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TWENTY YEARS OF TESTING VARIETIES AND STRAINS OF WINTER WHEAT AT THE KANSAS AGRICULTURAL EXPERIMENT STATION

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WHEAT VARIETY TEST PLOTS, KANSAS AGRICULTURAL EXPERIMENT STATION, 1927

This picture was taken on the Agronomy Farm of the station, Manhattan, Kan. All plots were planted on the same day at the same rate and on ground prepared in a similar way.

TWENTY YEARS OF TESTING VARIETIES AND STRAINS OF WINTER WHEAT AT THE KANSAS AGRICULTURAL EXPERIMENT STATION[1]

S. C. SALMON[2] AND H. H. LAUDE

The year 1930 marked the twentieth season of continuous testing of varieties and strains of winter wheat under practically the same management at the Kansas Agricultural Experiment Station. This has been a period of unprecedented activity in crop improvement, of which variety and strain testing is a part. During this time many strains and varieties of wheat have been tested, many hopes have been buried, and perhaps a few things have been learned. As at numerous other stations, this work was first prosecuted in accordance with the pure-line theory of Johannsen; that is, it consisted very largely of the selecting and testing of pure lines from adapted varieties. It soon became apparent, however, that the method was not broad enough or inclusive enough to meet the needs of the situation, and in recent years hybridization has become of constantly increasing importance.

Also it has been learned, here as elsewhere, that the random crossing of varieties to induce variation or in the hope of securing favorable chance combinations is too uncertain a method on which to base a crop-improvement program. It has come to be realized that objectives must be more specific. Along with this has come the realization that if objectives are to be more specific it is necessary that the relation between these specific objectives and the ultimate goal—whether the latter be better yield, better quality, or greater economy in production—be more clearly demonstrated. These changes appear to be a part of a more general change which agronomic experimentation is undergoing; namely, the change from the cut-and-try or empirical method usually characteristic of a beginning science to the more effective and in general the more useful inductive method generally characteristic of older sciences.

The present publication has two general objectives in view. One is to present the data pertaining to different varieties and strains that have accumulated, or rather such of them as may be of general interest, the other is to present something of the changing viewpoint as it has affected and is affecting the crop-improvement

Acknowledgment.—The data at Manhattan and at the Fort Hays branch station were secured in coöperation with the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. The authors desire, also, to acknowledge the valuable assistance of I. K. Landon, superintendent of the southeastern Kansas experiment fields, of A. F. Swanson, in charge of cereal investigations at the Fort Hays branch station, of F. A. Wagner, superintendent of the Garden City branch station, of T. B. Stinson, superintendent of the Tribune branch station, and of E. H. Coles, superintendent, and B. F. Barnes, formerly superintendent of the Colby branch station, for data secured at these experiment fields and stations, respectively.

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work of the Kansas station. The authors take the liberty to suggest a viewpoint of crop improvement that is somewhat different from that which generally prevails or at least different from that which has prevailed in the past. For this viewpoint they claim neither originality nor uniqueness; merely that it is sound and gives emphasis to certain features which they believe should receive more attention in any well-rounded crop-improvement program.

WHEAT BELTS OF KANSAS

Kansas grows approximately twelve million acres of wheat annually of which, according to Clark and others (7), about 91 per cent consists of the hard-wheat varieties, Turkey, Blackhull, and Kan-

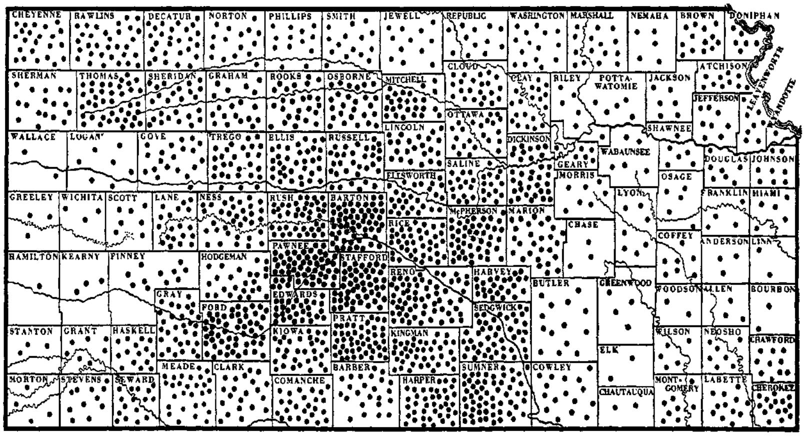


FIG. 1.—Average annual acreage of wheat in Kansas, 1920 to 1929. (Each dot represents 5,000 acres.)

red. Most of the remainder is soft wheat comprising the varieties Fulcaster, Harvest Queen, Currell, and others. The hard wheats are grown most extensively throughout the central and western parts of the state where drought, hot winds, and winterkilling are in general most prevalent. Wheat is grown most extensively in the central portion of the state, south of the Smoky Hill river, extending toward the southwest corner of the state and also to the Oklahoma boundary in Sumner and Harper counties. (Fig. 1.) In this region the broad level plains, fertile soil, moderate rainfall, and relatively mild winters make conditions almost ideal for wheat growing.

North of this area wheat is also grown extensively but generally in smaller units and more frequently competes with other crops such as corn, particularly in the northern tier of counties. The land is rolling and hence not so well adapted to the use of labor-saving machinery. In northwestern Kansas conditions are very similar to south central Kansas, except for a somewhat lower rainfall and more severe winters. Southwestern Kansas is the most recently developed wheat region of the state. Extensive methods of production are the rule in this area which, like south central Kansas, is characterized by broad level plains particularly well adapted to the use of labor-saving machinery. The principal crop hazards in southwestern Kansas are low rainfall, hot winds, soil blowing, and hail. In recent years foot rots, including "take all," have caused extensive damage.

Southeastern Kansas is a typical soft-wheat belt characterized by a high rainfall and relatively mild winters. The soil is residual and generally speaking is less productive than in central and western Kansas. Wheat is grown particularly on the poorer soils, such crops as corn and alfalfa occupying the more fertile areas. It so happens that during the period in which variety tests have been conducted in this region, winterkilling has occurred more frequently than in any other section of the state. This is believed to be an exceptional condition and must be considered in interpreting the results reported here.

Both hard and soft wheats are grown in northeastern Kansas. Wheat is relatively less important here than in other sections of the state. Hard wheat is grown for the most part on the upland where the soil is frequently somewhat thin and where there is more danger from winterkilling and drought. Soft wheats are usually chosen for growing on bottom land, but they are grown also on upland, particularly following seasons in which there has been no winterkilling but in which lodging occurred.

Kansas grows practically no spring wheat, the acreage generally amounting to no more than a few thousand acres. It is only in seasons where there is difficulty in getting a crop started in the fall or in which it fails to survive the winter that a considerable acreage of spring wheat is sown, and the tendency even then is to grow other spring-seeded crops. Such spring wheat as is grown is confined almost entirely to northwestern Kansas.

There are two regions of the state where relatively little wheat is grown, namely, the bluestem pasture region (Flint Hill region) of eastern Kansas, consisting of a long somewhat triangular area with the apex near Manhattan and the base on the Oklahoma border, and the short-grass pasture region of west central Kansas. The former is characterized by a sharply rolling topography, and the latter by a somewhat less productive soil than either southwestern or northwestern Kansas, which combined with the severe climate increases the hazards as compared with those regions.

EXPERIMENTAL METHODS

Variety tests have been conducted at the main station at Manhattan; on the four branch stations at Hays, Colby, Garden City, and Tribune; on the southeastern Kansas experiment fields at Moran, Columbus, and Parsons; and in extensive experiments in cooperation with farmers. These experiments carried out in cooperation with farmers will hereafter be referred to as cooperative experiments. (Fig. 2.)

Excepting the coöperative experiments, these variety tests usually have consisted of triplicate plots of each variety, the plots ranging from one-fiftieth to one-fortieth acre in size. At the Hays branch station a common practice has been to use duplicate plots of each variety on each of two methods of preparing the ground; namely, on fallow and on early-plowed cropped land, thus making four plots of each variety. Ordinarily seeding has been done at the rate and

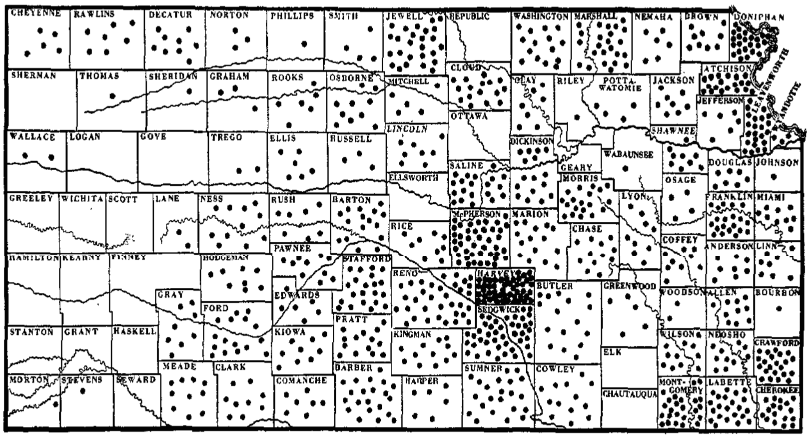


FIG. 2.—Coöperative wheat-variety experiments with farmers, 1914 to 1930. Each dot indicates a completed test. Seventy-six per cent of all tests put out were completed.

time considered best for the locality in which the experiments have been conducted.

In the coöperative experiments with farmers the common practice has been to supply seed from the main station which is sent directly to the county agricultural agent or vocational agriculture teacher, who selects the coöperator, assists him in locating a uniform field, and often assists in seeding. Usually from six to eight varieties are included in each experiment. The general practice has been to seed one drill width or two drill widths of each variety across the field in the portion chosen for the experiment. Thus the area required is small and the opportunity for securing uniform ground is even better than on most experiment stations where 75 to 100 or even more plots are grown. The county agricultural agent or teacher of vocational agriculture harvests the test either alone or with the assistance of a representative of the Agricultural Experiment Station. Practically all tests are inspected by a representative of the station before harvest, and if for any reason they are unsatisfactory, as for example because of very uneven ground, volunteer wheat, failure to secure a uniform stand, unequal damage by grasshoppers or other insects or diseases, etc., the test is discarded and is not harvested.

Yields are based on ten rod-rows, systematically distributed over a selected portion of the plot. This portion is chosen from the part of the field which at harvest appears to be most uniform. The representative of the Agricultural Experiment Station and the county agricultural agent or teacher of vocational agriculture select the area for harvesting. The rod-rows are harvested by hand and the crop is placed in burlap bags and shipped by express to the main station for threshing.

No extensive study has been made to determine the relative accuracy of the cooperative experiments as compared with other experiments, but data which have been secured incidentally from time to time lead the authors to believe that the results are comparable in accuracy to those secured on average experiment fields. One reason for this, as has been intimated, is the small number of varieties included in the test and consequently the opportunity for securing uniform ground. Also, choosing at harvest the location for yield comparisons permits using the crop as the indicator of soil uniformity. In most cases samples of the crop have been supplied the Department of Milling Industry for determinations of protein content, yield of flour, quality of flour, etc. The results of these studies will be reported elsewhere.

INTERPRETATION OF DATA

In so far as statistical methods appear to be applicable and useful they have been used in the interpretation of the yield data. Some of the difficulties and limitations in applying such methods to field experiments have been pointed out by one of the authors elsewhere (41). The differential response of varieties to seasonal conditions, as pointed out by Salmon (42) and by Sachs (39), must be considered if erroneous deductions are to be avoided. Probable errors have been calculated for the most part by the point binomial method described by Salmon (43). This method gives substantially the same ratio of D/E as any other and is especially useful in interpreting such data as are presented herein because of its simplicity and ease of application.

YIELDS OF HARD AND SOFT WHEATS

Extensive experience has shown rather definitely and clearly that hard wheats are more productive than soft wheats in all but the eastern part of the state. It has seemed desirable to have experimental evidence of this fact, and consequently varieties of both classes have been grown on the same field and under comparable conditions at Manhattan, at the southeastern Kansas experiment fields, at the branch stations in western Kansas, and in many of the cooperative experiments with farmers. Since Fulcaster has been known to be in general the highest-yielding variety of the soft wheats, it has been grown most extensively. Hence, comparisons will for the most part be made with this variety as a representative of the soft wheats. The relative yields of Fulcaster and Kanred at Manhattan and the branch stations are given in Table I, and for the coöperative experiments in Tables II and III. The average yields of the leading varieties of each class at Manhattan and on the southeastern Kansas experiment fields are given in Tables IV, XVII, and XVIII.

The average yield of Fulcaster at Manhattan for the 16-year period it has been grown, is 30.5 bushels, as compared with 31.1 for Kanred and 29.3 for Turkey, a difference of 0.6 bushel in favor of Kanred and of 1.2 in favor of Fulcaster as compared with Turkey. Fulcaster was also grown in 1911 and 1912 on a different field in comparison with Turkey, and in 1913 in comparison with Bearded Fife, a hard wheat similar to Turkey. The average yield of Fulcaster for these three years was 20.6 bushels and of the hard wheats 29.7. On the southeastern Kansas experiment fields, soft wheats in general have yielded about the same as the hard wheats. Thus at Moran and at Parsons the difference between the leading varieties of each class is a half bushel per acre or less. On the Columbus experiment field, Blackhull, the highest-yielding variety of hard wheat, leads by a slight margin over Michigan Wonder, the best soft wheat. Winter injury or winterkilling in 1928 and in 1930 was undoubtedly

TABLE I.—RELATIVE YIELDS OF KANRED AND FULCASTER AT MANHATTAN AND AT THE BRANCH STATIONS.

(Yield in bushels per acre.)

YEAR.	Manhattan.		Hays.		Colby.		Tribune.		Garden City.	
	Fulcaster.	Kanred.	Fulcaster.	Kanred.	Fulcaster.	Kanred.	Fulcaster.	Kanred.	Fulcaster.	Kanred.
1914	35.3	35.2	....	....	....	....	....	....	....	....
1915	21.2	26.0	....	....	....	....	....	....	....	....
1916	24.0	33.6	....	....	....	....	....	....	....	....
1917	10.3	16.6	....	....	....	....	....	....	....	....
1918	18.0	21.7	....	....	....	....	....	....	....	....
1919	....	....	....	....	....	....	....	....	....	....
1920	27.2	31.2	....	....	....	....	....	....	....	....
1921	25.1	23.3	23.1	29.1	....	....	....	....	....	....
1922	37.9	37.1	9.9	16.0	....	....	....	....	....	....
1923	35.8	36.1	(a)	(a)	....	....	....	....	....	....
1924	30.4	34.0	34.1	33.1	34.0	39.8	6.7	29.5	34.3	40.2
1925	27.9	29.3	11.9	13.5	20.8	30.6	5.8	12.0	20.5	26.0
1926	42.6	29.5	17.7	19.3	16.8	14.5	13.3	16.1	21.5	33.6
1927	44.0	33.9	7.9	9.5	(a)	(a)	.6	.6	(a)	(a)
1928	41.6	47.8	34.2	39.5	33.5	48.8	(a)	(a)	(a)	(a)
1929	26.9	16.5	17.7	16.4	....	....	18.2	21.6	29.0	35.5
1930	39.5	35.4	34.2	37.9	....	....	29.4	36.1	34.8	44.8
Average	30.5	31.1	21.2	23.8	26.3	33.4	12.3	19.3	28.0	36.0

(a) Missing data. For detailed explanation of the missing data at the four branch stations in western Kansas for years indicated, see footnotes, Table V, page 21.

TABLE II.—RELATIVE YIELDS OF KANRED AND FULCASTER IN COÖPERATIVE EXPERIMENTS WITH FARMERS, 1915-1930.

(Arranged by counties.)

COUNTY.	Number of experiments.	Average yield—bushels per acre.		Gain—Kanred over Fulcaster.
		Kanred.	Fulcaster.	
Allen	4	18.7	20.5	—1.8
Anderson	3	18.3	21.6	—3.3
Atchison	12	23.1	21.9	1.2
Barber	6	18.2	19.8	—1.6
Barton	9	15.5	14.9	.6
Brown	6	33.3	32.9	.4
Butler	12	21.3	22.1	—.8
Chase	11	26.2	24.9	1.3
Cherokee	8	18.8	21.9	—3.1
Cheyenne	5	24.7	22.3	2.4
Clark	7	20.1	18.9	1.2
Clay	6	17.3	17.3	.0
Cloud	7	23.3	21.3	2.0
Coffey	8	26.1	23.0	3.1
Comanche	6	24.5	25.2	—.7
Cowley	5	40.1	32.3	7.8
Crawford	17	15.8	17.7	—1.9
Decatur	8	22.8	18.7	4.1
Dickinson	12	28.2	28.2	.0
Doniphan	23	26.1	26.2	—.1
Douglas	5	16.7	17.4	—.7
Edwards	5	16.5	12.6	3.9
Ellis	3	13.2	13.0	.2
Ford	8	20.7	16.4	4.3
Franklin	16	24.6	25.9	—1.3
Graham	3	8.6	7.8	.8
Gray	6	29.0	21.0	8.0
Greenwood	4	13.9	11.2	2.7
Harper	6	24.8	24.0	.8
Harvey	13	21.3	19.8	1.5
Hodgeman	7	21.7	17.6	4.1
Jackson	8	23.7	21.7	2.0
Jefferson	6	20.4	22.9	—2.5
Jewell	11	19.0	16.2	2.8
Kingman	6	15.8	16.3	—.5
Kiowa	7	17.2	17.6	—.4
Labette	8	24.7	24.6	.1
Lane	1	16.8	14.4	2.4
Leavenworth	13	23.2	21.9	1.3
Lincoln	8	22.6	26.5	—3.9
Linn	4	17.3	16.8	.5
Lyon	3	14.4	20.3	—5.9
Marion	7	27.4	27.8	—.4
Marshall	14	20.0	18.8	1.2
McPherson	25	20.3	20.5	—.2
Meade	9	23.2	19.1	4.1
Miami	3	16.1	21.4	—5.3
Mitchell	1	11.2	18.0	—6.8
Montgomery	6	21.8	22.4	—.6
Morris	19	27.2	25.7	1.5
Nemaha	4	27.2	23.9	3.3
Neosho	8	16.8	18.6	—1.8
Ness	8	22.2	17.5	4.7
Norton	2	7.2	8.5	—1.3
Osage	4	16.4	20.7	—4.3

TABLE II.—CONCLUDED.

COUNTY.	Number of experiments.	Average yield—bushels per acre. Kanred.	Fulcaster.	Gain—Kanred over Fulcaster.
Osborne	2	18.2	21.5	—3.3
Ottawa	10	31.0	29.7	1.3
Pawnee	6	25.9	26.4	—.5
Phillips	1	11.8	15.4	—3.6
Pottawatomie	4	35.6	27.8	7.8
Pratt	7	18.9	17.7	1.2
Rawlins	7	19.4	18.8	.6
Reno	23	21.6	21.4	.2
Rice	5	19.8	21.1	—1.3
Riley	1	26.4	21.9	4.5
Rush	3	23.4	21.6	1.8
Russell	3	29.8	27.6	2.2
Saline	12	26.4	29.0	—2.6
Sedgwick	21	18.0	17.2	.8
Shawnee	8	27.7	22.5	5.2
Sheridan	1	32.6	31.3	1.3
Smith	4	15.6	16.2	—.6
Stafford	11	23.2	24.3	—1.1
Stevens	1	12.6	8.8	3.8
Sumner	15	20.2	19.2	1.0
Thomas	1	4.5	2.0	2.5
Wabaunsee	1	12.8	13.4	—.6
Wallace	2	11.4	7.1	4.3
Washington	4	16.4	15.1	1.3
Wilson	4	16.2	20.3	—4.1
Woodson	2	16.3	20.4	—4.1
Wyandotte	3	19.8	18.6	1.2
Total	598			
Average (weighted)		21.8	21.2	0.6

TABLE III.—RELATIVE YIELDS OF KANRED AND FULCASTER IN COÖPERATIVE EXPERIMENTS WITH FARMERS, 1915 TO 1930.

(Arranged by years.)

YEAR.	Number of experiments.	Average yield—bushels per acre. Kanred.	Fulcaster.	Gain—Kanred over Fulcaster.
1915	4	11.4	17.1	—5.7
1916	1	29.6	24.5	5.1
1917	4	33.9	28.0	5.9
1918	27	32.5	25.8	6.7
1919	23	24.3	25.5	—1.2
1920	21	23.9	20.4	3.5
1921	44	22.4	20.5	1.9
1922	47	20.8	23.3	—2.5
1923	67	16.7	18.7	—2.0
1924	62	27.3	24.4	2.9
1925	48	18.0	17.8	.2
1926	50	21.4	20.8	.6
1927	40	17.3	18.1	—0.8
1928	51	26.9	23.8	3.1
1929	53	16.4	18.3	—1.9
1930	56	22.7	21.4	1.3
Total	598			
Average (weighted)		21.8	21.2	0.6

a factor in placing the hard wheats near or at the top, in what may be considered as typical soft-wheat territory.

At the branch stations, all of which are located in western Kansas, Kanred leads by a significant margin over Fulcaster, the principal or only variety of soft wheat included in these tests. Thus, Fulcaster has been grown for nine years in which yields were secured at Hays, similarly for four years at Colby, six years at Tribune, and five years at Garden City. The average differences in yield in favor of Kanred in these tests are: 2.6 bushels, 7.1 bushels, 7 bushels, and 8 bushels per acre, respectively.

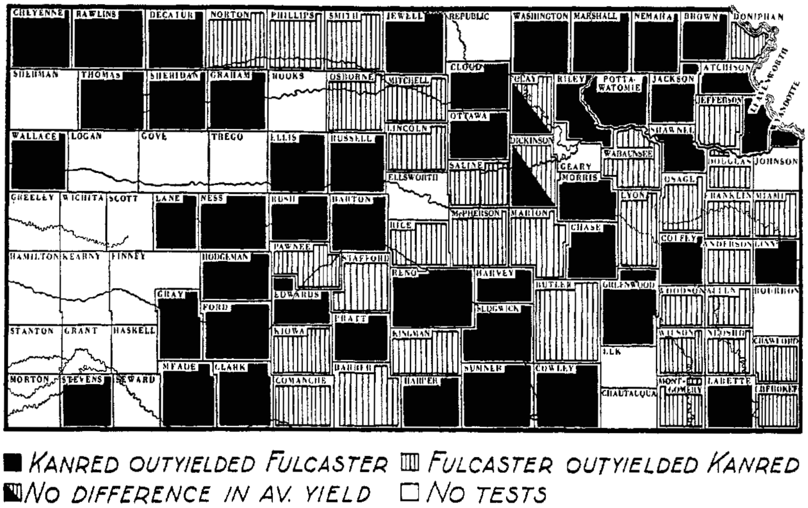


FIG. 3.—Relative yields of Kanred and Fulcaster by counties in 598 coöperative experiments, 1915 to 1930.

The cooperative experiments with farmers are of special interest because of the large number (598) and the fact that they are distributed throughout the state. Considering the state as a whole, there can scarcely be said to be any real difference in yield, the average difference being only 0.6 bushel. Kanred has yielded most in 325 tests which is only about 3.2 times the probable error of the deviation from the expected number. There is, however, a marked difference for different sections of the state as shown in figure 3 and Table II. Thus it will be seen that in eastern and south central Kansas Fulcaster has equaled or exceeded Kanred in yield, whereas in northern and western Kansas it has produced lower yields, thus agreeing with the results secured at the branch stations. It is not likely that Fulcaster over a longer period of years will yield as much as Kanred in south central Kansas, the reason for its relatively high yield in these tests probably being a series of unusually mild winters, as was also the case at Manhattan.

There is also a marked difference in seasons as shown in Table III. In three years since 1918 Kanred has led by a material margin. The data previous to 1918 are worthy of but little emphasis because of the small number of tests.

It is of considerable interest to note that throughout eastern and central Kansas it is difficult on the basis of yield tests alone to demonstrate any clear-cut difference between Fulcaster and the leading varieties of the hard winter wheats. This fact is of considerable interest in several respects. In the first place it has a bearing on the interpretation of the relative yields of Kanred and Turkey and of Kanred and Blackhull to be discussed later, supporting as it does the supposition that the lack of severe winters during the past 12 years has been a material factor in determining the yields of these varieties. No other explanation for the high yield of Fulcaster seems logical since all existing data, particularly those of the winter hardiness nurseries of the United States Department of Agriculture, have shown it to be materially less winter hardy than the hard winter wheats.

Moreover the data have a bearing on the problem of seasonal variability. This problem will be discussed later.

The data also suggest that the principal factor which causes hard wheats to be more satisfactory than soft wheats in the hard-winter-wheat belt is the resistance of the former to winterkilling and drought. There is no certain evidence that Fulcaster is less drought-resistant than the hard wheats, other than the fact that it has produced low yields generally throughout western Kansas even in seasons when there was no observable winter injury. In the case of other soft wheats, particularly Harvest Queen, lack of ability to produce satisfactory yields under conditions of drought is unmistakable. Possibly in this case, as with other awnless varieties, this reaction is related to the absence of awns. Certainly at least it is true that this and other awnless varieties of wheat so far tested are peculiarly susceptible to drought or drought and heat, or perhaps to high temperatures alone, during the later stages of development.

The work of Grantham (18), Hays (21), Clark and others (9), Stevens (48) and others, has shown beyond a reasonable doubt that awnless varieties in general tend to yield less than awned varieties which are otherwise similar. Clark (5) observed this relation for awned and awnless segregates from a Kota X Hard Federation cross under conditions of drought at Mandan, N. Dak. General observations by the authors have suggested that the difference in yield between awned and awnless varieties is likely to be unusually large when high temperatures combined with drought occur during the fruiting period.

If the lack of adaptability of soft wheats to the Great Plains area can be demonstrated to be due to lack of ability to survive drought, or drought and heat and winterkilling, the way would be paved for transferring some of the valuable characteristics of the soft wheats such as stiff straw, resistance to Hessian fly, and resistance to Septoria and leaf rust to the hard wheats. At least there seems to be no valid reason why there should not be combined in one variety some of the desirable characteristics of the two groups. The data presented are not sufficient to be more than suggestive along this line. They do, however, illustrate in a rather precise way the need of knowing something more than is usually known regarding the reasons for differences in yields observed in variety tests.

VARIETIES OF HARD WHEAT

As already noted, Turkey, Blackhull, and Kanred are the principal varieties of hard winter wheat grown in the state. Indeed there are no others of importance except for a few thousand acres each of Superhard, a selection from Blackhull, and of Iobred in northeastern Kansas, and of a few other miscellaneous varieties such as Coöperatorka (Imported Russian Turkey), Redhull, etc., which appear from time to time. Hence, much of the discussion will relate to the three major varieties. Many others have been included in the experiments, especially those at Manhattan, and attention will be called to such of these as are likely to be of interest to other investigators. Since complete discussions of the varietal experiments at the branch stations are contemplated in connection with reports of the individual stations, attention here to the work at those places will be confined for the most part to the three varieties mentioned and to such others as have a bearing on special questions or problems that have arisen from the work as a whole.

YIELD TESTS OF HARD WINTER WHEATS AT MANHATTAN

The primary objective of the plot tests at the main experiment station at Manhattan has been to compare the yields of the standard and widely grown varieties with those of promising new varieties from the cereal breeding nursery, from various agricultural experiment stations in the United States, from the United States Department of Agriculture, and from farmers who have produced or introduced new varieties thought by them to be of value. In recent years a conscious effort has been made to include varieties and to secure data which would aid in elucidating some of the general principles which determine the value of varieties. In all years data pertaining to dates of heading and ripening, winterkilling, diseases of various kinds, insect damage, yellowberry, etc., which appeared to be of value, have been recorded.

Table IV gives the yields for those varieties which were grown in 1930 and had been grown for a period of two years or more. It does not appear to be worth while to include the yield of all varieties and strains which have been tested, since a large number have been tested from time to time and have been discarded because of low yield or other undesirable characteristics. Mention will be made, however, of those which may possibly be of interest to other investigators even though they are no longer being grown. Data pertaining to winterkilling, diseases, insects, lodging, etc., are very intermittent for the reason that these phenomena occur only occasionally. Hence such data are not tabulated here, but will be referred to as occasion warrants.

In practically all cases the yields recorded are averages for three plots. The plots have varied from about 5 to 6.5 feet wide and from about 175 to 190 feet long. The area has varied from about one-fiftieth to one-fortieth of an acre. Two border rows have been cut out in all cases just preceding harvest.

It will be noted that Kanred has given the highest average yield for the twenty-year period during which it has been grown, exceeding Turkey by 2.7 bushels and Kharkof by 3.1 bushels per acre. Blackhull has produced the highest yield for the 12 years it has been grown, its average yield being 1.6 bushels above Kanred and 3.3 bushels above Turkey. The highest -yielding variety of any for the period included is Tenmarq, which has produced an average yield of 5.2 bushels more than Kanred for the seven-year period it has been grown. Blackhull has produced slightly higher yields than Superhard, the difference, however, being no greater than may be attributed to plot and seasonal variability. These two varieties cannot be distinguished from each other in the field, though there is a marked difference in the appearance and texture of the grain, that of the Superhard being darker and harder. Since the relative yields of these varieties are of special interest, more will be said about them in connection with the data from the branch stations and the cooperative experiments with farmers.

Oro from the Oregon Agricultural Experiment Station is of interest because of its stiff straw and its resistance to bunt. Its average yield is slightly less than that of Kanred for the four-year period it has been grown. The difference is largely due to the low yield of Oro in 1927, when it produced only 25.7 bushels as compared with 35.5 bushels for Kanred. No reason for this marked difference is known other than the fact that Oro ordinarily ripens a little later than Kanred and this seemed to be a factor of more than usual importance in 1927.

Fulhard has exceeded Kanred in yield by 3.2 bushels for the four-year period it has been grown. This variety was selected from Fulcaster by Mr. C. O. Johnston, associate pathologist, Bureau of Plant Industry, U. S. D. A. The grain is hard in spite of the fact that it was selected from a soft wheat. It possesses a fairly high degree of resistance to Hessian fly, a fact of more than usual interest since only one other variety of hard wheat as shown by Painter, Salmon, and Parker (35) is known to possess such resistance. It is considered of some promise, but has not been tested sufficiently to determine its value. It appears to be about as winter hardy as Fulcaster, from which it was selected.

2—2545

TABLE IV.—YIELD OF VARIETIES OF HARD RED WINTER WHEAT AT MANHATTAN, 1911 TO 1930.

(Bushels per acre.)

NAME.	C. I. No. (*a*).	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.
Kanred	5146	34.6	19.8	37.1	35.2	26.0	33.6	16.6	21.7	20.7	31.2	33.3	37.1
Turkey	1558	31.1	13.2	33.6	36.1	23.0	22.2	13.1	16.3	20.9	29.3	31.0	37.1
Kharkof	6206	(*b*)26.1	11.9	35.6	36.0	22.9	24.6	14.7	16.9	22.9	29.1	31.0	31.1
Blackhull	6251	......	......	......	......	......	......	......	......	25.7	32.4	33.1	36.4
Tenmarq	6936	......	......	......	......	......	......	......	......	......	......	......	......
Superhard	8054	......	......	......	......	......	......	......	......	......	......	......	......
Oro	8220	......	......	......	......	......	......	......	......	......	......	......	......
Fulhard	8257	......	......	......	......	......	......	......	......	......	......	......	......
Early Blackhull	8856	......	......	......	......	......	......	......	......	......	......	......	......
Kanred × Hard Federation	Ks. 2627	......	......	......	......	......	......	......	......	......	......	......	......
Prelude × Kanred	8886	......	......	......	......	......	......	......	......	......	......	......	......
Kanred × Marquis	Ks. 2644	......	......	......	......	......	......	......	......	......	......	......	......
Kharkof Selection (Hays No. 2)	6686	......	......	......	......	......	......	......	......	......	......	......	......

(*a*) Accession record number, Division of Cereal Crops and Diseases, Bureau of Plant Industry, Washington, D. C.
(*b*) Yield of Kharkof, C. I. No. 1448.

TABLE IV.—*Concluded.*

(Bushels per acre.)

NAME.	C. I. No. (*a*).	1923.	1924.	1925.	1926.	1927.	1928.	1929.	1930.	20 yrs., 1911-1930.	12 yrs., 1919-1930.	4 yrs., 1927-1930.
Kanred	5146	36.1	34.0	39.0	36.3	35.5	46.4	14.8	33.6	31.1	33.2	32.6
Turkey	1558	35.9	32.8	34.5	34.7	32.4	44.7	12.8	32.3	28.4	31.5	30.6
Kharkof	6206	32.4	32.1	33.7	30.6	35.3	45.5	14.2	32.9	28.0	30.9	32.0
Blackhull	6251	41.9	37.5	37.4	34.1	41.1	46.8	18.1	32.8	....	34.8	34.7
Tenmarq	6936	....	35.7	41.4	37.9	47.5	50.5	24.3	38.9	....	....	40.3
Superhard	8054	....	....	....	26.8	40.5	43.8	16.8	33.6	....	....	33.7
Oro	8220	....	....	....	....	25.7	46.4	18.0	32.9	....	....	30.8
Fulhard	8257	....	....	....	....	40.2	43.2	28.9	30.7	....	....	35.8
Early Blackhull	8856	....	....	....	....	....	38.9	17.4	28.5	....	....	....
Kanred × Hard Federation	Ks. 2627	....	....	....	....	....	54.4	26.4	25.4	....	....	....
Prelude × Kanred	8886	....	....	....	....	....	53.0	22.1	28.5	....	....	....
Kanred × Marquis	Ks. 2644	....	....	....	....	....	....	20.2	34.8	....	....	....
Kharkof Selection (Hays No. 2)	6686	....	....	....	....	....	....	12.2	32.0	....	....	....

Kanred X Hard Federation (Kansas No. 2627) is of interest because of its relatively short straw, early heading, moderately early maturity, and long-fruiting period. In a single plot test in 1928, the first year it was grown, it produced the highest yield of any variety in the test and also was the highest yielding of any variety of the hard wheats in 1929. Unfortunately the particular strain included here was found to be heterozygous for awn type. This variety in its present impure form is not suitable for distribution, but it is of interest in relation to the possibility of producing high-yielding varieties which are early and have short stiff straw, suitable for combine harvesting.

Prelude X Kanred (C. I. 8886) and Early Blackhull are of particular interest because of their very early maturity. These two varieties, on the average, head about a week earlier and ripen from four to six days earlier than Kanred, and usually Early Blackhull is the earlier of the two. The Prelude X Kanred has given the better yield at Manhattan and appears to be somewhat more winter-hardy and of higher quality. Their relative yield will be discussed elsewhere in connection with other data.

Kharkof Selection (Hays No. 2, C. I. 6686) is a variety of promise for western and particularly for northwestern Kansas, but has given lower yields than Kanred in both of the years it has been grown at Manhattan. Coöperatorka, a variety introduced from Russia and distributed by Mr. R. M. Woodruff of Pratt, Kan., has been grown extensively in recent years. It has given good yields at Manhattan, but elsewhere in the state it has yielded less than Turkey, Blackhull, or Kanred. In artificial freezing tests at Manhattan the survival has been materially less than that of Kanred and Turkey. In Russia, where it originated, it is well known to possess only a moderate degree of winter hardiness. It is somewhat resistant to bunt. The grain is short and apparently of good quality. In some seasons Cooperatorka develops purple straw.

Cheyenne (C. I. 8885), a selection from an importation of Turkey know as Crimean (C. I. 1435), made by the Nebraska Agricultural Experiment Station, is of interest because of its stiff straw. Experiments elsewhere indicate that it is winter hardy. It has produced good yields, but the period of the test is entirely too brief to afford any definite information as to its ability in this respect.

A number of varieties of more or less general interest have been grown from time to time and then discarded to make room for others. No attempt will be made to mention all that have been included, but it does appear worth while to discuss briefly those which are being tested at other agricultural experiment stations in the Great Plains.

Hussar (C. I. 4853) was grown from 1923 to 1928. The average yield was 2.6 bushels less than that for Kanred. Newturk (C. I. 6935) was grown from 1925 to 1929. Its average yield was 1.9 bushels less than Kanred and 0.8 bushel above that of Turkey. It produced the best yield of all varieties in 1929 and is one of the best-yielding awnless varieties ever included in these tests. In 1929 it was characterized by very weak crinkly straw, fully 90 per cent of the culms being broken over in the upper internode by a storm. Whether this is a heritable characteristic, or whether it occurred because of some accident of growth or relation between stage of growth and weather conditions, was not determined. A similar condition was observed in other varieties, but the damage was slight.

Regal (C. I. 7364) was grown for the three-year period, 1926 to 1928, and produced an average yield of 5.8 bushels less than Kanred. Early Kanred, a variety selected by Mr. F. A. Coffman at Akron, Colo., was grown in 1927 and 1928, and produced 10.2 bushels less than Kanred. The straw was very weak. Sherman (C. I. 4430) was grown from 1925 to 1927 and produced 3.8 bushels less than Kanred. Iobred (C. I. 6934) was grown for the four-year period, 1924 to 1927. It matured from one to four days later than Kanred and the average yield was 4.7 bushels less than Kanred. Montana 36 (C. I. 5549), a pure-line selection of Kharkof, was grown for the four-year period, 1921 to 1924, and produced 0.8 bushel per acre less than Kanred. Karmont, another pure-line selection of Kharkof, was grown for the same period and produced 3.4 bushels. less than Kanred.

Minturki (C. I. 6155) was grown for the five-year period, 1920 to 1924. It did not produce so much as Kanred in any year and in one year produced 6.4 bushels less. Its average was 2.2 bushels less than Kanred. The average loss compared with Turkey was 1.1 bushels. It headed and ripened on the average about two days later than Kanred.

Nebraska 60 was grown for the four-year period, 1921 to 1924. It produced an average yield of 0.4 bushel more than Kanred, which was regarded as of no significance. It was discarded for lack of space and in favor of Nebraska, 6 (C. I. 6249)) which had produced practically the same yield and had been grown since 1919.

YIELDS OF TURKEY, BLACKHULL, AND KANRED AT THE BRANCH STATIONS

The yield tests at the branch stations of special interest here are those relating to the three varieties, Turkey, Blackhull, and Kanred. The relative yields are presented in Table V. In a number of seasons complete failures have occurred because of drought, hail, or other causes. Averages in such cases are based on only those years in which yields were recorded, since when complete failure occurs a variety has no opportunity to express in bushels of grain whatever superiority it may possess. This method is advantageous in comparing varieties, but the reader interested in comparing yields on different branch stations or for different sections of the state should take into consideration the number of failures that have occurred and the reasons for them.

Kanred has produced a higher yield than Turkey at each of the branch stations regardless of whether a comparison is made for the full periods these varieties have been grown or for the shorter

TABLE V.—YIELDS OF TURKEY, KANRED, AND BLACKHULL AT MANHATTAN AND THE BRANCH STATIONS.

YEAR.	Manhattan.			Hays.			Colby.			Tribune.			Garden City.		
	Turkey.	Kanred.	Black-hull.	Turkey.	Kanred.	Black-hull.	Turkey.	Kanred.	Black-hull.	Turkey.	Kanred.	Black-hull.	Turkey.	Kanred.	Black-hull.
1911	31.1	34.6	....	....	....	....	....	....	....	....	....	....	....	....	....
1912	13.2	19.8	....	....	....	....	....	....	....	....	....	....	....	....	....
1913	33.6	37.1	....	....	....	....	....	....	....	....	....	....	....	....	....
1914	36.1	35.2	....	21.2	25.6	....	....	....	....	....	....	....	....	....	....
1915	23.0	26.0	....	(a)	(a)	....	33.7	34.3	....	2.0	8.0	....	14.1	15.4	....
1916	22.2	33.6	....	33.9	36.4	....	28.8	42.6	....	....	....	....	15.3	17.2	....
1917	13.1	16.6	....	19.2	20.9	....	(b)	(b)	....	....	....	....	....	....	....
1918	16.3	21.7	....	10.1	10.8	....	9.3	14.3	....	....	....	....	....	....	....
1919	20.9	20.7	25.7	9.2	12.6	9.5	33.0	40.1	44.5	10.3	11.6	....	23.6	24.7	....
1920	29.3	31.2	32.4	25.8	34.9	33.1	11.3	28.4	21.0	(b)	(b)	....	(d)	(d)	....
1921	31.0	33.3	33.1	27.2	29.1	33.0	37.1	43.5	34.0	9.4	19.4	0.0	(d)	(d)	....
1922	37.1	37.1	36.4	10.5	16.0	14.5	40.5	47.4	43.9	8.5	6.0	7.2	(d)	(d)	....
1923	35.9	36.1	41.9	(c)	(c)	(c)	(b)	(b)	(b)	(b)	(b)	(b)	(d)	(d)	....
1924	32.8	34.0	37.5	33.7	33.1	43.4	36.3	39.8	37.8	23.9	29.5	16.7	19.6	40.2	45.1
1925	34.5	39.0	37.4	12.9	13.5	15.8	29.2	30.6	29.9	9.4	9.9	8.1	28.5	26.0	26.0
1926	34.7	36.3	34.1	14.9	19.3	20.7	18.4	14.5	16.6	14.3	16.1	16.5	28.0	33.6	31.7
1927	32.4	35.5	41.1	9.3	9.5	8.4	(b)	(b)	(b)	1.2	0.6	1.1	(b)	(b)	(b)
1928	44.7	46.4	46.8	36.3	39.5	38.4	46.6	48.8	46.7	(b)	(b)	(b)	(c)	(c)	(c)
1929	12.8	14.8	18.1	14.4	16.4	21.7	15.8	18.1	19.2	22.6	21.6	21.4	32.0	35.5	39.5
1930	32.3	33.6	32.8	36.9	37.9	36.7	44.7	39.7	42.8	34.1	36.1	34.8	44.0	44.8	35.5
Average Turkey-Kanred (e)	28.4	31.1	....	21.0	23.7	....	29.6	34.0	....	13.6	15.9	....	25.6	29.7	....
Average Turkey-Kanred-Blackhull (e)	31.5	33.2	34.8	21.0	23.8	25.0	31.3	35.1	33.6	15.4	17.4	13.2	30.4	36.0	35.6

(a) Damage by hail, rain, and army worm destroyed the value of the variety trial and no yields were recorded.
(b) Crop failure due to dry fall and poor germination, winter killing, or drought.
(c) Crop destroyed by hail.
(d) Value of variety tests destroyed by jack rabbits.
(e) Averages are based on only those years in which yields were recorded. They do not include those years in which there was a complete failure of all varieties of the comparisons.

periods during which Blackhull also has been included. For the former periods the average differences in favor of Kanred are 2.7 bushels at Hays, 4.4 bushels at Colby, 2.3 bushels at Tribune, and 4.1 bushels at Garden City. Blackhull has produced higher yields than Turkey at all stations except Tribune; and higher than Kanred at Hays, substantially equal to Kanred at Garden City, slightly less at Colby, and 4.2 bushels less at Tribune. The probable reasons for these differences will be discussed later.

YIELDS OF TURKEY, BLACKHULL, AND KANRED IN COOPERATIVE EXPERIMENTS WITH FARMERS

A rather unique feature of variety testing in Kansas has been the extensive series of cooperative experiments with farmers in all parts of the state, as shown in figure 2.

Turkey and Kanred have been included in 760 such experiments; and Turkey, Blackhull, and Kanred in 571. The former comparison includes all seasons from 1914 to the present time (1930) and the latter all seasons from 1919 to the present time. Table VI gives the number of experiments, the average yields for Turkey and Kanred, and the average difference between them for each county in which such experiments have been conducted, and Table VII gives similar data for all experiments in which all three varieties have been compared. The data in the latter table are in part a duplication of the former, so far as the Turkey-Kanred comparison is concerned, but it seemed desirable to include both varieties for comparison with Blackhull.

The average gain in yield of Kanred over Turkey for the total of 760 tests is 1.2 bushels per acre and the probable error of this difference is .093 giving a ratio of D/E of 12.9. This indicates that the difference, though small, cannot by any reasonable chance be attributed to plot variability and similar errors.

Similarly, as an average for the 571 tests in which the three varieties were compared, Blackhull has outyielded Turkey by an average of 1.4 bushels and Kanred by 1 bushel. The ratios of D/E are 10.6 and 7.6, respectively, showing that these differences also cannot reasonably be attributed to plot variability. It should be noted specifically that the probable errors calculated here do not fully take into consideration the seasonal variations which will be discussed later.

TABLE VI.—RELATIVE YIELDS OF KANRED AND TURKEY IN COÖPERATIVE EXPERIMENTS WITH FARMERS, 1914 TO 1930.

(Arranged by counties.)

COUNTY.	Number of experiments.	Average yield—bushels per acre.		Gain—Kanred over Turkey.
		Kanred.	Turkey.	
Allen	1	23.6	19.8	3.8
Atchison	13	22.0	22.1	—.1
Barber	17	19.5	19.1	.4
Barton	14	17.0	16.8	.2
Brown	5	33.5	29.7	3.8
Butler	13	21.6	22.1	—.5
Chase	11	25.4	24.1	1.3
Cherokee	2	23.3	24.0	—.7
Cheyenne	5	24.7	25.4	—.7
Clark	8	20.1	18.6	1.5
Clay	7	17.5	17.0	.5
Cloud	15	23.0	22.9	.1
Coffey	7	25.1	24.9	.2
Comanche	7	22.6	22.5	.1
Cowley	10	39.4	37.5	1.9
Crawford	16	17.4	16.9	.5
Decatur	9	20.9	19.0	1.9
Dickinson	15	28.0	24.6	3.4
Doniphan	21	26.7	27.1	—.4
Douglas	6	17.3	16.3	1.0
Edwards	4	16.7	16.9	—.2
Ellis	5	14.6	12.3	2.3
Ford	15	22.0	20.2	1.8
Franklin	16	24.3	23.6	.7
Graham	3	8.6	7.3	1.3
Gray	8	25.2	24.7	.5
Greenwood	5	14.1	10.9	3.2
Harper	6	24.8	24.2	.6
Harvey	30	22.5	19.9	2.6
Hodgeman	8	20.2	17.7	2.5
Jackson	3	20.0	21.0	—1.0
Jefferson	5	20.2	19.5	.7
Jewell	24	23.7	20.4	3.3
Johnson	1	17.0	14.1	2.9
Kingman	11	17.2	16.9	.3
Kiowa	8	17.8	19.0	—1.2
Labette	3	34.5	29.1	5.4
Lane	2	13.4	14.2	—.8
Leavenworth	17	23.3	21.3	2.0
Lincoln	8	19.8	21.8	—2.0
Linn	1	24.7	18.8	5.9
Lyon	8	22.1	20.2	1.9
Marion	12	22.5	22.9	—.4
Marshall	19	21.5	20.3	1.2
McPherson	37	21.1	19.6	1.5
Meade	10	22.7	23.0	—.3
Miami	3	16.0	17.5	—1.5
Mitchell	5	25.5	23.4	2.1
Montgomery	5	20.1	18.8	1.3
Morris	19	27.1	25.6	1.5
Morton	1	10.2	13.4	—3.2
Nemaha	4	27.0	28.9	—1.9
Neosho	7	16.4	18.0	—1.6
Ness	11	19.6	18.7	.9
Norton	2	7.2	7.9	—.7

TABLE VI.—*Concluded.*

COUNTY.	Number of experiments.	Average yield—bushels per acre.		Gain—Kanred over Turkey.
		Kanred.	Turkey.	
Osage	4	16.2	14.8	1.4
Osborne	8	20.3	21.2	—.9
Ottawa	15	30.6	26.6	4.0
Pawnee	11	27.3	24.3	3.0
Phillips	1	11.8	14.2	—2.4
Pottawatomie	4	35.6	32.2	3.4
Pratt	11	20.6	20.5	.1
Rawlins	7	19.4	20.3	—.9
Reno	32	23.7	22.2	1.5
Rice	7	21.6	22.9	—1.3
Riley	1	26.4	25.4	1.0
Rooks	6	19.0	17.2	1.8
Rush	6	20.9	20.1	.8
Russell	3	29.8	26.8	3.0
Saline	16	25.7	25.7	.0
Sedgwick	24	17.9	16.2	1.7
Shawnee	8	25.4	22.9	2.5
Sheridan	1	32.6	33.1	—.5
Smith	4	15.6	13.4	2.2
Stafford	18	23.2	22.8	.4
Stevens	1	12.6	5.9	6.7
Sumner	20	20.0	18.4	1.6
Thomas	1	4.5	4.4	.1
Trego	2	29.4	23.9	5.5
Wabaunsee	1	12.8	15.5	—2.7
Wallace	2	11.4	10.0	1.4
Washington	13	20.3	18.2	2.1
Wilson	1	7.2	6.2	1.0
Woodson	1	14.1	16.5	—2.4
Wyandotte	3	19.7	18.5	1.2
Total	760			
Average (weighted)		22.3	21.1	1.2

TABLE VII.—RELATIVE YIELDS OF KANRED, TURKEY, AND BLACKHULL IN COÖPERATIVE EXPERIMENTS WITH FARMERS, 1919 TO 1930.

(Arranged by counties.)

COUNTY.	Number of experiments.	Average yield—bushels per acre.			Gains in yield.		
		Kanred.	Turkey.	Blackhull.	Blackhull over Kanred.	Blackhull over Turkey.	Kanred over Turkey.
Allen	1	23.6	19.8	22.1	—1.5	2.3	3.8
Atchison	8	26.4	26.0	27.2	.8	1.2	.4
Barber	12	19.3	19.4	19.9	.6	.5	—.1
Barton	13	16.6	16.4	18.9	2.3	2.5	.2
Brown	5	33.5	29.6	35.4	1.9	5.8	3.9
Butler	14	21.6	22.2	23.0	1.4	.8	—.6
Chase	7	17.3	17.8	19.2	1.9	1.4	—.5
Cherokee	2	23.2	24.0	22.0	—1.2	—2.0	—.8
Cheyenne	5	24.7	25.4	27.1	2.4	1.7	—.7
Clark	7	20.1	19.1	22.5	2.4	3.4	1.0
Clay	6	17.3	17.6	19.4	2.1	1.8	—.3
Cloud	10	23.6	24.8	24.8	1.2	.0	—1.2
Coffey	7	25.1	24.9	25.4	.3	.5	.2
Comanche	7	22.6	22.5	22.0	—.6	—.5	.1
Crawford	15	17.4	16.7	19.1	1.7	2.4	.7
Decatur	8	22.7	21.9	22.1	—.6	.2	.8
Dickinson	12	29.2	26.7	32.3	3.1	5.6	2.5
Doniphan	17	26.6	26.4	29.5	2.9	3.1	.2
Douglas	4	13.3	15.7	16.6	3.3	.9	—2.4
Edwards	4	16.7	16.9	14.5	—2.2	—2.4	—.2
Ellis	4	14.1	11.9	15.2	1.1	3.3	2.2
Ford	13	19.5	18.6	19.8	.3	1.2	.9
Franklin	9	20.0	20.8	20.2	—.2	—.6	—.8
Graham	3	8.6	7.3	8.1	—.5	.8	1.3
Gray	7	26.6	25.9	26.5	—.1	.6	.7
Greenwood	4	16.5	12.7	14.8	—1.7	2.1	3.8
Harper	6	24.8	24.1	22.7	—2.1	—1.4	.7
Harvey	17	21.5	19.9	19.8	—1.7	—.1	1.6
Hodgeman	8	20.2	17.7	19.1	—1.1	1.4	2.5
Jackson	3	20.1	21.0	22.5	2.4	1.5	—.9
Jefferson	4	18.8	20.1	24.1	5.3	4.0	—1.3
Jewell	11	19.9	17.1	19.6	—.3	2.5	2.8
Kingman	10	17.6	16.9	17.5	—.1	.6	.7
Kiowa	7	17.2	18.7	19.8	2.6	1.1	—1.5
Labette	3	34.5	29.1	36.1	1.6	7.0	5.4
Lane	1	16.8	17.2	11.6	—5.2	—5.6	—.4
Leavenworth	8	24.7	24.3	26.0	1.3	1.7	.4
Lincoln	8	19.8	21.8	20.5	.7	—1.3	—2.0
Linn	1	24.7	18.8	23.8	—.9	5.0	5.9
Lyon	4	13.7	13.3	18.6	4.9	5.3	.4
Marion	9	24.7	25.3	27.0	2.3	1.7	—.6
Marshall	13	19.3	19.1	20.4	1.1	1.3	.2
McPherson	25	19.3	18.8	19.7	.4	.9	.5
Meade	10	22.8	22.9	24.6	1.8	1.7	—.1
Miami	1	9.7	15.6	18.9	9.2	3.3	—5.9
Mitchell	4	24.9	21.8	24.6	—.3	2.8	3.1
Montgomery	5	20.1	18.8	19.6	—.5	.8	1.3
Morris	14	23.1	22.9	25.6	2.5	2.7	.2
Morton	1	10.2	13.4	11.1	.9	—2.3	—3.2
Nemaha	1	10.9	11.1	11.4	.5	.3	—.2
Neosho	7	16.3	18.0	22.1	5.8	4.1	—1.7
Ness	9	22.0	21.5	21.2	—.8	—.3	.5
Norton	2	7.2	7.9	11.4	4.2	3.5	—.7
Osage	4	16.4	14.8	15.9	—.5	1.1	1.6
Osborne	5	21.7	22.9	23.3	1.6	.4	—1.2

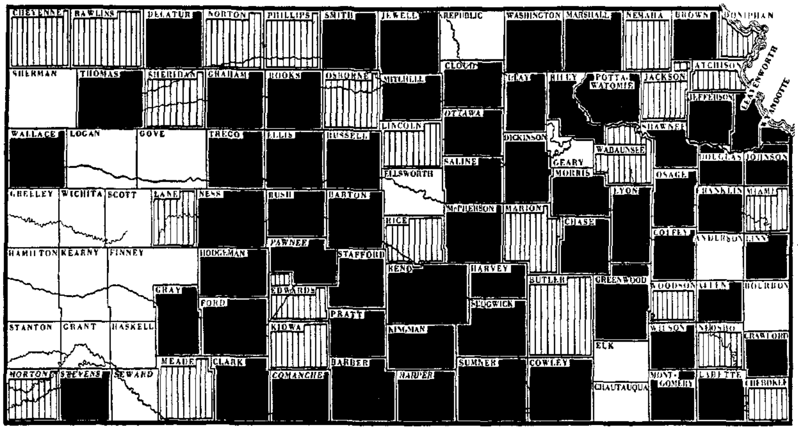
TABLE VII.—*Concluded.*

COUNTY.	Number of experiments.	Average yield—bushels per acre.			Gains in yield.		
		Kanred.	Turkey.	Blackhull.	Blackhull over Kanred.	Blackhull over Turkey.	Kanred over Turkey.
Ottawa	8	24.1	21.8	25.0	.9	3.2	2.3
Pawnee	8	28.2	26.2	31.4	3.2	5.2	2.0
Phillips	1	11.8	14.2	11.3	—.5	—2.9	—2.4
Pottawatomie	4	35.6	32.2	31.4	—4.2	—.8	3.4
Pratt	11	20.6	20.4	19.8	—.8	—.6	.2
Rawlins	5	17.4	18.5	18.3	.9	—.2	—1.1
Reno	29	22.3	21.2	23.9	1.6	2.7	1.1
Rice	6	22.1	23.8	21.9	—.2	—1.9	—1.7
Riley	1	26.4	25.4	25.8	—.6	.4	1.0
Rooks	2	16.0	10.7	12.2	—3.8	1.5	5.3
Rush	5	21.6	22.7	24.5	2.9	1.8	—1.1
Russell	3	29.8	26.8	25.9	—3.9	—.9	3.0
Saline	13	25.9	26.6	28.5	2.6	1.9	—.7
Sedgwick	22	18.2	16.6	18.9	.7	2.3	1.6
Shawnee	3	19.3	16.8	17.4	—1.9	.6	2.5
Sheridan	1	32.6	33.1	37.1	4.5	4.0	—.5
Smith	4	15.6	13.4	14.9	—.7	1.5	2.2
Stafford	12	22.3	23.3	22.8	.5	—.5	—1.0
Stevens	1	12.6	5.9	12.8	.2	6.9	6.7
Sumner	13	19.3	18.5	18.4	—.9	—.1	.8
Thomas	1	4.5	4.4	4.9	.4	.5	.1
Wabaunsee	1	12.8	15.5	17.6	4.8	2.1	—2.7
Wallace	2	11.3	10.0	9.1	—2.2	—.9	1.3
Washington	6	21.1	18.9	22.9	1.8	4.0	2.2
Wilson	1	7.2	6.2	16.1	8.9	9.9	1.0
Woodson	1	14.1	16.5	16.9	2.8	.4	—2.4
Wyandotte	2	16.0	14.4	13.6	—2.4	—.8	1.6
Total	571						
Average (weighted)		21.1	20.7	22.1	1.0	1.4	0.4

REGIONAL ADAPTATION OF TURKEY, BLACKHULL, AND KANRED

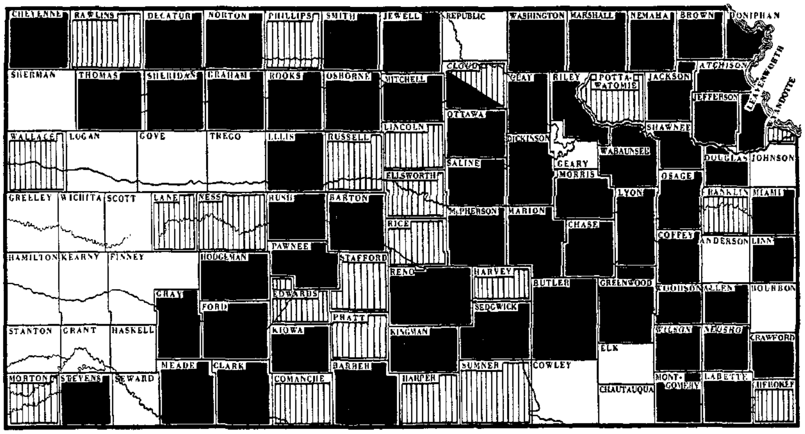
A question of much interest and importance is that relating to the regional adaptation of these varieties. That is to say, are there any sections of the state in which one or more of them is relatively better adapted? An attempt has been made to answer this question by indicating for each county of the state that variety of the three which has produced the best average yield in the cooperative experiments. It has seemed best to confine the comparison in each case to two varieties only. These comparisons are shown in figures 4, 5, and 6.

It will be noted that so far as Kanred and Turkey are concerned there are no particular sections of the state where one variety seems to be especially adapted. One may distinguish a triangular area, the base of which coincides with the Oklahoma border from Cowley to Clark counties and the apex of which is occupied by Rooks and Graham counties, where Kanred clearly has outyielded Turkey more consistently than elsewhere; but whether this indicates a difference in adaptation or is due to a larger number of tests in that area in those seasons which favored Kanred, cannot now be determined, since, as will be shown later, seasonal variation has been a very important factor. There is also perhaps less difference between Kanred and Turkey in the northwest corner of the state than elsewhere, but this probably is to be attributed to the small number of tests in that section and the fact that these tests have, been made mostly in recent years when there has been less than the average difference between these two varieties. Probably for this section of the state, the data secured at the branch stations at Colby and Trib-



■ KANRED OUTYIELDED TURKEY ▥ TURKEY OUTYIELDED KANRED □ NO TESTS

FIG. 4.—Relative yields of Kanred and Turkey by counties in 760 coöperative experiments, 1914 to 1930.



■ BLACKHULL OUTYIELDED TURKEY ▥ TURKEY OUTYIELDED BLACKHULL
◩ NO DIFFERENCE IN AV. YIELD □ NO TESTS

FIG. 5.—Relative yields of Blackhull and Turkey by counties in 571 coöperative experiments, 1919 to 1930.

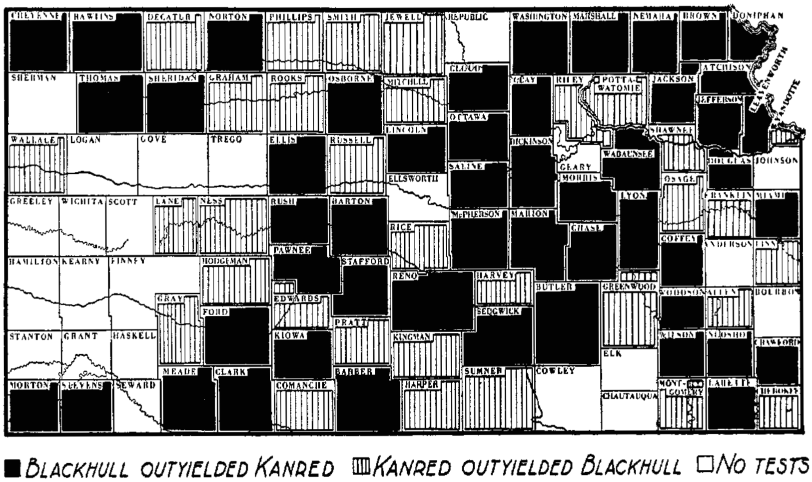


FIG. 6.—Relative yields of Blackhull and Kanred by counties in 571 coöperative experiments, 1919 to 1930.

une (located in Thomas and Greeley counties, respectively) are entitled to more weight. They show a clear advantage for Kanred.

Also it is difficult to establish any clear-cut differences in adaptation of Blackhull as compared with Kanred and Turkey, although it appears that in eastern Kansas Blackhull leads over Kanred and Turkey more consistently than elsewhere. Thus in the east half of the state, Blackhull averaged higher than Kanred in 32 of the 42 counties, while in the west half it outyielded Kanred in 21 of the 39 counties in which tests were made. Likewise, Blackhull yielded more than Turkey in 35 and equal to Turkey in one of the 42 eastern counties, whereas it outyielded Turkey in only 23 of the 39 western counties. The same observation with respect to northwestern Kansas applies here as in the Turkey-Kanred comparison. That is, the number of tests in this region has been decidedly limited and probably the data from Colby and Tribune, which indicate that Blackhull is inferior to Turkey and Kanred, should be given most weight. This conclusion is supported by the thoroughly established fact that Blackhull is less winter hardy than either Kanred or Turkey, and by the fact that most farmers of northwestern Kansas are not growing Blackhull but continue to grow Turkey and Kanred.

SEASONAL VARIATION IN YIELD OF KANRED, TURKEY, AND BLACKHULL

It has been noted that Kanred has produced better average yields than Turkey at Manhattan, at each of the four branch stations, and in the 760 cooperative experiments with farmers in various parts of the state. The agricultural experiment station and branch station tests comprise a total of 66 station years and approximately

200 plots of each variety, excluding those seasons when both varieties completely failed. The cooperative experiments have been conducted during a period of 17 years and in 85 of the 105 counties of the state. The gain in yield for Kanred at the. stations ranges from 2.3 bushels at Tribune to 4.4 bushels at Colby. The differences range from about 10 per cent at Manhattan to about 17 per cent at Tribune. The average gain in the coöperative experiments with farmers is 1.2 bushels or about 6 per cent, but is based on a very large number of tests and cannot be attributed to such usual sources of error as plot variability, errors in measuring plots, loss of grain in threshing, etc., as already pointed out.

Similar statements can be made with respect to Blackhull except for the northwest corner of the state where winter injury has evidently been a factor. Thus, the average yield of Blackhull is higher than the average of Turkey in all tests except the branch station test at Tribune and as high or higher than Kanred in all tests except at Tribune and Colby.

These are very extensive experiments and, since they comprise every section of the state and practically every condition which is met with in general farm practice, they would seem to show in the best possible way the relative merits of these varieties. It would appear, therefore, that these data are conclusive evidence that Blackhull is a more productive variety than Kanred and that Kanred is more productive than Turkey for average conditions in the Kansas hard-winter-wheat belt.

TABLE VIII.—RELATIVE YIELDS OF KANRED AND TURKEY IN COÖPERATIVE EXPERIMENTS WITH FARMERS, 1914 TO 1930.

(Arranged by years.)

YEAR.	Number of experiments.	Average yield—bushels per acre.		Gain—Kanred over Turkey.
		Kanred.	Turkey.	
1914	14	29.8	27.7	2.1
1915	26	23.9	21.5	2.4
1916	28	28.1	20.7	7.4
1917	17	27.1	24.4	2.7
1918	46	27.2	24.9	2.3
1919	39	23.1	20.4	2.7
1920	29	21.2	20.5	0.7
1921	59	21.8	18.5	3.3
1922	52	22.7	21.2	1.5
1923	77	17.2	18.2	—1.0
1924	61	27.2	26.3	0.9
1925	54	17.9	16.9	1.0
1926	51	21.4	20.5	0.9
1927	43	17.4	16.5	0.9
1928	52	27.1	27.0	0.1
1929	55	16.4	17.8	—1.4
1930	57	22.5	23.2	—.7
Total	760	....	....	....
Average (weighted)	....	22.3	21.1	1.2

It is doubtful, however, if the evidence is as conclusive as the above data would seem to show. This may be seen by arranging, by years, the data from the coöperative experiments as is done in Tables VIII and IX. The trends of these relative yields in coöperative experiments with farmers are shown graphically in figures 7 and 8.

TABLE IX.—RELATIVE YIELDS OF KANRED, BLACKHULL, AND TURKEY IN COÖPERATIVE EXPERIMENTS, 1919 TO 1930.

(Arranged by years.)

YEAR.	Number of experiments.	Average yield—bushels per acre.			Gains in yield.		
		Kanred.	Turkey.	Blackhull.	Blackhull over Kanred.	Blackhull over Turkey.	Kanred over Turkey.
1919	10	23.4	20.4	27.2	3.8	6.8	3.0
1920	24	22.0	20.9	22.7	.7	1.8	1.1
1921	47	22.1	18.6	21.2	—.9	2.6	3.5
1922	51	22.6	21.3	25.0	2.4	3.7	1.3
1923	74	16.9	18.0	18.4	1.5	.4	—1.1
1924	60	26.6	26.1	26.4	—.2	.3	.5
1925	53	17.9	17.0	19.9	2.0	2.9	.9
1926	51	21.3	20.4	23.3	2.0	2.9	.9
1927	43	17.4	16.5	20.3	2.9	3.8	.9
1928	52	27.1	27.0	26.2	—.9	—.8	.1
1929	54	16.6	17.9	16.6	.0	—1.3	—1.3
1930	52	22.6	23.3	23.1	.5	—.2	—.7
Total	571	....	....	....	....	....	....
Average (weighted)	....	21.1	20.7	22.1	1.0	1.4	0.4

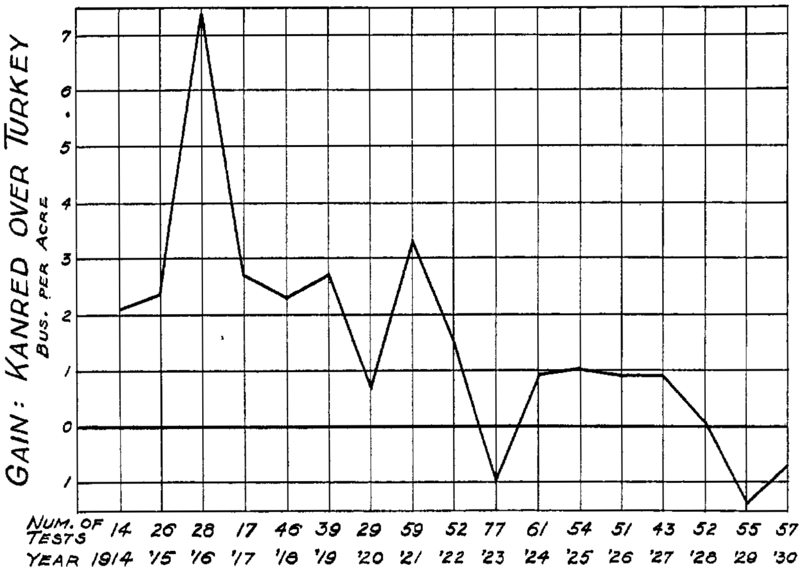


FIG. 7.—Relative yields of Kanred and Turkey by years in coöperative experiments, 1914 to 1930.

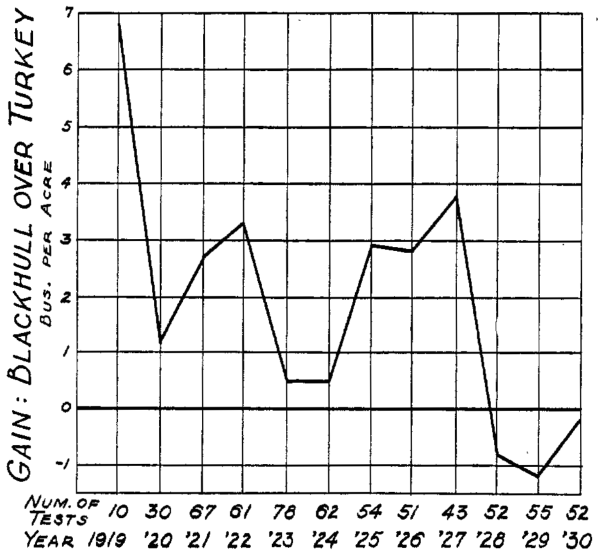


FIG. 8.—Relative yields of Blackhull and Turkey by years in coöperative experiments, 1919 to 1930.

A consideration of the yearly gains in yields at the main station at Manhattan and at the branch stations as shown in Tables X and XI also places certain limitations on the production data.

TABLE X.—GAINS IN YIELD OF KANRED OVER TURKEY AT MANHATTAN AND THE BRANCH STATIONS.

YEAR.	Gain in yield—bushels per acre.				
	Manhattan.	Hays.	Colby.	Tribune.	Garden City.
1911	3.5	....	....	....	....
1912	6.6	....	....	....	....
1913	3.5	....	....	....	....
1914	—.9	4.4	....	....	....
1915	3.0	(a)	0.6	6.0	1.3
1916	11.4	2.5	13.8	....	1.9
1917	3.5	1.7	(a)	....	....
1918	5.4	.7	5.0	....	....
1919	—.2	3.4	7.1	1.3	1.1
1920	1.9	9.1	17.1	(a)	(a)
1921	2.3	1.9	6.4	10.0	(a)
1922	.0	5.5	6.9	—2.5	(a)
1923	.2	(a)	(a)	(a)	(a)
1924	1.2	—.6	3.5	5.6	20.6
1925	4.5	.6	1.4	.5	—2.5
1926	1.6	4.4	—3.9	1.8	5.6
1927	3.1	.2	(a)	—.6	(a)
1928	1.7	3.2	2.2	(a)	(a)
1929	2.0	2.0	2.3	—1.0	3.5
1930	1.3	1.0	—5.0	2.0	.8
Average	2.8	2.7	4.4	2.3	4.0

(a) Missing data. For detailed explanation of the missing data at the four branch stations in western Kansas for years indicated, see footnotes, Table V, page 21.

TABLE XI.—GAINS IN YIELD OF BLACKHULL OVER KANRED AND TURKEY AT MANHATTAN AND THE BRANCH STATIONS.

(Bushels per acre.)

YEAR.	Manhattan.		Hays.		Colby.		Tribune.		Garden City.	
	Kanred.	Turkey.	Kanred.	Turkey.	Kanred.	Turkey.	Kanred.	Turkey.	Kanred.	Turkey.
1919	5.0	4.8	—3.1	0.3	4.4	11.5	....	....	....	....
1920	1.2	3.1	—1.8	7.3	—7.4	9.7	....	....	....	....
1921	—.2	2.1	3.9	5.8	—9.5	—3.1	—19.4	—9.4	....	....
1922	—.7	—.7	—1.5	4.0	—3.5	3.4	1.2	—1.3	....	....
1923	5.8	6.0	(a)	(a)	(a)	(a)	(a)	(a)	....	....
1924	3.5	4.7	10.3	9.7	—2.0	1.5	—12.8	—7.2	4.9	25.5
1925	—1.6	2.9	2.3	2.9	—.7	.7	—1.8	—1.3	....	—2.5
1926	—2.2	—.6	1.4	5.8	2.1	—1.8	.4	2.2	—1.9	3.7
1927	5.6	8.7	—1.1	—.9	(a)	(a)	.5	—.1	(a)	(a)
1928	.4	2.1	—1.1	2.1	—2.1	.1	(a)	(a)	(a)	(a)
1929	3.3	5.3	5.3	7.3	1.1	3.4	—.2	—1.2	4.0	7.5
1930	—.8	.5	—1.2	—.2	3.1	—1.9	—1.3	.7	—9.3	—8.5
Average	1.6	3.2	1.2	4.0	—1.5	2.4	—4.2	—2.2	—.5	5.1

(a) Missing data. For detailed explanation of the missing data at the four branch stations in western Kansas for years indicated, see footnotes, Table V, page 21.

It will at once be apparent that the higher yields of Kanred as compared with Turkey are due almost entirely or very largely to the differences secured in the earlier part of the period. Thus in the coöperative experiments Kanred produced substantially higher yields than Turkey every year for the first nine years with perhaps one exception; whereas, during the last eight years there have been three in which it has yielded less than Turkey and in the other five the average difference is less than a bushel. The average gain (weighted) for Kanred for the first nine years is 2.75 bushels per acre, a difference that is 13.7 times the probable error of the difference. On the other hand there is only 0.04 of a bushel per acre difference in the average yield for the last eight years, which is only 2.1 times the probable error of the difference.[3] Thus there would seem to be no question as to the superiority of Kanred for the first nine years but considerable question as to any superiority for the last eight years.

The results in the tests at Manhattan and the branch stations show a similar trend. Thus the average difference at Manhattan for the first eight years is 4.5 bushels and for the last eight years only 2 bushels. At Hays the average difference for the first eight years of the 15-year period is 3.7 bushels and for the last seven years only 1.5 bushels; at Colby for the first seven years the average difference

3. There may be some question as to whether probable errors should be calculated from the original data of each individual test as was done here and elsewhere in this bulletin or from the average yields for each year as presented in Tables VIII and IX. The latter method gives a much larger probable error because the yield differences are not independent of each other but are related to season. However, this latter method gives a value altogether too large since, as pointed out by Salmon (*42*) and by Sachs (*39*), this is the inevitable result when varieties respond differently to seasonal conditions. Hence, neither method can be considered accurate when there is a differential response to seasons as there is here. So far as the present purpose is concerned, namely, to show that the observed differences for the two periods are not due to plot variability and similar errors, the method here used would seem to be adequate.

is 8.1 bushels and for the last six only 0.1 bushel. The rather meager data at Tribune suggest a similar relation but no such relation is evident at Garden City. Taking the results as a whole they seem to show an unmistakable tendency for the difference between Kanred and Turkey to be less in recent years than formerly.

What then is the reason for this apparent decline in relative yielding ability of Kanred, or if one prefers, for the higher relative yields of Turkey in recent years? This question would seem to be of peculiar importance not only for the purpose of determining the relative value of these varieties, but also from the standpoint of interpreting experiment-field data in general and in relation to the consideration of yield tests in particular. Thus if the explanation is nothing more than seasonal variation it may be concluded that seasons will come again which favor Kanred wheat, and that one may confidently expect larger average yields from it than from Turkey. If this is the explanation, however, it is apparent that more attention must be given to seasonal variation in the future.

If, on the other hand, it can be shown that conditions are changing or that one or both of the varieties are different than they were twenty years ago, one may no longer be justified in assuming that Kanred is more productive than Turkey. But proof of this would also suggest a need of some changes in our fundamental concepts of crop improvement. The question, therefore, seems to be one of considerable importance and worthy of serious attention. Some of the reasons that have been suggested are as follows: (1) Deterioration of Kanred, (2) improvement of Turkey (3) a change in available fertility such as might be brought about by deterioration of soil or better farming methods, (4) an increase in diseases to which Kanred is susceptible or a decrease in diseases to which Turkey is susceptible, and (5) fluctuations in seasons.

The first explanation is the one usually favored by the layman, but it is hardly tenable from the technical point of view. It is conceivable that natural crossing with inferior varieties, or deleterious mutations, might bring about such deterioration, but if so it is more than probable that their effect would be offset by natural selection and especially so when the seed has been cleaned thoroughly and graded every year as has been true in this case. Any large amount of natural crossing such as has been described by Leighty and Taylor (29) would almost certainly have been detected.

The reader unfamiliar with the experimental work reported here may logically raise the question whether wholesale mechanical mixtures amounting to practical substitution of another variety for Kanred or Turkey may not have occurred. Such accidents do occur, but the authors regard the possibility as a very remote one in the present case. Seed for the coöperative experiments, and until recently for the branch stations excepting the Fort Hays branch station, both of Kanred and of Turkey has been supplied from the Agronomy Farm at Manhattan, where the two varieties have been grown in isolated fields. Extreme care has been exercised to keep them separate, pure, and properly labeled. These fields have been examined each year and it is confidently believed that any such substitution or wholesale mixing would have been detected.

Evidence for this belief has been supplied by Johnston and Bower (25) who subjected about 200 samples of Kanred wheat in each of two years (1922 and 1923) grown by members of the Kansas Crop Improvement Association to infection by certain forms of stem rust from which Kanred was known to be immune. Of 638 plants of Kanred from the cereal breeding nursery only nine or about 1.5 per cent proved susceptible, whereas only five out of a total of 933 seedlings of improved Turkey used as checks escaped infection. A smaller number of Kanred plants from the Agronomy Farm studied at the same time, showed about 3 or 4 per cent mixture on this same basis.

Further evidence is afforded by a statistical study of the length of the beaks on the outer glumes of 500 heads each of Kanred and Turkey grown side by side on the Agronomy Farm in 1929. The mean length of the beaks as shown in Table XII is considerably greater for Kanred than for Turkey, thus agreeing with the findings of Clark, Martin, and Ball (6), at least to the extent of showing that the Kanred as grown in 1929 had materially and significantly longer beaks than Turkey.

TABLE XII.—BEAK LENGTH OF THE OUTER GLUMES OF KANRED AND TURKEY WHEATS.

(Manhattan, 1929.)

PORTION OF HEAD.	Mean beak length—mm.		
	Kanred.	Turkey.	Difference.
Base	7.15 ± .07	3.39 ± .04	3.76 ± .08
Center	12.86 ± .11	7.96 ± .13	4.90 ± .17
Tip	15.62 ± .13	11.04 ± .16	4.58 ± .20

The assumption that Turkey has gradually improved as a result of natural selection would seem to be perfectly reasonable and fully adequate in many respects. Thus, if it be assumed that in 1906, when the selection that is now Kanred wheat was made, Turkey contained a small amount of Kanred or a similar strain, and if it be further assumed that this strain on the average yielded 15 per cent[4] more than the remainder making up the Turkey mixture, it would require nothing more than an application of the compound interest law to explain in a satisfactory way the decline in the difference in yield of the two varieties. That is to say, it would be reasonable to

4. Excepting at Garden City the increase in yield for Kanred as compared with Turkey approximates or is greater than 15 per cent for the experiments previous to 1920.

expect under the conditions set forth that a strain of a more productive variety mixed in Turkey would gradually increase until it made up a sufficient proportion of the whole to account for the decrease in the gain of Kanred over Turkey.

It would be expected, however, though not necessarily, that if such were the case other changes would be apparent, such for example as a change in the time of maturity, in beak length, or in resistance to rust. It is true there has been a change in rust reaction of Kanred, but it appears more reasonable to attribute this to new forms of rust than to a change in Kanred or Turkey wheat. No other changes have been observed. On the contrary, Kanred appears to mature as much earlier at the present time as it did when the two varieties were first grown in comparison with each other and, as has already been pointed out, there is no evidence of a change in average beak length. This evidence cannot be regarded as critical, since it would be possible to have a change in productivity without a morphological change in the variety. The theory, therefore, while plausible has no convincing evidence in its favor.

It might be assumed that the experimental conditions under which these varieties have been grown, particularly as regards the coöperative experiments with farmers, may be responsible for the changed relation of the two varieties. Twenty years ago the common practice was to plow the ground in the latter part of August or early September and seed about the middle of September. At the present time a large proportion of the ground is prepared for wheat in July or early August. In the western part of the state fallow is used much more extensively than formerly. There has probably been a change in the date of seeding, the average date being somewhat later than was the case twenty years ago. It is conceivable, at least, that Turkey wheat is better adapted to the later conditions than is Kanred. This assumption, however, does not appear to be supported by the experimental facts. Thus there has been no material change in the preparation of the ground for the variety tests at Manhattan or the branch stations. It has always been well prepared and usually prepared early. Also, if this were the true explanation, larger yields of Turkey would have been obtained in cooperative experiments in recent years than formerly. This is not the case, as reference to Table VIII will show.

It might also be assumed that the difference between Kanred and Turkey is due to certain diseases which are more prevalent or less prevalent to-day than 20 years ago. Kemp and Metzger (27), for example, have found it possible to explain a differential response of certain varieties of wheat at the Maryland station on this basis. One of the reasons that Kanred wheat was more productive than Turkey, in the early years of the experiment, was the resistance of the former to certain forms of stem rust and the susceptibility of Turkey to the forms generally occurring in the state (32). Another was the resistance of Kanred to leaf rust as shown by Melchers and Parker (33). An increase in those physiologic forms of rust to which Kanred is susceptible or a decrease in the prevalence of rust might thus furnish an adequate explanation.

The fact that stem rust has not been a material factor in determining yields in more than one season, 1923, in the last 10, and then only in the northwest corner of the state, is in agreement with this theory. However, stem rust has never been a very important factor in determining yields of wheat in the state as a whole and the loss in northwestern Kansas, referred to above, could have materially affected the experimental data only at the Colby and Tribune branch stations, there having been but few cooperative experiments with farmers in that region. Stem rust was prevalent over the state in 1915, 1919, and 1923 and undoubtedly caused some damage, but reference to Table VIII will show that whatever influence it may have had in determining the relative yields of Kanred and Turkey, in those particular years, it could not have been a predominant factor so far as the relative yields for the earlier part of the experimental period are concerned. It would thus seem that while differential damage from rust in the earlier part of the experimental period and an increase in recent years of those forms to which Kanred is susceptible, may have played a part, it is scarcely adequate as a complete explanation.

No direct evidence is available bearing on the question of whether leaf rust was actually responsible for the yield differences in the earlier period. The work of Johnston (26) and of Mains (31) shows that leaf rust can cause considerable damage and it is known that in recent years Kanred has been very susceptible to leaf rust. Altogether, it is probable that some but not all of the differences referred to may be attributed to this factor.

The theory that fluctuations in seasons is the true explanation seems to the authors to have considerable evidence in its favor. For one thing this explanation agrees with the fairly well established fact that Kanred is more winter hardy than the strain of Turkey used in those tests, and the fact as pointed out in another publication (44) that winterkilling has been less and winter temperatures higher in recent years than normal. Undoubtedly the principal reason for the marked difference in yield between Kanred and Turkey at Manhattan in 1912 was the difference in winterkilling. The same was true in 1917, although the difference in yield in this case was not great because both varieties were badly injured and yields were low. It is probable that the very large difference in 1916 was due to a difference in winter injury although no plants of either variety were actually killed. In that season the fields in eastern Kansas were covered with an ice sheet for about six weeks during the middle of the winter, and when growth started in the spring Kanred was noticeably more vigorous than Turkey and other varieties.

Quisenberry and Clark (38) have shown that Kanred is probably somewhat more winter hardy than Kharkof in the winter hardiness nurseries grown by the United States Department of Agriculture, in coöperation with about twenty agricultural experiment stations. They have not included the particular strain of Turkey with which Kanred has been compared in Kansas. From other sources, however, it is known that this strain of Turkey is no more hardy and is probably less hardy than the Kharkof referred to. Other data on winter hardiness at various places and from artificial freezing tests leave little opportunity for doubting that Kanred is somewhat more hardy than the Turkey grown in these tests.

Further studies of climatological data may show that seasonal fluctuation in respect to factors other than low winter temperature

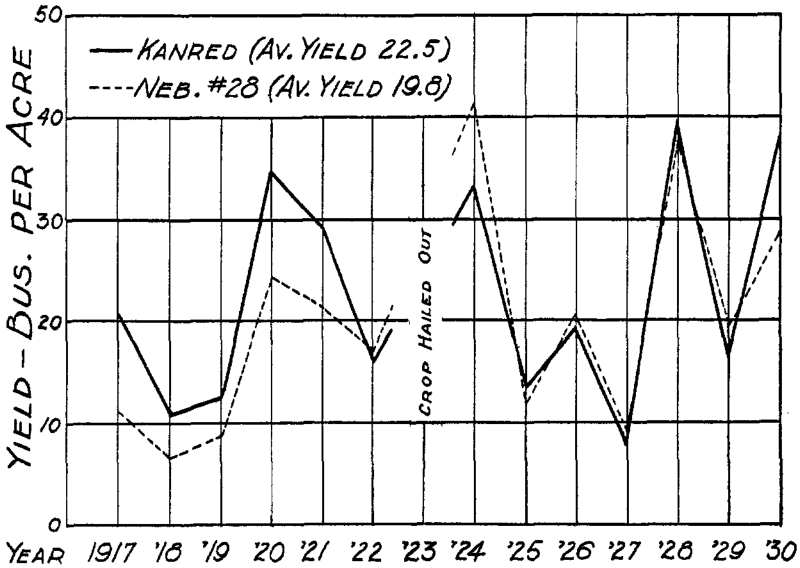


FIG. 9.—Comparative yields of Kanred and Nebraska 28, Fort Hays branch station, 1917 to 1930.

may also have had an influence on the relative yields of Kanred and Turkey. The theory that seasonal fluctuation is the true explanation is in agreement with the relative yields of other varieties also, as for example, Fulcaster and Turkey at Manhattan and Nebraska 28 and Kanred at Hays. Figure 9 shows graphically the comparative yields of Nebraska 28 and Kanred at the Hays station over a period of 13 years. In the first five years of the period Kanred outyielded Nebraska 28 every year, the average difference being 7.3 bushels. In the six-year period beginning in 1924, Nebraska 28 outyielded Kanred in four seasons and averaged 1.7 bushels higher.

Turning now to Blackhull (Tables VII and IX it will be seen that in the cooperative experiments during the first four years this variety was tested, it produced marked gains as compared with Turkey and was better than Kanred. This was followed by two years, 1923 and 1924, when the yields of all three varieties were substantially alike, then by three years in which Blackhull was well in the lead, to be followed in turn by a three-year period, 1928 to 1930, in which it produced less than Turkey every year and about the same or less than Kanred. These facts may be seen more clearly in figure 8, which shows the gains in yield of Blackhull over Turkey in the coöperative experiments. Relative yields at the branch stations exhibit a similar fluctuation from season to season, thus substantiating the conclusion that seasonal variation is a dominating factor to be considered in interpreting the yields of Blackhull and other varieties.

It is also of interest in this connection to note that in recent years Blackhull has failed to maintain its reputation for resistance to lodging. (See Table XXVII.) Thus at Manhattan during the last four years Blackhull has lodged practically as much every year, and in one year more, than Turkey. In cooperative experiments with farmers it has lodged as much or more than Turkey during the last three years and substantially the same results have been obtained at the branch stations.

TENMARQ

Attention has been called to the fact that in a seven-year test at Manhattan, Tenmarq has produced the highest average yield of any variety. This variety is a selection from a cross between P1066 (a strain very similar to Kanred) and Marquis made by M. N. Levine under the direction of Dr. John H. Parker in 1917. Tenmarq is characterized by a moderately stiff straw and resistance to lodging (See Table XXVI), moderate resistance to leaf rust, and extreme susceptibility to Hessian fly as shown by Painter, Salmon, and Parker (35). Tenmarq is slightly more winter hardy than Blackhull, as shown by Quisenberry and Clark (38), but is much less winter hardy than Turkey and Kanred. It appears to be more susceptible to scab than many other varieties. It heads and ripens about the same time or slightly earlier than Blackhull, that is, from one to three days earlier than Kanred.

Tenmarq has been grown in comparative tests with Kanred, Turkey, Blackhull, and other varieties for seven years at Manhattan, five years at Hays, three years each at Colby, Garden City, and Tribune, and in 106 coöperative experiments with farmers covering four years. The average yields are given in Tables XIII and XIV, those for Manhattan being repeated for the sake of ready reference. Yields are compared for the most part with Blackhull, since it appears that if grown commercially it will be limited to about the same area as Blackhull on account of winterkilling, and also because Blackhull has produced the highest average yield of the varieties grown for the same period at Manhattan, where there is the longest yield record.

TABLE XIII.—RELATIVE YIELDS OF TENMARQ AND BLACKHULL AT MANHATTAN AND THE BRANCH STATIONS.

(Bushels per acre.)

YEAR.	Manhattan.		Hays.		Colby.		Tribune.		Garden City.	
	Ten-marq.	Black-hull.	Ten-marq.	Black-hull.	Ten-marq.	Black-hull.	Ten-marq.	Black-hull.	Ten-marq.	Black-hull.
1924	35.7	37.5	....	....	....	....	....	....	....	....
1925	41.4	37.4	....	....	....	....	....	....	....	....
1926	37.9	34.1	17.3	20.7	....	....	....	....	....	....
1927	47.5	41.1	9.7	8.4	....	....	....	....	....	....
1928	50.5	46.8	39.2	38.4	50.5	46.7	....	....	....	....
1929	24.3	18.1	20.0	21.7	21.7	19.2	25.4	21.4	38.5	39.5
1930	38.9	32.8	40.2	36.7	43.5	42.8	33.8	34.8	45.0	35.0
Average	39.5	35.4	25.3	25.2	38.6	36.2	29.6	28.1	41.8	37.3

TABLE XIV.—RELATIVE YIELDS OF TENMARQ, BLACKHULL, KANRED, AND TURKEY IN COÖPERATIVE EXPERIMENTS.

YEAR.	Number of experiments.	Average yield—bushels per acre.			
		Tenmarq.	Blackhull.	Kanred.	Turkey.
1927	1	34.1	21.3	13.0	24.5
1928	7	32.8	24.4	24.9	24.7
1929	47	20.4	16.7	17.9	16.8
1930	51	24.7	23.0	23.3	22.7
Total	106	....	....	....	....
Average (weighted)	....	23.4	20.3	20.9	20.2

It will be seen that Tenmarq has produced higher yields than Blackhull in all cases except at Hays, where the yields are substantially the same. It also has produced a higher average yield than Turkey at Manhattan, Hays, Colby, Garden City, and Tribune; a higher average yield than Kanred at Manhattan, Colby, and Garden City, slightly more at Hays, and approximately the same at Tribune. In coöperative experiments with farmers it has yielded substantially more than Blackhull, Kanred, or Turkey. Its high yield record may be due in part to its slightly early maturity.

From present yield data there appears to be no section of the state where Tenmarq is better adapted than in other sections, though the fact that it is but slightly hardier than Blackhull suggests that it probably will not be adapted to northern and particularly northwestern Kansas.

The excellent yield record of this variety, its superior quality, relatively stiff straw, and resistance to leaf rust should make it of great interest to winter wheat investigators in the Great Plains. However, its marked susceptibility to Hessian fly and susceptibility to scab should be considered. The pronounced effect of seasonal variation in other cases, the clearly demonstrated lower degree of winter hardiness, as compared with Kanred and Turkey, together with the fact that recent winters have been milder than may normally be expected, would suggest caution in predicting relative yields of Tenmarq for the future.

SUPERHARD

This variety, also known as Superhard Blackhull, has attracted considerable attention in recent years because of the fine appearance of the grain it produces and because of the claims made for it by its originator and others. It has been grown in comparative field tests for four years at Tribune, Garden City, and Colby and for five years at Hays, and Manhattan. It has been grown in 199 coöperative experiments with farmers for the period 1926 to 1930. Its average yields compared with Blackhull at the branch stations are given in

TABLE XV.—RELATIVE YIELDS OF SUPERHARD AND BLACKHULL AT MANHATTAN AND THE BRANCH STATIONS.

(Bushels per acre.)

YEAR.	Manhattan.		Hays.		Colby.		Tribune.		Garden City.	
	Black-hull.	Super-hard.	Black-hull.	Super-hard.	Black-hull.	Super-hard.	Black-hull.	Super-hard.	Black-hull.	Super-hard.
1926	34.1	26.8	20.7	22.1	16.6	15.5	13.4	12.1	28.0	32.0
1927	41.1	40.5	8.4	9.8	(a)	(a)	1.1	.9	5.5	5.5
1928	46.8	43.8	38.4	37.9	46.7	42.1	(a)	(a)	(a)	(a)
1929	18.1	16.8	21.7	22.3	19.2	21.0	21.4	25.4	39.5	44.0
1930	32.8	33.6	36.7	36.6	42.8	36.4	34.8	36.1	35.0	38.0
Average	34.6	32.3	25.2	25.7	31.3	28.8	17.7	18.6	27.0	29.0

(a) Missing data. For detailed explanation of the missing data at the three branch stations in western Kansas for years indicated, see footnotes, Table V, page 21.

TABLE XVI.—RELATIVE YIELDS OF SUPERHARD AND BLACKHULL IN COÖPERATIVE EXPERIMENTS WITH FARMERS.

YEAR.	Number of experiments.	Average yield—bushels per acre.		Gain—Superhard over Blackhull.
		Superhard.	Blackhull.	
1926	3	34.6	31.9	2.7
1927	48	19.9	20.3	—.4
1928	50	26.5	26.3	.2
1929	47	16.4	16.7	—.3
1930	51	22.6	23.0	—.4
Total	199			
Average (weighted)		21.7	21.8	—0.1

Table XV, and in cooperative experiments with farmers in Table XVI. The Manhattan data are included with those from the branch stations for ready reference.

Superhard has produced slightly better yields than Blackhull at Hays, Tribune, and Garden City and somewhat lower yields at Manhattan and Colby. It produced slightly less than Blackhull in the cooperative tests with farmers in three seasons and slightly more in the other two. Altogether there seems to be no reason to believe it is more productive than Blackhull for the conditions of these experiments.

In the field it cannot be distinguished from Blackhull. It heads and ripens at the same time and lodges to about the same degree. At Colby and in cooperative tests with farmers it has winterkilled somewhat more than Blackhull, but on the Columbus experiment field in Southeastern Kansas, where severe injury occurred in 1930, it killed no more than Blackhull. Quisenberry and Clark (38) as a result of two years' tests in the winterhardiness nurseries of the United States Department of Agriculture report almost the same survival for Blackhull and Superhard.

The grain of Superhard is darker than Blackhull and the test weight averages somewhat higher. The baking quality of the flour will be discussed in a forthcoming publication.

VARIETIES OF SOFT WHEAT

A discussion of varieties of soft wheat is of practical interest only for eastern Kansas, since this group is known not to be adapted to other portions of the state. The most extensive tests have been conducted in southeastern Kansas, partly for the reason that wheat is grown more extensively there than in northeastern Kansas and also because it is more typically a soft-wheat region. There are located in this section the southeastern Kansas experiment fields which have afforded an opportunity for conducting such tests.

The relative yields of soft-wheat varieties at Manhattan are given in Table XVII, those for the southeastern Kansas experiment fields in Table XVIII, and for the leading varieties in cooperative experiments in Table XX. Since in the latter the number of tests is variable the average yields of each are given in comparison with Fulcaster in the same tests.

TABLE XVII.—YIELD OF VARIETIES OF SOFT WINTER WHEAT AT MANHATTAN, 1914 TO 1930.

(Bushels per acre.)

NAME.	C. I. No.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.
Harvest Queen	6199	30.9	20.1	27.3	....	18.2	17.8	31.3	17.8	31.8	32.0
Fulcaster	6471	35.3	21.2	24.0	10.3	18.0	....	27.2	25.1	37.9	35.8
Nebraska 28	5147	....	....	31.7	1.2	10.4	30.7	30.8	18.6	30.3	19.9
Currell	3326	....	....	....	....	....	....	....	....	....	....
Michigan Wonder	Ks. 500	....	....	....	....	....	....	....	....	....	....
Kawvale	8180	....	....	....	....	....	....	....	....	....	....

TABLE XVII.—*Concluded.*

(Bushels per acre.)

NAME.	C. I. No.	1924.	1925.	1926.	1927.	1928.	1929.	1930.	Average.		
									15 years, 1914-1930 (*a*).	13 years, 1916-1930 (*a*).	5 years, 1926-1930.
Harvest Queen	6199	33.2	28.5	34.3	33.7	40.4	19.6	39.1	29.2	29.7	33.4
Fulcaster	6471	30.4	27.9	42.6	44.0	41.6	26.9	39.5	31.8	32.3	38.9
Nebraska 28	5147	26.5	20.6	29.2	38.4	32.3	24.3	28.3	....	26.3	30.5
Currell	3326	....	24.8	32.0	30.7	36.8	19.9	34.0	....	....	30.7
Michigan Wonder	Ks. 500	....	....	....	....	42.3	23.5	39.6	....	....	....
Kawvale	8180	....	....	39.2	43.8	46.8	29.5	38.0	....	....	39.4

(*a*) 1917 and 1919 omitted.

YIELDS OF SOFT WHEAT AT MANHATTAN

At Manhattan Fulcaster has produced the best average yield of the soft-wheat varieties, the average being 2.6 bushels per acre above that of Harvest Queen, the variety grown for the longest period of time in comparison with it. Giving due regard to fluctuations in seasons, it is probable that there is no practical significance in the difference in the yield of these two varieties under the conditions at Manhattan. Fulcaster is known to be less winter hardy than Harvest Queen and it is reasonable to expect that over a longer period of years more injury from winterkilling might be expected.

Currell has been included for a six-year period and during that time has yielded less than Fulcaster and Harvest Queen in practically every season. Currell is without doubt the least winter hardy of any of the varieties included in these tests. Although no winterkilling has occurred during the period it has been grown, it is nevertheless quite likely that some damage has occurred. No other reasonable explanation for the lower yield of Currell as compared with that of other varieties can be suggested, although other unrecognized factors may play a part.

Michigan Wonder has been included for three years and has yielded a trifle more each year than Harvest Queen, the variety which it most nearly resembles. It appears to lodge a little more than Harvest Queen. It is not likely that the differences in yield reported here are significant.

During the five years it has been grown, Kawvale has produced an average yield slightly in excess of that of Fulcaster, but this undoubtedly is not significant. In fact, it has yielded less than Fulcaster in three years out of the five.

Nebraska 28 has been included in these tests for a total of 15 years, the particular reason for including it being the fact that for many years it was the earliest-maturing or in fact the only very early-maturing variety available for testing. It is, therefore, of interest in connection with the question of whether earlier-maturing varieties may be of value. For the 13-year period in which it has been compared with Harvest Queen and Fulcaster it has produced 3.4 bushels per acre less than Harvest Queen and 6 bushels less than Fulcaster. The relative yields of early- and late-maturing varieties will be discussed more fully later.

As in the case of the hard wheats, a number of soft-wheat varieties have been grown for a few years and discarded for various reasons. Of these Shepherd (C. I. No. 6163) was grown from 1925 to 1927 and produced an average yield 8.5 bushels less than Fulcaster for the period. Shepherd had the strongest straw of any variety included, as an average for two years in which the strength was measured by breaking tests (40). Nittany (Penn. No. 44) was grown from 1923 to 1925 and produced 1.7 bushels less than Fulcaster.

A very early variety of soft wheat known as Zimmerman was grown from 1914 to 1927. Its average yield was 0.6 bushel less than that of Harvest Queen for the 13-year period for which it is comparable. It yielded better than Harvest Queen in five of the thirteen years. These results are of particular interest in view of the fact that this variety on the average headed seven days and ripened four days earlier than Harvest Queen.

YIELDS OF SOFT WHEAT ON THE SOUTHEASTERN KANSAS EXPERIMENT FIELDS

The data from the southeastern Kansas experiment fields show there was very little difference in yield between the leading varieties, Blackhull, Kanred, Michigan Wonder, Harvest Queen, and Kawvale. Kawvale has been tested for a shorter period than the others. In 1930 severe winter injury occurred which afforded an opportunity to study the relative susceptibility of different varieties to such injury. Accordingly the per cent of winterkilling was estimated for each variety in each field and these data are presented in Table XIX. The high relative yields of the hard-wheat varieties, Kanred and Blackhull, in a region ordinarily considered a typical soft-wheat region, were apparently due to the winterkilling which occurred in 1930 and to a less degree in 1928. By reference to Table XIX it may be seen that the average winterkilling for Fulcaster on the three fields in 1930 was 52.3 per cent, as compared with 4.8 per cent for Kanred and 38.3 per cent for Blackhull.

TABLE XVIII.—RELATIVE YIELDS OF LEADING VARIETIES OF WHEAT ON THE SOUTHEASTERN KANSAS EXPERIMENT FIELDS.

(Bushels per acre.)

PLACE AND YEAR.	Kanred.	Blackhull.	Kawvale.	Fulcaster.	Harvest Queen.	Michigan Wonder.	Currell.
Columbus:							
1925	18.9	26.9	....	27.4	21.9	27.4	21.9
1926	42.1	42.7	....	37.2	35.4	40.2	37.1
1927	8.5	9.4	9.9	5.3	5.8	7.3	4.6
1928	33.1	34.2	35.6	31.5	24.1	31.9	14.4
1929	14.0	15.8	12.2	15.6	16.6	15.1	15.3
1930	23.8	21.4	24.6	17.1	27.1	25.2	4.9
Average, 1927-1930	19.9	20.2	20.6	17.4	18.4	19.9	9.8
1925-1930	23.4	25.1	....	22.4	21.8	24.5	16.4
Moran:							
1927	7.0	5.1	....	2.6	3.6	4.6	2.3
1928	23.3	23.5	23.2	20.1	20.2	23.3	13.7
1929	16.6	15.3	14.5	18.9	18.4	21.5	17.7
1930	13.9	12.2	12.0	8.6	12.8	10.3	2.0
Average, 1928-1930	17.9	17.0	16.6	15.9	17.1	18.4	11.1
1927-1930	15.2	14.0	....	12.6	13.8	14.9	8.9
Parsons:							
1925	13.5	21.2	....	15.5	14.5	12.8	12.0
1926	18.0	17.9	....	16.2	21.8	16.7	21.0
1927	14.8	15.3	....	12.0	9.8	14.2	8.0
1928	27.5	21.5	25.2	20.2	31.0	29.0	12.2
1929	17.0	20.0	20.0	22.0	21.5	22.5	18.5
Average, 1928-1929	22.3	20.8	22.6	21.1	26.3	25.8	15.4
1925-1929	18.2	19.2	....	17.2	19.7	19.0	14.3
Grand average for tests including Kawvale	19.7	19.3	19.7	17.7	19.7	20.7	11.5
Grand average for all tests	19.5	20.2	....	18.0	19.0	20.1	13.7

TABLE XIX.—WINTERKILLING OF LEADING VARIETIES OF WHEAT ON THE SOUTHEASTERN KANSAS EXPERIMENT FIELDS, 1930.

VARIETY.	Columbus, average of three plots.	Moran, average of two observations on each of two plots.	Parsons, average of two observations on each of two plots.	Average (not weighted).
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Currell	92.7	90.7	92.2	91.9
Michigan Wonder	11.7	30.0	30.8	24.2
Harvest Queen	3.7	23.3	29.1	18.7
Fulcaster	50.0	49.5	57.5	52.3
Kawvale	7.3	20.8	20.0	16.0
Kanred	6.0	1.7	6.7	4.8
Blackhull	33.3	40.8	40.8	38.3
Early Blackhull	48.3	....	....	....
Minturki	2.0	....	....	....
Fulhard	53.3	....	....	....
Tenmarq	28.3	....	....	....

In 1928 Fulcaster winterkilled 25 per cent whereas Kanred and Blackhull were not injured at all. In 1930 more than 90 per cent of the Currell was killed and approximately the same amount was killed in 1928. Winterkilling is known to be very unusual in this region and consequently the yield data here presented must be interpreted with this fact in mind. It should not be concluded that because the hard winter wheats have excelled in yield in these tests they can be expected to do so over a long period of years.

Of the soft wheats, Michigan Wonder and Harvest Queen appear to be the leaders. This result is also without doubt due to winterkilling in so far as the comparison related to Fulcaster and Currell, the last two mentioned varieties being materially less winter hardy. Kawvale has yielded the same as Harvest Queen for the period it has been tested, and has yielded two bushels more than Fulcaster, the variety most widely grown in southeastern Kansas.

YIELDS OF SOFT WHEAT IN COOPERATIVE EXPERIMENTS WITH FARMERS

In the coöperative experiments with farmers, only Michigan Wonder and Kawvale have yielded as much or more than Fulcaster, as shown in Table XX. On the other hand, Harvest Queen, Currell, Fultz, Poole, Mediterranean, Miracle, Red Rock, and Nittany have given essentially the same or lower yields. In some cases a distinction must be made between northeastern and southeastern Kansas and in most cases seasonal variations have played a leading role. These relations will be considered later by a comparison of the individual varieties that have been tested most extensively.

TABLE XX.—AVERAGE YIELD OF LEADING VARIETIES OF SOFT WHEAT COMPARED WITH FULCASTER IN COÖPERATIVE EXPERIMENTS IN EASTERN KANSAS.

VARIETY.	Years tested.	Number of tests.	Average yield—bushels per acre.		Difference.	D/E (a).
			Variety named.	Fulcaster in same test.		
Harvest Queen	1915-'30	363	21.7	23.2	—1.5	8.0
Currell	1915-'30	305	21.9	23.6	—1.7	9.4
Fultz	1915-'16 and 1923-'28	133	20.2	22.4	—2.2	8.5
Miracle	1915-'19	90	22.6	25.9	—3.3	7.0
Poole	1923-'28	112	20.9	23.3	—2.4	7.4
Mediterranean	1917 and 1919-'24	79	21.8	23.9	—2.1	4.7
Michigan Wonder	1925-'30	76	23.9	23.5	.4	1.6
Kawvale	1928-'30	50	23.3	20.9	2.4	2.5
Red Rock	1919-'21	42	19.0	21.4	—2.4	4.4
Mediterranean (Mo. No. 31)	1915	10	16.9	17.1	—.2	.0
Nittany (Penn. 44)	1923	6	21.7	28.6	—6.9	3.7

(a) Calculated by the point binomial method described by Salmon (48). This ratio has no useful meaning here other than that it indicates the improbability that the observed differences may be due to chance location of plots, errors in harvesting, threshing, etc. If the ratio is three or more it is reasonably certain (odds 21 to 1) that the difference is not due to such variation. This ratio does not fully measure seasonal variation (though it appears to do so as well as any) except where one may justly assume that the conditions are homogenous and the period of test a representative one. As shown later, this assumption cannot safely be made in most cases.

None of the varieties tested less extensively has shown any particular promise, either with respect to yield or other characters, as compared with Fulcaster, and hence only brief mention of them appears to be called for at this time,

Fultz is grown to some extent in southeastern Kansas, but the acreage is apparently decreasing. It seems to have no advantage over Fulcaster, and in 133 cooperative experiments in eight years it averaged 2.2 bushels per acre lower in yield than Fulcaster. It yielded about the same or lower than Fulcaster every year and showed no particular adaptation to any locality.

Poole was tested in 112 cooperative experiments from 1923 to 1928 in which it also was shown to be inferior to Fulcaster. The average difference in yield was 2.4 bushels. Fulcaster outyielded Poole every year and in all localities of eastern Kansas.

Mediterranean was studied in comparison with Fulcaster in 79 cooperative experiments in seven seasons in which it was inferior every year and in most of the counties in which tests were made.

A locally grown variety known as Miracle was included in 90 cooperative experiments from 1915 to 1919. Although similar in general appearance to Fulcaster, it was inferior, averaging 3.3 bushels lower in yield.

Red Rock was included in 42 cooperative experiments from 1919 to 1921. Its late maturity may account for the tendency to produce shriveled grain and perhaps for the fact that it yielded lower than Fulcaster each year, averaging 2.4 bushels less.

Nittany was grown in six tests in 1923. It matured late and produced a low yield of shriveled grain.

FULCASTER AND HARVEST QUEEN

Since Fulcaster and Harvest Queen are the two leading varieties of soft wheat in the state, they have been tested most extensively. Fulcaster is the leading commercial variety in southeastern Kansas, and Harvest Queen in northeastern Kansas as far south as Johnson and Douglas counties. It is also grown in a small area along the southern border of the state just east of central Kansas and extending into Oklahoma. In recent years Harvest Queen has been increasing, especially in central Kansas as far west as Salina on river and creek bottom lands.

As already noted, Harvest Queen, on the Southeastern Kansas experiment fields, has produced somewhat higher yields than Fulcaster, the average difference for the 15 station years being 1 bushel per acre. This appears to be attributable in the main to the greater winter hardiness of Harvest Queen. On the other hand, Fulcaster leads by a considerable margin at Manhattan, the difference in that case for a 15 year period being 2.6 bushels per acre. In 363 cooperative experiments with farmers, reported in Table XXI, Fulcaster also leads, the average difference being 1.5 bushels. There appears to be a significant difference in adaptation to different parts of the state as indicated in figure 10, which shows those counties in which Fulcaster has produced the higher yield and likewise those in which Harvest Queen has produced the higher yield.

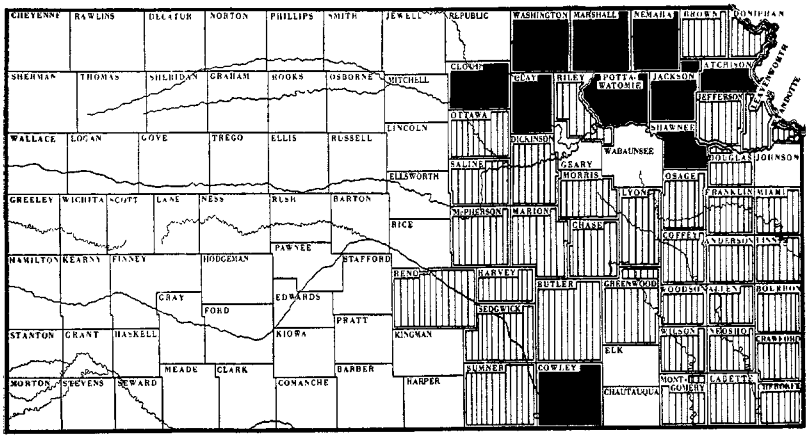
It may be observed that Fulcaster leads in yield in practically all cases except in northeastern Kansas, and in Cowley county in the southern portion of the state. This is in accordance with the commercial distribution of the two varieties. The superiority of Harvest Queen in northeastern Kansas can easily be explained by the difference in winter hardiness, although this cannot be verified so far as the cooperative experiments are concerned since no winter injury in either variety has been recorded. There seems to be no adequate explanation for the superiority of Harvest Queen in Cowley county, nor for the fact that it is grown there and in surrounding regions on a commercial scale. The superiority of Fulcaster for the remainder of the region is in accord with the fact that an awned variety ordinarially is more productive than awnless varieties, as already pointed out.

Harvest Queen has outyielded Fulcaster in only five years of the 16 and then only by very small differences, as shown in Table XXII. Apparently seasonal variation has played a minor role in determining the relative yield of these two varieties.

TABLE XXI.—RELATIVE YIELDS OF FULCASTER AND HARVEST QUEEN IN COÖPERATIVE EXPERIMENTS, 1915 TO 1930.

(Arranged by counties.)

COUNTY.	Number of experiments.	Average yield—bushels per acre. Fulcaster.	Average yield—bushels per acre. Harvest Queen.	Gain—Fulcaster over Harvest Queen.
Allen	8	24.5	21.8	2.7
Anderson	7	19.9	16.9	3.0
Atchison	15	23.5	24.3	—.8
Bourbon	1	31.8	21.5	10.3
Brown	6	32.9	31.4	1.5
Butler	6	27.1	22.9	4.2
Chase	9	28.4	27.0	1.4
Cherokee	16	22.8	19.4	3.4
Clay	2	22.1	22.1	.0
Cloud	1	10.5	10.6	—.1
Coffey	10	22.9	21.9	1.0
Cowley	6	29.5	33.1	—3.6
Crawford	18	17.5	15.7	1.8
Dickinson	11	29.6	27.8	1.8
Doniphan	23	26.2	25.2	1.0
Douglas	6	18.0	17.9	.1
Ford	1	19.3	16.9	2.4
Franklin	17	25.3	21.8	3.5
Greenwood	4	11.2	9.5	1.7
Harvey	1	23.5	22.5	1.0
Jackson	8	21.7	22.7	—1.0
Jefferson	6	22.9	20.0	2.9
Jewell	5	13.6	13.6	.0
Labette	19	24.4	20.6	3.8
Leavenworth	16	22.3	20.5	1.8
Linn	7	16.7	14.6	2.1
Lyon	2	26.3	24.9	1.4
Marion	2	29.2	26.8	2.4
Marshall	10	20.0	20.4	—.4
McPherson	7	23.8	21.2	2.6
Miami	9	23.0	21.0	2.0
Montgomery	18	23.8	20.8	3.0
Morris	8	25.7	25.6	.1
Nemaha	4	23.9	25.7	—1.8
Neosho	8	18.6	17.7	.9
Osage	4	20.7	16.1	4.6
Ottawa	6	26.0	25.6	.4
Pottawatomie	4	27.8	28.3	—.5
Reno	10	23.4	22.2	1.2
Riley	1	21.9	17.9	4.0
Saline	2	30.3	26.2	4.1
Sedgwick	8	24.9	14.3	10.6
Shawnee	8	22.4	22.8	—.4
Sumner	7	22.3	21.5	.8
Washington	2	15.3	18.5	—3.2
Wilson	10	28.7	27.4	1.3
Woodson	1	14.6	10.0	4.6
Wyandotte	3	18.6	17.3	1.3
Total	363			
Average (weighted)		23.2	21.7	1.5



■ HARVEST QUEEN OUTYIELDED FULCASTER ▥ FULCASTER OUTYIELDED HARVEST QUEEN

FIG. 10.—Relative yields of Fulcaster and Harvest Queen by counties in 357 coöperative experiments in eastern Kansas, 1915 to 1930.

TABLE XXII.—RELATIVE YIELDS OF HARVEST QUEEN AND FULCASTER IN COÖPERATIVE EXPERIMENTS, 1915 TO 1930.

(Arranged by years.)

YEAR.	Number of experiments.	Average yield—bushels per acre.		Gain—Fulcaster over Harvest Queen.
		Fulcaster.	Harvest Queen.	
1915	9	19.2	16.2	3.0
1916	18	20.2	18.2	2.0
1917	17	29.4	29.8	—.4
1918	39	27.3	28.4	—1.1
1919	30	26.4	22.7	3.7
1920	27	19.8	20.1	—.3
1921	45	20.5	18.6	1.9
1922	44	22.8	19.0	3.8
1923	33	20.3	17.4	2.9
1924	22	26.8	26.3	.5
1925	20	20.8	20.7	.1
1926	19	23.0	23.5	—.5
1927	14	21.4	17.5	3.9
1928	11	26.8	27.1	—.3
1929	10	22.3	20.0	2.3
1930	5	28.8	25.3	3.5
Total	363	....	....	....
Average (weighted)	....	23.2	21.7	1.5

FULCASTER AND CURRELL

Currell is the leading variety in the southern half of Cherokee county, the extreme southeastern county of the state. In this region it is highly prized because of its early maturity and stiff straw. The flour enjoys an excellent reputation as a soft-wheat flour. Probably the earlier ripening of the variety is somewhat overemphasized; since the color of the glumes gives a field the appearance of being ripe some time before it is ready for harvest. At Manhattan it has headed only a very little earlier and has ripened about two days earlier than Fulcaster. On the southeastern Kansas experiment fields it has headed two days earlier and ripened one day earlier than Fulcaster.

In only one season, 1929, has Currell produced a higher average yield than Fulcaster in the cooperative experiments reported in Table

TABLE XXIII.—RELATIVE YIELDS OF FULCASTER AND CURRELL IN COÖPERATIVE EXPERIMENTS WITH FARMERS IN EASTERN KANSAS, 1915 TO 1930.

(Arranged by years.)

YEAR.	Number of experiments.	Average yield—bushels per acre.		Gain—Fulcaster over Currell.
		Fulcaster.	Currell.	
1915	10	18.3	17.0	1.3
1916	16	20.5	18.3	2.2
1917	17	29.2	25.8	3.4
1918	34	28.3	26.6	1.7
1919	26	26.1	24.4	1.7
1920	16	21.2	21.2	.0
1921	35	19.3	17.9	1.4
1922	29	22.8	21.2	1.6
1923	30	21.5	19.9	1.6
1924	22	26.8	24.4	2.4
1925	18	21.5	20.5	1.0
1926	19	23.0	22.8	.2
1927	13	21.9	18.7	3.2
1928	11	26.8	23.8	3.0
1929	4	19.9	22.1	—2.2
1930	5	28.8	26.6	2.2
Total	305	....	....	....
Average (weighted)	....	23.6	21.9	1.7

XXIII, and in that season the number of tests was very small. Data presented in Table XXIV show that it has not produced constantly higher yields than Fulcaster in any section of the state except in Cowley and Sumner counties, and it has been grown in only a few trials there. The average difference in yield for the 305 cooperative experiments that have been conducted, is 1.7 bushels.

As already pointed out, Currell is clearly less winter hardy than Fulcaster and without doubt the difference in yield is in part due to this fact. However, in years when no winterkilling was apparent, it has failed to show any great superiority in yield as compared with Fulcaster. Aside from greater susceptibility to winterkilling and leaf rust there seems to be no adequate explanation for the low

TABLE XXIV.—RELATIVE YIELDS OF FULCASTER AND CURRELL IN COÖPERATIVE EXPERIMENTS, 1915 TO 1930.

(Arranged by counties.)

COUNTY.	Number of experiments.	Average yield—bushels per acre.		Gain—Fulcaster over Currell.
		Fulcaster.	Currell.	
Allen	7	26.9	25.9	1.0
Anderson	7	19.9	19.2	.7
Atchison	11	24.1	23.3	.8
Bourbon	1	31.8	24.5	7.3
Brown	5	36.4	28.9	7.5
Butler	3	27.4	23.2	4.2
Chase	4	29.2	26.1	3.1
Cherokee	16	22.6	20.4	2.2
Clay	1	13.5	15.0	—1.5
Cloud	1	10.5	9.0	1.5
Coffey	8	22.5	22.1	.4
Cowley	6	29.5	32.7	—3.2
Crawford	19	17.9	17.2	.7
Dickinson	10	29.4	28.4	1.0
Doniphan	20	27.1	24.4	2.7
Douglas	6	18.1	17.3	.8
Ford	1	19.3	15.0	4.3
Franklin	18	24.7	23.0	1.7
Greenwood	3	14.0	12.9	1.1
Jackson	8	21.7	21.5	.2
Jefferson	6	22.7	22.3	.4
Jewell	2	13.2	14.1	—.9
Labette	20	24.6	23.9	.7
Leavenworth	15	23.0	19.4	3.6
Linn	7	16.7	15.5	1.2
Marshall	10	21.4	18.7	2.7
McPherson	5	22.3	18.3	4.0
Miami	9	23.0	20.6	2.4
Montgomery	15	23.8	21.7	2.1
Morris	5	23.8	21.9	1.9
Nemaha	3	23.7	22.5	1.2
Neosho	9	19.8	18.3	1.5
Osage	4	20.7	20.1	.6
Ottawa	3	31.9	25.5	6.4
Pottawatomie	4	27.8	24.0	3.8
Reno	9	24.3	23.4	.9
Riley	1	21.9	23.0	—1.1
Shawnee	8	22.5	22.4	.1
Sumner	2	22.3	25.7	—3.4
Wilson	9	30.1	25.8	4.3
Woodson	1	14.6	15.8	—1.2
Wyandotte	3	18.6	17.9	.7
Total	305	....	....	....
Average (weighted)	....	23.6	21.9	1.7

yield of Currell other than the fact it is an awnless variety. At least the tests so far conducted have revealed no other distinct defects in this variety that Fulcaster does not also possess.

There has been no opportunity to observe the resistance of Currell to lodging except for one year at Manhattan when it lodged less than Harvest Queen. The straw has been among the strongest as measured by a breaking test (40). It appears to be, in common with several other soft wheats, highly resistant to leaf blotch (Septoria).

MICHIGAN WONDER AND HARVEST QUEEN

Michigan Wonder and Fulcaster have given approximately the same yields in the tests in which the two have been compared excepting on the southeastern Kansas experiment fields, where Michigan Wonder has been materially better, partly on account of greater winter hardiness. Michigan Wonder is an awnless variety similar to Harvest Queen in all essential respects. If grown in Kansas on a commercial scale it would probably be in competition with Harvest Queen rather than with Fulcaster. Hence it seems more logical to compare it with Harvest Queen.

On the southeastern Kansas experiment fields Michigan Wonder has averaged slightly higher than Harvest Queen in yield, but the differences without doubt are within the limits of plot and seasonal variability. Essentially the same can be said of the experiments at Manhattan. As an average of the 76 experiments in cooperation with farmers comprising a six-year period, its yield was 1.4 bushels more than Harvest Queen. This difference is no greater than can be explained by plot variability since the ratio of D/E by the point binomial method is only 1.5. In three of the six years it has outyielded Harvest Queen by 3.5 bushels or more. In the other three years there has been no difference at all or the difference has been very slight.

It appears, therefore, that seasonal fluctuations may easily account for such differences as have been recorded, but the number of seasons is too small to permit any definite conclusions regarding this point. Such data as are available indicate that Michigan Wonder is no more resistant to winterkilling or to lodging than is Harvest Queen, and may be less resistant. There is no section of the state in which Michigan Wonder has given especially high yields as compared with other varieties. Its comparative resistance to winterkilling would suggest northeastern Kansas as the region in which it is most likely to find a place.

KAWVALE AND FULCASTER

Kawvale is a pure-line selection from Indiana Swamp made by the Kansas Agricultural Experiment Station and is of interest because of its high resistance to leaf rust and relatively high resistance to winterkilling and to Hessian fly. It is probably about as winter hardy as Harvest Queen and considerably more so than Fulcaster and Currell, the varieties which it possibly will replace if it becomes of commercial importance. The character and quality of the grain are roughly comparable to Fulcaster, but the grain is a little harder. It has shown a distinct tendency to shatter, and especially so if allowed to stand after it is ripe. Its resistance to Hessian fly is discussed in another publication (35).

As has already been pointed out, Kawvale in a five-year test at Manhattan has averaged 0.5 bushel more than Fulcaster. On the southeastern Kansas experiment fields, where it has been included for four years at Columbus, three at Moran, and two at Parsons, it has yielded materially more than Fulcaster because of its greater winter hardiness. (Fig. 11.) It has produced a better yield than Harvest Queen at Columbus, essentially the same as Harvest Queen at Moran, and less than Harvest Queen at Parsons. It was included in three coöperative tests with farmers in 1928, 28 in 1929, and 19 in 1930. It produced a better yield than Fulcaster in each of the three years, the average difference (weighted) being 2.4 bushels per acre.

FIG. 11.—Comparative winterkilling of Kawvale (left) and Fulcaster (right) on experiment field, Moran, 1929-'30. (Photograph taken April 14, 1930.)

The varation in seasons observed with other varieties may well occasion some doubt as to whether these gains in yield will be maintained over a period of years. That Kawvale shatters somewhat more easily than the hard wheats and apparently even somewhat more than Fulcaster, is a fact that must be considered in evaluating it. Its greater winter hardiness as compared with Fulcaster, and its resistance to leaf rust and Hessian fly are such as to merit considerable attention. Resistance to Hessian fly should make it of some promise as a parent for crossing with fly-susceptible varieties. Such observations as have been made with respect to lodging and the breaking strength of the straw suggest that it is as resistant to lodging as Fulcaster and may be more resistant. It appears to be a little earlier than Fulcaster, heading at Manhattan about a day in advance.

LEAF RUST, LEAF BLOTCH, AND YIELD

Leaf rust *(Puccinia triticina)* and leaf blotch *(Septoria tritici)* are present in some parts of Kansas nearly every year, but it is only occasionally that wheat yields are noticeably reduced by these diseases. The season of 1928-'29 was a favorable one for their development at Manhattan. It appeared that they might be a factor in reducing yields, and accordingly the per cent of leaf rust and the per cent of the upper leaves killed by Septoria were estimated by Mr. C. O. Johnston of the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture. The results together with the yields are given in Table XXV. The relation between yields and the per cent of leaf rust and the per cent of leaf blotch is shown graphically in figure 12, and the relation between yields and a disease index calculated by adding together the per cent of leaf rust and the per cent of leaves killed by leaf blotch is shown graphically in figure 13.

TABLE XXV.—YIELD IN RELATION TO LEAF RUST AND LEAF BLOTCH IN VARIETIES OF WINTER WHEAT, 1929.

(Manhattan, Kan.)

VARIETY.	C. I. No.	Yield, bushels per acre.	Per cent of leaf rust.	Per cent of leaf area killed by leaf blotch.
Hard Red Winter Series.				
Fulhard	8257	28.9	86.6	Trace
Kanred × Hard Federation	Kan. 2627	26.4	Trace	56.6
Tenmarq Selection	Kan. 2637	25.0	16 6	10.0
Tenmarq	6936	24.3	15.0	8.3
Kanred × Marquis	Kan. 2638	22.8	20.0	23.3
Prelude × Kanred	8886	22.1	Trace	86.6
Kanred × Marquis	Kan. 2644	20.2	20.0	30.0
Blackhull	6251	18.1	71.6	56.6
Oro	8220	18.0	80.0	13.3
Early Blackhull	8856	17.4	43.3	53.3
Kanred × Hard Federation	Kan. 2625	17.3	70.0	38.3
Superhard	8054	16.8	53.5	55.0
Kanred (checks)	5146	14.8	55.0	68.7
Kharkof	6206	14.2	80.0	26.6
Turkey	1558	12.8	83.3	31.6
Kharkof Selection (Hays No. 2)	6686	12.2	80.0	18.3
Newturk	6935	11.4	88.3	8.3
Soft Red Winter Series.				
Kawvale	6274	29.5	Trace	20.0
Fulcaster	6471	26.9	63.3	Trace
Nebraska No. 28	5147	24.3	60.0	8.3
Michigan Wonder	Kan. 500	23.5	63.3	Trace
Currell	3326	19.9	90.0	6.6
Harvest Queen	6199	19.6	83.3	Trace
Kanred (checks)	5146	16.5	30.0	80.0

NOTE.—The data represent the average of three series.

There would appear to be an unmistakable relation between yield and these two diseases. The relation is particularly evident if yield is considered in relation to both diseases, since it appears that to some extent the effect of each is the same and that one appears to supplement or add to the damage caused by the other. Thus in practically all cases a high yield is associated with a low disease index and *vice versa*. There appear to be two exceptions to this; namely, Fulhard, which produced a high yield though badly infected with leaf rust, and Kanred X Hard Federation (Kansas 2627),

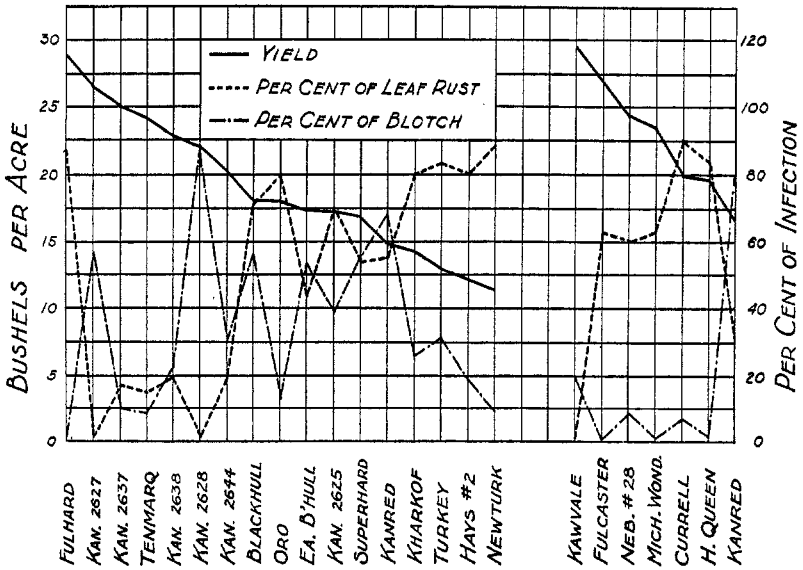


FIG. 12.—Relation between yields of varieties of wheat, and leaf rust and leaf blotch at Manhattan, 1929.

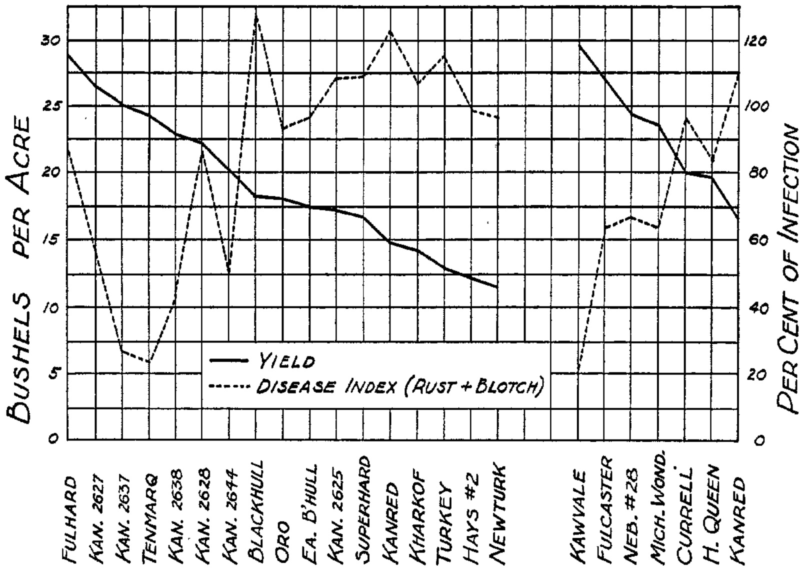


FIG. 13.—Relation between yields of varieties of wheat, and the combined effect of leaf rust and leaf blotch at Manhattan, 1929.

which also gave a relatively high yield though rather badly infected with Septoria.

In general the data pertaining to leaf rust are in agreement with the conclusion reached by Mains (31) and by Johnston (26) and those for Septoria agree with the conclusion of Kemp and Metzger (27) in Maryland, although the latter were dealing with Septoria glume blotch instead of leaf blotch.

Unfortunately no data are available which furnish any definite idea of the damage that may be expected from these diseases over a period of years. They appear to be nearly always present, but it is only occasionally at Manhattan that they develop to a sufficient extent to become dominant factors in determining yields as they appeared to have been in the season just mentioned. It appears that the importance of these diseases increases as the rainfall increases, and consequently it is probable that they are more important in eastern Kansas. In any event they appear to be of sufficient importance to deserve recognition in any program for the improvement of wheat varieties.

LODGING

The relative tendency of different varieties to lodge and the relation between lodging and breaking strength of the straw of different varieties has been discussed by one of the authors (40). Table XXVI gives in a summarized form the more pertinent data relating to leading varieties. Since some of the varieties were not grown in the earlier years the lodging is expressed as plus (+) or minus (—)

TABLE XXVI.—LODGING AND BREAKING STRENGTH OF STRAW OF CERTAIN VARIETIES OF HARD AND SOFT WINTER WHEATS.

(Manhattan, Kan.)

VARIETY.	C. I. No.	Lodging, plus (+) or minus (—) Harvest Queen.	Average breaking strength of straw, 1926 to 1930, pounds per straw.
		Per cent.	
Harvest Queen	6199	....	1.06
Fulcaster	6471	13.5	.96
Kawvale	5274	5.7	.86
Nebraska No. 6	6249	16.1	(a) .86
Tenmarq	6936	13.1	.80
Blackhull	6251	17.5	.79
Kharkof	6206	24.1	.75
Turkey	5592	23.1	.73
Kanred	5146	31.9	.68

(a) Average for four years only. The average for Kanred for the same years was 0.72.

Harvest Queen. The data would seem to verify the common opinions that there are marked differences in tendencies to lodge and that hard wheats as a group lodge more than soft wheats; that Blackhull on the average lodges less than Turkey and Kanred more. It appears, also, that tendency to lodge is related to breaking strength of the straw. Of special interest is the fact that in 1927, 1928, and 1929, Blackhull lodged approximately as much or more than Turkey and Kanred, although in earlier years it lodged materially less.

Additional data relating to certain varieties were secured from the coöperative experiments in 1928 and 1929. In 1928 observations were made on 70 of these experiments and in 1929 on about forty. The number of experiments in which each variety lodged in 1928, and the number in which each variety lodged and in which each lodged seriously in 1929, are shown in Table XXVII.

TABLE XXVII.—LODGING OF VARIETIES OF WHEAT IN COÖPERATIVE EXPERIMENTS IN 1928 AND 1929.

VARIETY.	Number of tests in which lodging occurred.		
	1928.	1929.	
		Slight lodging.	Serious lodging.
Kanred	16	21	3
Turkey	11	20	2
Blackhull	15	31	21
Superhard	15	31	22
Early Blackhull	....	36	26
Fulcaster	8	13	2
Tenmarq	....	15	5

It is of special interest to note that whereas Blackhull has the reputation of lodging less than Turkey and Kanred—a reputation which it appears to have merited previous to 1927—it lodged in more cases than did Turkey in 1928 and 1929. It thus appears that relative lodging, as well as relative yields, is greatly influenced by seasonal conditions.

TIME OF MATURITY AND YIELD

That there is a relation between the period of growth or the time of maturity and yield of most grain crops is so obvious as to require no comment, were it not for the fact that it has been practically ignored so far as an experimental determination of such a relation is concerned. It seems to have been taken for granted that all that is needed is simply to know that such a relation exists or that testing for yield automatically eliminates those varieties which do not mature at the best time. The latter assumption, of course, is sound, provided only that tests be sufficiently extensive and continued for a sufficient time to properly evaluate the time-of-maturity factor along with the others. The same is true of awned and awnless varieties, but it is probably no exaggeration to claim that the discovery of the relation between the awns and yield in wheat has increased the efficiency of breeding operations involving this character nearly 50 per cent because it makes it possible to eliminate a large proportion of the lower-yielding awnless segregates in early generations. An increasing recognition of the importance of seasonal variability in variety tests will no doubt bring to the attention of plant

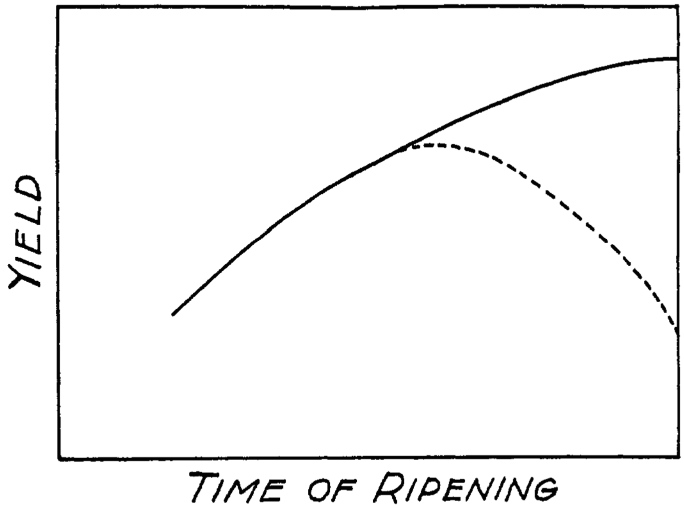


FIG. 14.—Diagrammatic illustration of the probable relation between time of ripening and yield. The solid line indicates the relation when conditions remain favorable throughout the growing season and the dotted line when they do not remain favorable.

breeders the need of knowing something more definite of the relation between yield and various varietal characteristics, including time of maturity.

On strictly theoretical grounds it may be expected that the relation is somewhat as illustrated in figure 14, in which the solid line indicates the yields that may be expected when conditions remain favorable throughout the growing season, and the dotted line the yield that may be expected when conditions do not remain favorable.

These curves express the belief that when there is plenty of moisture throughout the season but not an excess, when the soil is sufficiently fertile but not so fertile as to promote lodging, and when there are no diseases, insects or other disturbing factors, the longer a variety grows and yet fully matures before frost the more may it be expected to yield. If, on the other hand, conditions do not remain favorable throughout the season, then that variety which makes the best compromise between utilization of the entire growing season and escape of unfavorable conditions will yield the most. Since the latter situation is the usual one as far as winter wheat in Kansas is concerned, the information that is needed is what period of growth or time of maturity is most likely to correspond with the maximum point on the curve.

Probably this can be most usefully expressed by reference to some well-known variety such, for example, as Kanred or Turkey. Thus, for Kansas it may tentatively be assumed that the most favorable time of ripening corresponds to or is somewhat earlier than that for Kanred wheat. At least it has been assumed and apparently with good reason that one of the reasons for the higher yield of Kanred as compared with Turkey is its slightly earlier maturity, and similarly that one of the reasons for the better yield of Blackhull and Tenmarq is the fact that they mature a little earlier than Kanred. This assumption is also supported by the fact that varieties which mature later than Turkey, such as Minturki, Iobred, and Oro, have almost invariably yielded less than Turkey and Kanred so far as experimental evidence is available. Thus there seems to be good reason to believe that in Kansas or at least in central and western Kansas a variety to produce a maximum yield should mature as early as Kanred wheat and possibly somewhat earlier. It furthermore appears that an efficient wheat-breeding program depends not only on knowing that this is the case, but on determining with some degree of accuracy just how early such a variety should be.

Unfortunately there is very little experimental data bearing on this problem, largely for the reason already pointed out that the dominating idea in variety testing for the past 20 years has been to conduct empirical trials without much attention to general principles. As a result very few early varieties have been included in experimental trials for any length of time. Fortunately there are a few exceptions, and it, seems worth while to present such data as are available.

Possibly the most interesting and instructive data yet secured are those relating to the yield of Nebraska 28, a soft wheat, the product of a cross between Turkey and Big Frame made at the Nebraska Agricultural Experiment Station. This variety matures from 5 to 10 days earlier than Turkey. It has a relatively stiff straw but is among the less winter-hardy varieties, being comparable to Blackhull in this respect. It has been grown at Manhattan for 15 years. During this period it averaged 25 bushels per acre as compared with 31.3 bushels for Kanred. This period included one year, 1917, when Nebraska 28 was almost a complete failure because of winterkilling. Excluding this year its average yield is 26.7 bushels as compared with 32.3 for Kanred. During this 14-year period Nebraska 28 outyielded Kanred in three seasons.

This variety has been grown at the Hays station for 13 years. Its average yield for this period is 19.8 bushels, as compared with 22.5 bushels for Kanred, or a difference of 2.7 bushels. It outyielded Kanred in five years of the 13. It was grown at Colby in 1916, 1918, and 1920, the average yield being 37.3 bushels as compered with 33 for Turkey and 40.1 for Kanred.

As reported by Kiesselbach (28) Nebraska 28 has been grown at Lincoln, Neb., for 13 years. Its average yield for this period is 30.3 bushels as compared with 33.2 bushels for Turkey. It outyielded Turkey in four years of the 13. Zook and Burr (53) state that it was grown at the North Platte, Neb., station on summer-tilled land for eight years. In three of the eight years it produced 4.8, 14.4, and 5.1 bushels, respectively, more than Turkey. In two of the years lodging, and in another year a severe drought, were responsible for the low yield of the Turkey wheat. As an average for the eight years, Nebraska 28 produced 26.1 bushels per acre, which was 1.7 bushels more than Turkey produced. In a five year test on corn ground, Nebraska 28 produced an average yield of 16.7 bushels as compared with 15 for Turkey.

It was grown on the Columbus, Kan., experiment field in 1926 and 1927. The average yield was 2.1 bushels more than Harvest Queen and 1.4 bushels more than Fulcaster for the same period.

Clark and Martin (8) report a two-year yield record at the United States field station at Amarillo, Tex. In this case Nebraska 28 produced an average yield of 16.5 bushels as compared with 16.9 for Kanred. As reported by these authors this variety has been grown extensively in experimental tests throughout the Great Plains, but aside from those places which have been mentioned the yield in general has been relatively low on account of winter injury,

Another early variety of interest is Early Blackhull, selected by A. P. Haeberle of Clearwater, Kan., from Blackhull and included in the experimental trials at Manhattan since 1927. This variety matures almost as early as Nebraska 28 and probably is slightly less winter hardy. In the winter-hardiness nurseries in 1929 it was slightly less winter hardy than Blackhull. In other respects it is similar to Blackhull except that it is earlier. In the three years it has been grown at Manhattan it produced an average yield of 28.3 bushels as compared with 31.6 for Blackhull. At the Fort Hays branch station, where it has been grown for two years, it produced an average yield of 32.1 bushels as compared with 30.3 for Blackhull. This variety outyielded Kanred and Blackhull in 47 coöperative experiments with farmers in 1929 and yielded slightly lower than those varieties in 51 such tests in 1930.

Early Blackhull was included in the winter-hardiness nurseries in 1929 and at 10 of the stations yields were secured. At four of these, as reported by Quisenberry and Clark (38), Early Blackhull produced as high or substantially higher yields than Blackhull, the variety which it most nearly resembles. In three of the remaining tests in which lower yields were secured, a lower winter survival also was recorded.

Another interesting new variety is a cross between Prelude and Kanred. This variety is somewhat later than Nebraska 28 and is about as winter hardy. The average yield for the three years it has been grown at Manhattan is 34.5 bushels as compared to 31.6 for Kanred. Another early-maturing variety originating from the cross Kanred X Hard Federation produced an average yield of 35.4 bushels for this same period. Prelude X Kanred was also grown at Hays in 1929 and in that season produced an average yield of 22.2 bushels as compared with 16.4 for Kanred.

As pointed out in connection with the Manhattan data, Zimmerman, an awnless soft wheat heading and ripening about as early as Nebraska 28, was grown at Manhattan for the 13-year period, 1914 to 1927, and produced an average yield of 0.6 bushel less than Harvest Queen for the same period. It outyielded Harvest Queen in five of the 13 years and was approximately equal to Harvest Queen in two others. It was also grown in cooperative tests with farmers for a single year, 1921, but produced a very low yield in that season because of injury by a heavy freeze on March 27, when the temperature dropped to from 16 to 20 degrees. Zimmerman was jointing when the freeze occurred.

These data have been presented not to show that varieties of wheat which mature as early as Nebraska 28, Early Blackhull, Prelude X Kanred, Zimmerman, and others can usually be expected to yield as much as standard commercial varieties, but rather to show that there are some seasons and some conditions when such is the case and to emphasize the point that perhaps other varieties which do not mature so early but yet earlier than standard varieties may be expected to yield even better. Such varieties have not been available for testing, and consequently no data pertaining to this particular question are available.

In brief, the authors have had nothing more in mind than to point out that there is a fundamental relation between time of maturity (or time of heading) and yield, and that for certain sections of the state it is a reasonable assumption that varieties somewhat earlier than those generally grown would be desirable.

Yield, however, is not the only consideration. Even with a lower yield many farmers could afford to grow an early wheat on a part of their acreage to provide a better distribution of risks and of harvest labor. In the important wheat belts of the state this probably is fully as important as yield.

The problem of producing an early-maturing wheat satisfactory in other respects may not be so simple as it seems. It is probably not altogether chance that all early-maturing varieties so far available for testing have been deficient in winter hardiness. Hence, it may be difficult to combine in one variety early maturity and a satisfactory degree of winter hardiness. Quisenberry (36) points out that such a combination may be difficult but probably is not impossible. A physiologic correlation might be anticipated were it not for the fact that winter rye is the most winter-hardy cereal and at the same time one of the earliest to mature.

It is also probable that the risks are not all in favor of the earlier varieties. Thus, as already pointed out, Zimmerman and Nebraska 28 were badly damaged in 1921 by a late spring freeze when other varieties for the most part escaped, the former being more severely injured because of their advanced stage of development when the freeze occurred. It is probable that should winter-hardy, high-yielding, early-maturing varieties be produced, it would still be undesirable to depend on them alone because of the distribution of risks and labor as mentioned above.

SEASONAL VARIATION AND VARIETAL TESTING

The fact that yields and other experimental results vary from season to season and that this variation must be taken into account in the interpretation of such results is a fact well known to agronomists and is one frequently mentioned by writers on agronomic subjects. Even so, it is doubtful if its full significance and importance have been realized. Attention has been called to it in connection with the interpretation of certain results presented in this paper. It now seems desirable to discuss briefly its more general relation to varietal and strain tests and to crop improvement in general. Hopkins (23) more than 20 years ago called attention to the unusual variation in rainfall at North Platte, Neb., and the probability of serious error in estimating the agricultural possibilities of that region based on rainfall records for a short period of time. He called attention to a seven-year period in which every year but one had more than a normal rainfall, and in the exceptional year the rainfall was but slightly below normal; also to a nine-year period in which the rainfall for every year was distinctly below normal. Spillman (45) has called attention to the fact that 10-year averages of rainfall at Penn Yan, N. Y., may be in error as much as 7.5 per cent, considering the 60-year average as the true rainfall. Lyon (30), Kiesselbach (28), Carleton (4), Hilgard (22), and Mooers (34), to mention only a few observers, have emphasized in one way or another the need for careful consideration of this factor.

Engledow and Yule (16) and more recently Stadler (47) have attacked the problem from a datistical viewpoint. Stadler used as his material yields in a five-year test of 77 varieties of winter wheat grown in 10 distributed single rod-rows at the Missouri Agricultural Experiment Station. He found the standard deviation to be 7.1 bushels per acre (of which 6.7 bushels was due to seasonal variation) and the least significant difference (odds of 30 to 1) to be about 9.2 bushels for the five-year average, Because of this large variation, he says, “We are forced to the conclusion that this rather elaborate experiment has yielded very little useful information."

Stadler, however, is probably in error in intimating that seasonal variability is in general much smaller than in the experiment referred to. Calculation by the writers indicate that the standard deviation of yields of wheat at Manhattan due both to soil and to season, but mainly the latter, may be expected to range from 6.5 to 8 bushels per acre, or from 35 to 40 per cent of the mean yield; and on the dry lands of the Great Plains, particularly the branch stations of western Kansas, as much as from 8 to 10 bushels per acre, or from 50 to 75 per cent of the mean yield. It is probable that seasonal variation is greater in the Great Plains than in the corn belt or eastern states, where crop yields are less frequently and less severely limited by weather conditions.

Swanson (49) has recently stated that the standard deviations in yields for the several major crops at the Fort Hays branch station, Hays, Kan., are frequently greater than the mean yield of the crop. Still more disturbing, he points, out, is the way in which varieties are influenced by seasonal variation.

The data previously presented relating to the comparative yields of Kanred and Turkey, Kanred and Blackhull, Fulcaster and Turkey, Fulcaster and Kanred, and others, seem to fully corroborate the opinion that seasonal variation is not only the most important source of variation in field tests, but is so important that results for a few years, even up to 10 or 15 years, may be very misleading and inaccurate as a basis for predicting relative yields of varieties. Certainly, for example, no one familiar with the background of crop production in Kansas for the past 60 years would consider Fulcaster as good as Turkey for the Manhattan area (disregarding the difference in classes) in spite of the fact that Fulcaster has produced a slightly higher average yield than Turkey during the past 16 years; or as an equal to Kanred for central Kansas as a whole, although in approximately 300 cooperative tests with farmers it averaged practically the same yield as Kanred. Likewise it is questionable if the higher yield of Blackhull as compared with Turkey and Kanred can be expected to be maintained over a period, say of 25 years, and the same must be admitted to be to some extent true of Kanred as compared with Turkey.

The question is important, not only in relation to the interpretation of experiments that have been conducted, but also in relation to planning experiments. Thus, as Stadler (47) has pointed out, many of the refinements in plot technic which have been devised for the elimination of plot variability are of doubtful value if seasonal variability is ignored. It would appear, therefore, that the problem of accurate field tests cannot be solved until some means have been provided by which erroneous conclusions due to variation in seasons may be avoided.

At least a partial solution of the questions in the opinion of the writers lies in giving more attention to discovering those characteristics which enable one variety to yield more than another. Thus average yields of Fulcaster and of Blackhull as compared with Turkey and Kanred are discounted because of the well-known difference in winter hardiness and the known relation between lack of winter hardiness and yield. Were it not known that Fulcaster and Blackhull are deficient in winter hardiness, and were it not known that recent years have been characterized by winters milder than may normally be expected (44), there would be no reason for doubting their ability to continue to produce high yields. It is possible, of course, that these varieties possess qualities of sufficient importance to justify growing them in spite of these deficiencies, but if so a longer yield record or more information regarding other characteristics than is so far available would seem to be necessary to clearly establish the fact.

In a similar way a prediction as to the relative yields of Kanred and Turkey in the future turns on the question of why has Kanred produced better yields in the past. There seems to be no question as to the fact that it has done so, but there is a lamentable lack of information as to why it has done so. If it were definitely known that differential winterkilling in the earlier years was the cause, then one could predict with reasonable certainty that similar seasons would again occur and similar results again be secured. If, however, it were known that differential damage from stem or leaf rust was the cause and that there are now present in the state (as there seem to be) forms of rust to which Kanred is susceptible, the predicted result might be quite different. The same would be true had it been experimentally demonstrated that varieties do change as a result of natural selection in a way comparable to mathematical expectations. This lack of information so far as the past is concerned cannot now be remedied, but. there seems to be no good reason why more complete information cannot be secured in the future which will aid in deciding why certain varieties yield more than others.

A PROGRAM OF WHEAT IMPROVEMENT FOR THE FUTURE

It has been pointed out that the work of the 20-year period discussed in this bulletin as first inaugurated was based largely on the pure-line hypothesis of Johannsen. At the time this was proposed there was a growing sentiment that the theory of continuous improvement which was a corollary of Darwin's theory of natural selection was somewhat inadequate. That is to say, it was becoming increasingly apparent that crops could not be continually improved by selection within a given variety. Johannsen showed that this was true, the reason being that varieties of our self-fertilized crops consist of mixtures of pure lines which when isolated remain substantially pure thereafter. Much of the crop-improvement work since Johannsen's time has been based on the assumption that practically all self-fertilized crops consist of mixtures of such pure lines and that all that was necessary to secure marked improvement was to isolate these lines and determine their value. It seems also to have been assumed that if desirable pure lines should be lacking they might be expected to arise occasionally by mutation.

Another assumption that seems to have played a considerable part was that varieties and strains exist which may or may not differ morphologically from others, but which possess a mysterious, unknown, or indefinite something which for want of a better name has been called yielding capacity. In many cases the dominating idea apparently has been to isolate strains which possessed this capacity. Thus there have been developed elaborate systems of testing which in the mind of the breeder could be depended upon to make known the presence of such strains and demonstrate their worth.

There seem to be at least two good reasons why this procedure at the Kansas station has been less effective than expected. One is the very real difficulty in determining accurately the worth of strains because of the marked variation in seasons, as discussed on a preceding page. Thus, in spite of 20 years' continuous work in one case and 16 years' work in another, involving more elaborate tests than are often possible in similar work, uncertainty still exists as to the future relative yields of Kanred and Blackhull as compared with Turkey wheat.

The second is the fact that in a region such as Kansas, with rather severe and somewhat homogeneous conditions (geographically), natural selection may be expected to bring about an elimination of the distinctly low-yielding strains. It would then be expected that those which remain would yield approximately the same over a long period of years. It does not necessarily follow that such strains will be similar to one another, since the defects in any one may be compensated for by desirable qualities lacking in the others. The strain of Turkey wheat with which Kanred has been compared in the experiments reported here is probably the descendant of the Turkey wheat, brought to Kansas by Mennonite colonists in 1873. It has therefore been subjected to natural selection under Kansas conditions and probably under very similar conditions in Russia for a considerable period. Considering these facts, a marked difference in average yield of Kanred and Turkey would perhaps be as strange as would be a small difference or no difference at all.

Whether this is admitted to be the true explanation of the small difference or the lack of a difference between these varieties in recent years, would seem not to be important for the present discussion since it must at least be admitted (with the relative yields before us) that a further increase in yield by selection of pure lines in either of them (Kanred is probably no longer entirely pure) would be a difficult and very uncertain procedure. Hence it would seem to follow that whatever one may think of the pure-line method in general or regardless of what improvements have been secured by it elsewhere or in the past, it apparently offers little promise for further improvement in yield of hard red winter wheat varieties for Kansas.

The question therefore naturally arises as to the future. If 20 years or more are required to determine the relative yields of two varieties may it not be well to make more use of natural selection for the elimination of low-yielding lines instead of so much emphasis on the isolation of pure lines to be followed by elaborate yield tests. Some such procedure would certainly be less expensive and might perhaps well be substituted for the haphazard selection and testing of pure lines so characteristic of much of the plant breeding of the past. The authors desire to raise no doubts as to the effectiveness of the pure-line method when directed toward definite specific objectives and when the material from which the selections are made is known to be such as to promise success. Finally, the authors do not question in the least the progress that has been made with other crops and in other regions. They merely insist that the method has some limitations which were not realized at least in Kansas when the work here described was begun and possibly are not fully realized elsewhere at the present time, and furthermore that the time has arrived for a more effective and a more completely scientific method.

Instead of breeding or selecting for "high yielding capacity," if better yields are sought, will it not be more effective to determine those characteristics on which high yields depend, or more accurately those characteristics or qualities which limit the possibilities for high yields? Will the breeder not then find that instead of searching for an indefinite, fluctuating "capacity to yield" which like a will-o'-the-wisp is now here and now there, demonstrable in some seasons and on some soils but not others, he has before him a tangible objective, progress toward which can be measured and demonstrated? There can, of course be no objection to selection and breeding for "high yielding capacity" so long as one understands by this the ability to produce high average yields over a long period of years. There is a very real objection, however, if one fails to realize that capacity to produce high yields under favorable conditions (which is implied in the term "yielding capacity") often or perhaps usually means inability to produce satisfactory yields when conditions are unfavorable, and also if one fails to realize that in the Great Plains area at least "yielding capacity" as defined is not to be determined in any period as short as three to five years.

When such a program is put into operation it is soon found that characteristics known to be correlated with the final objective, say yield, are few in number and the crop breeder immediately has set before him another problem, namely that of discovering or defining such characteristics. To put the matter in another way, successful crop improvement may be thought of as depending on two kinds of knowledge: (1) A knowledge of what is wanted in terms of specific and definite variety characteristics and (2) how to get the desired characteristics combined in a single variety. The latter kind of knowledge is supplied by the science of genetics to which very important and valuable contributions have been made in recent years. The former has received very little critical attention so far as the hard-winter-wheat belt is concerned.

Not only will the winter-wheat breeder of the future find it to his advantage to know more about the factors determining yield, but he will also need to know something as to the relative importance of those factors. Septoria and leaf rust undoubtedly affect winter-wheat yields. But do they occur with sufficient frequency and virulence to justify expensive attempts to produce resistant varieties perhaps at the sacrifice of more important work? How desirable or how necessary is it to have varieties more winter hardy than Turkey or Kanred in northwestern Kansas or than Blackhull and Tenmarq for south central Kansas? Bunt causes severe losses. For those areas where it can be controlled by seed treatment, should attempts be made to control it by breeding, considering the rapid increase in complexity of a breeding program as the number of factors involved increases, not to mention new physiological forms of bunt that may arise?

The need for considering the relative importance of various objectives is perhaps greatest in those cases where the various characteristics, desired and undesired, are physiologically or genetically correlated. Thus, if it is impossible to produce an early-maturing variety of wheat that has a high yielding capacity (high yield with favorable conditions) or possesses a high degree of winter hardiness, the facts would be of the greatest importance to the breeder attempting to produce such a variety. It is conceivable, though not probable, that high yields and short straw are incompatible. Here, also, a knowledge of the true relation is almost essential in an efficient breeding program.

In most of the plant-breeding work of the past the primary objective has been higher yields. In the future more attention should be given to quality and to such characteristics as lodging, height of straw, shattering, distribution of risks by growing varieties which mature at different times, etc. For example, there seems to be no logical reason why varieties must be grown in central and western Kansas that lodge more easily than those grown in eastern Kansas, and it is difficult to see why it is necessary for a western Kansas farmer to harvest 3½ or 4 feet of straw, as he must, in a favorable year on fallow, when 24 or 30 inches might be sufficient with less draft on the soil, with less tendency to lodge, and with greater economy. The question of quality, unfortunately, is in about the same situation as that related to breeding for yield, and hence there would seem to be needed here, also, a better understanding of the factors that determine quality.

The authors hasten to add that the need for a better and more complete knowledge of variety characteristics as a basis for a crop-breeding program has been recognized by others. Thus, Hayes (19) has said that "the first step in the solution of a breeding problem is to determine what end results are to be sought," and that "knowledge of plant characters under different environmental conditions, and when possible the reasons for the same, is as essential as a knowledge of genetics." Biffen and Engledow *(1)* point out that the farmer is chiefly interested in knowing what varieties will yield, but that the "plant breeder must know not only this but why they are what they are." Goulden and Elders *(17)* state that "A knowledge of the relative value of desirable characters as well as a knowledge of their inheritance is of primary importance in the efficient and rapid solution of any plant-breeding problem." Hayes, Aamodt, and Stevenson *(20)* say, "The reason why certain varieties perform more satisfactorily than others is of great importance to the plant breeder. Such information furnishes the basis for a logical plan for the improvement of the crop." Immer and Ausemus *(24)* state that "A knowledge of the factors affecting yield is essential for the rapid and efficient solution of any plant-breeding problem." The work of Waldron *(50),* Engledow and his associates *(10), (11), (12)-(13), (14),* and *(15),* Sprague *(48),* Bridgeford and Hayes *(3)* Quisenberry *(37),* Bonnett and Woodworth *(2),* Roodworth *(52),* and others indicates an increasing appreciation of the need of knowledge of this kind.

It would thus appear that an efficient scientific winter wheat-breeding program for the future must depend more than heretofore on definite experimentally determined relations between specific varietal characteristics and the final objective whether that be a better yield or quality or more economical production. Probably it will never be possible—certainly not for a long time—to identify all the factors that go to make up such complex entities as, for example, yield or quality. Hence, yield tests and milling and baking tests will need to be continued probably on as elaborate or perhaps an even more elaborate scale than before. Waldron *(51),* for example, points out that in breeding spring wheats for resistance to stem rust, yield tests are essential for the reason that stem rust is one factor only in the determination of yield.

In brief it would appear that what is needed, and probably the chief thing that is needed, is recognition of and a wider use of the inductive method of science which emphasizes the value of knowing why instead of being satisfied with knowing how.

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