cells have masses of colored materials in them which give to the flour a darker color than is desired by present market fashions, and it is believed that these aleurone cells contain ferments which increase the dangers of spoiling in flour exported to foreign markets.

The floury cells, *f* and *e* in Fig. 264, fill up the mass of the kernel of wheat. Each floury cell has a thin wall, and its contents are principally starch granules—very small, nearly globular masses of definite composition (C6, H10, O5)—and masses of glutenous compounds, together with small amounts of fats and ash. The proportion of gluten is slightly larger 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.

The Amount and Quality of Gluten Important.—The percentages of gluten in wheats have much to do with the food and market values of flour made from the different varieties. But the quality of the gluten has even a greater influence on the prices of wheat than does the quantity. In quantity the gluten in the varieties of wheat tested by this station ranged from 17.9 per cent. to 8 per cent. The quality of this gluten, expressed in a scale of 100 points, ranged from 35 to 87½. In a general way wheats are grouped by millers into two classes. Those with weak gluten are called "soft" wheats, and those with strong gluten are called hard wheats. These terms are used in a somewhat confusing manner. Some classes of wheats which are hard when crushed, as between the teeth, have gluten of very poor quality, though they may have a high percentage in quantity, and will not make flour which will rise into a light loaf. This wheat is not wanted by millers at any price, since even a small percentage of it in a milling mixture will seriously injure the quality of the flour.

The gluten of wheat is composed of several nitrogenous compounds, mainly gliadin and glutenin. When these are present in the right proportions to each other they form a tough, elastic mesh within the dough or sponge, which is stretched by the gas developed in the interstices by the yeast germs. Prof. Harry Snyder, Minnesota Bulletin 54, pp. 37-38, says: "An excessive amount of gliadin and a small amount of glutenin make a soft, sticky dough. An excessive amount of glutenin and a small amount of gliadin prevent the gas from being retained and the bread from becoming light. * * * The gliadin, by binding

together the particles of flour, enables the dough to retain the gas. * * * The glutenin 'serves as a nucleus to which the gliadin adheres,' and it prevents the dough from becoming soft and sticky." Prof. Snyder found that a good sample of Red Fife wheat contained about 14 per cent. of protein compounds, 11.3 per cent. of which were gliadin and glutenin; the proportion of the two latter being about six of the gliadin to four of the glutenin. This wheat has very good gluten. Dough from Fife wheat flour rises high, is not "runny," and the gluten has the enduring power to rise again and again with successive "working down" of the dough. Prof. Snyder found a slightly greater proportion of gliadin to glutenin in Blue Stem wheat than in Fife wheat. Blue Stem proves in baking tests to be nearly or quite equal to Red Fife wheat if neither have ever been wet or otherwise injured.

Since good quality of gluten, together with at least fair quantity, is of so much importance, most careful attention must be paid to selecting and breeding varieties from which good flour may be made and to so harvesting and storing the grain that the gluten is perfectly preserved.

THE MODERN PROCESS OF MILLING WHEAT.

The making of wheat flour has been wonderfully revolutionized during the last quarter of a century. The burr mill has given way to the complex roller mill, with its graded product of flour, bran, shorts, and screenings. The great Pillsbury A mill has a capacity of 10,000 barrels of flour daily, requiring several trains to bring the wheat and remove the flour. The process in one of these mills is bewildering in its complexity. The grain is cleaned to remove the weed seeds and other foreign substances. It is scoured to remove the hairs from the outer end and even the chit is rubbed off. It is washed in water if infested with stinking smut. And if the bran is dry and brittle, the grain is moistened with steam or water to toughen the bran before the grain passes between the rolls so that the bran will not be crumbled up with the flour. The miller seeks only the interior of the kernel without

any foreign matter whatever, and his machinery and processes are all arranged for that purpose. If it were possible for the farmers to produce only plump kernels, well fatted up, full of starch, and with bran tough, smooth, and uninjured by exposure to the weather, the miller would have a less difficult task and could produce a still better flour. The farmers do not use the care nor develop the skill in raising the wheat that the millers do in manufacturing it into flour and there are some lessons farmers need to learn from the mills. They need to realize that the miller must have a good bran. He views the outside of the kernel. In purchasing he rarely even bites it in two that he may see the character of the inside. In purchasing a given variety of wheat he makes the price according to the plumpness and the color and general appearance of the bran. He wants the bran bright in color. If wheat has been alternately exposed to rain and sun in uncapped shocks, or has lain wet in the bin, the bran will have lost its tough texture and will crumble, small particles going with the flour through the finest silk sieves. This discolors the flour and injures its keeping qualities. Besides, the rising power of the gluten is injured by becoming wet or by heating in stack or bin.

METHODS OF BREEDING WHEAT.

Securing foundation stocks is the first requisite in preparing to improve wheat, since more depends upon the parent variety than upon the breeding. While much may be accomplished by scientific effort, it is too much to expect or hope that more can be thus accomplished in a few decades than has been done in many centuries of care by past generations of wheat growers. In previous pages are given the plans employed in collecting and testing in the field, in the mill, and in the bake-room varieties of wheat secured from many parts of the world. Since no one variety of wheat is adapted to giving the best results in all parts of the state, the best wheats are being tested on the several experiment farms, that the best old and best new wheats for each portion of the state may be known and distributed in the respective districts. With the increase of good varieties there is an adaptation of kinds to special conditions. Sandy soils will probably be best suited to certain wheats bred to resist drouth and a less liberal supply of plant food. Those farmers who have rich or moist lands and who keep much live stock to enrich their fields, will be especially partial to those varieties which have good ability for standing erect. With University Farm, Northwest Farm, and Northeast Farm, the Experiment Station is equipped to compare varieties of wheats for various conditions of soil and climate. Several tests at each farm are necessary, that reliable averages may be made for comparing the wheats. The varieties now in hand are an excellent basis for improvement by breeding.

Practical experience with nearly fifty newly originated varieties, as well as with some hundreds of collected wheats, clearly demonstrates that it is economy to give all wheats a thorough trial at

the experiment farms before distributing any to the farmers. Trials by the farmers with small samples, sent free, are in the aggregate expensive to the farmers and not very satisfactory. Our new wheats are sent out only after thorough trial as to yield and milling quality, and the chances are that each new kind distributed will prove valuable, in at least portions of the state. The station is originating many varieties, but only a few of the very best are being distributed. So far about three per cent. of the new wheats are especially promising, and these are being increased for sale. Since some of the new wheats are proving better than any of the old wheats, only new kinds are now being multiplied for distribution.

That a superior new wheat introduced into the state may prove of great value, we have only to realize the importance to the northwest of the introduction of Red Fife or of Blue Stem wheat. Little is known as to the history of how they came to be introduced, but what was done by individuals or by chance may be duplicated through systematic effort with still other superior varieties.

NOTE.—*A new variety can be rapidly multiplied.* In 1890 this station distributed, mostly in bag lots, a carload of superior Fife wheat, donated for that purpose by Mr. C. A. Pillsbury, of the Pillsbury-Washburn Milling Company of Minneapolis. In some townships this wheat had been so multiplied in several years that little else was grown.

A farmer at Park River, Walsh county, N. Dak., secured a small package of White Russian oats. In a decade these oats had been so multiplied that nearly the entire crop of the county was from this stock of seed.

Prof. W. A. Henry, director of the Wisconsin Experiment Station, in the first Annual Report of that station, pp. 17-21, gives the history of the introduction of Manshury barley into America. In a recent letter to the writers, Prof. Henry briefly states the facts thus: "This barley was carried from the mountains of Mantchooria to the King's Garden, Germany, and from there by a German-American visiting Germany to Iowa county, Wisconsin, and thence to the station. By this station it was disseminated all over the northwest, proving worth hundreds of thousands if not millions of dollars."

Our new wheat, Minn. No. 163, came from a single kernal planted in 1892. In 1893, seventy-five plants grown a foot apart each way were harvested; in 1894 a small field plot was grown; in 1895 a one-twentieth of an acre; in 1896 several plots; in 1897 a small field; in 1898 several small fields, resulting in about three hundred bushels of seed wheat, which was sold to about fifty farmers and planted in two-acre lots in the various counties of the state. At an annual increase of tenfold this wheat could be so increased as to make the entire crop of the state in seven more years, or in fifteen years from the planting of the single parent seed.

Mr. S. A. Bedford, superintendent of the Dominion Experiment Farm at Brandon, Manitoba, expressed the belief that the yield of oats in Manitoba had been increased on an average of two bushels per acre by the distribution of a few superior varieties during the several years since the establishment of the experiment farm at Brandon.

GREAT VARIATION AMONG WHEAT PLANTS.

Variability of individual plants of wheat is the basis for breeding. That this variation is considerable is demonstrated in many ways in our records of breeding wheat in the field-crop nursery, where each plant has the same space of ground as each other plant. In 1892 ten best plants, chosen by inspection out of 400 plants from seeds selected out of the bulk grain of each of three varieties, showed great variation in the several characteristics of time of ripening, length of spike, and height of plant. Especially was there great variation in the date of ripening. The plants each had a space 12 by 18 inches in area in which to grow and develop their individualities. Among the four hundred plants of McKendry's Fife, for example, plants were found which matured in ninety-seven days, others requiring one hundred and twenty-seven days. Among Power's Fife the range was from ninety-eight to one hundred and twenty-two days; and among Haynes' Blue Stem plants the range was from ninety-nine to one hundred and twenty-eight days.

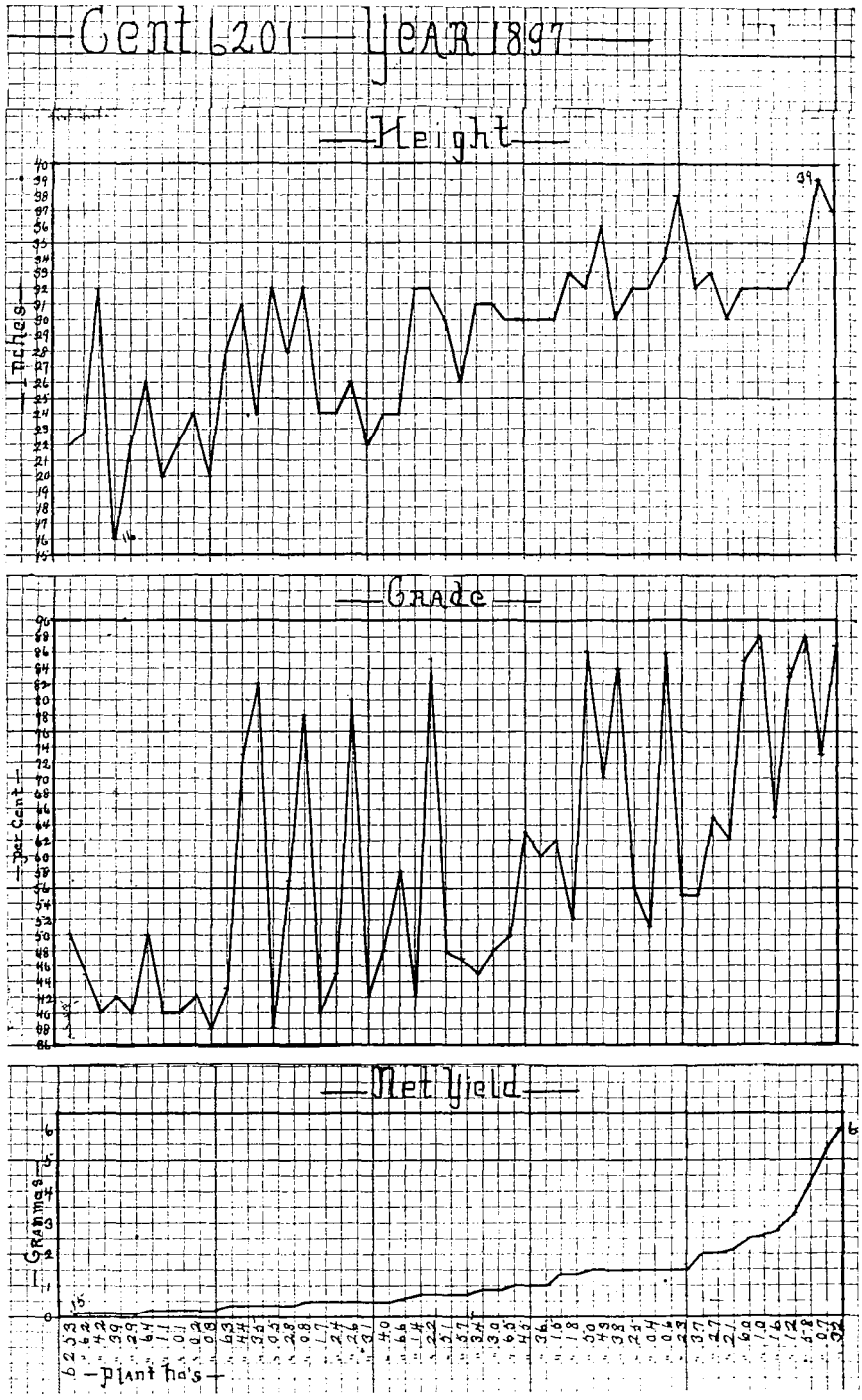
The ten plants which appeared to the eye as the best yielding plants out of the four hundred of each variety were harvested and notes taken as to height of plant, number of spikes, length of spikes, and yield of shelled grain. The following table shows the extremes of the variation in each case:

TABLE LIV.—Variation Among Best 10 Out of 400 Wheat Plants.

	Height of Plant	Length of Spikes	Number of Spikes	Yield Grams
Haynes' Blue Stem.....	31-39	4-4¾	19-31	15.4-19.4
Power's Fife.....	27-33	2¼-4	18-33	3.4-13.8
Mckendry's Fife.....	30-33	3½-4	22-33	6.8-16.7

NOTE.—In Chart I are fifty wheat plants arranged from left to right in the order of their yield. Vertical lines represent the plants. Horizontal lines represent, in the lower section, yields in grams; in the middle section, grades expressed in percentages; in the upper section, heights expressed in inches. The figures at the left of each section show the value of each line. These fifty plants are from a new variety springing from a single seed produced by crossing in 1892, and each year thereafter until 1897, selected to the best plant in one hundred, these plants being a part of the fifth generation of the cross and all from seeds from one plant of 1897.

CHART I.—Variation Among Fifty Wheat Plants. 6201—1897.



This variation is still more forcibly illustrated in Charts I., II., and III. In the lower section of Chart I. fifty plants are arranged in the order of their yield. Each vertical line represents a plant, the number of the plant being placed at the lower end of the line; and each horizontal line represents one-half of a gram in yield. The yield curve is drawn between points on the vertical lines representing the respective plants, where they cross the horizontal lines representing their yields. It will be observed that a few very large yielding plants cause the yield curve to rise very sharply at the right. Yield curves drawn of sixteen lots, of fifty plants each, all have this same feature showing that Quetelet's law is operative in the variation of yields of individual wheat plants, all from seeds of the same mother plant, and each allotted the same area of soil to grow upon as every other plant. This was true in case of stocks selected to a single mother plant for each of several years, of stocks selected for a few years, and of hybrid stocks selected for several years and others selected for only a few years.

The fifty plants plotted here grew consecutively in the field crop nursery, i. e., the plants were taken as they came, without selection. The yield curve shows that the plants ranged in yield from a fraction of one gram to six grams per plant.

In the middle section the curve is platted to show the quality or grades, expressed in percentages, of the grain of the respective plots as arranged in the lower section. Here is shown not only the widest variation, but also a wide variation from the yield curve in the lower section, though in general the grade curve rises with the yield curve.

In like manner the heights of the respective plants are graphically compared in the upper section.

Here, also, there is marked variation and the height in a gen-

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Quetelet's Law, which seems to be operative in the yields, grades and heights of individual wheat plants, and in the yields of varieties of wheat, may be briefly illustrated by taking the heights of 1,000 men of mature age, all from the same race and brought up in the same county. If placed in a row in the order of their heights, a line drawn over their heads is almost level throughout nearly its entire length. At the lower end it drops down sharply and at the upper end it rises sharply, *i. e.*, owing to the law of variation from the usual type, which, by the force of heredity, is in general maintained, there is an occasional marked variation in either direction.

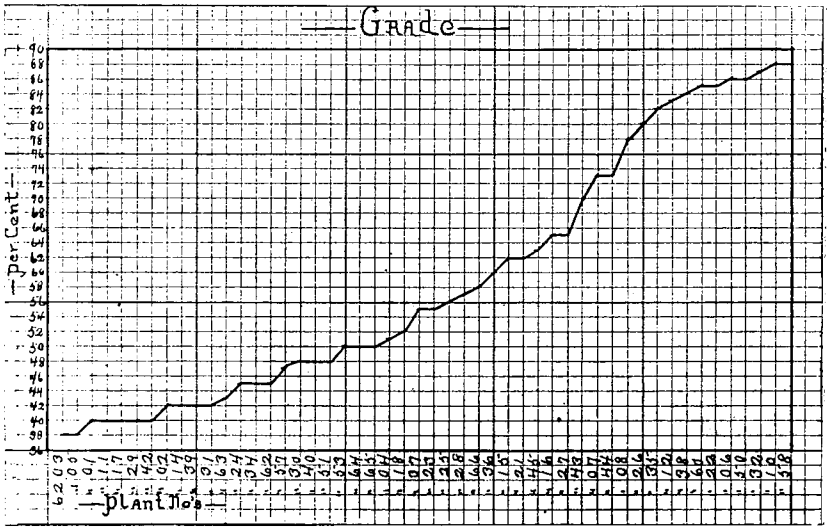
eral way corresponds to both the yield of the individual plants and the grade or quality of their grain. And much experience has shown the general rule that heavy yielding plants are tall and have grain of good grade. Height is not an important factor, except that in breeding, plants of great height are avoided, as such plants produce varieties which lodge. But grade is important, and care is needed to select plants which both yield well and produce grain of good quality. The great variation in the grades of the best yielding plants observed in comparing the lower and middle sections of Chart I is shown in all of a dozen similar charts. These charts represent several stocks which have been rigidly selected to a type for two to five years, by selecting each year to a single best mother plant, and also several cross-bred wheats which have been selected to a type for from one to four years, respectively.

Some of the variation among plants in the field crop nursery is due to inequalities in the soil and in other conditions. Insects and accidents may result in injury to some plants, and in rare cases some plants may have unusually rich spots of earth. As a rule, however, the unequal conditions are from causes which injure certain plants, and the selection of the best plant or plants practically is made from among those which have not been injured but have had the general good conditions of the field. Great care is taken to have the land in uniform condition. The field is prepared the previous year. Where fertilizing is needed it is done very carefully, usually by a bare or a green manure fallow. Commercial fertilizers could be evenly distributed, but since this form of fertility is not depended upon in Minnesota it is not desirable to use it.

Great variation among wheat plants which are the results of recent crossing between varieties has been observed in many cases. There is variation in all characters. Fig. LX. and the related text illustrate this variation.

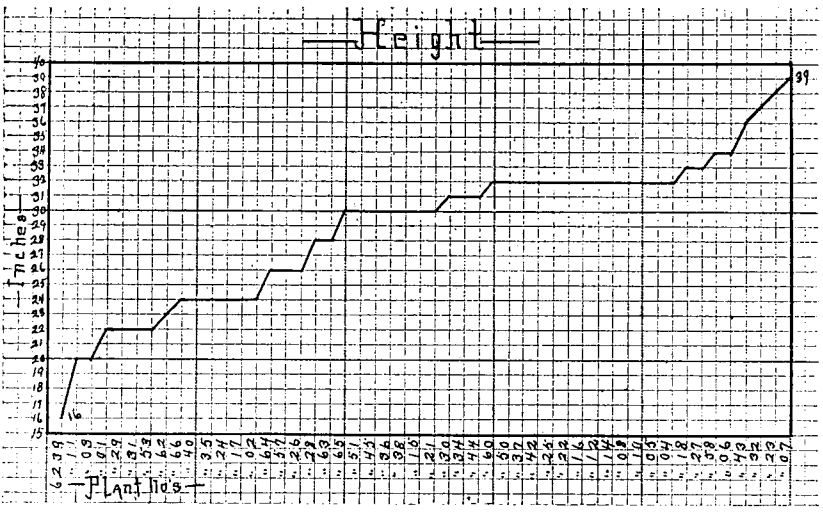
Two hybrid stocks arising from two kernels produced by pollenating two flowers on the same plant of one variety with pollen from one plant of another variety of wheat are found to differ in

CHART II.—Variation of Wheat Plants in Grade of Grain.



NOTE.—In Chart II. the same plants shown in Chart I. are arranged from left to right in the order of their grades. In a dozen similar charts the grades have been platted, but in only part of the cases do the curves conform to Quetelet's law.

CHART III.—Variation of Wheat Plant Height.



NOTE.—In Chart III. the same plants shown in Chart I. are arranged in the order of their heights. In this and in most of a dozen other similar charts made of wheat plants growing consecutively in nursery centgeners from single mother plants the height curve follows Quetelet's law, turning up sharply at the upper end and downward sharply at the lower end.

the number of forms they will break up into, and in the time required to select them to a true type. In other words, hybrids vary in their tendency to greater or lesser variation from type, even when the parents of two cross-bred stocks are the same two plants.

In each one thousand plants of wheat there are a few phenomenal yielders, and the method of single-seed planting makes it practicable to secure these exceptional plants, and from these new varieties can be made.

By no means all the varieties made from single mother plants, or those made by mechanically mixing together the seeds from several single mother plants, will prove large yielding varieties. Some plants grow vigorously when in the nursery where room and plant food are abundant, but when crowded in the field their progeny do not do well, and the variety is not a large yielder. It is found necessary to make ten new varieties, more or less, to secure one which is a marked improvement.

Quetelet's law is operative among varieties produced from single mother plants as is shown by the yields of thirty varieties produced from single mother plants grown in the nursery in 1892.

When applied to the choicest varieties there is one or a few exceptional kinds. In Chart IV are plotted the averages of six yields each of the eight varieties which were the best of their respective classes among the thirty wheats originated from single mother plants in 1892. Here No. 169 stands out prominently as the best yielding wheat. Out of these thirty wheats three varieties are giving strong proof of promise, and one variety, Minnesota No. 169, is especially promising. The Englishman who explained his success in breeding hounds by the terse statement that he "bred many and hung many," and the Scotchman who put philosophy in the single word "tops" when refusing long prices for the few very best of his herd or flock, recognized the essence of Quetelet's law. This law should be more fully and broadly recognized in animal breeding and especially in plant breeding.

Put into practical form this law may be exemplified as follows: There are occasional plants of wheat, which upon being multi-

plied into varieties yield larger crops than the parent kind, adding one or more dollars per acre to the value of the crop.

(a) These best plants may be sought out in the nursery, where the seeds are planted singly in hills, by choosing the few best yielding plants of good grade from among each thousand plants.

(b) When hundreds of varieties are originated from single mother plants, or from mixed seed from several superior mother plants, and these varieties are tested in the field, a few out of each hundred will prove to be valuable new varieties.

(c) These foundation stocks will serve as better foundation stocks for further improvement by continued breeding, whether by selection alone, or by crossing followed by selection.

When applied to plant breeding, and animal breeding also, the most important point in connection with Quetelet's law is that *the selection of foundation breeding stocks should be made most carefully from among very large numbers.* The larger number we plot in the chart the greater the chance there is for securing phenomenal plants at the upper end of the line.

Science in Selecting and in Mating.—In animal breeding, men have become expert in that artistic ability which enables the live-stock expert to so select and mate his animals as to rapidly improve a herd or to establish a new breed. In the breeding of swine, some of the beef breeds of cattle, and meat producing breeds of fowls, the individual appearances as form, color, handling quality, etc., have been mainly depended upon in selecting the superior individuals, and in determining which individuals would blend in mating so as to best unite the desirable qualities and avoid the weak points of each. In breeding trotting horses and dairy cows, on the other hand, many of the most successful breeders have paid comparatively little attention to the form and other appearances, but have selected on the basis of actual performance records, as in the mile trotting race, or in pounds of milk and butter produced. Where actual performance can be recorded or where other principal characteristics, as amount of food required for a pound of grain, or the strength of fecundity, as determin-

ed by the number of young reared, can be reduced to figures, such facts are, as a rule, of greater weight in selecting among individuals than mere form or color or other outward appearances.

In the breeding of wheat, yield per acre and the grade of the grain have been used as the most important characteristics to be considered, and in making a choice among plants attention has been paid to little else. Other qualities, as rust resistance and quality of the gluten in the grain, have also come up for careful consideration both in the selection of the best varieties and of the best plants to increase yields and also to make crosses, the two parents of which if combined would make the greatest improvement.

It was found desirable to express all these qualities in some simpler form than in a mere tabulation of percentages. The curved line method of graphically displaying the yield and other characteristics have been found very helpful.

Chart IV containing graphic expressions of the various qualities of our three best old and eight best new wheats is introduced here for this purpose. (See the notes under the chart.)

1st. It serves as a method of comparing the value of the more intrinsic qualities with those of less value or with the mere fancy points in each variety or individual.

2d. This is a graphic way of expressing the many qualities of several complex individuals. It is a means of gaining a more comprehensive knowledge of the relative merits for specific purposes of the several varieties or individuals.

3d. The characteristics of various individuals or varieties thus graphically shown aids in selecting the two parent individuals in crossing so as to best combine the desired qualities and eliminate the undesirable characteristics of the two parent stocks.

Intrinsic Qualities vs. Fancy Points.—In Chart IV yield stands as the most important characteristic in the graphic score card. If the six sections were each represented on a percentage score card by its relative value, yield would properly be given the largest space and grade might take second place, grade meaning appearance of the grain—its ability to stand on appearances before the market.

The following named values, for purposes of illustration, are an aid in properly interpreting the chart:

PERCENTAGE SCORE CARD FOR COMPARING VARIETIES OF WHEAT.

1	Yields per acre	45
2	Grade of grain	20
3	Rust resistance	10
4	Quality of gluten	10
5	Amount of gluten	5
6	Coefficient of rise of gluten	10
		100

Giving yield such a prominent place as compared with other qualities might appear wrong. But the total weight per acre is the main factor in giving profits to the wheat grower. Several sections relate to the quality of the wheat, viz., 2, 4, 5, and 6, making a total of 45 per cent. almost too much in proportion to what is given for yield.

It will be observed that the rust-resistance curve in section 4 corresponds closely to the yield curve in section 1; i. e., those plants

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NOTE.—In Chart IV. are shown graphically several of the leading characteristics of eight newly-originated wheats, and on the right side of the chart three old standard wheats are shown. Of these latter, Minn No. 51, Haynes' Blue Stem, is the parent of the best new wheat, Minn. No. 169; and Minn. No. 66, Power's Fife, is the parent of Minn. No. 149.

The vertical lines represent the respective varieties which are given by number or name at the bottom of the line. In each of the six sections there are horizontal lines representing units of the various qualities. These run only through the range of figures, as given at the left ends of the lines, which include only the variations in yield in grade or in other qualities respectively, in their respective sections, and not the entire yield, etc. This graphic language is new to the common reader, but if once mastered it often conveys the ideas in a much more clear and comprehensive manner than would mere words and figures. The various sections have been given the same proportion of the whole height of the chart as each quality is given in the percentage score card in the text.

In section 1 the yields per acre are expressed in bushels of 60 pounds each, and since the yield is the quality to which the most value is attached the new and also the old varieties are arranged throughout the chart in the order of their yields

In section 2 the grades are expressed in percentages, thus making the comparison of yield and grade comparatively easy in the two sections.

In section 3 the relative rust resistance is shown in percentages.

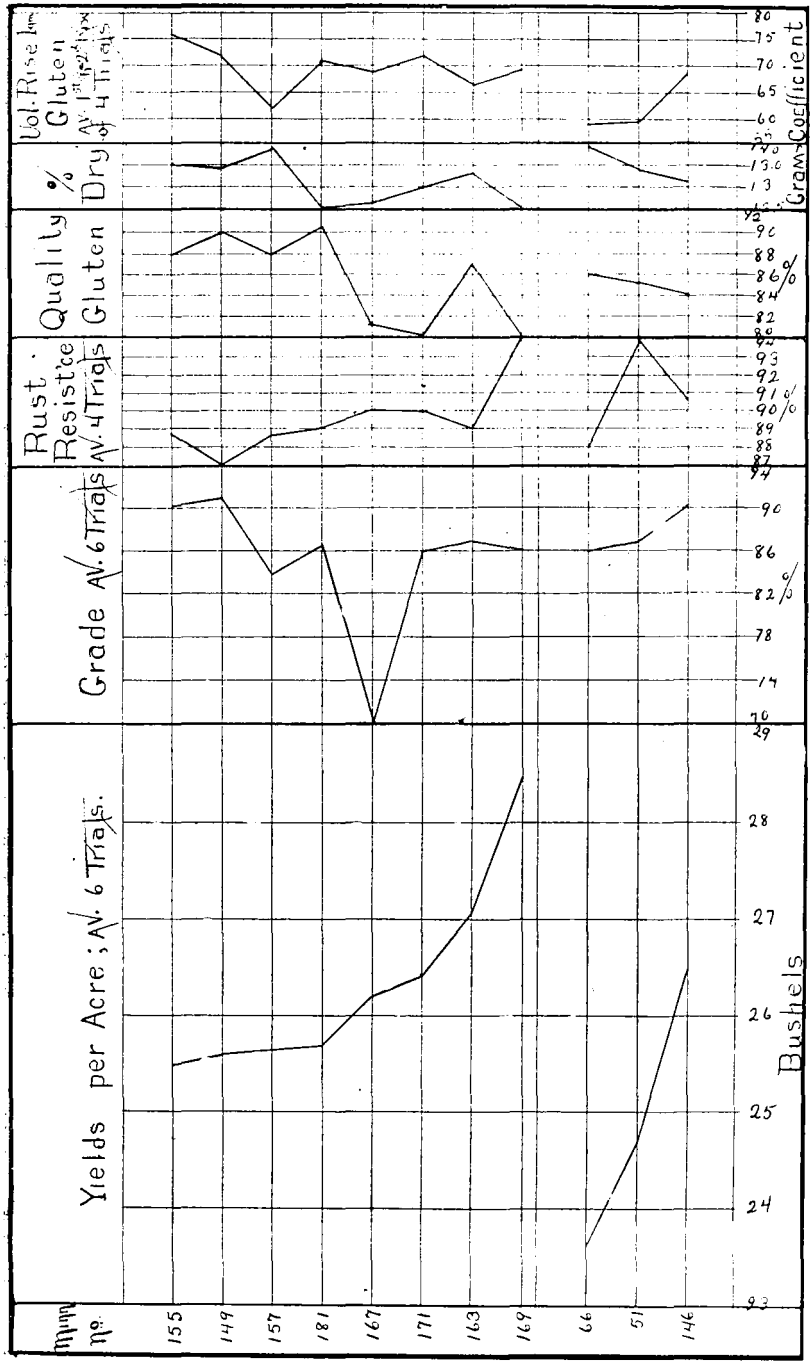
In section 4 is given the quality of the gluten as determined by the gluten test of the flour from each variety.

In section 5 is given the percentage of gluten in the flour from each variety.

In section 6 is given the quality of the flour as determined by the baker's sponge test, expressed in the volume of loaf produced by each percentage unit of gluten. This is obtained by dividing the grams of dry gluten in a hundred grams of flour into the volume of loaf of dough produced from the hundred grams of flour. These figures represent the averages between the volumes of the first and second rise of each kind of flour.

This graphic score card has been drawn so as to give the same relative space on the card to each quality as is given in the percentage score card above.

CHART IV.—Graphic Score Card of Varieties of Wheat.



which strongly resist rust are as a rule, able to yield well. It will be observed that in this percentage score card and also in the ghaphic score card no place is given for uniformity to type, length of spike, height of plant, and other points which are not relevant to the yields and quality which give value per acre to the farmer.

Score cards sometimes used, as by poultry judges, have ninety-five per cent. of their values placed on the mere fancy points, as the form of comb, and wattles, color of wing feathers, character of markings of the body feathers, the poise of the "stocking" feathers and even the color of the scaly skin on the lower portion of the leg. Weight is given a place and in some cases is given a relation to value, but quite as often a bird is scored down because it weighs above as below the standard, and it may thus come to be used as a mere fancy point. The actual amount of percentage of lean meat on the breast and legs of the fowls of a meat breed is overlooked, though it could be determined with fair accuracy by handling the fowl. "Fuss and feathers" have but little place in breeding plants and animals which are used for the production of foods and other useful products, though they may properly be taken into careful account in breeding pigeons, pet dogs, pansies, chrysanthemums and other animals and plants produced for pleasure.

Graphic Score Cards Used in Crossing.—Choosing animals to mate that the most nearly ideal young may be produced, and determining which varieties or individual plants of wheat to cross-pollinate to produce the most useful new varieties, are very difficult problems. Mere art may ofttimes suffice; and extensive mating followed by intelligent and careful selection will often result in the production of some good individuals. But to make the most rapid progress—to use a given amount of time and means to the best advantage—the many qualities of each parent should be considered, and the selections should be such as to unite the greatest number of strong points with the fewest weak ones.

Chart IV would aid in the selection of varieties between which crosses are to be made. Minn. No. 169 stands out prominently as one parent to choose for crossing. Minn. No. 163 being the

next best yielder of good grade, fair in rust resistance—a point in which Minn. No. 169 is very strong,—good in quality of gluten, very good in the amount of gluten, and fair in amount of loaf a given amount of gluten will make, would well mate the large yielding Minn. No. 169.

Minn. No. 66 would not seem so promising to use for crossing with Minn. No. 169 as would Minn. No. 163. Its smaller yield is not sufficient to overcome the advantage of its superior weight per bushel and its slightly greater per cent. of dry gluten; and, besides, it is below Minn. No. 169 in rust resistance and in the coefficient of its ability to rise in the loaf.

A score card at best can represent only part of the factors which the breeder must take into consideration. One quality not placed in the graphic score card, because common only to the Blue Stem varieties, is the weakness of the chaff in holding tight about the berry. In case of Minn. No. 169 there is some loss from shelling and from the spreading chaff allowing the bran of the berry to be exposed to rains, dews, and sun and thus rendered brittle and light colored. Nos. 163 and 66, being Red Fife varieties, have tightly clinging chaff, and would be equally well adapted to crossing with this new Blue Stem variety to increase the strength with which the chaff holds to the grain.

Since Minn. No. 169 is the better wheat, the best progeny would probably be the few selected from the cross-bred stocks which resembled that parent. And by producing the progeny in very large numbers and seeking the best, those plants most nearly combining all the good qualities of both parents could be found and used in making new varieties. Experiments might prove that it would be advantageous to use Blue Stem wheat a second time, making the cross-bred wheats three-fourths of the blood of Minn. No. 169 and only one-fourth the blood of Minn. No. 163.

The many questions which arise as to how best to proceed in making crosses are somewhat difficult of solution because of the large number of plants which must be used and the long series of years through which the resulting varieties must be tested in the field and in the mill before final results are reached and the varie-

ties have won a place among the wheats which are chosen for general distribution throughout the state.

HOW NEW VARIETIES OF WHEAT ARE ORIGINATED.

The breeding of field crops was begun by the Minnesota Experiment Station in 1889. In case of wheat, corn, oats, and barley, of which many varieties exist, the effort was to first secure the best obtainable kinds, that the work of breeding might be centered on making the best varieties still more useful. In case of timothy, clover, and other species which had not been broken up into agricultural varieties, systematic breeding was at once begun, using the common kinds of those crops for the foundation stocks. Encouraging progress was made from the start with timothy, though the process is of necessity long, because of the perennial habit of this grass, necessitating two or three years for the growth and selection of each generation. Severe winters have destroyed stocks of common red clover, and very little has been accomplished with that crop, excepting that something has been learned as to methods of breeding it. While most effort has been expended on wheat, and most accomplished, numerous other crops have been dealt with in the field crop nursery. Since each species needs a somewhat different method of breeding, the work with oats, barley, millet, flax, field peas, beans, and brome grass has given a larger knowledge of the subject, aside from the production of new varieties of these crops.

WHEAT BREEDING BEGUN IN 1889.

In 1889 Red Fife and Blue Stem wheats were crossed as found growing on several farms in the Red River Valley. All the resulting kernels were accidentally destroyed. In 1890 a large number of wheat flowers were cross-pollinated at Warren, Marshall county, Minn., and fourteen grains were harvested. These seeds were planted near Fargo in 1891, and the resulting plants were shipped by express and lost, thus again destroying the start in the breeding of these two famous hard wheats. Valuable

facts, however, were secured. Eight out of thirteen of the resulting plants, inspected when in blossom, proved to be true crosses, showing that these two wheats will cross fertilize.

Field Crop Nursery Begun in 1890.—The growth of individual plants of timothy and wheat in 1890 and 1891, planted in hills one seed in a place, had demonstrated that it was practicable and desirable to deal with individual plants in breeding these field crops.

At Fargo and Power, N. Dak., 400 kernels of each of eight wheats were planted singly in hills 12 by 18 inches apart, in 1892. The following named varieties were used: Power's Fife, Minn. No. 66; Glyndon 818, Minn. No. 480; Glyndon 753, Minn. No. 116; Haynes' Blue Stem, Minn. No. 51; Risting's Fife, Minn. 476; Glyndon 811, Minn. No. 168; and Glyndon 761, Minn. No. 481. Besides selecting the best plants from each variety, and making many crosses among the best plants, the variation of each variety grown in this nursery way was critically studied, as mentioned in a previous paragraph.

IMPROVING A GOOD VARIETY OF WHEAT.

Besides the numerous varieties of wheat which have been in the field crop nursery for some years, the station has recently placed in nursery plots, under present plans of breeding, stocks of a dozen varieties which have proven to be the best out of the several hundreds tried for a series of years in field trials, and several promising varieties originated by crossing which having been for some years in field trials have been returned to the field crop nursery to be used as foundation stocks from which to produce still other new varieties. One of the collected wheats, Bolton's Blue Stem, Minn. No. 146, received from Thomas Bolton, Park River, N. Dak., stands out prominently as the best variety among 200 collected prior to 1894. In ten yields it averaged nearly two bushels more than the other best yielding kinds, and is among the best in percentage and quality of gluten. The methods employed with this wheat will illustrate the plan of selecting wheat in use at present.

Breeding Bolton's Blue Stem Wheat, Minn. No. 146.—In the spring of 1898 there were selected from bulk grain, grown in

Fig. 265. Planting wheat in the field crop nursery. The planting frame consists of two 2x10 planks 42 feet long, held together by movable cross-ties. On the inner edge of each plank a nail is driven every four inches. A cross-board 52 inches long is placed with its ends against these nails. Notches every four inches along the edge of this cross-board indicate the position of hills of wheat. When one row is planted the board is pushed forward four inches against the next two nails.

the field trials the previous year, 1200 kernels of Minn. No. 146. The hardest large kernels were chosen, and these were planted singly, in hills four inches apart each way. These kernels were

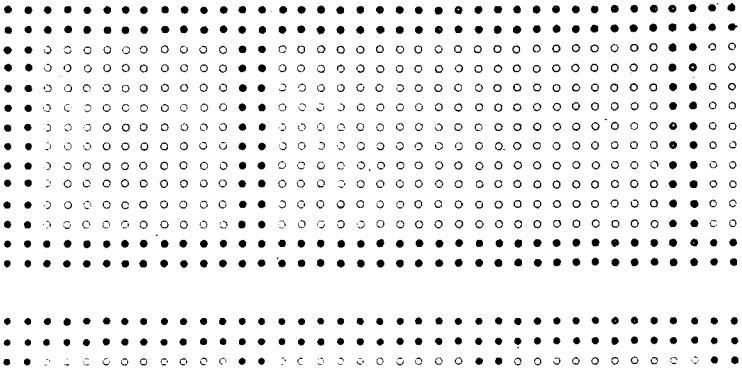


Fig. 266. Plan of planting nursery wheat. The circles represent plants within the *centgener, the dots the border plants. The 18-inch alley is widened to 34 inches by the removal of the border rows either side.

planted by using the planting frame shown in Fig. 265. This frame is forty-two feet long, and fifty-two inches wide between the planks, giving room for fourteen plants crosswise and one

*Asterisk Refers to the plot or group of plants grown from seeds of a single mother plant.

hundred twenty-four lengthwise. The plots, or "frames," of plants are placed eighteen inches apart so that there may be alleys in which the workmen may stand when cultivating and harvesting. The alleys necessitate throwing out the border plants, since these have more soil and sunlight than do those in the center of the plot. The outer two rows are in all cases discarded, leaving the plot ten plants wide and one hundred twenty long, twelve hundred plants in the full frame. The plan of planting is shown in Fig. 266. Where the supply of seed is small, as in case of some newly-crossed plants, the two border rows are planted with another variety of wheat, a bearded kind being used around a beardless wheat, and vice versa. And when a limited number of seeds of several varieties or stocks are planted in the frame, they are separated by two rows of "border" wheat, as shown in the diagram.

The system of numbering in use has proved very simple and

Fig 267. In the foreground is the field crop nursery when the plants are several inches high. In the background are shown newly-originated varieties of *Bromus inermis* and of timothy.

convenient, and is adapted to an extensive system of records. The first plant of the first plot or stock of wheat is numbered 101, and if there are not more than 100 plants in the plots the first plants of the next plots are 201, 301, etc. If some century, as the eighty-fifth, for example, contained a full frame of twelve hundred plants, they would be numbered from 8501 to 9700, inclusive; and the first plant of the next plot 9701. In case there are only a few plants in the centgener, as in the first generation of a cross-bred stock, the last numbers of the hundred will be blank, since it is best to begin the numbers for the succeeding stock on the even hundred and one. This is a great help in running back the history of any given stock through the various year books in which are kept the planting notes, the harvesting notes and other data gathered annually, and aids in compiling a history of any stock to which an especial interest may have become attached. In harvesting, each plant is given its actual nursery number, as 1161, and this number together with the year always makes it possible to find in the storage boxes, where the seeds from all choice plants are preserved, the envelope containing seeds of any plant which may be desired; and it also facilitates reference to the notes wherever they may have been recorded.

Wheat Crop Nursery History Book.—After the notes of several years had accumulated the station had books of printed blanks made in which were recorded the histories of all nursery stocks of each kind of crop, as wheat, oats, barley, and field peas. Table LV. shows the notes for one year. This extends over a double page, and a similar page is used for the notes of each year. The margins of succeeding leaves are trimmed off showing the three left-hand columns of the first page, that the one set of names and numbers may be used for the blanks for each of ten years.

Note:—Table LV. is a page from the Crop Nursery History Book, into which are carried the notes of the best plants which are selected from which to plant nursery plots the next year. These notes are copied from the Nursery Year Book, (see Table LVII.) and from the envelopes on which are placed data gathered at harvest time and in the seed laboratory where the seeds are weighed and inspected. Twenty pages, with printed blanks as in this table, are set apart for each group of stocks, two pages being required for the notes of each year. The numbers in the third column are written with red ink and are used much as names for the respective nursery stocks. Succeeding pages have their margins clipped off, showing the names of the varieties, and the red numbers on the first of the ten pairs of pages.

TABLE LV.—Wheat; Crop Nursery History, 1892.

Names of Varieties							Spike		Chaff			Berry												
												Per Cent.												
Names of Parental Stocks I. G.	Minnesota No.	Red No.	Century No.	Nursery No.	Height of Plant	Days Maturing	Number	Length	Color	Smooth or Hairy	Bearded or Awnless	Holds, Per Cent.	Color	Size	Form	Condit'n of Bran	Plumpness	Grade	Names of Crosses	Numbers of Crossed Plants	No. of Crossed Heads	No. of Flowers Handled	No. Grains Harvested	True Cross	Rust	Net Yield	Tabulated in C. K. Y. B. Page
Bolton's Blue Stm	146	1	10501	10519	47	107	8	8.8	M	H	A	85	88	..	85	82	85	85	.....	... .	...	...	...	...	3	7.0	84
Welman's Fife....	528	2	24101	24126	37	99	7	8.0	M	S	A	87	95	...	93	90	91	93	.....	....	...	...	...	...	2	4.4	104
....	.....	3	2	24184	46	99	5	9	M	S	A	89	96	...	95	93	90	95	.....	....	...	...	...	...	3	4.0	102
		4																									
		5																									
McKendry's Fife .	181	6	9301	9302	42	106	6	9.5	M	S	A[b]	90	96	...	96	94	94	95	....	....	...	...	...	...	2	6.4	80
.....	.....	7	.....	9357	45	107	8	8.8	M	H	A	87	94	...	90	88	91	92	.....	....	...	...	...	...	1	6.0	82
		8																									
		9																									
		10																									
Preston	.....	188	11	11801	11840	44	106	7	10	R	S	B	90	94	..	90	90	85	90	{Power's F.} {x Preston}	7633 x 11810	1	14	5	...	6	5.4	90
.....	.....	12	.....	11849	46	106	6	9.5	R	S	B	89	92	...	91	90	86	90	.....	....	...	...	...	...	10	4.7	90
		13																									
		14																									
Advance	185	15	13101	13123	40	106	5	11	M	S	B	83	95	...	92	90	87	94	.. ..	.....	...	...	...	...	4	5.1	92
.....	.....	16	.....	13189	41	107	4	11	W	S	B	89	90	...	90	90	82	89	....	.....	...	...	...	...	9	5.1	94
		17																									
		18																									
Glyndon 811.....	168	19	22901	22929	43	99	7	9.7	W	S	A	90	90	...	93	90	90	90	.....	.....	...	...	...	...	4	5.1	96
.....	.....	20	.....	22938	44	100	7	10	M	S	A	88	88	...	90	88	88	89	.....	.....	...	...	...	...	9	5.2	96
....	.....	21	....	22940	44	99	9	8.7	W	S	A	91	90	...	91	89	88	90	.....	.....	...	...	...	...	8	5.1	96
.. ..	.....	22	.....	22987	45	100	8	8.	M	S	A	88	94	...	95	90	90	92	.....	.....	...	...	...	...	6	6.3	98
		23																									
Bolton's Blue Stm	146	24	26301	26322	42	99	7	7.5	M	H	A	81	85	...	88	87	78	85	{Preston x} {B. B. S.}	11849x26322	2	26	9	...	1	4.4	104
....	.....	25	.....	26387	49	101	4	10	S	S	A	80	95	...	87	91	85	94	....	....	...	...	...	...	5	4.6	106

TABLE LVI.—Blank Form as Made up from the Crop Nursery History Book, Showing the Important Facts of Several Promising Stocks for Five Years.

Names of Parental Stocks.	Minnesota No.	1894					1895					1896					1897					1898				
		Nursery No.	Centgener Strength	Centgener Rust Resistance	Grade	Net Yield	Nursery No.	Centgener Strength	Centgener Rust Resistance	Grade	Net Yield	Nursery No.	Centgener Strength	Centgener Rust Resistance	Grade	Net Yield	Nursery No.	Centgener Strength	Centgener Rust Resistance	Grade	Net Yield	Nursery No.	Centgener Strength	Centgener Rust Resistance	Grade	Net Yield
Power's Fife	485	1781	85	85	90	7.7	13003	80	88	93	26.	13531	90	83	89	18.	4916	86	89	83	5.	15724	92	92	96	5.6
Power's Fife	483	1752	86	87	91	5.6	11247	80	86	92	21.2	13223	90	85	88	16.	4741	85	88.5	78	3.6	15525	91	99	93	5.4
Haynes' Blue Stem	487	1814	91	91	89	2.3	16705	83	93	90	15.5	14024	91	90	85	12.2	5174	87	89.	78	5.6	15921	91	99	92	4.0
Haynes' Blue Stem	489	1846	90	93	88	4.1	18526	81	95	89	18.3	14226	91	92	86	12.9	5351	88	90.	75	7.0	16127	92	96	90	2.6
Power's Fife X H. B. S.		1751/1828	93	....	....	2.8/2.1	11015/17504	90	....	....	11.3/6.5	17140	....	....	....	7.	9248	....	....	80	4.5	20223	....	98	92	4.3
H. B. S X H. B. S.		1828/1828	90	....	....	2.8/2.8	17508/17525	88	....	....	10.3/12.2	17152	....	....	....	6.8	....	....	....	....	....					
H. B. S. X G. 753		1828/1800	96	....	....	2.8/5.4	17525/15531	92	....	....	12.2/9.2	17155	....	....	....	4.5	9703	....	100	81	3.2	21122	....	99	89	3.7
H. B. S. X P. F.		4833/1962	95	....	....	4.4/7.7	15406/23011	92	....	....	17.1/17.6	16936	....	....	....	9.6	7501	....	....	81	5.8	18425	....	99	91	5.7
																	7508	....	....	80	5.2	18521	....	98	84	3.5

In Table LVI. are collected the most important items of several stocks for a number of years illustrating how they can be brought together from the history book that the best nursery stocks may be chosen for multiplication and the poorer ones discarded.

Two small fields of one to two acres each are used for the cereal crop nursery, and two of similar size for the leguminous crop nursery. Only one of the two fields is used each year, the other being subjected to a preparatory process, that the land may be in uniform condition and free from weeds. The field which is not in use is sown to a green crop, as peas or oats, which is plowed under or mowed for hay or silage as the needs of the soil may demand. Care is used to keep the soil in good heart, but not so rich as to cause the plants to fall down, and to have the surface soil uniform in fertility and in mechanical condition. These small fields are admirably adapted to the purpose. Surface drainage is especially attended to, that no injury may result from the soil being washed about during heavy showers. The land is fall plowed and no horses are allowed on the field in the spring, but it is pulverized and made into a fine seed-bed by using the hand hoe and garden rake.

Planting the Seed.— These seeds are planted by hand as shown in Fig. 265. A pointed dibble is used and each seed is placed one and a half inches deep and carefully covered. The plots are cultivated by means of small hand-weeding claws as soon as the plants have appeared, and as often afterwards as the condition of the soil or the presence of weeds may require. The hills are all carefully inspected before the plants have formed tillers, and whenever two plants are found in a hill one is removed.

The Harvesting is mainly a matter of elimination. The two border rows are first clipped off with sheep shears, care being used to remove all the heads and not to injure the remaining plants.

Recording the Notes.— The presence of numerous stocks necessitates the use of system in recording the notes. The planting

notes are entered each year in a Crop Nursery Year Book, referred to in the notes as C. N. Y. B. 1899, C. N. Y. B. 1900, etc. Into this book are entered the planting records, including the nursery

Fig. 268. Removing the border rows.

number of the mother plant of the previous year; the century number of the present year, thus, 101, 201, etc.; the Minnesota variety number; the variety or class name; the date and the number of seeds planted. At harvest time general notes are made in this

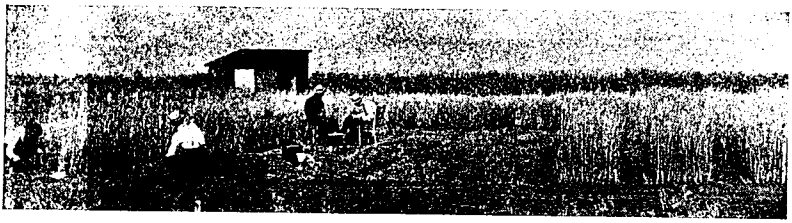


Fig 269. The men at the left are clipping out all the plants except the best, while those in the center are taking notes on the best plants and harvesting them, saving the heads in envelopes. The field-house where the note books are kept at harvest time is shown in the background

book, on the strength and other characteristics and facts regarding the entire plot, leaving all notes on the individual plants to be made on the envelopes mentioned in a future paragraph.

In the left-hand column are Roman numerals and capital letters. All stocks classed under "I." are being improved by selection alone, while all marked, II., are results of crosses which are being selected to large yield and uniformity of type. The character, IV., is used to designate other stocks which are in experiments where a study of methods of breeding, rather than the making of varieties, is the object sought. Columns are also placed in this book for the insertion of the pages in the Wheat Crop Nursery History Book (W. C. N. H. B.) and in the Crop Nursery Year Book (C. N. Y. B.) of the previous year. On the following page is a copy of the blank form used in the year book, in which the planting notes only have as yet been entered.

In making the selection, careful men clip out all but the best plants. In going over the plot the first time about half the plants are removed. A second time half or more of the remaining plants are removed, and a third or fourth time through the plants are reduced to five to ten per cent of the whole number. Thus among twelve hundred plants of Minn. No. 146 only about seventy-five are left standing. In other cases where only one hundred seeds were planted, ten of the best are left for harvesting. The preference is usually given to plants which have several culms of nearly the same height, bearing large well filled heads. See Fig. 270.

Harvesting Choice Plants.—Each of these ten, or seventy-five plants, as the case may be, is given a nursery number. Large paper envelopes are given numbers corresponding to the numbers of the choice plants. On these envelopes is a mimeographed blank form into which are written all the notes regarding the plant, the heads of which are placed within. The spikes are cut off without any straw, and placed in the envelopes and these envelopes in turn are placed in paste-board boxes $7 \times 10\frac{1}{2} \times 12\frac{1}{2}$ inches in size. In case spikes are not dry it is necessary to pack the storage boxes loosely and to leave the flaps of the envelopes open that the grain may dry out and retain strong germinating power.

Seed Selection in Winter.— In the winter season the unthreshed heads of the selected plants are weighed. These gross weights

TABLE LVII.—Blank Form as Filled Out in the Crop Nursery Year Book.

	Nursery No. of Parent Plant in 1898	Cent. No. 1899	Minn. No.	NAME OF VARIETIES, AND OF VARIETIES USED IN MAKING CROSSES.	Date Plant'd	No. of Seeds Plant'd	Plot or Centgener							
							Type	Strength	Rust	Smut	Ergot	W.C.N.H.B. (1221) Page	C.N.Y.B. (1898) Page
IA	138	101	66	Power's Fife	4–18	100						1	
	851	601	51	Haynes' Blue Stem	4–18	100						1	
	921	701	181	McKendry's Fife	4–18	100						1	
	1546	1201	287	McKissick's Fife	4–18	100						1	
IE	2904	2201	157	Glyndon 753	4–18	100						17	
	4601	3401	155	Glyndon 818	4–19	100						17	
IG	6204	4501	226	Improved Fife x $\frac{\text{Blount's Fife}}{\text{Ward's Prolific}}$	4–19	100						37	
	6303	4601	231	Improved Fife x $\frac{\text{Horn Blende}}{\text{Gypsum}}$ x Blodette	4–19	100						37	
	6803	5001	264	Pringle's Defiance	4–19	100						37	
	7003	5201	266	$\frac{\text{Fultze}}{\text{Gypsum}}$ x Horne Blende	4–19	100						37	
IH		11801	289	H. B. S x Glyndon 761	4–21	1180							
		15101	292	Risting's Fife x Risting's Fife	4–22	1180							
IIC				IMPROVEMENT BY CROSSING AND SELECTION.									
	16924	20301	494	H. B. S x H. B. S	4–24	100						54	
	17022	20401	495	H. B. S. x Power's Fife	4–24	100						54	
IID				$\frac{\text{Risting's Fife}}{\text{Risting's Fife}}$ x H. B. S	4–24	100						98	
	18223	21601		Power's Fife	4–24	100						98	
	18315	21801		H. B. S. x Glyndon 753	4–25	100						107	
	21122	25401		$\frac{\text{H. B. S.}}{\text{McKendry's Fife}}$ x Power's Fife	4–25	100						72	
IIE	21725	26201		H. B. S. x Glyndon 818	4–25	100						72	
	22030	26501											
IIG	$\frac{26638}{12070}$	27001	$\frac{146}{188}$	Bolton's Blue Stem x Preston	4–25	4						95	
	$\frac{22675}{10228}$	27201	$\frac{x}{181}$	$\frac{\text{H. B. S.}}{\text{Power's Fife}}$ x McKendry's Fife	4–25	2						95	
	$\frac{236\ 5}{13101}$	27501	$\frac{146}{185}$	Bolton's Blue Stem x Advance	4–25	1						95	

I, in the first column signifies that the stock is being improved by selection II, signifies that the stocks have been crossed.

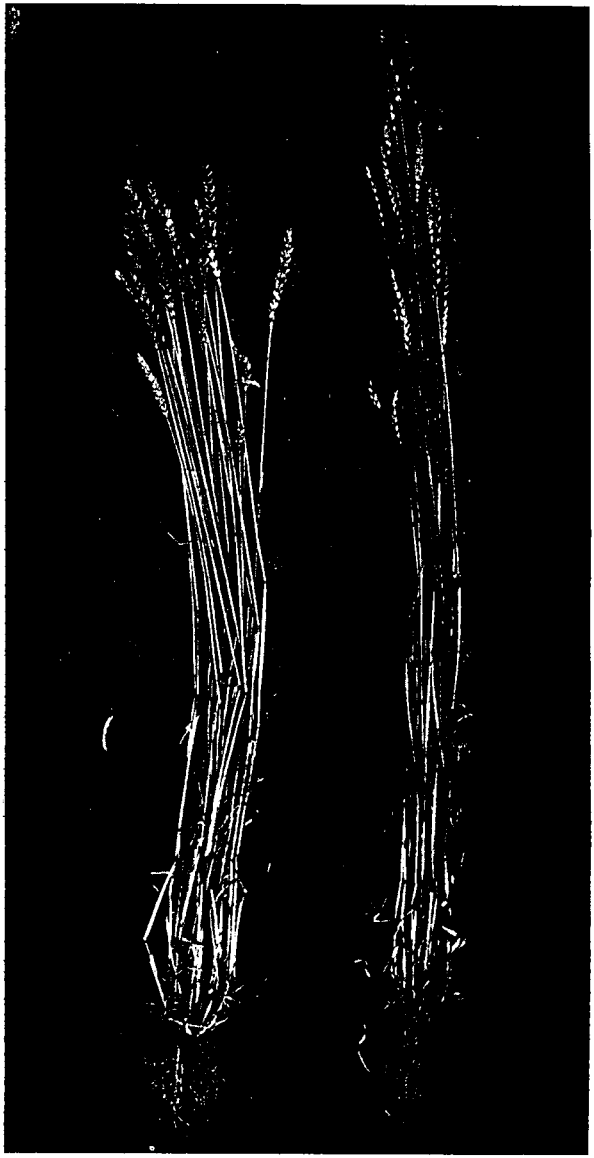


Fig. 270. The plant at the right has culms very uneven in length, while that at the left has no very tall culms, but many of nearly the same height.

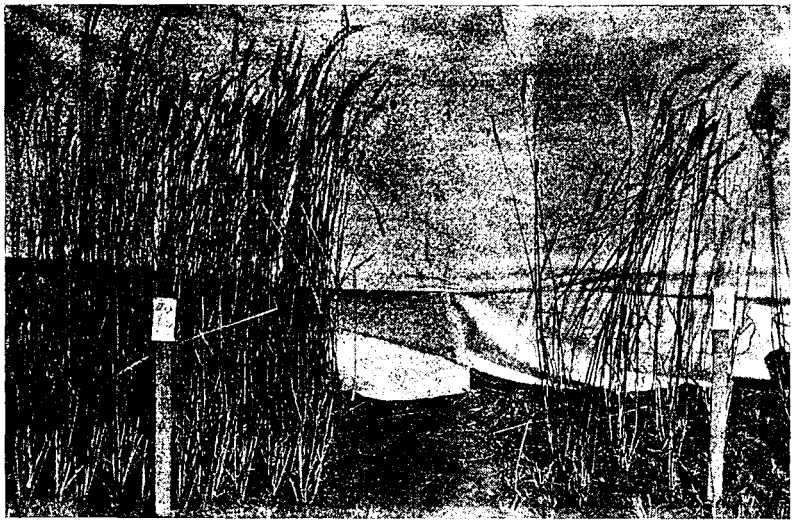


Fig. 271. At the left is shown a plot of 100 plants with the border rows cut away. At the right, ninety of the centgener have been removed leaving the best ten plants to be harvested and stored in the envelopes.

Fig. 272. Taking notes and harvesting the best nursery plants.

Table LVIII.—Blank Form on Envelopes.

I. G. "98" Nursery No. 24126.

WHEAT

Date Ripe	7/30
Height	37
Stiffness	88
Rust	3
Spikes—Number	7
Length	8 c. m.
Chaff—Smooth or Hairy	S
Bearded or Awnless	A
Holds	87
Berry—Color	95
Size	
Form	94
Ergot	0
Loose Smut	0
Stinking Smut	0
Plumpness	91
Condition of Bran	90
Grade	93
Gross Yield	6.0
Net Yield	4.4
C. N. H. B.—221—Page	40
1898 C. N. Y. B.—220—Page	100

give data for eliminating more of the poorer plants, thus avoiding the expense of shelling all but a small number of the very best plants. Before weighing, notes are taken as to the number and length of the spikes, and any other notes which special experiments may require. The shelling is carefully done by hand.

Fig. 273. The seed laboratory where the seeds are stored, where, in winter, all the seeds are weighed and threshed out and the best are selected for planting the next year.

The seeds are then weighed, judged as to quality or grade, and other notes, as the color and form of berries, may also be made on the grain if desired, as in case of cross-bred stocks.

These notes on the right margins of the envelopes can all be laid side by side where the grades and other qualities may be easily compared and the best plants chosen as mother plants of

nursery centgeners the next season or for mothers of new varieties.

Varieties are not at once started from mother plants chosen the first year from among those springing from the 1200 seeds selected from bulk grain and grown in a "full frame." Several of the best plants are chosen and centgeners—one hundred or more plants from a single mother plant—are planted the next season. Here the "strength of row", the average yield of all the plants of the centgener, and other characters, are recorded.

Fig. 274. Small plots where the seed from the nursery plots is being increased to quantities sufficient for field trials.

After choosing the best plants from the best centgeners the remaining seeds are harvested in bulk and at once multiplied. Thus while a few of the very best plants are used for further breeding in the nursery, the bulk of the seed from the centgeners is multiplied, forming a variety which soon enters the competitive field trials.

Recapitulating the Steps in Breeding by Selection we have: 1st. Secure those varieties which yield large crops of wheat of superior quality. 2nd. Plant a large number of the seeds from the bulk grain the first year in the nursery. 3rd. By some suitable method find the choicest plants which are most promising for mother plants. 4th. The second year plant from each of

these a hundred or more plants. 5th. Choose from the strongest stocks the choicest plants as mother plants with which to continue the breeding. 6th. After discarding the poorer plants of these strongest stocks of the second year, save the seeds in bulk from the remaining plants. 7th. Use this bulk seed the next year to plant a small field plot. 8th. The following year there is sufficient seed to sow a twentieth acre plot where it can be regularly compared with the other wheats in the variety tests. 9th. When the twentieth acre plot is harvested there is sufficient seed, if the variety is promising, to supply seed to other stations. By testing the varieties several times the average yields show the relative values of the varieties. 10th.

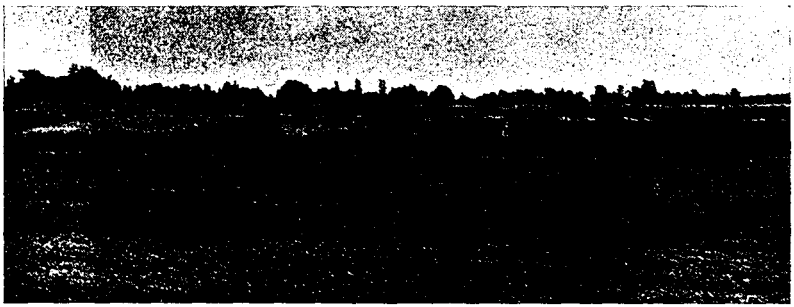


Fig. 275. Uniform field trial plots, 1/20 acre each.

At least the larger part of the new varieties can now be discarded and only those of greatest promise need be retained. 11th. After testing a wheat one or two years it is milled and the flour is tried, as by the gluten test and the baker's sponge test. 12th. The field tests are continued for a series of years and a new wheat is disseminated when it has been fully demonstrated that it is of special value in the entire state or in some particular locality in the state. 13th. Great care is used in distributing new wheats of promise. They are sold to farmers who have good lands free from noxious weeds and who will raise crops of the seed for sale.

Selecting varieties for each soil and each locality must, of necessity, proceed but slowly. Promising varieties are very re-

Fig. 276. The first five-acre field of Minn. No. 163 wheat, in 1898. This variety came from a single plant in 1892, and was first disseminated in 1899.

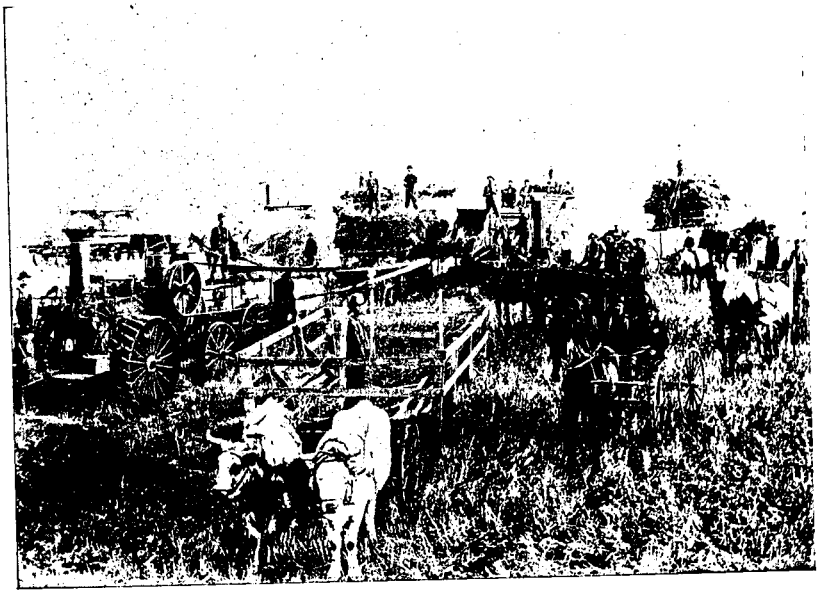


Fig. 277. A large steam threshing outfit in operation in shock threshing. Self-feeding and measuring attachments; "basket" grain racks; hundred bushel grain boxes or tanks on the wagons; cook shanty on wheels where the crew is "boarded."

luctantly discarded. But the introduction of many varieties would lead to a confusion of names, and with the aid of the several substations it seems wise to reduce the number to be distributed to the minimum. If several are disseminated within a decade, each will find that portion of the state where it is adapted to produce the best crops of wheat.

CROSSING FOLLOWED BY SELECTION.

Bolton's Blue Stem and Minnesota No. 163 have been chosen as two wheats to use as foundation stocks in producing cross-bred wheats. Crossing followed by selection as a means of producing improved varieties of wheat has some features not necessary in the improvement by the method previously described by selection alone. To secure stocks for crossing the varieties are first introduced into the field crop nursery in full frames of bulk seed, and are subjected to rigid selection for two or more years, as in improvement by selection. From among these stocks strong yielding plants are taken for the parents of crosses. Thus the best plants from the best varieties are used for foundation stocks in making out-crosses and in-crosses, and time is not wasted on weak varieties nor on weak plants of good varieties.

How Wheat is Cross-Pollinated.—The stocks of wheat to be used for crossing are grown in the nursery, where each plant has an area 4 x 4 inches square. When approaching the flowering period superior plants are chosen and marked with a card placed in a tin label, which is borne by a tall stake. From some of the largest spikelets all the florets are removed except a dozen, more or less, of the strongest ones. This is done just before these florets are ready to blossom, that the anthers may be removed before they break open and cause self-fertilization. This work must be done with much care. If handled roughly the florets are often so injured that fertilization is not effected. If the anthers are permitted to become too nearly ripe they usually burst open while being removed, and cause self-fertilization. Since the florets open very early in the morning it would seem wise to remove the an-

Fig. 278. Crossing wheat.

2. 1. 3.

Fig. 279 No. 1—Blue Stem spike chosen for female flowers; 2—same after removal of all florets except 14 of the strongest; 3—Fife spike from which pollen is used.

thers in the afternoon and apply the pollen early the next day; or, in case the florets are not yet ripe, to add fresh pollen the second day. General experience is the guide so far, since exact experiments to determine the best time and manner of removing the anthers has not been completed.

Fig. 280 shows the operator removing the smaller spikelets at the base of the spike. The upper spikelets are also removed as shown in Fig. 279. When all the spikelets excepting the six or

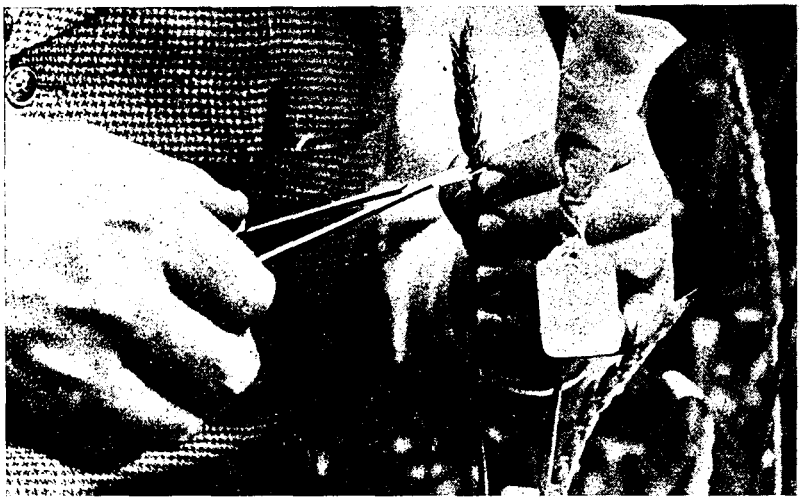


Fig. 280. Removing the flowers of the smaller later spikelets at the base of the spike, leaving only the strongest florets to be supplied with pollen from another plant. In front of the operator's left hand is a spike which has been cross-pollinated, then covered by wrapping about it a piece of tissue paper, which is tied on.

eight in the center of the spike are removed, the small florets in the center of these are also clipped off with sharp pointed dissecting scissors, leaving only the twelve to sixteen strong lower florets of the several spikelets, all being at nearly the same stage of maturity. Care is used to remove all the anthers from every one of these flowers and to so withdraw them by means of sharp pointed tweezers that no pollen is left within the floral envelope. The anthers gradually turn yellow when nearing ripeness. The eye soon becomes experienced in determining, from the partially

changed color, when the floret is nearing the period of fertilization. Florets found so far advanced that there is danger of self-pollination are discarded and removed. The anthers having been removed from all the flowers, the spike is covered with tissue paper. This is wrapped loosely about the spike and tied above and below to prevent the entrance of foreign pollen. In case of flowers which are nearly ripe, pollen is at once applied before covering the flowers. Careful experimentation might show that it would be economy of time in producing a given number of cross-bred grains to apply pollen at the time of emasculating the flowers and again the next morning, and even a third time early the second morning. However, since each cross-bred kernel is capable of varying so as to make a number of types, it is not difficult to produce more new varieties than the station has time to develop and test. Pollen from the plant used as the male parent is secured by selecting anthers which are ripe, as shown by their yellow color, and by the ease with which the pollen grains roll out when the pollen sacks are broken.

The operation of removing the anthers and of inserting pollen cannot be shown in detail by means of photographs. The fine points of the tweezers are inserted between the flowering glume

Fig. 281. Opening the floret to remove the anthers.

and the palea, as shown in Fig. 281, and as they are allowed to spring apart the floret is opened, and the anthers removed. Care must be taken to avoid injury to the stigma and to the ovary by opening the floret too wide, or by otherwise using the parts of the floret in a rough manner. The difficulties of removing the anthers are shown in 5 and 4 A in Plate XXV., page 413. To insert pollen the tweezers are again used to open the floret, as in Fig. 282. The pollen is carried into the floret by grasping a ripe anther in the tweezers and inserting it between the two portions of the chaff, care being used that the pollen sacks are open and

Fig. 282. Inserting a ripe anther from the plant used as the male parent into the floret of the plant used as the female parent.

that pollen falls thickly upon the stigma. When ripe the pollen grains no longer adhere to the walls of the pollen sacks but roll about as particles of flour. These ripe anthers are taken from florets on a spike of wheat plucked from the plant used as the male parent. Other plans may be used, as employing a small steel spatula to carry the pollen to the stigma.

Of the flowers handled, the percentage producing seeds has been larger and more of these have proven true crosses when the labor in crossing has been executed with great care. From

five to twenty-five per cent. of the flowers handled produced seeds, and part of these are not true crosses, as shown by their resemblance to the mother plant only, self-pollination having occurred. Those plants resulting from out-crossing which do not show any of the characteristics of the variety used for the male parent are discarded as not being true crosses, though it is recognized that an occasional true cross may so completely resemble the female parent as to not show the male type, at least not in the first two generations.

In making in-crosses it is very important that the emasculating and pollinating be done with care, that all resulting plants may be true crosses, since the parents are similar and there are no means of determining whether there is a true cross or the seed has resulted from self-fecundation.

The nursery number of the plant used as the male parent, as well as the number of the plant to which the pollen is applied, also the date of handling, are placed on a card which is attached to the culm below the crossed head. When ripe both parent plants are harvested and a record made of their yield, so that the history of the "performance record" of the parent plants may be complete. The handled spike is placed in a small envelope, which is placed with the remaining heads of the mother plant in a large envelope.

Each kernel of wheat found in the handled spike becomes a mother plant. The first year it is placed in the nursery with an individual number. The second year a hundred, more or less, of the seeds of each plant of the first generation are planted. Any stocks which do not appear reasonably strong are at once discarded.

Here the method of procedure is as yet an unsettled problem. So far it has been our custom to save only the one best plant from the centgener. It now seems logical to save several, or to save all the strong plants in bulk, grow them in field plots for a few years that they may have time to vary, and then to introduce them into the nursery selection again, using one or two thousand seeds and saving only several of the best resulting plants. Henceforth the selection of the best plants in the nursery and

the multiplication of their seeds take the same course as where varieties are originated by selection alone, as described in a former section.

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 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. We have abundant proofs of the greater variation of cross-bred stocks.

In Fig. 283 is an illustration of unusual variation resulting from crossing two varieties of wheat. Of the three spikes in the upper row the one at the left is the Fife parent, the one at the right is the Blue Stem parent, and the one in the middle represents the average of the spikes produced in 1894 on plant No. 1874, though there was considerable variation in the several spikes. One hundred seeds were planted in 1895 from this mother plant, and all the variations represented in the middle and lower rows were found. In the progeny of no other cross-bred seed have we seen such a marked tendency to vary. The two varieties of wheat which were crossed never have more than very short awns, while among the progeny are several types with awns of various lengths. The chaff on some of the plants was hairy like the Blue Stem parent, on others smooth like the Fife parent, thus giving proof that a true cross had been made. In form of spike, some resembled one parent and some the other, while numerous spikes were quite different from either in this particular. Thus the second head from the left in the middle row had a square form like the so-called "square-headed" wheats. The second from the left in the lower row has its rachis shortened at the upper end, producing a broader top to the spike, as with the so-called "club wheats." Several of the plants had dark brown chaff, others chaff with a light metallic tinge, each of which are like types of wheat quite distinct from

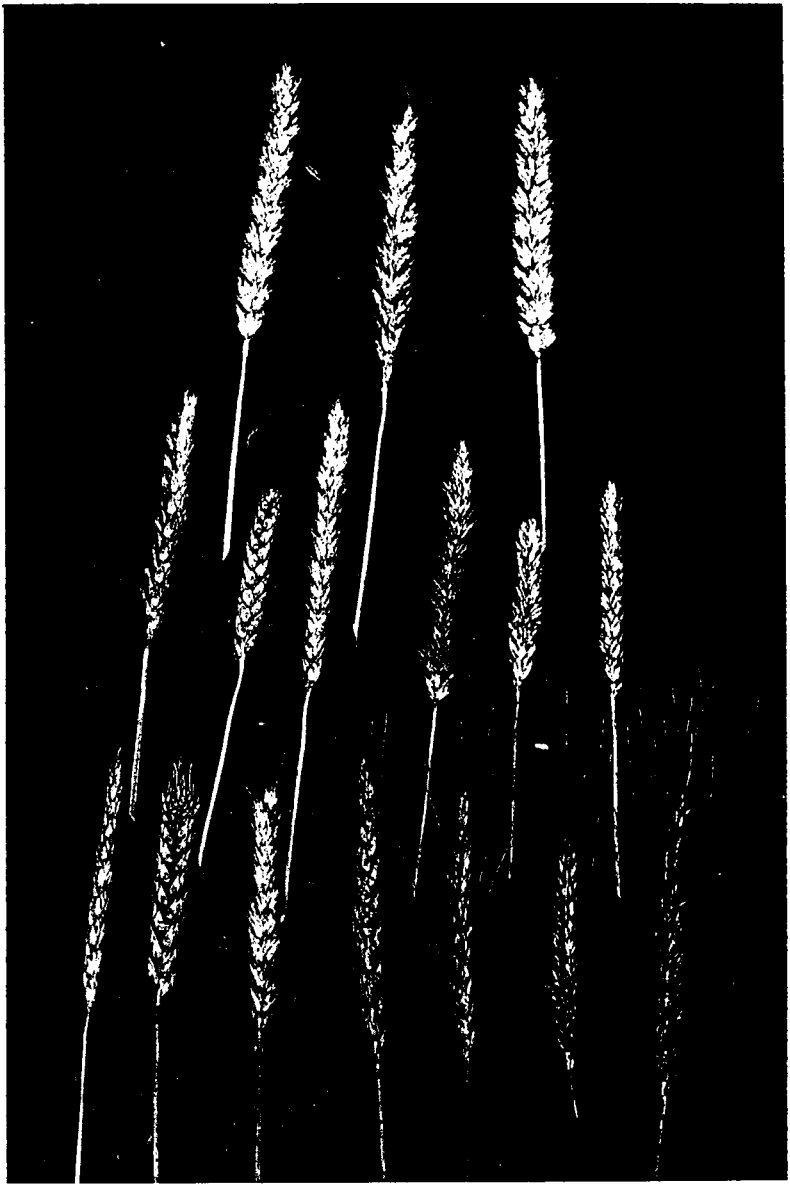


Fig. 283. In the upper row the right-hand spike is the Blue Stem parent, the left hand one the Fife parent, and the central spike is the average spike of the single plant of the first generation. The spikes in the middle and lower rows are forms which appeared in the 100 plants of the second generation, all of which came from seeds from the single plant of the previous year.

either of the white chaffed parents of this cross. The causes of these variations, the laws governing them, their relation to parental wheats which may have entered into previous crosses of either parental kind, a probability of the continuance of the tendency to vary, and similar questions suggested by these results, —open up many questions for experimentation.

Great variation occurred in strength and also in yield. In the case above mentioned stocks from several plants grown in 1895 were planted in 1896. There was much variation in the strength of the several stocks. In some nearly all the plants were strong, in others most of the plants were weak; and there was great variation in the strength of the plants in the plot. The best plant was chosen from each of the three stocks, and a plot was planted from each of these plants in 1897. From two strongly bearded plants of two of the best stocks of the previous year plots grown in 1897 proved to be very strong, apparently worthy of making into two varieties, though both came from the same cross-bred seed of 1893. A third plot planted in 1897 was from the best plant of a weak stock of the previous year. It had been observed in 1896 that some of the plants from this cross bore but few seeds, and this entire stock was almost sterile. The seeds grown in 1896 generally failed to grow in 1897. Only eight per cent. produced mature plants, and these were weak. This branch of the stock, unlike the two bearded branches, had apparently inherited the tendency to vary strongly in the downward direction, or was a non-fertile hybrid,—a mule.

The two strong stocks were continued in the nursery in 1898, by planting plots from the strongest plants of each, and they again produced plots of vigorous plants, one of them being among the very strongest stocks in the nursery.

This is an extreme case of variation resulting from crossing two varieties which are not closely related, as shown by the hairy chaff of one parent and the smooth chaff of the other. And there are variations towards stronger and towards weaker types. The weaker forms are very easily eliminated by selection. The labor required is to select from among the better forms those which

are the very best. As it now appears, one of the best two stocks will prove superior, but it may require a number of field trials and milling tests to decide which of these wheats is most profitable to grow, or it may be found that one is useful in one part of the state and the other in another part. Such variation is engendered by crossing wheats that from a single kernel a number of useful, yet distinct, varieties of wheat may arise. The production of variations requires only a few minutes or at most a few hours. Years are required to properly select the progeny of a cross-bred stock so as to secure the most useful varieties.

Time Required to Reduce Cross-bred Wheats to a Uniform Type.—Several wheats known to be true crosses have been developed by multiplying the seeds from single mother plants of the second to fourth generation after the cross, and in each case little or no variation has occurred among the plants in the field.

In 1894 a plant was grown from a grain resulting in 1893 from a cross between Blue Stem and Fife parents. The seeds of this plant were placed in the nursery in 1895. Of the resulting plants seventy-two per cent. had hairy chaff like the Blue Stem, and twenty-eight per cent. had smooth chaff like the Fife.

In 1896 seeds from several hairy plants produced plants seventy-six per cent. of which had hairy chaff, and seeds from several of the smooth chaffed plants produced plants eighty-two per cent. of which were smooth chaffed.

In 1897 seeds from hairy chaffed plants of the previous year produced plants of which ninety-eight per cent. were true to type; and of the plants from seeds of smooth chaffed plants ninety-seven per cent. were without hairs on the chaff.

In 1898 of the hairy chaffed type ninety-nine and one-half per cent. and only ninety-one per cent. of the smooth chaffed plants came true to type.

If newly originated cross-bred wheats can be reduced to type in so few years, as is indicated by the facts above mentioned, the making of cross-bred varieties is not difficult from the standpoint of uniformity. In the effort to secure large yields with superior quality, botanical appearances, it would seem, will take care of

themselves. These facts indicate also that individuals 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 very small when compared with the increased value of varieties which will raise the average yield per acre even only a part of a bushel.

FIELD MANAGEMENT FOR WHEAT.

The average yield per acre of wheat in Minnesota is several bushels below where it should be maintained, and the quality is not as good as is warranted by our exceptional conditions of soil and climate. The cultivation of this crop is not given that attention which its importance in Minnesota farming demands, nor which the intelligence of our farmers should guarantee. In their endeavor to induce farmers to leave off exclusive wheat growing, those who seek to promote better methods of farming have too often berated the crop rather than its abuse; and the best methods of cultivating wheat have not been sufficiently emphasized. While wheat farming should be condemned, raising wheat as one of the prominent features of the general farm is worthy of much encouragement.

There are many farmers who cannot profitably bring wheat into their system of farm management. This is especially true of the owners of light sandy lands who cannot afford to grow crops which will remove so much fertility from the farm as does wheat. Some dairymen and stock growers can make better use of their land in producing stock food than by growing grain for sale. But most of the farmers of the state can use this crop with profit on a limited portion of their arable fields. Those who have the most live stock can produce the largest and most profitable crops of wheat, and they, having an abundance of manure, can best afford to grow those crops which exhaust the fertility of the fields.

HOW SHALL WE ROTATE CROPS?

Systematic rotation, using some crops to prepare the soil for others, is not so clearly understood, nor its importance so fully

realized, as would be greatly to the advantage of our farmers. Our rich soils have led us into profligate and wrong practices in the management of our fields. Rotation is the planting of crops in a regular order of succession, which is repeated from one series of years to another. An example of a simple, short rotation is as follows: Wheat, clover, corn; wheat, clover, corn; etc.

Since the small cereals succeed best after cultivated and grass crops, and these crops succeed well after the cereals, there is an advantage in growing these classes of crops in alternation, rather than in planting each continuously upon separate fields. Next to producing profitable crops and to keeping up the fertility of the soil, keeping down weeds is the most important result of rotating the crops in a given field.

Some of the points which must be considered in planning a rotation of crops on the fields of a farm may be enumerated as follows:

1. Devise a plan of rotation, or plans of rotations, which will maintain the fertility of each field and will at the same time give yearly profits from the farm.

2. Devise and make a drawing of a plan of the farm which shall be divided into several permanent fields. Where practicable each field should be fenced and connected with the barnyards by a centrally located lane, that each field may be pastured during any portion of year.

3. Where the farm is all arable land it pays best, as a rule in Minnesota, to bring it all under systems of rotation, unless the location of some fields seriously interferes,—none being laid down to grass permanently, nor other portions subjected to growing continuous crops of grain.

4. To retain the larger part of the fertility on the farm, the major part of the land should be planted to coarse forage and concentrated grains to be fed to live stock, growing grain, potatoes, and other exhaustive crops for market on only twenty-five per cent., or less, of the total area.

5. In addition to a good plan of rotating the crops where corn,

grass, clover, etc., are used to keep down the weeds, and to keep up the fertility for the exhaustive crops, each crop should be planted, cultivated and harvested in the best possible manner.

6. Keep sufficient live stock to consume most of the crops produced; using them to make as large quantities of manure as is practicable. This manure should be most carefully saved, and spread rather thinly on the fields, that its greatest effect may be secured.

7. Avoid turning under ripe weed seeds; kill out all noxious weeds, as mustard, quack grass, burdock, thistles, etc., by raising special crops, by bare fallowing, or by attacking each individual plant as the particular kind of weed may require.

8. Grow wheat, flax, barley, oats, potatoes, and other exhaustive crops for sale when they are sufficiently profitable to equal the cash returns for live stock products, and pay also for the decrease they cause in the fertility of the fields.

9. A farm on which one-third of the land is devoted to growing grain, one-third to growing grass, and one-third to growing rough forage for feeding live stock in winter, can be kept up in fertility if part of the grain, as well as all of the forage, is fed on the farm.

10. Too much land in pasture can be avoided by growing corn, sorghum, and other crops for soilage or for succulent annual pasturage in midsummer, when pasture grasses are dormant—these crops to be cured and used for dry fodder if ample rainfall results in such a heavy yield of forage in the regular pasture fields that they are not needed for pasturage.

11. A few small fields near the barn are needed on which to grow annual forage for soilage, silage or dry fodder, or crops of roots in alternation with the grains, for which these cleaning crops so thoroughly prepare the soil.

12. Rotation of crops, thoroughly planned, and held to in a systematic though not too rigid manner, brings with it a more orderly arrangement of the farm business, and the farmer works to greater advantage, with clearer purposes, and efforts centered for a longer time on definite objects. His work has greater

cumulative effects. He has larger ultimate objects to work for, and has greater interest and pride in his work.

PLANS FOR CROP ROTATION.

In Fig. 284 is given a plan for rotating the crops on a 160-acre nearly level prairie farm. This particular rotation would suit some farms in southern Minnesota, and with minor modifications it would work well on many farms.

Lack of space here will not admit of an extended discussion of how to use this kind of a drawing, with accompanying table, for a farm not planned as is this one. Those who are apt in arithmetical and mechanical problems will be able to make similar plans and tables for the future arrangement of their farms and field crops.

This farm is arranged for two sets of fields, one of six fields of twenty acres each, the other of three fields of ten acres each. On the six larger fields there is a six-year rotation. In this rotation corn is followed by wheat, and with the wheat timothy and clover are seeded. If the grass does not grow sufficiently well to make a stand it is plowed under and wheat and grass are again sown. The grass is used for meadow for one or two seasons, and the third (or the second and third) year it is used for pasture. Where more convenient some fields may be used for meadow for the two or three years, and other fields may be used for pasture during their periods in grass, though there are advantages in having all the fields fenced so that the aftermath and other shift pastures may be utilized, and so that the grass may be in pasture during the last year. The pasture is followed

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Note.—The following convenient classification of pastures and meadows is used:
Permanent Pastures.—Lands which are sown to grasses with a view to using them permanently as pastures.
Rotation Pastures.—Fields on which grasses and clover used for pasture are grown in alteration with grain and cultivated crops under a system of rotation.
Annual Pastures.—Fields on which are grown in the rotation annual crops, as rye, rape, or corn, which are pastured off.
Shift Pastures.—Second crops, as aftermath on timothy, clover, or other meadows; grain stubble, standing corn stover; grasses used for pasture in the early spring before plowing for fodder corn or other late planted crop; rape or turnips planted among grain and pastured off in autumn; crops injured by hail or otherwise and used for pasture before being plowed down, etc.; etc.

by a small grain crop. Here sufficient oats and barley should be grown for feed. If more grain is grown than can be fed out, wheat or flax may be substituted for a part of the oats or barley during this sixth year. The seventh year the rotation is again begun with a crop of corn.

The rotation shown in Fig. 284 and Table LIX. provides about the right proportion of grain and feed crops for a farm centrally located in the southern half of the state. In the heavy lands of the Red River Valley more small grain might seem wise, and on our thin soils in some sections of the eastern portion of the state less grain would be better. The sketch of the rotation on the farm, together with the tabular statement, is not given as a model so

Table LIX. Showing Crops on Each Field Each Year.

	Corn.	Wheat.	Meadow.	Rotation Pastures.	Annual Pastures.	Oats.	Barley.	Flax.	Mangels.	Potatoes.	Fodder Corn.
1902	A 20	B 20 I 10 E 10	C 20 D 20	G 20	H 10	I 10	.....	.....	F 2	F 1	F 7
1903	I 20	A 20 H 10 B 20	C 20	D 20	F 10	G 10	.....	G 10	E 2	E 1	E 7
1904	G 20	I 20 D 10 F 10	B 20 A 20	C 20	E 10	D 10	.....	.....	H 2	H 1	H 7
1905	D 20	G 20 E 10 I 20	A 20	B 20	H 10	C 10	C 10	.....	F 2	F 1	F 7
1906	C 20	D 20 H 10	G 20 I 20	A 20	F 10	B 10	B 10	.....	E 2	E 1	E 7
1907	B 20	C 20 D 20 F 10	G 20	I 20	E 10	A 10	.....	A 10	H 2	H 1	H 7

Note.—The letters in the squares under the columns for each crop indicate the fields, as named in Figs. 284, 285 and 286, and the figures show the acres of the crop planted in the respective fields.

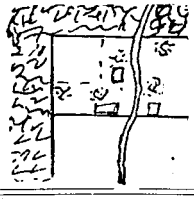
MAJOR ROTATION.—Fields A, B, C, D, G and J.

1. Corn—C. 1. Wheat—W. 2. Meadow—M. 1. Rotation Pasture—R. P.
1. Oats, Barley, Flax or Wheat—O., B., F. or W.

MINOR ROTATION.—Fields E, F and H.

Wheat—W. Fodder Corn, Roots and Potatoes—F. C., R. and P.
Annual Pasture—A. P.

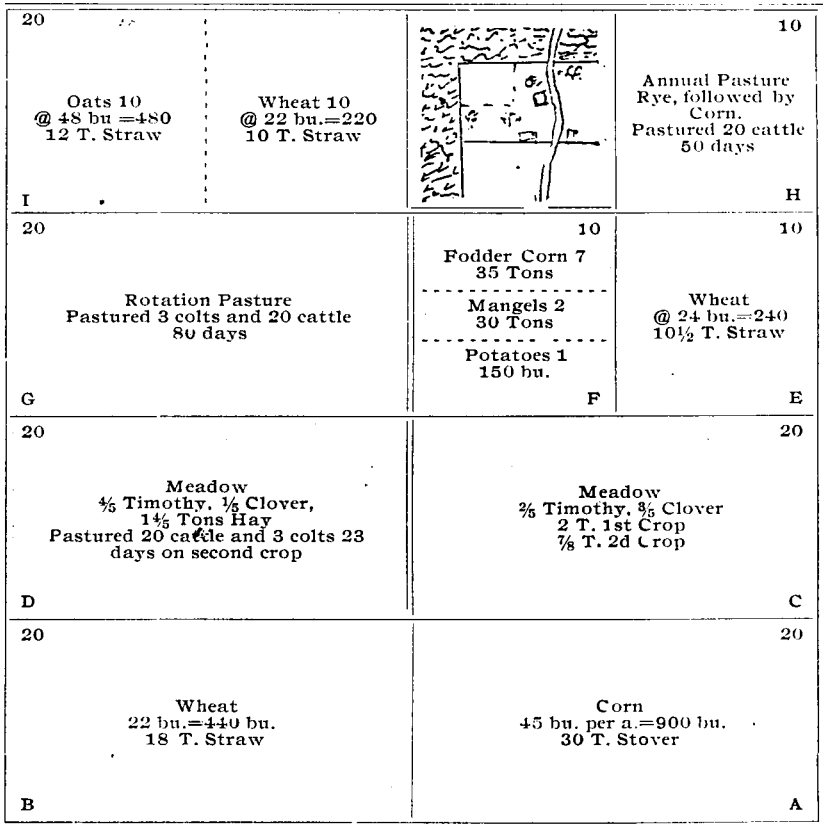
Fig. 284.—Rotation of Crops.

20 O., B., F. or W., 1902. C., 1903. W., 1904. M. or W., 1805. M., 1906. R. P., 1907. I		10 A. P., 1902. W., 1903. C. F., R. and P., 1904. A. P., 1905. W., 1906. C. F., R. and P., 1907. H
20 R. P., 1902. O., B., F. or W., 1903. C., 1904. W., 1905. M. or W., 1906. M., 1907. G	10 C. F., R and P., 1902. A. P., 1903. W., 1904. C. F., R. and P., 1905. A. P., 1906. W., 1907. F	10 W., 1902. C. F., R. and P., 1903. A. P., 1904. W., 1905. C. F., R. and P., 1906. A. P., 1907 E
20 M., 1902. R. P., 1903. O., B., F. or W., 1904. C., 1905. W., 1906. M. or W., 1907. D	20 M. or W., 1902. M., 1903. R. P., 1904. O., B., F. or W., 1905. C., 1906. W., 1907. C	
20 W., 1902. M. or W., 1903. M., 1904. R. P., 1905. O., B., F. or W., 1906. C., 1907. B	20 C., 1902. W., 1903. M. or W., 1904. M., 1905. R. P., 1906. O., B., F. or W., 1907. A	

Note.—The letters in the lower corners of the several fields of this 160 acre farm are used as names of the respective fields, all of which are fenced; and the figures in the upper corners show the number of acres in the fields. The crops grown in each field for each of six years are shown in the center of the field by the abbreviations, which are explained above. As shown here and in Table LIX, the crops are alternated from field to field in such a manner that nearly similar amounts of each crop are grown each year. By adding crops in the same order of succession, the rotation can be continued indefinitely for each field.

much as to illustrate the method of making a working plan which will be on record for reference at any time. At the close of each crop year the plan should be redrawn, if any changes are needed, that they may be inserted in the new plan and in the tabulated statement. Besides this general plan, another plan of the farm should be drawn at the end of each year, giving the actual history of the crops grown the previous year. Such a plan for the year 1902 is shown in Fig. 285.

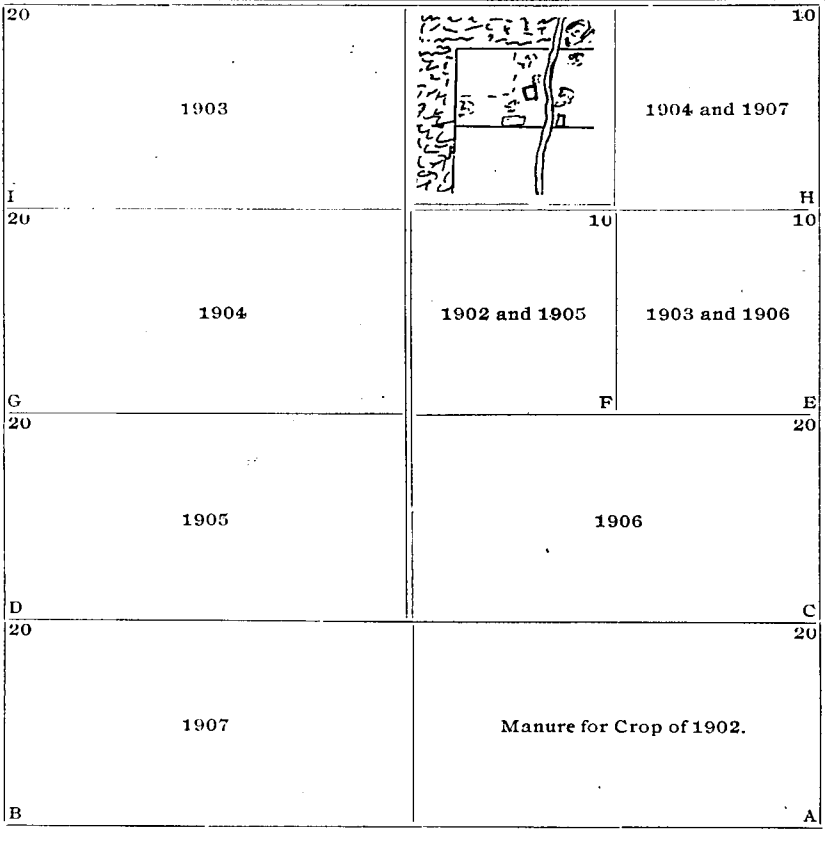
Fig. 285.—History of Yields of Crops Grown in 1902.



Note.—Fig. 285 shows a plan of recording the history of the crops on each field for a given year. Such a history for each of ten years would be very interesting and valuable as an aid to further plan the farm and field management.

Since the manure should be applied to the corn crops in the major rotation, and to the cultivated crops, as fodder corn and roots, in the minor rotation, the plan for manuring the fields can be shown in another drawing as in Fig. 286. This provides that thirty of the 150 acres shall be manured each year; the fields of the major rotation, receiving manure once in six years, and the fields in the minor rotation once in three years. Since the fields

Fig. 286.—Dates for Manuring Each Field.



Note.—In Fig. 286 is a plan of the farm shown in Figs. 284 and 285, in which are noted the years in which manure is to be applied to each field. By comparing this Fig. with Fig. 284, it will be seen that fields A, B, C, D, G and I are manured every sixth year when the field is planted to corn; and that fields E, F and H are manured every third year when fodder, corn, roots or potatoes are planted.

of the minor rotation may become too rich for crops of wheat, if manured every third year, and since the larger fields will take care of more manure, it may be best occasionally to manure these smaller fields only once every second course, or every sixth year. Spreading the annual accumulation of manure out over twenty or thirty acres of ground will insure that no piece of land be at any time too heavily manured for wheat, even though it be heavy land. On our richer lands ten tons of manure per acre applied to a corn crop grown preparatory to growing a crop of wheat is better than more. In other words, we get more benefit to wheat from manure if spread thinly than if applied to a lesser amount of land. And this is also true regarding the crop of corn or roots which should be grown between the manuring and a crop of wheat. It will be observed in manuring on the minor rotation fields that a cultivated crop or a crop of annual pasturage is grown after the manure is applied before the wheat is planted. While wheat receives a benefit from a direct application of stable manure from being better nourished, it also receives an injury which often more than counter-balances the benefit. Its growth of leaves, stems and roots is made too strong in the early part of the season, and the overgrown plants produce comparatively little seed of poor quality. The less active residue of the manure when wheat follows a crop of corn to which manure was applied greatly benefits the wheat without injuring it, and in the interim the corn will have taken most valuable toll from the manure. Unlike the wheat, corn gets great good and rarely any injury from freshly applied barnyard manure.

Fig. 287 shows a 160-acre farm with most of its fields growing grain continuously, while on a comparatively small portion of the land near the buildings permanent pastures and meadows are maintained.

There is a most serious loss in two ways. The permanent pastures in our climate, subject as it is to summer droughts, do not yield well; not so well as rotation pastures. But worse than this is the loss from poor crops of grain on the remainder of the farm. These outer fields need the beneficial influence of being

occasionally seeded to grass, and the fields now used for pasture would produce excellent grain. More land should be in grass, less should be in grain, and more stock should be kept as a means of retaining and even increasing the supply of available plant food in the fields. The difference of profit under the two systems of field and farm management is brought out in the next section.

Wheat Farming vs. Wheat on the General Farm.—The history of all Minnesota counties which have been settled for twenty years or longer is similar in that good crops of wheat were pro-

Fig. 287.—A Poorly Planned Farm.

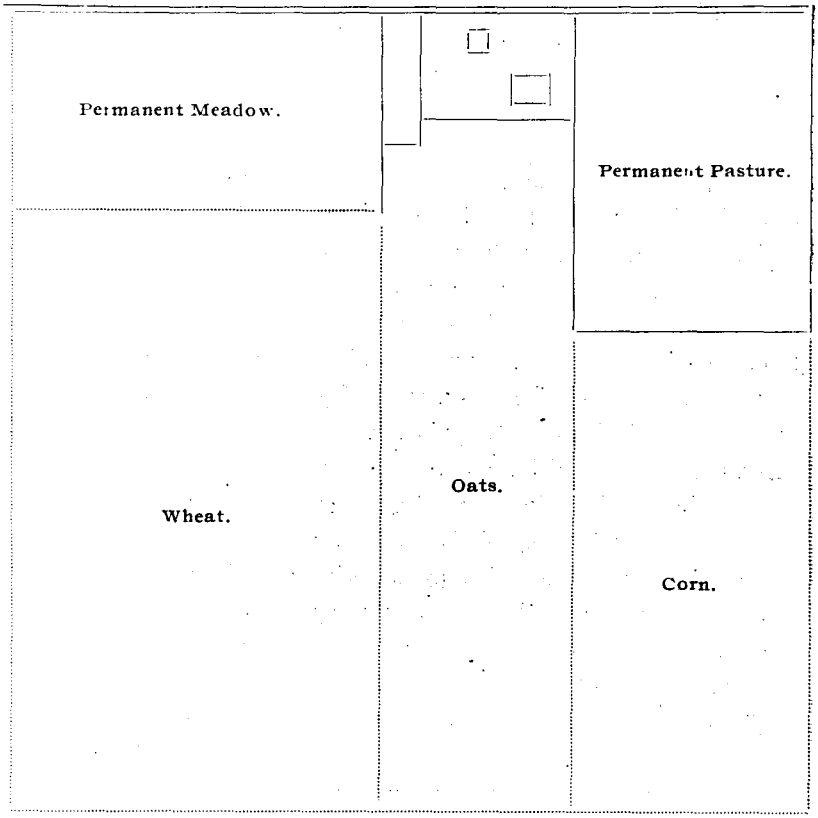


Fig. 287. A poor rotation on a grain farm of 160 acres. The only rotation is to change the wheat with the oats and corn, alternate years. Dotted lines mark fields and solid lines mark fences.

duced for a period of ten to twenty years, but sooner or later there was a decline in yield and in quality. There was an occasional good crop, but the yields and grades become more irregular and unsatisfactory. The comparatively low average yield per acre, with the prevailing low prices, resulted in small profits to the farmers. This decline in wheat crops has been observed in all parts of the state; earlier in southeastern counties and during recent years in the western and northwestern counties. And adjacent states have had the same experience. Some of the causes can be enumerated, only part of which operate in any one district in any given year. Prominent among these causes of reduced crops of wheat may be mentioned rust, weeds, chinch bugs and smut.

On the other hand, farmers and communities which have introduced large numbers of domestic animals into their plan of farm management and have practiced rotation in their field crops, with wheat as only one of the principal diversities, have met with much better financial success. This fact has come to be generally recognized and the proof has recently been placed on a mathematical footing by means of statistics gathered by Mr. L. G. Powers, then State Commissioner of Labor. From the records of mortgage foreclosure sales in the wheat growing counties, and also in counties where wheat is only one of several products, among which live-stock and dairy commodities are prominent,

TABLE LX.—Proportion of Mortgage Foreclosure Sales for 18 years in the State, in Wheat Counties, in Counties where Diversified Farming is Practised and in Suburban Districts.

Years	Entire State 1 to	Average	Fifth District Hen'pin Co. 1 to	Average	Stock and Dairy counties 1 to	Average	Wheat counties 1 to	Average
1880-1	135		299		108	108	183	
1884-5	130		329	314	196		83	95
1886-7	167		243		306		107	
1890-1	144	151	166		295		94	118
1892-3	200		171		396	356	141	
1894-5	130		98	94	352		81	98
1896-7	153		83		320		115	
Average	151		199		282		115	

he has collected the average mortgage foreclosure sales showing that wheat farming has not been so profitable as diversified farming. In Table LX. are given his summaries showing the relative mortgage foreclosure sales in the two classes of counties. The summaries are given for biennial periods and extend through eighteen years. The left-hand column of figures shows that in the entire state there was sold under mortgage foreclosures one acre to every hundred fifty-one acres of assessed lands, the range being from one acre in one hundred and thirty to one in two hundred acres.

In the right-hand column, showing the proportion of mortgage foreclosure sales in the wheat-raising counties of the western and northwestern parts of the state, the average rises to one acre sold under mortgage to every one hundred and fifteen acres assessed; the range for the biennial periods being from one in eighty-one to one in one hundred and eighty-three. The latter is for the biennial period of 1880-1, at which time comparatively few of the many mortgages, then newly made, had fallen due. During the last fifteen years the condition of the farming business in this "wheat belt" had not become better nor particularly worse. The mortgage foreclosure sales of farm lands averaged about one-fourth more than for the entire state.

In the next to the right-hand column are figures representing the proportion of mortgage foreclosure sales in the southeastern corner of the state. Here, at the beginning of the period covered by the statistics, wheat was still grown in large quantities, and the proportion of land sold under mortgage to the total on the assessment rolls was one to one hundred and eight. Very soon after this the farmers began to increase their herds, to raise timothy and clover seed instead of wheat, to grow corn for stock and to develop co-operative dairying. The effect on their prosperity was immediate and lasting. The figures in the table show that the mortgage foreclosure sales soon ran down to about one-fourth the former proportion, and the local bankers testify that the farmers became lenders rather than borrowers of money. It is not too much to say that still better systems of field and farm

management could be practiced which would add as much more to the prosperity as has the change from grain farming to general farming. Better farming has already been entered upon, and really good farming is sure to come at an early date.

In marked contrast to the prosperity of the farmers in the district where general farming has gotten a fair foothold is the condition of land speculators near the large centers of population. Mr. Powers has tabulated the averages for the Fifth Congressional district, which is composed of Hennepin county, in which are located the city of Minneapolis and the summer resorts about Lake Minnetonka. The figures are given in the center of the table. The mortgage foreclosure sales here increased about as they had decreased in the southeastern counties. Doubtless in the Fifth district the mortgage foreclosures were largely due to the payment of speculative prices for lands near the city or near the lake. When the hard times came the large debts could not be carried, and the speculators lost the lands.

In conclusion Mr. Powers says substantially as follows: The agricultural department of the State University and its various experiment stations have rendered the farmers of the state great assistance in ascertaining by experiments and investigations what lines of farming can profitably be pursued in the various sections of the state, and the conditions under which such profit can most fully be attained. In this way the school-house and its students prove potent agencies in ameliorating bad financial conditions.

Causes of Poor Profits in Wheat Farming.—The several causes which lead to poor profits from raising little else than wheat are not as yet well understood. Some factors may be enumerated as follows: (1) In raising wheat after wheat the land is left in poor mechanical condition for wheat; (2) the store of available plant food is gradually reduced; (3) the humus of the soil is reduced to a low point; (4) weeds become numerous; (5) chinch bugs and some other insects thrive on land kept continuous in a crop on which they feed; (6) rust is present

in quantities to overwhelm the plants of wheat; (7) poor methods of managing the soil and crop too often are faults of the wheat farmer; (8) wheat raising provides profitable employment for farm labor for only a part of the year; (9) planting a large acreage to small grains requires much labor at given seasons of the year, and crowds out other crops and enterprises which, if started, would give profitable employment at seasons when the wheat, oats, barley, and flax require no labor; (10) wheat farming leads to the wasteful expenditure of money in poorly preserved farm machinery; (11) raising small grains, as practiced, calls into action less intelligence and gives less individual employment to the farmer, his wife and his children, than comes from carrying on the more complex, yet more enjoyable, occupation of general farming with live stock, wheat, and other specialties; (12) grain farming does not build up the wealth of the community so rapidly as general farming; (a) there is less permanent farm investments, as fertility, buildings, fences, etc.; (b) there is less development of villages and towns in merchandising, manufacturing and financial establishments; (13) the community of interests is far less in the grain farming community than among people who raise stock, vegetables, fruits, etc., along with grain.

WHEAT IN ROTATION PAYS WELL.

Wheat, if properly grown, is by all means our most profitable grain crop, and easily stands at the head of all Minnesota products in the amount of money it brings. In 1898 the income to the state from the wheat produced approximated fifty million dollars, while the dairy products brought about twenty million dollars.

While we have been promoting other lines of farming that the large acreage of wheat might in part give way to other crops, we have given too little attention to methods of making the wheat we should raise pay us better profits per acre. This has been in part due to the great difficulties met, and the long time

required in determining questions of field practice. Manufacturers of machinery have done very much to improve the methods of planting and harvesting wheat, but methods of farming calculated to prepare fields for wheat are wrought out but slowly.

The North Dakota Experiment Station has shown that where wheat after wheat in the Red River Valley yields only moderate crops, wheat after corn or other cultivated crops, or wheat after grass, yields very good crops. In the older sections of the state many farmers who for a time left off raising wheat have again placed this among the crops raised in the rotation. Ohio, Pennsylvania, New Jersey, and other eastern states, where the surplus of fertility has been exhausted and commercial fertilizers must be purchased, are raising considerable wheat even with present low prices. The strong reasons for continuing this crop in the rotation are there appreciated. As our southeastern counties swing from the extreme of all grain to no wheat, a medium point is found and a limited acreage of wheat is grown.

The advantage of using previous crops to prepare the land for good wheat crops has been most clearly demonstrated by the North Dakota Experiment Station. From a report made by Prof. John H. Shepperd, in the Eighth Annual Report of that station, the six following tables have been compiled:

TABLE LXI.—Wheat Continuously.

PLOT	1892	1893	1894	1895	1896	1897
1	21.5	8.2	20.0	24.0	16.1	13.1
2	19.3	10.0	21.8	23.0	17.9	15.0
14	21.1	8.1	20.3	22.5	15.8	17.8
19	20.0	11.8	22.6	24.5	16.4	18 2
24	19.4	8.6	18.3	23.5	19.5	14.5
25	17.3	9.5	15.5	23.0	11.4	10.3
Average of 6 plots	19.8	9.4	19.7	23.4	16.2	14.8
General Average						17.2

In Table LXI. are given the yields of wheat for 1892 to 1897, inclusive, of six plots on which wheat had been grown continuously for several previous years.

TABLE LXII.—Wheat after Fallow.

PLOT	1892	1893	1894
4	Bare fallow.	11.8	23.8
15	Bare follow.	16.0	25.8
20	Bare fallow.	19.6	25.6
26	Bare fallow.	14.1	21.0
Average 4 plots		15 4	24.0
General Average		.19.7	

In Table LXII. the record is given of the yields of wheat in 1893 and 1894 on plots on which the continuous wheat cropping was avoided by a bare fallow in 1892.

TABLE LXIII.—Wheat After Cultivated Crop.

PLOT	1892	1893	1894
5	Corn 33 bu.	14.4	25.0
6	Corn 37 bu.	17.2	24.8
12	Rape 5½ T.	19.6	26.3
13	Mangels 7½ T.	18.5	26 3
Average of 4 Plots		17.4	25.6
General Average		.....21.5	

In Table LXIII. are given the yields of wheat for 1893 and 1894 on plots on which corn, rape or potatoes were cultivated in 1892.

TABLE LXIV.—Wheat After Barley, Oats, Spring Rye.

PLOT	1892	1893	1804
21	Spring Rye 13.2	10.6	18.5
22	Barley 29 bu.	6.4	18.5
23	Oats 75 bu.	10.1	18.0
Average of 3 Plots		9.0	18.3
General Average		.....13.7	

In Table LXIV. are found the yields of wheat in 1893 and 1894 on plots which grew crops of barley, oats, or spring rye in 1892.

Table LXV. Yield of Wheat in Rotations. Bushels per Acre.

	No. of Trials.	1892.	1893.	1894.	Average for 2 years, 1893 and 1894.	Av. Gain or Loss 1893.	Av. Gain or Loss 1894.	Av. Gain or Loss for Two Years.
Wheat continuously.....	6	19.8	9.4	19.7	14.5	.....	.....	.....
Wheat after Fallow.....	4	fallow	15.4	24.0	19.7	+6.0	+4.3	+5.2
Wheat after Cultivated Crops.....	4	{cult. crps}	17.4	25.6	21.5	+8.0	+5.9	+7.0
Wheat after Oats, Barley and Spring Rye.....	3	{oats barley and rye.}	9.0	18.3	13.3	—0.4	—1.4	—0.9

In Table LXV. are collected the averages of all the four tables mentioned. Here we are able to compare the yields of wheat under continuous cropping; following the bare fallow, twice plowed; following crops of corn, potatoes or rape kept clean of weeds by thorough tillage; and following the other spring grains, barley, oats, and spring rye.

The difference in average yield for the first year after the alternating crop is shown in the seventh column. There is an increased yield on the fallow land of six bushels per acre; and of eight bushels on the land on which crops were cultivated. On the land on which oats were grown the previous year, there was raised four-tenths of a bushel less of wheat in 1893 than on the land which had been in wheat continuously. The second year following the fallow, column eight shows the increased yield to have been four and three-tenths bushels; and following cultivated crops there was an increase of five and nine-tenths bushels; while following oats, barley and spring rye there was again a decreased yield.

In column 9 the average increased or lessened yields for the two years are given. It should be here noted that the third year there was but little increased yield on the plots which had been fallowed or had borne a different crop in 1892. The good effect lasted only to the first and second years.

Table LXVI. Yield of Wheat after Rotation Meadow. Bushels per Acre.

Plot.	1892.	1893	1894.	1895.	1896.	Av. Result 2 years '95 and '96.	Gain 1895.	Gain 1896.	Av. Gain 2 Years.
		Clo. & T. Hay	Clo. & T. Hay						
16	19.6	2070	3225	31	20.5	25.8	7.6	4.3	6.0
Av. 6 Plots Wheat Continuously	19.8	9.4	19.7	23.4	16.2	19.8	.....	.....	.....

In Table LXVI. we have in comparison with the plots growing wheat continuously a plot which had been in timothy and clover meadow for two years. Here the average increased yield was six bushels per acre.

The record of this experiment is of great value. In 1893 and 1894, on land which had grown wheat continuously for ten years, twelve plots of wheat yielded an average of fourteen and five-tenths bushels of grain per acre. This is about the average yield of large sections of our state. By bare fallowing one year the yields of wheat were increased four to six bushels per acre for the two succeeding years. By growing a crop of corn, potatoes, rape, or by sowing clover and timothy, the yields were increased six to eight bushels per acre. Broadly stated, this experiment shows that the yields per acre on our wheat farms will be increased thirty to fifty per cent. by alternating the wheat with other crops. This necessitates growing in rotation with the wheat those crops which can be marketed only through the medium of live stock. It means that to make profits out of wheat we must produce wheat as one of several farm products. We must use stock and the crops which they consume to help us grow wheat.

PREPARING CORN LAND FOR WHEAT.

The first and most important consideration in preparing land for wheat following corn or other hoed crop is that the cultivation be so thorough as to leave the land free of weeds. The recent development of the corn harvester, and a better selection of varieties of corn for each locality, have started a new impetus in corn growing. Corn for fodder and corn for ears and stover are rapidly invading the wheat districts, increasing the live stock interests, aiding in raising wheat, and yet by means of live stock aiding in retaining the fertility of the land. The front line of the corn belt has moved northward fifty miles within several years, and it is traveling more rapidly than ever.

As a matter of necessity, weedy corn land must be fall-plowed or spring-plowed for wheat; but as a rule, in most sections of Minnesota, the corn stubble which has been kept clean of weeds should not be cross-plowed. That wheat does well after corn without plowing is a matter of common experience in all parts of the state. In case the corn stubble is fall or spring plowed, the soil is made loose to the depth of several inches. Where the seed is sowed broadcast without plowing and cover'd with the disk harrow, smoothing with the Scotch harrow, only the upper half of the furrow slice is made loose and open. The lower portion of the furrow slice, having become compact since it was plowed a year before for the corn crop, has become thoroughly connected with the capillary moisture below. The top of the moist soil—the moisture line—does not remain at the bottom of the furrow slice, as in case of the replowed land, but rises part way through the furrow slice, and stops at the bottom of the layer of earth made loose by the disk harrow. This lower half or two-thirds of the furrow slice is the richest part of the soil. It contains not only much of the manure which has been applied, but plant food which has risen with the upward flow of the capillary water, and which has been deposited with the evaporation of the water from the surface of the soil. It makes

a difference with the crop whether the plant finds sufficient water in the lower part of the furrow slice to allow it to gather food there, or whether it must find all its nourishment in the subsoil.

PREPARING THE SOIL FOR THE SEED.

In most instances spring wheat should be planted in Minnesota very soon after the frost has left the surface soil. To this end stubble or grass land should be plowed in the fall; and corn stubble or potato land should be cleaned of stalks or other rubbish, and where practicable pulverized in the autumn. Where grass and clover seeds are to be sown with the wheat crop, it is especially important that the wheat and accompanying seeds be sown while the soil is moist and cool, that there may be a better chance of securing a catch of grass. Failure to get a stand of grass occurs less frequently when the wheat is sown after corn than after most other crops.

Corn stubble should be broken down to the ground when the soil is frozen. For this purpose a heavy square timber or a railroad iron drawn by hitching one or two horses to either end can be utilized. Cornstalk cutters are in some cases useful, but a sharp disk harrow often makes it unnecessary to use a stalk cutter, even where the corn was husked from the standing stalks. In some cases it will be wise to thoroughly pulverize the corn stubble land before seeding, so that a drill may be used to advantage. In other cases the better plan is to sow the wheat broadcast and cover with the disk harrow, the corn cultivator, or other implement which will turn the soil up to the depth of two or three inches. In case a farmer has only a shoe drill, that implement may be successfully used instead of the broadcast seeder, where the disk is to follow the sowing. By drilling the wheat in shallow, it is so placed that it will be turned under by the disk or other cultivator. Any good method which plants the wheat at the proper depth and leaves the surface soil level and smooth will succeed.

Grass sod should be fall-plowed for wheat. Early plowing is

often the better for timothy, while in case there is growing a heavy second crop of clover it is wiser to defer the plowing until a crop can be removed or until it has developed a large tonnage of green manure. The crop is worth more for feed than for green manure, if there is at hand profitable live stock to make use of it, since the manure can largely be returned to the land. Grass makes a good preparation for wheat; while the atmospheric nitrogen added by the clover to those soils which have been depleted of this fertilizing substance often increases the following crop of grain several bushels per acre.

Stubble land after small grain crops is of necessity, or of choice, very much used for crops of wheat. This land cannot be gotten into good mechanical condition for wheat. The stubble and weeds are coarse, do not quickly decay into humus, and tend to make the furrow slice too loose for capillary water to rise into it, and too open, allowing too free circulation of air. Wherever practicable, in a climate which is subject to periods of drought, and in which grain crops are planted continuously, it pays to burn the stubble and weeds. The fire destroys many weed seeds, and destroys the coarse materials which would do more harm than good. The extra cost of making less than a ton of barnyard manure to take the place of the humus-making stubble and of the nitrogen lost in burning is far less than the loss arising from coarse stubble in the furrow slice and weed seeds in the soil. Burning the stubble and not making manure by keeping live stock is, however, undoubtedly harmful to the soil.

But, taking into consideration all things, early autumn plowing is the most important point in the preparation of stubble land for wheat. By early plowing many weeds will be covered before the seeds have ripened, the stubble will have some time in which to become softened and rotted, and the soil will be compacted through the influence of the fall rains, and will have its capillary connections made more intimate with the subsoil.

In the spring care should be taken in preparing the seed bed to thoroughly pulverize the upper two or three inches of soil. Where the winds are not likely to cause the soil to drift, it is

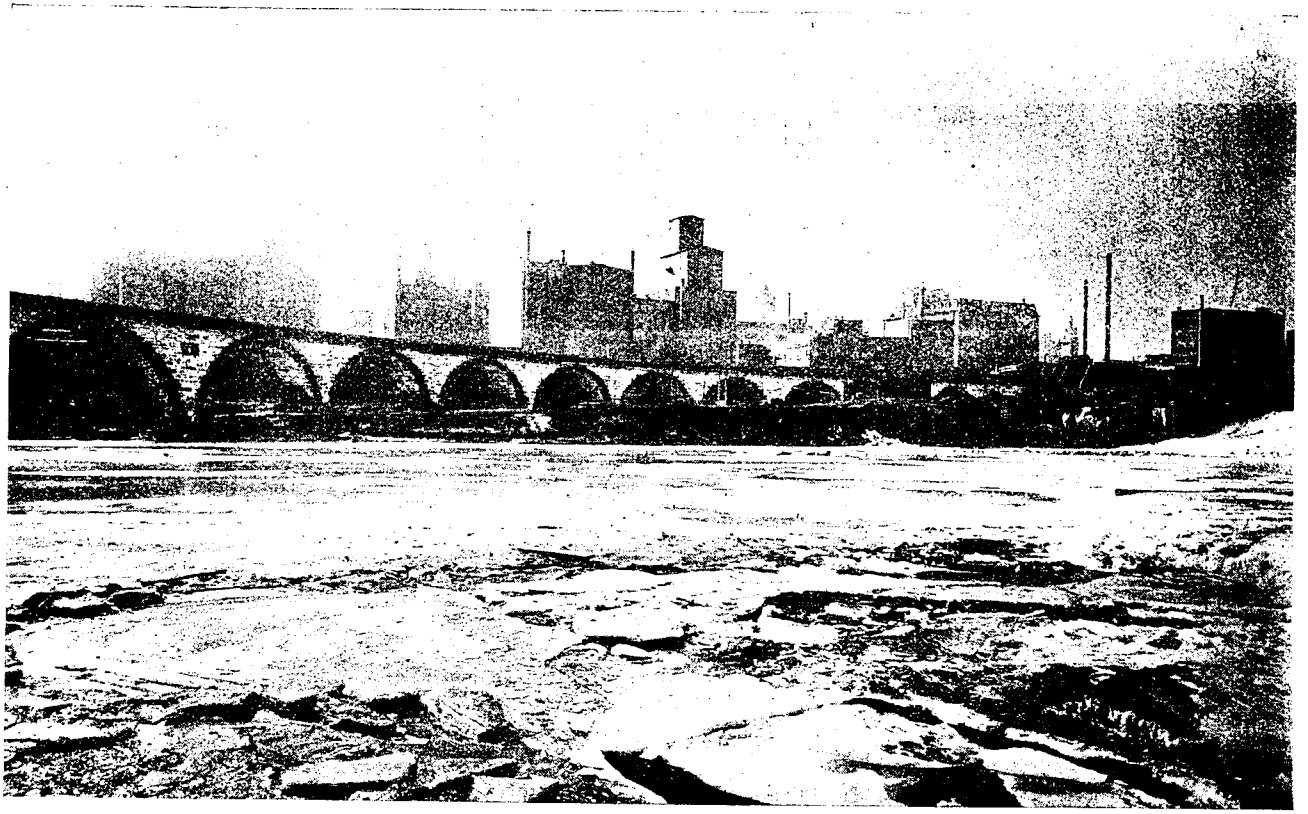


Fig. 288.—View of Minneapolis Milling District.

wise to make the surface fine and smooth. Where drifting occurs it is necessary to leave the seed bed coarser, and especially to avoid using the roller, or the plank or "floater".

KIND OF SEED TO SOW AND AMOUNT.

Our extensive studies of wheat raising has emphasized the importance of Blue Stem and Red Fife wheat. Our farmers are occasionally urged by grain men and others to market the stock of Blue Stem or Fife wheat they have on hand and get fresh seed from "the prairie" or from "timber land," or from "clay soil," or in a word from conditions in some way radically differing from those on their own farm. This is not good policy, because, so far as known, it has not been generally proved. We feel certain that too much importance has heretofore been attached to changing seed wheat. Prof. C. A. Zavits, of the Ontario Agricultural College, has recently published experiments which demonstrate that wheat is improved if kept long on the same farm and the seed is yearly subjected to careful bulk selection. The point of far greater importance is to get a wheat of known good quality and with a record for successive large yields per acre in the same general vicinity. Changing seed merely to make a change has dangers as well as advantages. The danger of getting wheat which will not yield well under conditions new to it gives need of the greatest precaution, and next in importance is the care to avoid bringing new weeds upon the farm. A third source of danger is in the introduction of stinking smut. A very good general rule when a change of seed is deemed necessary is to procure the seed of some reliable and neat farmer within the neighborhood, or within a day's drive. By careful inquiry as to the presence of wild oats, mustard, Russian thistles, and other noxious weeds, also smuts, and by carefully inspecting the wheat in the bin, or by sample, the purchaser can avoid introducing these weeds and smut upon his farm. The statements of a trustworthy farmer regarding the yields and grades he has secured for a series of years should have much to do in

determining whether his seed wheat is the variety wanted. A few to several bushels of a superior variety of wheat purchased of the experiment station, of a seed dealer, or of some careful farmer, will quickly multiply into all the seed needed for the entire farm. The amount of seed to sow varies between one bushel and one and one-half bushels for sowing early in the spring. In a season which opens up early, with ample moisture in the soil, in a cool spring, with a rich, well compacted furrow slice, one bushel of perfectly sound seed planted in a fine seed bed with a shoe or hoe drill will furnish a sufficient number of plants to stool out and make the necessary thick stand of wheat. Where the conditions are less favorable for "stooling out," a larger number of seeds is required. If the soil be loose, open and droughty, if the season opens up late, if the planting is delayed so that the cool, moist stooling period is mostly passed before the wheat will be far enough developed to branch out, or if other conditions are present to prevent the wheat thickening up,—more seed should be planted. One and one-fourth bushels per acre is usually the best amount to sow where the drill is used. Where the wheat is sown broadcast about a peck more of seed is required.

DEPTH AND METHOD OF PLANTING.

The Depth to Sow Wheat varies between one inch and three and one-half inches. Where the soil is firm underneath and mellow on the surface, two inches is about the proper depth to run the drill shoes or hoes. Where the ground is compact and moist, and the seed is planted in the first part of an early spring, quite as good results will doubtless come from planting only an inch deep. The wheat plant does well to start near the surface of the soil and to spread its roots in the upper portion of cool, moist earth. On the other hand, the young plants can come up through three inches or more of very loose earth, and as the season advances, where the soil is more open and droughty, there is need for planting to a greater depth, that the seeds may be able to get moisture to start germination, and that the roots may at

once enter into moist soil where they can secure plant food as soon as the leaves have expanded sufficiently to use it.

The seeds should be planted as evenly in depth as is practicable, especially if in a droughty soil, so as to insure that all germinate together promptly. The chains following the shoes of the shoe drill help to cover the grain. The common Scotch harrow is a great aid in smoothing down after cultivating in broadcasted grain, and after the hoe drill, and in most cases it should follow even the shoe drill. The exceptions are in cases where further pulverizing with the harrow would result in the soil drifting worse before the wind. The press wheel following the shoe of the shoe drill, as the wheel of the modern two-horse corn planter follows the shoe of that machine, is useful under some conditions. Press wheels cause heavier draft on the team, make the drill somewhat more complicated and therefore difficult to handle, and have no advantage on heavy moist soils where wheat is planted early in the spring on well prepared land, and are not well adapted to planting wheat on corn stubble ground. They have, however, a wide field of usefulness. Where the conditions are such that the seeds and young plants are subjected to a lack of moisture in the early spring, the press wheel adds to the yield of grain. Where the grain is placed on light soils, especially if planted late, the press wheel compacts the soil about the seeds, just as in planting corn with the hoe we tread on every hill, or just as we tread the loose earth about the roots of a newly planted tree. Farmers in western counties, and those who have light open soils, find press shoe drills very useful, as do the farmers west of the eastern tiers of counties in the Dakotas, where the rainfall is often scant in the springtime.

It often pays to thoroughly harrow the ground two or more times immediately after the grain is sown, so as to make the seed bed more compact below and fine and mellow at the surface. Experiments we have conducted prove that harrowing the grain after it has come up is dangerous, and has caused injury in a number of cases. It lessened the yield in proportion to the amount and lateness of the harrowing. The benefit coming from

the destruction of weeds among the young wheat was more than counter-balanced by the injury the harrow teeth did the wheat plants. More experiments are needed to determine the amount of harrowing best to do after wheat is planted, and the length of time it may be continued. But at present we are inclined to advise care in using even light harrows to kill weeds among wheat, oats, or barley when it is a few inches high. The preparation of the soil should be so thorough that only a small amount of harrowing shall be needed after the crop is planted.

Little can be done for good crops of wheat during its growth, except to pull out by hand mustard, lamb's quarters, thistles, and other large growing weeds which would mature their seeds before harvest or would interfere with harvesting and handling the grain. Very poor, weedy crops of wheat had often better be plowed under before harvest time. Expense for harvesting is thus avoided, and the land is fallow-plowed for the succeeding crop. Where pasturage is needed the crop can be pastured during the time the plowing down is in progress. Or the crop can be mowed for hay when in the flowering stage, or a little later. This gives opportunity to plow the field before harvest, and thus prevent most of the weeds from ripening their seeds.

HARVESTING AND STORING WHEAT.

A discussion of the general practice of harvesting the crop, storing the bundles and threshing, storing and marketing the grain must be kept for future bulletins. A few matters, however, in connection with varieties and with the quality of grain for market and for seed cannot well be passed by.

1. Wheat makes the best flour if allowed to become mature before it is cut.

2. The loss of quantity from shelling is great if the wheat is allowed to become over-ripe before reaping.

3. Blue Stem wheat, owing to its open chaff, shells worse than most other varieties of wheat, and therefore it is more important that it be harvested as soon as ripe, and there is more excuse, where this variety is grown, for beginning the harvest early.

4. Wheat should be well shocked in round shocks, twelve to eighteen bundles in a shock, set compactly and covered with two good cap bundles, which should be replaced as often as blown off.

5. Wheat should be stacked or threshed as soon as practicable after the shocks have become sufficiently dry. Stacking is rapidly replacing shock threshing, and this change should continue. Better quality in the wheat, and a greater acreage of early fall plowing, will amply repay for the additional expense, and the threshing can be more economically done.

6. Blue Stem wheat is more easily injured while it is in the shock than other varieties, because its chaff does not fold snugly about the berry, permitting rains, dews, sun, and wind alternately to affect it, making the bran more brittle and lighter in color. Therefore it is especially important that this variety be well shocked and that the shocks be capped, even in our windiest, dryest counties; and that it should be stacked. Where its bran and color are perfectly preserved Blue Stem grades as high as Fife wheat.

7. Great care should be used in stacking and storing grain which is to be used for seed, that injury to the germinating qualities, by moisture or by heating in the stack or bin, may be entirely avoided.

8. Thoroughly cleaning the wheat which is to be used for seed is of the utmost importance. Small and shriveled kernels of wheat as well as all kinds of weed seeds should be removed. In fanning the wheat a strong wind blast should be used as the heavy, hard kernels are the ones desired for seed. Where one has only a small quantity of very choice wheat for propagation, hand picking will often be advisable to remove barley, rye, oats or other grains which cannot be removed by machinery and which will detract from the value of the wheat when ready for sale for seed.

9. Seed wheat, as well as seed corn, should be tested, as in earth in the house, in a place not too warm, that its germinating ability may be determined. Where wheat shows below ninety-five per cent. germination it should be most thoroughly

cleaned and more than the ordinary amount of seed used per acre, or if very poor it should be discarded.

10. Wheat for seed should be sold and bought on the strictest honor for trueness to name and variety, for freedom from weed seeds and smut, and upon personal inspection in the field or bin, or at least by sample.

11. The farmer who desires a reputation for growing good seeds which will prove useful to his neighbors must have good land. By means of live stock and the crops they use he must keep the land free of foul weeds, and he must be a good seedsman, always selling seeds of good quality, and thoroughly cleaned and graded.

The writers take pleasure in expressing their thanks to the many students and helpers, and to others, who have aided in the experiments in testing varieties and in breeding wheat. Messrs. C. P. Bull and A. S. Williams, and Miss Mary Cheeney have aided in preparing the illustrations; Messrs. Warren W. Pendergast, L. B. Bassett, C. S. Scofield, and C. P. Bull, students in the college of agriculture, have assisted in working out the plans of recording the notes in the field crop nursery. Numerous students and laborers have attended to the details with most praiseworthy interest and care.

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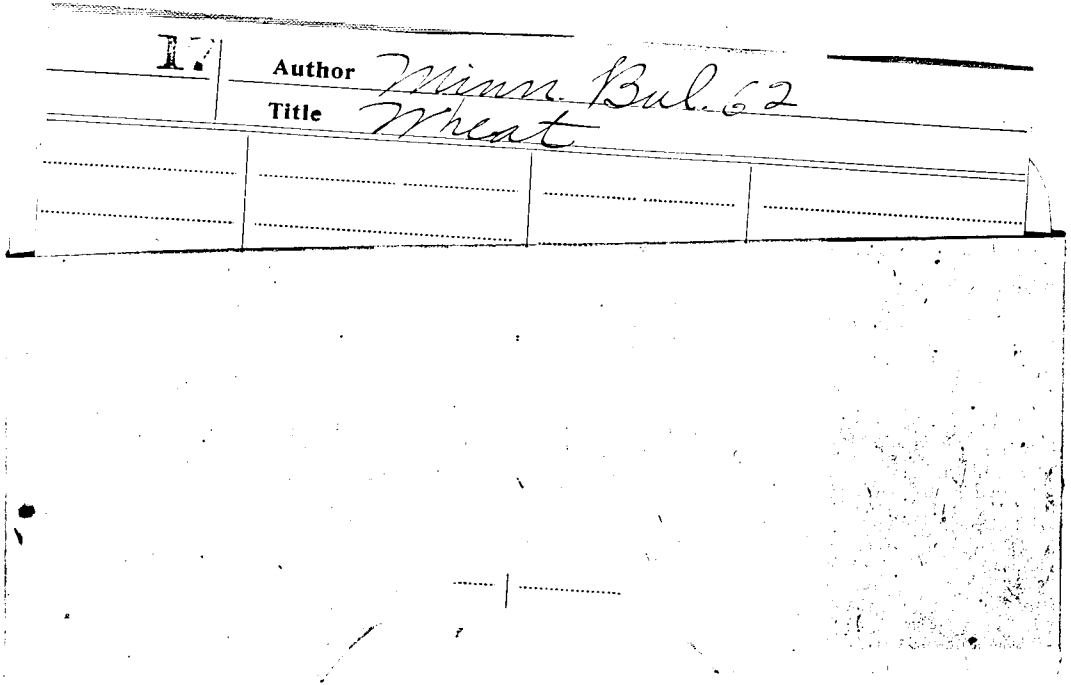
The forbearance of the governing board and of the public in awaiting results from this line of experiments is here acknowledged, and the belief is expressed that in the future the benefits will accrue more rapidly both in superior varieties and in a better knowledge of wheat improvement.

SUMMARY OF CONCLUSIONS.

1. Satisfactory methods of field, milling, and baking tests of varieties of wheat have been devised.
2. Among several hundred varieties of wheat tried by the experiment station, Blue Stem and Red Fife are best for Minnesota.
3. Wheat breeding is outlined, with record blanks and methods of hybridizing illustrated, and the plan of disseminating new varieties is given.
4. Wheat flowers open very early in the morning, and are generally self-pollenated.
5. Immense value is wrapped up in that kernel of wheat which when multiplied into a variety adds a bushel per acre.
6. Kernels from which are produced large yielding plants, good nursery plots, and superior field plots, become mothers of improved commercial varieties.
7. Wheat plants, especially hybrids, vary greatly in yield, in grade or quality, in rust resistance, and in other characteristics.
8. By systematic selection of bulk or hybridized wheats, improved varieties are originated at slight cost as compared with their value.
9. Three out of thirty varieties first originated by selection are being disseminated, and several new hybrids are very promising.
10. The relation between breeding plants and breeding animals is pointed out, and useful deductions are drawn.
11. Many unsolved problems are suggested, and the importance of further study in breed and variety formation is emphasized.
12. Wheat farming has paid, but not so well as general farming where most of the crops are fed to live stock. Wheat should be grown on only a small part of the land, where yields will be large.
13. Field and farm management can be reduced to a system under which profits can be made and the farm become more fertile.

Fig. 289.—Harvesting Wheat on a Bonanza Farm.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