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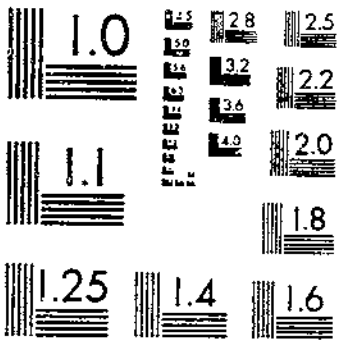

MICROCOPY RESOLUTION TEST CHART
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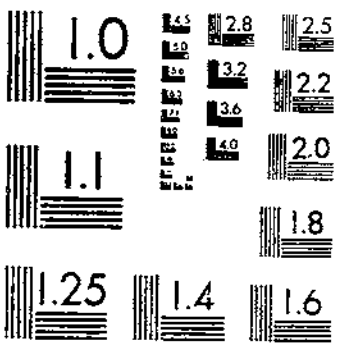

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BREEDING HARD RED WINTER WHEATS FOR WINTER HARDINESS AND HIGH YIELD

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CONTENTS

IMPORTANCE OF HARD RED WINTER WHEATS

The hard red winter wheats occupy the largest acreage of any class of wheat grown in the United States. According to the varietal survey of 1924 by Clark and others (4),[2] about 41 per cent of the total wheat acreage of the United States was of the hard red winter class. This class of wheat is grown chiefly in the central and southern sections of the Great Plains area of the United States.

One of the most important factors limiting the northern expansion of the hard winter wheat acreage is winterkilling. The long, cold, and often rather dry winters frequently cause severe losses from killing. During the 26-year period from 1901 to 1926 an average of about 10 per cent of the total winter-wheat acreage of the United States was abandoned annually, largely because of winter injury.

[1] The writers acknowledge the assistance and cooperation received from the following persons during the course of these investigations: John H. Martin, agronomist, had charge of the work from 1919 to 1925. John H. Parker, of the Kansas Agricultural Experiment Station, aided in making some of the crosses and in growing the material during the first years. V. H. Florell made some of the crosses at Chico, Calif. The following men assisted in growing the material: R. W. May, formerly at Moccasin, Mont.; D. B. Bayles, Moccasin, Mont.; R. W. Smith, Dickinson, N. Dak.; L. R. Waldron, Fargo, N. Dak.; G. F. Sprague, North Platte, Nebr.; F. A. Coffman, formerly at Akron, Colo.; and A. F. Swanson, Hays, Kans. Crude-protein and milling and baking results were obtained in cooperation with the Grain Division of the Bureau of Agricultural Economics.

[2] Italic numbers in parentheses refer to "Literature cited," p. 28.

The growing of hard red winter wheat in the Great Plains area dates back to 1873, when Turkey wheat was first introduced from Russia by Mennonite immigrants to Kansas and other States. This variety was first grown in Kansas, and, owing in large measure to its winter hardiness and high yields, it soon replaced the varieties of soft wheat then grown. Since this early date the growing of hard winter wheats has been extended farther and farther north, being limited chiefly by severe winter weather.

As a general rule, winter wheat is more productive than spring wheat wherever winter wheat can survive the winter. It also ripens earlier, thus being less exposed to injury from rust and drought. In the growing of winter wheat farm labor is better distributed than in the growing of spring wheat.

As a class the hard red winter wheats are fairly winter hardy, but many of the varieties will not survive the winters in the northern Great Plains area. Various cultural practices have been developed to reduce winterkilling, such as seeding in furrows, seeding in standing stubble, and mulching the crop with straw. These practices help to catch and hold more snow, thus affording a protective covering against rapid changes in temperature.

WINTER HARDINESS

While various cultural practices have been of great value in reducing losses due to winterkilling, they are recognized as a temporary rather than a permanent solution of the problem.

The possibility of developing hardier varieties through breeding has been recognized for many years. Considerable breeding work has been done in this country and in Europe to produce hardier varieties. Most of the European work has been done in Russia and Sweden. Russian varieties have shown considerable promise when introduced into this country, but the hardiest varieties from Sweden, which are soft wheats, have been less hardy than the hard red winter varieties grown in the United States and Russia.

In 1919 the Office of Cereal Crops and Diseases, in cooperation with certain State experiment stations, started extensive investigations on the problem of winter hardiness in wheats. As one part of this study, uniform winter-hardiness nurseries were established in cooperation with numerous stations in the northern United States and in Canada to test the hardiness of the existing varieties. The results of the first five years of this work, published by Clark, Martin, and Parker (*3*), showed definitely that varieties differ greatly in their ability to resist unfavorable winter conditions and that Turkey was not the hardiest variety. In general, the varieties that had the greatest hardiness were poor in quality or low in yield. Such varieties as Minhardi, Buffum No. 17, and Odessa proved to be the hardiest, but as they are soft wheats and very late in maturing they are not suited to commercial growing in the Great Plains area.

The second phase of this work was to enlarge the breeding program with the object of combining hardiness, quality, and yield. Earlier breeding for winter hardiness had been carried on in North Dakota by Clark (*1*) and by workers in Minnesota. The results reported by Hayes and Garber (*5*) in developing the Minhardi and Minturki varieties in Minnesota demonstrated the possibilities of success by

this method of attack. The purpose of this bulletin is to report the progress of the breeding resulting from the enlarged program started in 1919.

ACRE YIELD

The development of hardy strains of hard red winter wheat must be associated with an increased acre yield. High yield is the end result and may be obtained from strains not having the greatest comparative hardiness, provided the winters are not too severe. A high degree of winter hardiness must be associated with high yield if a winter variety is to be successfully grown in the Northern States.

MATERIAL AND METHODS

The choice of high-yielding varieties possessing good quality, earliness, or other desirable characters, for crossing with hardy varieties; the method of growing and selecting the material; and the choice of locations for testing the progeny were considered in developing the breeding program.

VARIETIES USED AS PARENTS

The original crosses were made at Manhattan, Kans., and Chico, Calif., in 1919 and 1920. The varieties Turkey, Kanred, Kharkof, Eureka, and Nebraska No. 28 were the principal parents, having good yield and quality but lacking hardiness. The varieties Minhardi, Odessa, Minessa, Buffum No. 17, and four Beloglina-Buffum hybrid strains were used as hardy parents. For a description and history of these varieties, see Clark, Martin, and Ball (*2*). About 45 combinations, including reciprocal crosses, were made with these and other varieties. At the time the crosses were made, relatively little was known of the merits of some of the parent varieties. For this reason many crosses were made, and the least promising were soon discarded.

STATIONS AT WHICH TESTING WAS DONE

Part of the crossed kernels obtained in 1919 at Manhattan, Kans., and Chico, Calif., were sown at Chico and part at Manhattan in the fall, in order to insure against loss and to obtain an ample supply of seed the following year.

The entire F_2 generation was grown at Manhattan, Kans., in 1920–21. Beginning in 1921–22 the hybrid and parental material was grown at various northern stations in the United States. The original plan included growing most of the material in bulk, although some of the more promising crosses were continued by individual-plant selections. The plan used was to grow plant selections from the more promising crosses in plant rows until they apparently were homozygous and then increase the best of these to rod rows as rapidly as seed was available.

In addition to the crosses that were carried in plant rows, seed of each F_2 was bulked and grown in bulk from year to year in rows approximately 132 feet long. Table 1 gives a summary of the number of plant rows, rod rows, and bulk rows seeded at the various cooperating stations during the period from 1921 to 1928. This summary shows that most of the work has been done at Dickinson, N. Dak., and Moccasin, Mont. In all, 26,085 rows were seeded in these tests.

TABLE 1.—*Number of plant, rod, and bulk rows of wheat sown in winter-wheat breeding nurseries at 11 experiment stations, 1920–21 to 1927–28*

Station	1920–21 plant rows	1921–22			1922–23		1923–24		1924–25			1925–26			1926–27		1927–28		Total rows
		Plant rows	Rod rows	Bulk rows	Plant rows	Bulk rows	Plant rows	Bulk rows	Plant rows	Rod rows	Bulk rows	Plant rows	Rod rows	Bulk rows	Rod rows	Bulk rows	Rod rows	Bulk rows	
Manhattan, Kans.	481												60		50		50		641
Chico, Calif.	260																		260
Dickinson, N. Dak.		358	1,020		2,084		1,600		340	500	48	460	552	30	535	30	1,000	30	8,586
Moccasin, Mont.		407	702	50	1,970	60	1,150	60		500	60	740	552		742		1,520		8,579
Fargo, N. Dak.		470	105		1,200		826			800									3,401
Mandan, N. Dak.			597		654	60		60											1,371
Akron, Colo.					430		430												860
St. Paul, Minn.							615					500							1,115
North Platte, Nebr.												108	60		150		150		528
Hays, Kans.												216	60		150		150		576
Bozeman, Mont.												108							168
Total	741	1,295	2,433	50	6,344	120	4,621	120	340	1,800	108	2,242	1,284	30	1,627	30	2,870	30	26,085

DIFFICULTIES IN STUDYING WINTER HARDINESS IN THE FIELD

A general summary of the results obtained from the various stations for each year in which material was grown is given in Table 2. It will be seen that hardiness data were not obtained every year. In many cases the killing was so severe that all the material was lost. In other cases there was little or no killing and the least hardy strains survived 100 per cent. Another difficulty was caused by the fact that fall germination often was very poor, and some of the plants did not emerge until spring, thus making spring-stand counts worthless. In some cases the killing may not have been caused by extreme cold but by soil blowing, drought, heaving, or smothering by ice crusts. Because of these difficulties it seemed desirable to grow the material at several stations and over a period of years.

While this work was outlined primarily as an improvement project, an attempt was made to obtain data on inheritance of winter hardiness in a few of the more promising crosses.

In presenting the results of these studies, only the data from stations where partial killing occurred will be considered.

TABLE 2.—*Spring condition of the wheats in the winter-wheat breeding nurseries at 11 experiment stations, 1920–21 to 1927–28*

Station	Spring condition in season of—							
	1920–21	1921–22	1922–23	1923–24	1924–25	1925–26	1926–27	1927–28
Manhattan, Kans.	Killing in less hardy hybrids.					No killing	No killing	
Chico, Calif.	No killing							
Dickinson, N. Dak.		Nearly complete killing on fallow; heavy killing on stubble land.	Complete killing on fallow; very heavy killing on stubble land.	Only moderate killing, some varieties surviving 100 per cent.	Killing on nonhardy strains; good differentiation of strains.	Fall germination poor; some spring germination; killing severe.	Nearly complete killing; only most hardy varieties showed any survival.	Fairly good differentiation of strains.
Moccasin, Mont.		No killing	Emerged in winter and spring; killing occurred only in nonhardy hybrids and parents.	No killing	Very little killing except in nonhardy strains.	Only light killing	Very little killing	Rather severe killing, only most hardy lines showing good survivals.
Fargo, N. Dak.		No killing except in Eureka and Eureka-Buffum crosses.	Poor emergence in fall; completely killed.	Severe killing, only hardy strains surviving.	Complete killing			
Mandan, N. Dak.		Complete killing	Complete killing					
Akron, Colo.			Emerged in winter; some killing, due largely to drought and soil blowing.	Very little killing				
St. Paul, Minn.				do		Rather heavy killing.		
North Platte, Nebr.						No killing	No killing	Some killing.
Hays, Kans.						do	do	Little killing.
Bozeman, Mont.						Very little killing		

INHERITANCE OF WINTER HARDINESS

A number of F_3 rows of the cross Buffum No. 17 × Eureka were grown in comparison with the parents at Fargo, N. Dak., in 1922 and at Moccasin, Mont., in 1923. No killing had occurred in this material in the F_2 generation. Data as to the winter survivals of this material are presented in Table 3. At Fargo the percentages were based on actual counts made in the fall and spring, whereas at Moccasin they were based on estimates of spring stands, in which the Buffum No. 17 parent (which showed no killing) was used as the standard of comparison.

TABLE 3.—*Survival, in frequency classes, of F_3 winter-wheat hybrid strains and parents grown at Fargo, N. Dak., in 1922 and at Moccasin, Mont., in 1923*

Station, year, variety, and hybrid strains	Number of rows with survival percentage of—						Total rows	Average survival (per cent)
	0	10	30	50	70	90		
Fargo, N. Dak., 1922:								
Buffum No. 17						7	7	90.0
F_3 hybrid strains				3	8	109	120	87.7
Eureka				1	3	3	7	75.7
Moccasin, Mont., 1923:								
Buffum No. 17						13	13	90.0
F_3 hybrid strains	31	144	52	17	6	7	257	19.1
Eureka	0	6	4	2	1		13	26.0

At Fargo the average survival of the hybrids was intermediate between that of the two parents, while at Moccasin the hybrids showed an average survival which was lower than that of either parent. Hybrids less hardy than Eureka were obtained, as well as some segregates as hardy as Buffum No. 17.

Table 4 presents survival data obtained from F_3 hybrid strains of Kanred × Minhardi and Minturki × Turkey (C. I.[3] No. 6152) crosses at Dickinson, N. Dak., in 1923. The hybrids had not been subjected to killing previously. In each case the hybrids and parents showed about the same range of survival, but the average of the hybrids was slightly less than that of either parent. In each cross some hybrid rows had as high a survival as the hardiest parent rows.

TABLE 4.—*Survival, in frequency classes, of F_3 winter-wheat hybrid strains and parents grown at Dickinson, N. Dak., 1923*

Cross and parents, and hybrid strains	Number of rows with survival percentage of—					Total rows	Average survival (per cent)
	0	10	30	50	70		
Kanred × Minhardi:							
Minhardi	5	3	1		1	10	13.0
F_3 hybrid strains	101	53	20	7	4	185	9.5
Kanred	4	4	1	1		10	12.0
Minturki × Turkey (C. I. No. 6152):[1]							
Minturki	2		1		2	5	34.0
F_3 hybrid strains	41	30	12	9	7	99	16.2
Turkey (C. I. No. 6152)	2	3			1	6	16.7

[1] The initials "C. I." refer to accession numbers of the Office of Cereal Crops and Diseases.

In addition to the F_2 material grown at Dickinson in 1923, F_4 strains of three crosses and F_5 strains of one cross also were grown. The data are presented in Table 5. For the F_4 strains of the three crosses, Minessa × Turkey (C. I. No. 6152), Minhardi × Eureka, and Beloglina-Buffum (C. I. No. 5547) × Odessa (C. I. No. 3687), the average survival of the hybrids was intermediate between that of the two parents, although individual rows were obtained which were hardier than the hardiest parental row. The F_5 strain of Turkey (C. I. No. 1558) × Odessa (C. I. No. 3687) showed an average survival slightly higher than that of the Odessa parent, and 13 of the 63 hybrid strains grown were hardier than the hardiest parent row.

TABLE 5.—*Survival, in frequency classes, of F_4 and F_5 winter-wheat hybrid strains and parents grown at Dickinson, N. Dak., 1923* [1]

Cross and parents, and hybrid strains	Number of rows with survival percentage of—											Total rows	Average survival (per cent)
	0	5	15	25	35	45	55	65	75	85	95		
Minessa × Turkey (C. I. No. 6152):													
Minessa	2	1	1	1			1					6	16.7
F_4 hybrid strains	25	15	15	14	6	3	3	1	1			83	15.7
Turkey (C. I. No. 6152)	1	2	1									4	6.3
Minhardi × Eureka:													
Minhardi									1	1		2	80.0
F_4 hybrid strains	2	2	3	7	8	4	5	5	5	4	2	47	46.7
Eureka		2			1							3	15.0
Beloglina-Buffum (C.I.5547) × Odessa (C. I. No. 3687):													
Beloglina-Buffum No. 17			1			1	1					3	38.3
F_4 hybrid strains	5	7	7	12	11	3	3	3	2			53	27.7
Odessa		1	1		1	1						4	25.0
Turkey (C. I. No. 1558) × Odessa (C. I. No. 3687):													
Odessa	1	1				1						3	16.7
F_5 hybrid strains	37	0	2	0	0	2	1	7	2	1	2	63	17.5
Turkey	2	1										3	1.7

[1] Progenies of surviving plants at Dickinson in 1922.

It would seem safe to conclude from these data that winter hardiness is a heritable character but of a very complex nature and that it is greatly influenced by environment. By selection it is possible to recover hybrid lines which are as hardy as, and in some cases hardier than, the hardy parents. This seems to indicate that parent varieties possess different factors for hardiness, which when combined may give increased hardiness.

Martin (*7*) briefly summarized these results and pointed out the difficulties of studying the inheritance of this character in the field.

LABORATORY METHODS USED TO CHECK FIELD RESULTS

Owing to the difficulty of studying the inheritance of winter hardiness in the field, several investigators have been endeavoring to develop laboratory methods which will give a better index to the probable hardiness of strains than can be obtained in the field. Recent investigations by Martin (*7*) and Hill and Salmon (*6*) tend to show that the best test is the actual exposure to certain low temperatures. Because of difficulties in developing a satisfactory hardening-off process, the laboratory tests have not exactly paralleled the results obtained under field conditions. Hill and Salmon pointed out that the laboratory

methods indicated that Kanred and Kharkof were more hardy than Minhardi. This reaction is probably caused by the methods used in hardening off, as Kanred and Kharkof may be able to withstand sudden drops of temperature better than Minhardi, provided the latter is not well hardened off.

During the winter of 1927–28 all of the winter-wheat hybrids and leading parents grown in nursery experiments at Dickinson, N. Dak., and Moccasin, Mont., were subjected to freezing tests in the laboratory at Manhattan, Kans.[1] The object of these studies was to accumulate information on the hardiness of new strains and to perfect the methods so as to check field results and speed up the breeding program. Some progress was made in perfecting the technique, so that the greenhouse results correlated rather closely with the behavior in the field. More work along this line is being done.

GROWING THE HYBRID MATERIAL

The F_1 plants of all crosses grown at Chico, Calif., and Manhattan, Kans., in 1919–20 furnished an abundant supply of seed. One head from each plant was seeded at Chico and the remainder at Manhattan. In the fall of 1920, 481 plant rows were space-planted at Manhattan, Kans., with the seed from the F_1 plants. Winter-survival data were obtained on this material, the rows were harvested in bulk, some of the least promising crosses were discarded, and the remaining material from each cross and reciprocal was bulked.

The F_2 generations of all crosses were grown at Manhattan, Kans. The winter of 1920–21 was rather mild, and the killing that occurred was due largely to an early spring freeze. The injury was not severe, except in the less hardy combinations. A summary of the survival data obtained in the spring of 1921 is presented in Table 6.

Each cross and its reciprocal were grown separately, and the percentage of winter survival was determined on each. In the summary, however, the crosses and reciprocals have been combined, as the data failed to show any marked differences in percentages of survival. The crosses are presented in Table 6 in the order of average survival. It will be seen that most of the material showed a rather high average survival.

The combinations showing the most hardiness were those that had as one parent such varieties as Minhardi, Minessa, Turkey (C. I. No. 6152), Padui, and Beloglina-Buffum (C. I. Nos. 5545 and 5547). The differences in killing were not wide enough to give a real index of the hardiness possessed by the various combinations. Such combinations as Minhardi × Buffum No. 17 and Padui × Odessa did not show as good survival as might be expected, on the basis of the known hardiness of the parents. This may be explained partially by the fact that both parents in these crosses, while hardy, are not adapted to Kansas conditions. The cross Kanred × Nebraska No. 28 had a survival of only 70 per cent, but as neither of these two varieties is outstanding in hardiness, little hardiness would be expected in this cross. On the other hand, the lowest survival, 67.5 per cent, was recorded for the cross Kanred × Buffum No. 17. As the Buffum No. 17 parent is much more hardy than Nebraska No. 28, it would be expected to produce hardier hybrids.

[1] This work was conducted by B. B. Bayles in cooperation with the Kansas Agricultural Experiment Station, under the supervision of S. C. Salmon.

TABLE 6.—*Average percentage of winter survival of the F_2 generation of various winter-wheat hybrids grown at Manhattan, Kans., during the winter of 1920–21*

[The figures in parentheses are accession numbers of the Office of Cereal Crops and Diseases]

Cross	Plant rows grown	Survival
	Number	*Per cent*
Minhardi (5140) × Beloglina-Buffum (5545)	3	95.1
Minessa (6151) × Turkey (6152)	20	94.9
Padui (6153) × Beloglina-Buffum (5545)	4	93.9
Kanred (5146) × Beloglina-Buffum (5547)	3	93.7
Kanred (5146) × Turkey (6152)	4	93.4
Minturki (6155) × Turkey (6152)	13	93.2
Kanred (5146) × Minhardi (5140)	8	92.8
Minhardi (5140) × Beloglina-Buffum (5547)	1	92.6
Baeska (6156) × Minhardi (5140)	1	92.6
Minturki (6155) × Beloglina-Buffum (5546)	8	92.4
Minessa (6151) × Baeska (6156)	19	92.1
Kanred (5146) × Padui (6153)	12	91.3
Montana No. 36 (5540) × Odessa (3687)	6	89.8
Minturki (6155) × Baeska (6156)	7	89.8
Kanred (5146) × Beloglina-Buffum (5548)	2	89.0
Minessa (6154) × Eureka (5170)	39	87.8
Buffum No. 17 (3330) × Eureka (5170)	30	87.6
Kanred (5146) × Montana No. 36 (5540)	7	87.4
Odessa (6151) × Turkey (6152)	5	87.2
Minhardi (5149) × Buffum No. 17 (3330)	1	87.1
Minhardi (5140) × Minturki (6155)	1	87.1
Baeska (6156) × Odessa (6151)	12	86.9
Minhardi (5149) × Eureka (5170)	30	86.2
Odessa (6151) × Montana No. 36 (5540)	6	86.1
Kanred (5146) × Beloglina-Buffum (5545)	7	85.9
Minturki (6155) × Beloglina-Buffum (5545)	1	85.5
Kanred (5146) × Odessa (6151)	11	85.1
Minhardi (5140) × Beloglina-Buffum (5548)	2	85.0
Beloglina-Buffum (5547) × Odessa (3687)	8	84.5
Odessa (6151) × Padui (6153)	16	83.4
Padui (6153) × Odessa (3687)	24	83.1
Kanred (5146) × Minturki (6155)	28	82.7
Eureka (5170) × Turkey (6152)	25	82.2
Beloglina-Buffum (5545) × Odessa (3687)	19	82.1
Eureka (5170) × Odessa (6151)	23	82.0
Kanred (5146) × Eureka (5170)	13	81.5
Kanred (5146) × Minessa (6154)	11	80.8
Odessa (6151) × Beloglina-Buffum (5547)	5	78.2
Beloglina-Buffum (5548) × Odessa (3687)	4	74.9
Eureka (5170) × Minturki (6155)	30	74.8
Minturki (6155) × Odessa (6151)	5	73.1
Minturki (6155) × Odessa (3687)	1	70.6
Kanred (5146) × Nebraska No. 28 (5147)	2	70.0
Kanred (5146) × Buffum No. 17 (3330)	6	67.5

The most promising F_2 material grown at Manhattan in 1920–21 was transferred to northern stations, where the conditions were more severe and therefore the percentage of killing likely to be higher. The F_2 plants grown from each F_1 plant row were harvested in bulk. Each lot was divided into four parts and seeded in the fall of 1921 at Mandan and Dickinson, N. Dak., and Moccasin, Mont. At Dickinson the material was seeded in 18-foot rows, duplicate plantings being made on fallow and on stubble land.

The F_1 and F_2 material grown at Chico, Calif., in 1920–21 produced an abundant crop. Selections were made in the F_2 from some of the crosses, and the remainder was bulked for each cross and reciprocal. The seed from the F_1 plants was sent to Fargo and Moccasin. The F_2 selections were sent to Fargo, Dickinson, and Moccasin. The bulk material was sent to Moccasin.

From Table 2 it is seen that there was no killing at Fargo in 1921–22 except in Eureka and Eureka crosses. There was complete killing at Mandan and no killing at Moccasin in this period.

Table 7 presents a summary of the Dickinson data, which shows that in 1921–22 the killing was very much more severe on fallow land than on stubble land. Three varieties of winter rye are included in this table for comparison, and all show high survival on fallow; however, in the case of rye there was spring germination on the fallow land. The highest survival for wheat on fallow land was from Buffum No. 17, which showed a survival of 5.6 per cent, whereas most of the strains were completely killed.

In Table 7 the varieties and hybrids are arranged in order of their survival on stubble land. Odessa (C. I. No. 6151) showed the highest survival for wheats, followed by Minhardi. These two wheats are known to be very hardy, but generally Minhardi is the hardier. Crosses containing Odessa, Minhardi, Buffum No. 17, and Beloglina-Buffum strains showed the most hardiness. The hardiest cross, Minturki × Odessa (C. I. No. 3687), had a winter survival of 44.4 per cent. The difficulties of obtaining critical data are emphasized by the fact that Eureka and Minturki showed nearly identical percentages of survival, although it is a well-known fact that Minturki is much hardier than Eureka.

TABLE 7.—*Percentage of winter survival of F_3 winter-wheat hybrid strains and parents grown in rod rows on fallow and on stubble land at Dickinson, N. Dak., 1921-22*

Name of cross or parent	C. I. No.	Percentage survival on—	
		Fallow land	Stubble land
Dakold (rye)[1]		[2] 100	80.0
Odessa	6151	.2	68.9
Advance (rye)[1]		[2] 100	64.8
Swedish (rye)[1]		[2] 100	62.0
Minhardi	5149	1.7	46.4
Minturki × Odessa (C. I. No. 3687)		0	44.4
Bacska × Odessa (C. I. No. 6151)		.1	38.4
Odessa	4475	0	36.8
Buffum No. 17	3330	5.6	36.6
Minhardi × Eureka		.7	34.4
Kanred × Buffum No. 17		1.2	33.2
Beloglina-Buffum (C. I. No. 5517) × Odessa (C. I. No. 3687)		.5	30.0
Odessa (C. I. No. 6151) × Padui		1.3	29.5
Minessa × Turkey		2.2	27.2
Odessa (C. I. No. 6151) × Beloglina-Buffum (C. I. No. 5547)		0	26.9
Beloglina-Buffum	5548	.6	25.8
Minturki × Odessa (C. I. No. 6151)		0	24.4
Minessa	6154	.7	24.3
Minturki × Beloglina-Buffum (C. I. No. 5548)		0	24.1
Turkey	6152	.2	23.2
Odessa (C. I. No. 6151) × Turkey (C. I. No. 6152)		.9	22.1
Beloglina-Buffum	5547	.3	20.9
Eureka × Odessa (C. I. No. 6151)		0	20.5
Minhardi × Beloglina-Buffum (C. I. No. 5545)		1.5	19.3
Odessa	3687	.3	19.3
Kanred × Minessa		.2	18.8
Minhardi × Minturki		1.0	17.5
Kanred × Turkey		0	16.7
Beloglina-Buffum	5545	.6	14.9
Eureka × Turkey		0	14.6
Padui × Beloglina-Buffum (C. I. No. 5545)		.8	14.0
Kanred	5146	.1	13.0
Padui	6153	.6	12.2
Beloglina-Buffum (C. I. No. 5545) × Odessa (C. I. No. 3687)		.6	11.9
Minturki × Beloglina-Buffum (C. I. No. 5545)		0	11.6
Minessa × Eureka		.1	11.6
Padui × Odessa (C. I. No. 3687)		1.1	11.4
Kanred × Beloglina-Buffum (C. I. No. 5548)		.5	10.8
Kanred × Odessa (C. I. No. 6151)		.3	10.5

[1] Included for comparison.

[2] Largely spring germination.

TABLE 7.—*Percentage of winter survival of F_3 winter-wheat hybrid strains and parents grown in rod rows on fallow and on stubble land at Dickinson, N. Dak., 1921–22*—Continued

Name of cross or parent	C. I. No.	Percentage survival on—	
		Fallow land	Stubble land
Beloglina-Buffum	5546	0	9.5
Beloglina-Buffum (C. I. No. 5548) × Odessa (C. I. No. 3687)		0	9.2
Eureka	5170	0	8.7
Minturki	6155	.2	8.5
Kanred × Beloglina-Buffum (C. I. No. 5547)		.2	7.7
Kanred × Beloglina-Buffum (C. I. No. 5545)		.2	5.0
Kanred × Padui		.1	4.9
Eureka × Minturki		0	4.2
Montana No. 36 × Odessa (C. I. No. 3687)		.3	3.3
Minturki × Bacska		0	3.3
Montana No. 36	5519	0	1.5
Minessa × Bacska		0	1.0
Bacska	6156	0	.2
Padui × Eureka		0	.2

PLANT-ROW RESULTS

From the rows showing good winter survival at Dickinson in 1921–22, plant selections were made and the seeds sown at Dickinson, Mandan, and Fargo, N. Dak., and Moccasin, Mont. There was complete killing at Fargo and Mandan and practically no killing at Moccasin.

THE F_4 GENERATION

At Dickinson, N. Dak., the material was space-planted in 8-foot rows, and a summary of the winter-survival data is presented in Table 8.

All the rows of a cross and its reciprocal and the parent check rows are combined, and the percentage survivals on a row basis are shown in frequency distributions. The total number of rows grown and the average percentage of winter survival are given. The parents and crosses are arranged according to the average percentage of survival. It will be seen that the average survival ranges from 52.5 to 0 per cent. Because of the influence of soil conditions on winter-killing, the data based on only a few rows are not so reliable as those based on many rows. The hardiest crosses were Kanred × Minessa and Minhardi × Eureka, with average survivals of 51.3 and 43.8 per cent, respectively. The Minhardi parent had a survival of 21 per cent, and the Kanred × Minhardi hybrids showed an average survival of 7.5 per cent. Padui and Bacska showed little winter resistance, and the 10 rows of the Minhardi × Minturki cross were all killed.

TABLE 8.—*Summary of winter survival of F_4 winter-wheat hybrid strains and parents grown on stubble land at Dickinson, N. Dak., 1922–23*

Name of cross or parent	C. I. No.	Number of rows with survival percentage of—																				Total rows	Average survival (per cent)
		0	2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5	92.5	97.5		
Beloglina-Buffum	5548									1						1						2	52.5
Kanred × Minessa			2		1		1	1		2			1	1	2		2	2				2	17	51.3
Beloglina-Buffum	5546											1											1	47.5
Minhardi × Eureka		2		2	3		6	1	5	4	2	3	2	2	3	1	3	1	2	1		2	45	43.8
Minturki × Odessa (C. I. No. 6151)							1		2		2	2					1						8	42.5
Odessa (C. I. No. 6151) × Beloglina-Buffum (C. I. No. 5547)		2						1		1		3			1	2							10	40.5
Minturki	6155	3						2	1			2			1		1	1		1			12	40.2
Minturki × Odessa (C. I. No. 3687)							2	1	2		2		1										8	34.4
Kanred × Odessa (C. I. No. 6151)				2		2	1		1						1		1						8	30.0
Beloglina-Buffum	5547	1			1							1		1									4	29.4
Minturki × Beloglina-Buffum (C. I. No. 5546)		2	2	2	4	1	1	1	2	1	2	2	1	2		1	1						25	29.1
Kanred × Beloglina-Buffum (C. I. No. 5545)			1		2	2			1	1			1			1							9	28.1
Beloglina-Buffum (C. I. No. 5547) × Odessa (C. I. No. 3687)		5	2	6	4	3	6	6	5	5	1	2	2	1	2	1	2						53	27.2
Beloglina-Buffum	5545	1	1															1					3	26.7
Padui × Beloglina-Buffum (C. I. No. 5545)		1			1	1	2	3	1		2												11	25.0
Eureka × Minturki			1	2			3	1		1		2											10	24.5
Kanred × Minturki			3	4	1	3	2	1	1		1	1	1	1					1				20	24.5
Eureka × Turkey (C. I. No. 6152)		3	2	3	1	2	2	1	1			2	1								1		19	22.1
Minhardi	5149	6		2	1			1							1		1		1				13	21.0
Buffum No. 17	3330		1							1													2	20.0
Minessa	6154	2	1		1		1		1	1			1										8	20.0
Beloglina-Buffum (C. I. No. 5545) × Odessa (C. I. No. 3687)			2		1		4		1	1													9	19.7
Odessa	6151	1	1	1	1		1		1					1									7	19.3
Beloglina-Buffum (C. I. No. 5548) × Odessa (C. I. No. 3687)		5	1	3	2	6	2	5	3	1	1	1											30	18.8
Eureka	5170			3		1			1	1													6	18.3
Minessa × Eureka			7		3	3	5	2	1	2	1												24	17.7
Minturki × Turkey (C. I. No. 6152)		41	18	8	5	8	6	8	2	5	3	6	3		2	3	1	1					120	16.4
Odessa	3687	4	1	1	2		1			1	2												12	15.0
Turkey (C. I. No. 6152) × Minessa		25	9	8	9	8	6	3	5	1	3	2		1		1	1						82	14.3
Kanred	5146	7	1	3			1	2						1	1								16	13.0
Kanred × Buffum No. 17		4	1	4	5	2	1	2			1												20	12.5
Turkey	6152	4	4	1	1	2			1							1							14	11.8
Buffum No. 17 × Eureka		1	1	2	1	1	2																8	11.6
Kanred × Minhardi		108	28	16	6	8	5	8	3	2		5	1		3		1						194	7.5
Padui × Odessa (C. I. No. 3687)		17	2	1			1	2	1						1								25	7.4
Kanred × Turkey (C. I. No. 6152)		4	1	9	3	1																	18	6.9
Minhardi × Beloglina-Buffum (C. I. No. 5545)		9	2		1	1	2																15	5.3
Odessa (C. I. No. 6151) × Padui		22	6	1	2	1																	32	2.0
Padui	6153	2	2																				4	1.3
Odessa (C. I. No. 6151) × Turkey (C. I. No. 6152)		12	2																				14	.4
Bacska × Odessa (C. I. No. 6151)		16	2																				18	.3
Turkey	1558	11	1																				12	.2
Minhardi × Minturki		10																					10	0
Bacska	6156	1																					1	0

THE F_5 GENERATION

Selections made at Dickinson in the F_5 generation were grown in plant rows at Fargo and Dickinson, N. Dak., and at Moccasin, Mont., in 1923–24. There was no killing at Moccasin. Killing at Fargo was very severe in all strains grown with the exception of Dakold rye. The Fargo data are presented in Table 9. Buffum No. 17 was the hardiest wheat variety, with a survival of 37.5 per cent, and the Kanred × Buffum No. 17 cross was the hardiest of the hybrids. Many of the less-hardy parents and hybrid strains were completely winterkilled or nearly so. Selections made from the surviving hybrid material and reseeded at Fargo in the fall of 1924 were completely killed, so that this material was lost.

The data obtained from Dickinson, N. Dak., in 1923–24 are presented in Table 10. Killing was not so severe as at Fargo, as in no case was any strain or row completely killed. Buffum No. 17 was the hardiest variety, with a survival of 67.5 per cent—slightly better than Dakold rye, which had a survival of 62.5 per cent. Kanred × Odessa progeny were the hardiest of the hybrids. Several hybrid combinations containing Buffum No. 17, Minhardi, or Odessa as the hardy parent showed very good survival. Inconsistencies are present in these data, however, as Kanred and Eureka had nearly identical percentages of survival, whereas it is known that Kanred is much hardier than Eureka. Of the hybrids, the Buffum No. 17 × Eureka hybrid material showed the poorest survival.

TABLE 9.—*Summary of winter survival of F_3 winter-wheat hybrid strains and parents grown in plant rows at Fargo, N. Dak., 1923–24*

Name of cross or parent	C. I. No.	Number of rows with survival percentage of—																				Total rows	Average survival (per cent)
		0	2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5	92.5	97.5	
Dakold (rye) [1]																						3	3	97.5
Buffum No. 17	3330									1													1	37.5
Kanred × Buffum No. 17		1		2	2						1	1	1	1					1				10	32.3
Padui × Beloglina-Buffum (C. I. No. 5545)		4		2	1	1		1		1	1	1		1									13	19.8
Minhardi × Minturki			3	2	2	2	2	2		1	1		1										16	19.7
Minessa	6154		2	1	1		1	1	1														7	15.4
Minhardi	5179	2		3	1			2		1													9	14.7
Odessa (C. I. No. 6151) × Beloglina-Buffum (C. I. No. 5547)		9	4	3	2	4	2		2	3	1												30	13.1
Kanred × Minhardi		45	4	6	2	4	1	3	4	3	2		1	1		1		1					78	10.7
Beloglina-Buffum	5545		1			1																	2	10.0
Kanred × Beloglina-Buffum (C. I. No. 5545)		8	4	2			2	1	2														10	8.6
Odessa	3687	5	1	2	1		1				1												11	8.3
Beloglina-Buffum (C. I. No. 5547) × Odessa (C. I. No. 3687)		22	12	2			3	3					1	1				1					45	8.5
Turkey × Minessa		27	8	6	2	2	3	2	2	1		1											54	7.4
Minturki × Beloglina-Buffum (C. I. No. 5546)		22	4	9	2	3	3		1	1													45	6.5
Minturki × Odessa (C. I. No. 3687)		10	5	7	5	1			1														29	6.1
Eureka × Minturki		3	2		1		1																7	5.7
Kanred × Minessa		34	6	5	4	2		2	2	1													56	5.3
Odessa	6151	1	3			1																	5	5.0
Beloglina-Buffum (C. I. No. 5548) × Odessa (C. I. No. 3687)		17		1	4	1				1													24	4.7
Minturki × Odessa (C. I. No. 6151)		16	1	1	2		3																23	4.5
Minhardi × Eureka		45		3	2	1					1				1		1						54	4.5
Minessa × Eureka		13	1		1	1					1												17	4.4
Beloglina-Buffum	5546	1		1																			2	3.8
Minturki	6155	7	2	1	2																		12	3.1
Turkey	1558	2	1	1																			4	2.5
Kanred × Odessa (C. I. No. 6151)		15	7	1	1	1																	25	2.2
Beloglina-Buffum	5547	3		1																			4	1.9
Beloglina-Buffum (C. I. No. 5545) × Odessa (C. I. No. 3687)		7	2	2																			11	1.8
Kanred × Minturki		46	4	4				1															55	1.2
Kanred	5146	12			1																		13	1.0
Minturki × Turkey (C. I. No. 6152)		40	1					1															42	.7
Turkey	6152	4	1																				5	.5
Eureka	5170	5	1																				6	.4
Padui × Odessa (C. I. No. 3687)		5	1																				6	.4
Eureka × Turkey (C. I. No. 6152)		8																					8	0
Padui	6153	1																					1	0
Beloglina-Buffum	5548	1																					1	0

[1] Included for comparison.

TABLE 10.—*Summary of winter survival of F_5 winter-wheat hybrid strains and parents grown in plant rows at Dickinson, N. Dak., 1923–24*

Name of cross or parent	C. I. No.	Number of rows with survival percentage of—																					Total rows	Average survival (per cent)
		2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	62.5	67.5	72.5	77.5	82.5	87.5	92.5	97.5			
Buffum No. 17	3330														1								1	67.5
Dakold (rye) [1]										1		1								1			3	62.5
Kanred × Odessa (C. I. No. 6151)					1			2	2	3	7	3	5	3	1	1	2	1	2				33	59.5
Minhardi	5149						1	2		3		2	1	3	1	1							3	17	59.0
Kanred × Buffum No. 17 F_2										1	1	7	3	1			1						1	15	57.8
Minhardi × Eureka								1	9	7	10	13	11	5	7	5	5	1	1				2	77	56.6
Minturki × Turkey (C. I. No. 6152)			1			4	6	3	6	15	25	17	16	16	16	7	5	3	2				2	144	54.3
Beloglina-Buffum (C. I. No. 5547) × Odessa (C. I. No. 3687)		1		1	2	2	2	4	3	5	11	6	7	1	1	3		2	4				6	61	54.0
Minturki × Odessa (C. I. No. 3687)								2	1	2	9	3	5	2	4	1								29	52.7
Kanred × Beloglina-Buffum (C. I. No. 5545)						1	4	1	2	6	5	2	5	2	2	1	4			1				36	51.7
Beloglina-Buffum	5547									3		1				1								5	50.5
Turkey (C. I. No. 6152) × Minessa					1		5	6	8	18	16	9	13	8	8	3	2					2		99	50.5
Minessa	6154						1	2	1			3	2	1	1	1								12	50.4
Beloglina-Buffum	5545									1	1	1	1											4	50.0
Kanred × Minhardi		1			3	3	12	15	27	22	29	15	20	16	9	9	4	5	1				4	195	49.6
Odessa (C. I. No. 6151) × Beloglina-Buffum (C. I. No. 5547)				1	1		2	1	5	3	2	2	3	3	2		2						1	28	49.3
Turkey	6152					1		1	1	2	5		1		2			1						14	49.3
Eureka × Minturki					1				2	2	4	3	3		2									17	49.0
Beloglina-Buffum	5548								1			3												4	48.8
Minturki	6155			1			1	3	1	3	3	4	1	2	1		1	1						22	48.4
Odessa	6151						1		1			2	1	1										6	48.3
Do	3687				1	1	1		3		3	1	1	2	2		1							16	48.1
Kanred × Buffum No. 17							1		2	1		2	1			1								8	47.5
Minessa × Eureka						1	2	4	5	1	8	6	1	4										32	45.0
Kanred	5146					1	1	3	4	5	3	2	4		2									25	44.9
Eureka	5170						1	1	2		2	2			1									9	44.7
Minhardi × Minturki							1	3	5	7	4	5		1	1									27	44.2
Beloglina-Buffum (C. I. No. 5548) × Odessa (C. I. No. 3687)				1	4	3	4	9	8	10	8	7	8	1	2	1	1	2		1				70	44.1
Beloglina-Buffum	5546						1		1		1			1										4	43.8
Kanred × Minturki						3	5	11	15	7	10	6	3	3	2	3	1							69	43.5
Kanred × Minessa			1	2	6	3	3	13	21	11	10	8	7	4	2	1				1	4			97	43.3
Beloglina-Buffum (C. I. No. 5545) × Odessa (C. I. No. 3687)					1	2	2		2	1	1					1	2							12	42.6
Padui × Odessa (C. I. No. 3687)						1	2	2	2	1	3	1										1		13	42.5
Padui	6153								1	1														2	40.0
Padui × Beloglina-Buffum (C. I. No. 5545)					2	2		1	2	5	3	1						1						17	39.9
Minturki × Beloglina-Buffum (C. I. No. 5546)				2	2	7	4	14	12	12	5	2	3		2							3		68	39.5
Eureka × Turkey (C. I. No. 6152)						2	3	4	4	1	4	3	1											22	38.9
Minturki × Odessa (C. I. No. 6151)				2	2	5	5	5	2	12	5	2	4	1										45	37.6
Buffum No. 17 × Eureka						1	4		3	1	2	1												12	36.3
Turkey	1558			1				1	2	1														5	32.5

[1] Included for comparison.

SUMMARY OF WINTER SURVIVAL OF HYBRID SELECTIONS AND PARENTS

Detailed data on winterkilling of hybrid selections and parents are available from Manhattan, Kans., in 1921, and from Dickinson, N. Dak., from 1922 to 1924, also from Fargo, N. Dak., in 1924. At these stations partial killing was recorded in the spring of the years mentioned, and the material for growing the following year was selected from the surviving plants. Table 11 presents a summary of these data. In no case were parents grown at Manhattan in 1921; only those hybrids are included which had been grown through the entire series of years. The parents and hybrids are ranked according to the average winter survival from 1922 to 1924. For sake of comparison the 1921–1924 average is also included for the hybrids.

TABLE 11.—*Summary of winter survival of hybrid strains and parents grown in plant rows at Manhattan, Kans., and at Dickinson and Fargo, N. Dak., in stated years*

Name of cross or parent	C. I. No.	Average percentage of survival						
		Manhattan, 1921	Dickinson			Fargo, 1924	Average	
			1922 [1]	1923	1924		1921–1924	1922–1924
Buffum No. 17	3330	.....	36.6	20.0	67.5	37.5	.....	40.4
Odessa	6151	.....	68.9	19.3	48.3	5.0	.....	35.4
Minhardi	5149	.....	46.4	21.0	58.0	14.7	.....	35.3
Minhardi × Eureka	.....	86.2	34.4	43.8	56.6	4.2	45.0	34.8
Minturki × Odessa (C. I. No. 3687)	.....	70.6	44.4	34.4	52.7	6.1	41.6	34.4
Odessa (C. I. No. 6151) × Beloglina-Buffum (C. I. No. 5547)	.....	78.2	20.9	40.5	49.3	13.1	41.0	32.5
Beloglina-Buffum	5548	.....	25.8	52.5	48.8	0	.....	31.6
Kanred × Buffum No. 17	.....	67.5	33.2	12.5	47.5	32.3	38.6	31.4
Odessa (C. I. No. 3687) × Beloglina-Buffum (C. I. No. 5547)	.....	84.5	30.0	27.2	54.0	8.5	40.8	29.9
Kanred × Minessa	.....	80.8	18.8	51.3	43.3	5.3	39.9	29.7
Minessa	6154	.....	24.3	20.0	50.4	15.4	.....	27.5
Minturki × Odessa (C. I. No. 6151)	.....	73.1	24.4	42.5	37.6	4.5	36.4	27.3
Beloglina-Buffum	5548	.....	9.5	47.5	43.8	3.8	.....	26.2
Do	5547	.....	20.9	26.4	50.5	1.9	.....	25.7
Kanred × Odessa (C. I. No. 6151)	.....	85.1	10.5	30.0	59.5	2.2	37.6	25.6
Beloglina-Buffum	5545	.....	14.9	26.7	50.0	10.0	.....	25.4
Minturki	6155	.....	8.5	40.2	48.4	3.1	.....	25.1
Turkey × Minessa	.....	94.9	27.2	14.3	50.5	7.4	38.9	24.9
Minturki × Beloglina-Buffum (C. I. No. 5546)	.....	92.4	24.1	20.1	39.5	6.5	38.3	24.8
Padui × Beloglina-Buffum (C. I. No. 5545)	.....	93.9	14.0	25.0	39.9	19.8	38.5	24.7
Kanred × Beloglina-Buffum (C. I. No. 5545)	.....	85.9	5.0	28.1	51.7	8.6	35.9	23.4
Odessa	3687	.....	19.3	15.0	48.1	8.6	.....	22.8
Turkey	6152	.....	23.2	11.8	49.3	.6	.....	21.2
Eureka × Minturki	.....	71.8	4.2	24.5	49.0	5.7	31.6	20.9
Minhardi × Minturki	.....	87.1	17.5	0	44.2	19.7	33.7	20.4
Minessa × Eureka	.....	87.8	11.6	17.7	45.0	4.4	33.3	19.7
Beloglina-Buffum (C. I. No. 5548) × Odessa (C. I. No. 3687)	.....	74.9	9.2	18.8	44.1	4.7	30.3	19.2
Odessa (C. I. No. 3687) × Beloglina-Buffum (C. I. No. 5545)	.....	82.1	11.9	19.7	42.5	1.8	31.6	19.0
Eureka × Turkey	.....	82.2	14.6	22.1	38.9	0	31.6	18.9
Kanred	5146	.....	13.0	13.9	44.9	1.0	.....	18.2
Eureka	5170	.....	8.7	18.3	44.7	.4	.....	18.0
Kanred × Minhardi	.....	92.8	0	7.5	49.6	10.9	32.2	17.0
Padui × Odessa (C. I. No. 3687)	.....	83.1	11.4	7.4	42.5	.4	29.0	15.4
Padui	6153	.....	12.2	1.3	40.0	0	.....	13.4

[1] The F_3 hybrid data in 1922 are averages of F_2 lines grown in rod rows.

The hardiest parents are Buffum No. 17, Odessa (C. I. No. 6151), and Minhardi, followed by the several Beloglina-Buffum strains, Minessa and Minturki, the least hardy parents being Padui, Eureka, and Kanred. This general order agrees fairly well with the results obtained from the uniform winter-hardiness nurseries, except that Eureka usually is much less hardy than Kanred or Padui.

Of the hybrids, Minhardi × Eureka showed the best survival. In most cases the hybrids showed a survival intermediate to that of

the parents. There are, however, exceptions; in some instances the hybrids ranked higher than either parent, as, for example, the combinations Minturki × Odessa (C. I. No. 3687) and Kanred × Minessa. In some cases the hybrids were less hardy than either parent. Kanred × Minhardi, Minhardi × Minturki, and Odessa (C. I. No. 3687) × Beloglina-Buffum (C. I. No. 5545) showed this condition. The Minhardi × Eureka cross showed an average survival of 34.8 per cent, while the Kanred × Minhardi cross averaged 17 per cent. This clearly indicates that certain combinations give more hardiness than others.

BULK-ROW RESULTS

In addition to the material grown in plant rows from year to year, several of the hybrid combinations were carried in bulk rows. The seed was obtained from the F_2 generation of the various crosses grown at Manhattan, Kans., and Chico, Calif., in 1920–21, and was continued at Moccasin, Mont., from 1922 to 1925. Winter survivals were recorded for each row in each year. These data are presented in Table 12. In this table the hybrids are ranked in the order of their average survival. In all cases the data from reciprocal crosses have been combined. In 1922 and 1924 no killing occurred in any of the rows. There is little difference in the average survival of the different combinations. Of the 36 combinations grown, 26 had an average survival of 90 per cent or more. Only two combinations, Bacska × Odessa (C. I. No. 6151) and Bacska × Odessa (C. I. No. 3687), had survivals of less than 80 per cent.

TABLE 12.—*Summary of winter survival of winter-wheat hybrid strains grown in 8-rod bulk rows at Moccasin, Mont., 1922–1925*

Name of cross	Percentage of survival				
	1922	1923	1924	1925	Average
Beloglina-Buffum (C. I. No. 5546) × Odessa (C. I. No. 3687)	100	98	100	100	99.5
Beloglina-Buffum (C. I. No. 5548) × Odessa (C. I. No. 3687)	100	98	100	100	99.5
Kanred × Beloglina-Buffum (C. I. No. 5547)	100	100	100	95	98.8
Padui × Beloglina-Buffum (C. I. No. 5515)	100	95	100	100	98.8
Kanred × Minhardi	100	95	100	100	98.8
Beloglina-Buffum (C. I. No. 5545) × Odessa (C. I. No. 3687)	100	95	100	100	98.8
Minturki × Odessa (C. I. No. 3687)	100	95	100	100	98.8
Kanred × Buffum No. 17	100	95	100	100	98.8
Minturki × Beloglina-Buffum (C. I. No. 5540)	100	98	100	95	98.3
Kanred × Padui	100	98	100	95	98.3
Kanred × Minessa	100	98	100	95	98.3
Odessa (C. I. No. 6151) × Padui	100	94	100	98	98.0
Padui × Odessa (C. I. No. 3687)	100	90	100	100	97.5
Minhardi × Eureka	100	89	100	100	97.3
Karmont × Odessa (C. I. No. 3687)	100	98	100	90	97.0
Kanred × Beloglina-Buffum (C. I. No. 5545)	100	98	100	90	97.0
Minturki × Turkey (C. I. No. 6152)	100	97	100	90	96.8
Kanred × Minturki	100	97	100	90	96.8
Kanred × Odessa (C. I. No. 6151)	100	95	100	90	96.3
Minessa × Turkey (C. I. No. 6152)	100	88	100	95	95.8
Kanred × Turkey (C. I. No. 6152)	100	88	100	95	95.8
Odessa (C. I. No. 6151) × Karmont	100	80	100	95	93.8
Odessa (C. I. No. 6151) × Turkey (C. I. No. 6152)	100	75	100	95	92.5
Eureka × Minturki	100	70	100	88	91.8
Minessa × Eureka	100	80	100	80	90.0
Eureka × Odessa (C. I. No. 6151)	100	77	100	83	90.0
Minessa × Bacska	100	75	100	80	88.8
Eureka × Turkey (C. I. No. 6152)	100	65	100	60	88.8
Buffum × Eureka	100	58	100	95	88.3
Kanred × Eureka	100	75	100	80	88.8
Odessa (C. I. No. 6151) × Beloglina-Buffum (C. I. No. 5547)	100	50	100	100	87.5
Bacska × Minhardi	100	70	100	75	86.3
Kanred × Karmont	100	95	100	50	86.3
Minturki × Barska	100	70	100	57	81.3
Bacska × Odessa (C. I. No. 3687)	100	65	100	50	78.8
Bacska × Odessa (C. I. No. 6151)	100	55	100	60	77.5

The bulk hybrids were grown at Moccasin in rows approximately 132 feet long. Each year the entire row was cut and threshed, and from this seed a random sample was obtained for seeding the next crop. Yields were determined on each row and are shown in Table 13. In this table the hybrids are arranged in the order of their average yield. Kanred × Beloglina-Buffum (C. I. No. 5547), which produced the highest average yield, also was one of the highest for winter survival. The second highest yielding hybrid combination was Kanred × Buffum. The lowest yielding hybrid, Bacska × Odessa (C. I. No. 6151), also was the poorest for winter survival.

TABLE 13.—*Summary of yields of the winter-wheat hybrid strains grown in 8-rod bulk rows at Moccasin, Mont., 1922–1925*

Name of cross	Yield per acre				
	1922	1923	1924	1925	Average
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*
Kanred × Beloglina-Buffum (C. I. No. 5547)	30.0	37.0	37.5	18.0	30.6
Kanred × Buffum	27.0	29.0	34.5	23.0	28.4
Minturki × Turkey (C. I. No. 6152)	29.5	30.0	33.3	20.5	28.3
Kanred × Minhardi	28.5	24.0	35.5	24.0	28.0
Karmont × Odessa (C. I. No. 3687)	29.5	21.5	43.0	18.0	28.0
Kanred × Turkey (C. I. No. 6152)	29.5	23.0	39.5	19.0	27.5
Minturki × Beloglina-Buffum (C. I. No. 5546)	27.5	26.5	38.0	18.0	27.5
Kanred × Minessa	34.0	24.0	34.5	17.0	27.4
Padul × Beloglina-Buffum (C. I. No. 5545)	29.5	22.0	39.0	18.0	27.1
Beloglina-Buffum, (C. I. No. 5548) × Odessa (C. I. No. 3687)	27.5	20.5	39.0	20.5	26.9
Minessa × Turkey (C. I. No. 6152)	28.3	24.3	28.0	25.5	26.5
Kanred × Karmont	28.0	22.0	42.5	13.0	26.4
Odessa (C. I. No. 6151) × Karmont	27.5	19.5	39.0	19.0	26.3
Kanred × Padul	28.0	22.5	35.0	19.5	26.2
Kanred × Minturki	29.0	23.0	34.8	17.5	26.1
Kanred × Beloglina-Buffum (C. I. No. 5545)	29.5	22.0	37.5	15.5	26.1
Odessa (C. I. No. 6151) × Padul	26.5	30.5	23.0	24.0	26.0
Kanred × Odessa (C. I. No. 6151)	31.5	22.0	35.5	15.0	26.0
Beloglina-Buffum (C. I. No. 5545) × Odessa (C. I. No. 3687)	25.5	20.0	30.0	17.5	25.5
Beloglina-Buffum (C. I. No. 5547) × Odessa (C. I. No. 3687)	23.0	27.0	32.0	19.0	25.3
Minhardi × Eureka	27.8	20.5	30.8	21.0	25.0
Padul × Odessa (C. I. No. 3687)	25.0	22.5	32.0	20.0	24.9
Kanred × Eureka	38.0	10.5	35.5	14.0	24.5
Odessa (C. I. No. 6151) × Turkey (C. I. No. 6152)	30.0	19.5	27.5	20.5	24.4
Eureka × Odessa (C. I. No. 6151)	28.2	15.0	31.2	19.3	23.4
Eureka × Minturki	28.0	16.5	32.8	16.5	23.4
Minturki × Odessa (C. I. No. 3687)	24.5	23.0	29.0	17.0	23.4
Buffum × Eureka	27.0	13.0	32.5	19.0	22.9
Bacska × Odessa (C. I. No. 3687)	29.0	13.0	33.0	16.5	22.9
Minessa × Bacska	29.0	21.5	25.5	14.5	22.6
Minturki × Bacska	27.8	19.8	20.5	12.5	22.4
Eureka × Turkey (C. I. No. 6152)	26.5	13.3	31.0	18.5	22.3
Odessa (C. I. No. 6151) × Beloglina-Buffum (C. I. No. 5547)	20.5	15.5	35.5	17.0	22.1
Bacska × Minhardi	29.0	12.0	28.0	16.5	21.4
Bacska × Odessa (C. I. No. 6151)	24.7	14.5	27.8	14.0	20.3

At harvest time in 1925 head selections were made from the more outstanding crosses for survival and yield. These selections were grown in head rows at several stations in the winter-wheat belt. At this time these selections have not been grown long enough to determine their value.

After harvest in 1925 the least promising combinations were discarded, and those remaining were seeded at Dickinson, N. Dak., for growing under conditions of more severe winterkilling.

NURSERY EXPERIMENTS

As promising homozygous material became available from plant rows at the several stations it was advanced to nursery experiments.

TESTS IN NORTH DAKOTA AND MONTANA

At harvest in 1924 at Dickinson, N. Dak., the seed from the most hardy and promising plant rows which seemed to be homozygous was bulked and then seeded in rod rows at Dickinson, N. Dak., and Moccasin, Mont. The first year the material was grown in single rod rows replicated three times.[5] As rapidly as possible, the more outstanding strains were advanced to 3-row plots replicated three times. At Dickinson the material was seeded in stubble, whereas at Moccasin the seeding was done on fallow. In general, the same strains were grown at both places, although this practice was not followed entirely. After each harvest the strains were studied for quality of grain. The earlier studies were made on kernel appearance and texture and the later on crude-protein content. These data, together with data regarding winter hardiness and yield, furnished the basis for discarding the less promising strains. In all, 17 hybrid strains and 10 parent varieties have been grown at both the Moccasin and Dickinson stations for the 4-year period 1925–1928. Many other hybrid strains have been grown, but only those grown in all years are included in the tables.

TESTS AT DICKINSON, N. DAK.

Table 14 presents the winter survival and yield data obtained from 34 hybrid strains and 13 parent varieties grown in replicated rod rows at Dickinson, N. Dak., from 1925 to 1928, inclusive. A study of the data shows that during each of four winters killing was rather severe. The winter of 1926–27 was the most severe, the highest survival recorded being 10 per cent. The strain having the highest average survival for the 4-year period was Kanred × Minhardi (C. I. No. 8031), which had an average survival of 48 per cent. Minhardi and another strain of Kanred × Minhardi (nursery No. 130) were second, each with an average survival of 44.3. Other hybrid strains showed survivals nearly equal to Minhardi, while some were less hardy than Kanred and Turkey.

The varieties and strains are listed in the order of their average yield. The average yields are all low, ranging from 6 to 13.7 bushels per acre. In general, the hybrid strains giving the highest yields had as one parent such varieties as Minturki, Minhardi, or Buffum No. 17. Several strains gave higher average yields than either Minhardi or Buffum No. 17, and only four hybrid strains ranked below Minturki and Kanred.

The correlation between average yield and average winter survival is not so great as might be expected, since some of the strains ranking low for survival ranked rather high for yield. This would seem to indicate that strains probably differ in their ability to recover in the spring and to utilize the available supply of moisture and plant food.

[5] Triplicate rows.

TABLE 14.—*Average percentage of winter survival and acre yield of hybrid selections and parent varieties grown in replicated rod rows at Dickinson, N. Dak., 1925–1928*

Name of cross or parent	C. I. No.	Nursery No.	Percentage of survival					Rank for average survival	Yield in bushels per acre				
			1925	1926	1927	1928	Average		1925	1926	1927	1928	Average
Minturki × Beloglina-Buffum (C. I. 5546)	8033	162	35	27	4	64	32.8	27	30.6	3.5	3.9	17.0	13.7
Minhardi × Minturki		171	34	38	4	41	29.3	34	22.5	2.4	2.2	21.2	12.1
Do	8034	167	54	56	2	45	39.3	13	30.8	3.0	1.1	12.4	11.8
Minturki × Beloglina-Buffum (C. I. 5546)		160	31	14	2	65	28.0	41	18.3	2.7	3.8	21.9	11.7
Kanred × Buffum No. 17	8030	115	31	50	2	45	42.0	7	20.4	3.3	1.0	15.2	11.5
Turkey × Minessa	8028	44	42	18	3	28	22.8	40	21.7	2.9	3.6	17.9	11.5
Beloglina-Buffum (C. I. 5547) × Odessa (C. I. 3687)		178	24	33	8	90	38.8	14	18.2	3.0	8.3	16.1	11.4
Kanred × Minhardi	8031	126	41	58	9	56	48.0	1	24.0	3.9	8.1	9.2	11.3
Buffum No. 17	3330		29	45	4	65	35.8	17	16.4	5.9	2.3	20.0	11.2
Minhardi × Minturki	8047	160	50	40	1	67	39.5	11	25.5	3.2	1.0	14.0	10.9
Minturki × Beloglina-Buffum (C. I. 5546)		161	33	16	3	56	27.0	42	18.8	2.5	2.2	19.7	10.8
Kanred × Minhardi	8040	123	34	50	5	73	40.5	8	16.0	3.3	4.4	18.1	10.5
Minhardi	5149		32	71	4	70	44.3	2	18.5	5.0	2.5	15.0	10.3
Padui × Odessa (C. I. 3687)		175	30	16	8	71	31.3	31	19.3	2.8	3.5	17.5	10.3
Turkey × Minessa	8035	46	30	22	3	23	19.5	47	18.9	4.1	2.7	15.0	10.2
Kanred × Minessa	8045	136	27	51	3	60	35.3	18	17.2	3.6	1.7	16.1	9.7
Minhardi × Minturki		170	38	38	2	54	33.0	26	22.0	2.7	2.3	11.8	9.7
Padui × Odessa (C. I. 3687)		173	28	21	4	53	26.5	43	17.2	2.7	1.4	17.1	9.6
Minhardi × Minturki		169	38	37	3	36	31.0	32	20.4	3.9	2.3	11.3	9.5
Kanred × Minhardi		128	24	43	4	24	23.8	45	17.6	2.3	2.0	16.1	9.5
Padui × Odessa (C. I. 3687)		172	28	34	1	90	38.3	15	15.4	3.9	0	18.3	9.4
Odessa	3687		31	46	2	60	34.8	20	16.3	2.2	.7	18.2	9.4
Beloglina-Buffum	5545		18	72	3	77	42.5	6	10.2	2.1	1.8	22.9	9.3
Minessa	6154		26	61	1	46	34.3	21	15.8	5.7	0	15.7	9.3
Eureka × Minhardi	8036	76	22	78	3	59	40.5	8	17.3	3.3	2.8	12.4	9.0
Beloglina-Buffum (C. I. 5547) × Odessa (C. I. 3687)		177	19	37	10	69	33.8	22	15.0	3.5	6.0	11.3	9.0
Kanred × Beloglina - Buffum (C. I. 5545)		164	27	31	2	57	29.3	38	18.4	3.4	2.2	11.2	8.8
Beloglina-Buffum	5547		26	41	3	58	32.0	28	18.5	3.2	1.6	10.9	8.6
Kanred × Beloglina - Buffum (C. I. 5545)		165	21	75	3	73	43.0	4	9.9	3.5	2.7	17.9	8.5
Beloglina-Buffum	5548		30	70	2	60	42.8	5	13.0	4.1	1.0	10.0	8.5
Kanred × Minhardi		119	22	57	4	50	33.3	25	12.7	2.9	5.0	12.6	8.3
Do		130	27	77	3	70	44.3	2	15.7	2.6	2.2	12.1	8.2
Eureka × Minhardi		78	17	38	8	67	40.0	10	13.5	2.7	4.7	11.3	8.1
Kanred × Minhardi	8037	120	34	40	7	53	33.5	23	13.2	2.5	5.7	11.0	8.1
Kanred × Minturki		142	27	49	2	48	31.5	30	16.3	5.1	3.0	7.8	8.1
Beloglina-Buffum	5546		22	20	2	77	30.3	35	13.5	3.3	0	14.8	7.9
Kanred × Minhardi		133	23	65	7	39	33.5	23	15.1	2.7	2.8	9.3	7.5
Padui	6153		29	27	2	83	35.3	18	13.7	2.4	.8	12.4	7.3
Kanred × Minhardi		125	24	68	6	60	39.5	11	13.0	3.7	4.5	6.5	7.1
Minturki	6155		29	34	1	84	32.0	28	13.4	2.3	0	12.0	6.9
Kanred × Odessa (C. I. 3687)		148	28	57	3	26	28.5	40	12.7	4.9	2.8	6.2	6.7
Turkey	1558		21	48	T	79	37.0	16	9.7	2.7	0	13.0	6.4
Kanred	5146		21	62	T	39	30.5	33	11.1	3.7	.3	10.5	6.4
Turkey selection	6152		19	19	1	79	29.5	37	8.1	1.2	0	16.2	6.4
Kanred × Beloglina - Buffum (C. I. 5545)		151	24	51	4	43	30.5	33	11.4	2.8	3.2	7.3	6.2
Do		154	19	67	3	10	24.8	44	12.9	1.7	2.5	7.2	6.1
Kanred × Minhardi	8041	124	36	41	10	34	30.3	35	13.2	1.8	4.5	4.5	6.0

TESTS AT MOCCASIN, MONT.

In all, 39 hybrid strains and 12 parent varieties were grown at Moccasin, Mont., in replicated rod rows throughout the 4-year period from 1925 to 1928. The winter survival and yield data of these strains are presented in Table 15. Except in 1928, the winter-killing at Moccasin was rather light and almost no killing occurred in 1927. Three strains of Kanred × Minhardi had average survivals higher than Minhardi. Kanred × Minhardi (C. I. No. 8031) ranked first for average winter survival at Moccasin as well as at Dickinson.

TABLE 15.—*Average percentage of winter survival and acre yields of hybrid selections and parent varieties grown in replicated rod rows at Moccasin, Mont., 1925–1928*

Name of cross or parent	C. I. No.	Nursery No.	Percentage of survival					Rank for average survival	Yield in bushels per acre				
			1925	1926	1927	1928	Average		1925	1926	1927	1928	Average
Turkey × Minessa	.....	485	93	93	100	58	86.0	22	37.3	47.3	41.8	7.4	33.5
Minard	6690	.....	53	90	100	62	76.3	45	32.6	30.1	40.1	5.9	29.4
Padul × Beloglina-Buffum (C. I. 5545)	.....	517	95	88	100	47	82.5	30	33.6	43.1	32.7	6.5	29.0
Eureka × Turkey	.....	491	35	90	100	29	63.5	50	19.7	41.0	40.0	15.2	29.0
Kanred × Minhardi	8040	123	100	100	100	72	93.0	0	37.1	29.4	39.0	6.2	28.2
Do	.....	133	92	100	100	69	90.3	10	20.8	34.2	36.4	12.7	27.5
Turkey × Minessa	.....	53	95	100	100	60	88.8	14	25.5	32.7	45.1	5.7	27.3
Kanred × Minhardi	8044	132	92	99	100	62	88.3	15	25.6	30.9	44.9	7.9	27.3
Turkey × Minessa	.....	51	88	100	100	49	84.3	27	24.5	36.7	42.0	6.1	27.3
Beloglina-Buffum	5545	.....	75	98	100	53	81.5	34	23.6	35.5	37.6	11.4	27.0
Turkey × Odessa (C. I. 3687)	.....	518	73	92	100	47	78.0	43	23.9	41.2	36.0	6.9	27.0
Minturki × Beloglina-Buffum (C. I. 5546)	.....	160	82	97	100	50	82.3	33	27.1	32.1	40.2	8.3	26.9
Turkey × Odessa (C. I. 3687)	.....	197	85	100	100	32	79.3	38	30.1	33.0	37.2	6.9	26.8
Minessa × Eureka	.....	492	83	100	100	33	79.0	40	24.3	31.8	44.3	6.7	26.8
Kanred × Minhardi	.....	125	97	100	100	81	94.5	3	24.2	35.8	36.5	6.4	26.5
Minhardi	5149	.....	96	100	100	79	93.8	4	26.9	30.9	42.4	5.8	26.5
Kanred × Minhardi	.....	495	55	95	100	68	79.5	36	23.4	37.5	30.3	5.8	26.5
Eureka × Minhardi	8036	76	97	100	100	78	93.8	4	27.4	28.4	44.1	5.7	26.4
Do	.....	78	93	99	100	60	88.2	12	29.5	26.4	42.3	6.6	26.2
Kanred × Beloglina-Buffum (C. I. 5545)	.....	151	82	96	100	75	88.3	15	32.1	27.5	38.2	7.1	26.2
Eureka × Minhardi	.....	77	98	98	100	66	90.5	8	29.6	27.7	40.7	6.3	26.1
Turkey × Odessa (C. I. 3687)	.....	190	98	98	100	21	79.3	38	27.5	28.0	41.7	7.3	26.1
Minhardi × Minturki	.....	516	33	96	100	47	69.0	47	23.1	36.5	35.7	9.1	26.1
Kanred × Minhardi	8042	127	93	100	100	87	95.0	2	27.4	32.0	38.1	6.3	26.0
Minhardi × Minturki	8018	168	90	100	100	57	86.8	20	21.9	37.6	37.4	6.9	26.0
Beloglina-Buffum	5548	.....	93	100	100	49	85.5	24	23.0	31.9	41.3	7.4	25.9
Minturki × Beloglina-Buffum (C. I. 5546)	8033	162	83	97	100	51	82.8	29	27.0	33.1	32.6	10.7	25.9
Minturki × Turkey	8029	68	88	97	100	28	78.3	42	27.6	29.4	40.7	5.9	25.9
Minturki × Beloglina-Buffum (C. I. 5546)	.....	515	60	72	100	32	66.0	49	21.2	39.1	36.3	6.5	25.8
Minhardi × Eureka	.....	75	85	100	100	47	83.0	28	21.7	32.3	36.1	12.5	25.7
Minessa	6151	.....	98	98	100	68	90.5	8	25.1	29.0	41.2	7.1	25.0
Kanred × Minhardi	.....	128	85	100	100	56	85.3	26	22.0	34.0	42.3	4.0	25.0
Do	8013	131	87	98	100	68	88.3	23	23.9	33.8	35.7	8.2	25.4
Do	.....	130	88	100	100	54	85.5	24	26.7	30.3	40.7	3.0	25.2
Turkey × Odessa (C. I. 3687)	.....	135	97	100	100	29	81.5	34	24.8	32.8	38.4	4.6	25.2
Kanred × Odessa (C. I. 6151)	.....	148	93	97	100	61	87.8	18	25.7	31.6	38.4	4.2	25.0
Kanred × Beloglina-Buffum (C. I. 5545)	.....	153	65	98	100	55	79.5	36	22.4	31.6	37.8	8.2	25.0
Turkey selection	6152	.....	77	98	70	50	73.8	46	22.5	32.9	38.5	3.9	24.5
Kanred × Minhardi	.....	120	88	100	100	58	86.5	21	21.5	31.7	40.4	3.8	24.4
Kanred × Odessa (C. I. 6151)	.....	147	100	97	100	62	89.8	11	25.3	27.3	40.8	3.0	24.1
Kanred × Minhardi	8031	126	95	98	100	88	95.3	1	23.3	29.6	34.2	5.5	23.7
Kanred × Minessa	8045	136	100	100	100	57	89.3	12	23.9	28.8	27.9	3.3	23.5
Minhardi × Minturki	8034	167	80	99	100	51	82.5	30	25.2	28.7	32.3	6.4	23.2
Turkey × Minessa	8023	44	93	100	100	72	91.3	7	21.6	25.3	37.0	6.8	22.7
Kanred × Buffum No. 17	8030	115	92	97	100	64	88.3	15	21.9	25.6	33.4	9.6	22.6
Buffum No. 17	3330	.....	88	100	100	60	87.0	19	21.3	30.6	33.9	4.4	22.6
Odessa	6151	.....	73	98	100	36	76.8	44	22.4	28.4	35.3	3.2	21.8
Do	3687	.....	95	100	100	35	82.5	30	20.3	32.7	31.4	2.3	21.7
Minturki	6155	.....	80	93	100	37	70.0	40	21.6	27.6	29.8	6.1	21.3
Kanred	5148	.....	53	92	95	14	63.5	50	15.7	28.2	31.4	2.0	20.1
Turkey	1558	.....	43	92	100	32	66.8	48	10.5	30.5	25.8	3.4	17.6

The varieties and strains are ranked according to average yield per acre in bushels. Turkey × Minessa (nursery No. 485) ranked first, followed by Minard (C. I. No. 6690). Minard is a production of the Minnesota Agricultural Experiment Station. A total of 13 hybrid strains ranked higher in average yield than Minhardi. All of the hybrid strains grown show average yields higher than Turkey (C. I. No. 1558), Kanred, Minturki, Odessa, and Buffum No. 17 parents. The consistent high yield of Minhardi is hard to explain, since some years previous this variety was grown in plot tests at Moccasin and discarded because of low yield. Since it has been included in the nursery tests it has yielded well.

A comparison of the data in Tables 14 and 15 brings out the fact that winter conditions at Dickinson, N. Dak., are much more severe than at Moccasin, Mont. For this reason strains such as Minturki × Beloglina-Buffum (C. I. No. 5546) (C. I. No. 8033), Minhardi × Minturki (C. I. No. 8034), Kanred × Buffum No. 17 (C. I. No. 8030), and Turkey × Minessa (C. I. No. 8028), which are known to possess considerable winter hardiness, ranked well for yield at Dickinson, but at Moccasin they were surpassed by strains having less hardiness but greater yielding ability. It would seem, however, that hybrid strains are available which have greater winter hardiness and yielding ability than commercial varieties now grown.

TESTS IN KANSAS AND NEBRASKA

In the fall of 1925, 17 of the hybrid strains that appeared promising in the nurseries at Dickinson, N. Dak., and Moccasin, Mont., were selected for testing in Kansas and Nebraska. These strains were grown at Manhattan and Hays, Kans., and at North Platte, Nebr., during the season of 1925–26. The material was grown in single rows replicated three times.

Table 16 presents a brief summary of the data obtained with these strains and with Kanred at the three stations. In no case was there any winterkilling. At Manhattan a late frost in March, after the wheat had made some spring growth, caused slight injury in a few of the strains. In no case was any strain injured more than Kanred, and in most cases less.

TABLE 16.—*Summary of data obtained with 17 winter-wheat hybrid strains grown at Manhattan and Hays, Kans., and at North Platte, Nebr., 1925–26*

Name of variety or cross	C. I. No.	At Manhattan		Yield in bushels per acre				Remarks on strains at—	
		Frost injury in March	Date of first heads	Kansas		Nebraska, North Platte	Average	Hays	Manhattan
				Manhattan	Hays				
		Per cent							
Kanred (checks)	5146	10	May 21	30.0	23.7	27.0	27.2		
Kanred × Minhardi	8038	0	May 22	37.6	13.9	25.1	25.5	Promising	Good, very hard.
Turkey × Odessa	8050	10	May 21	30.0	16.5	26.1	24.4		Good vigor.
Turkey × Minessa	8029	5	do	31.0	12.6	21.8	24.0	Too late	Good.
Minhardi × Minturki	8047	5	May 23	27.5	15.8	28.4	23.9	Promising	Late.
Eureka × Minhardi	8036	0	do	27.6	15.5	27.6	23.6		Dark, hard.
Kanred × Minessa	8045	10	do	25.4	17.5	27.3	23.4	Too late	
Kanred × Minhardi	8044	10	May 19	28.1	17.4	24.2	23.2		Good, very hard.
Do	8043	10	May 20	27.6	18.8	23.0	23.1	Promising	Do.
Do	8037	0	May 21	27.1	16.6	21.9	22.9	Hurt some	Good.
Do	8040	0	May 21	25.3	14.9	28.5	22.9		
Minhardi × Minturki	8048	5	May 23	26.3	16.2	25.8	22.8	Hurt some	
Kanred × Minhardi	8042	0	do	29.0	13.5	25.2	22.6	Hurt	
Kanred × Minturki	8046	10	May 22	25.3	19.3	23.3	22.6	Promising	
Kanred × Minhardi	8039	0	do	25.5	16.1	23.9	21.8	do	Hard.
Do	8041	0	May 23	26.2	12.0	26.1	21.4	Worthless	
Turkey × Minessa	8035	5	May 26	19.8	7.6	23.1	16.8	Too late	
Beloglina - Buffum × Odessa	8049	5	do	17.1	8.7	24.3	16.7	do	

The strains are arranged in the order of the average yield at the three stations. Kanred, which was used as a check, produced the highest average yield. At Manhattan 3 of the 17 strains yielded more than Kanred. At Hays there were no strains which equaled Kanred, whereas at North Platte there were 2 strains which yielded slightly more than the checks. While these data are based on the results of only one year from replicated single rows, it would indicate that none of the new hybrid strains is any better than Kanred for yield under the conditions in Kansas and Nebraska.

DATE OF MATURITY

Table 16 presents dates of heading for each of the 17 hybrid strains grown at Manhattan in comparison with Kanred. Only 3 of the hybrids headed as early as or earlier than Kanred, whereas some strains headed as much as five days later. At Hays, Kans., all of the strains were so late that they were all discarded after the first-year test. At North Platte the differences in date of heading were not so marked.

For successful growing in Kansas a variety must not be later in maturity than Kanred, and it would be desirable to have varieties a few days earlier than Kanred. Under the conditions in Montana and North Dakota, earliness is not so important, and little attempt was made to obtain earliness. By growing the material under severe winter conditions the less hardy strains were eliminated, and by growing the hardier lines in the southern part of the hard red winter-wheat area it appears that most of the early strains had been eliminated. From the results obtained and from general observations it appears that the strains which are hardiest are also late in maturing. It would seem that for the material herein reviewed lateness and winter hardiness usually are associated.

UNIFORM WINTER-HARDINESS NURSERIES

Eight of the more promising hybrids were selected to be included in the uniform winter-hardiness nurseries, which are grown at experiment stations in the northern part of the United States and in Canada.

WINTER HARDINESS

Table 17 presents the winter-survival data obtained for these hybrids in comparison with several standard varieties. The average survival recorded in each year for a variety is based on reports from stations where partial killing occurred. Data from stations reporting either no survival or no killing were not used. In 1926, 18 stations reported partial killing; in 1927, 21 stations; and in 1928, 20 stations. The table shows the weighted average for the years grown and the percentage of survival in comparison with Kharkof. The varieties and strains are presented in the order of their percentage survival in terms of Kharkof. It is seen from these data that none of the new hybrid strains has as much hardiness as Buffum No. 17 and Minhardi. All of the hybrid strains are distinctly hardier than Kanred and Kharkof. The hardiest hybrid strains are Kanred × Buffum No. 17 (C. I. No. 8030), Turkey × Minessa (C. I. No. 8028), and Minturki × Beloglina-Buffum (C. I. No. 8033). Kanred × Minhardi (C. I.

No. 8031), which showed so well at Moccasin and Dickinson, ranked a little lower.

TABLE 17.—*Percentage of winter survival of winter-wheat hybrids and some standard varieties grown in the uniform winter-hardiness nurseries, 1926–1928*

Name of cross or variety	C. I. No.	Survival					Station years	Survival in terms of Kharkof
		In 1926, at 18 stations	In 1927, at 21 stations	In 1928, at 20 stations	Average (weighted)	Kharkof, same years		
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Number*	*Per cent*
Buffum No. 17	3330	69.7	71.6	64.5	68.6	52.8	59	120.9
Minhardi	5142	70.4	71.5	59.5	67.1	52.8	59	127.1
Kanred × Buffum No. 17	8030	70.4	69.4	60.2	66.8	52.8	59	126.1
Turkey × Mluessa	8028	70.5	67.3	58.2	65.2	52.8	59	123.5
Minturki × Beloglina-Buffum	8033	67.8	69.8	57.8	65.1	52.8	59	123.3
Eureka × Minhardi	8036	.....	67.0	57.2	62.2	51.1	41	121.7
Minturki	6155	66.1	67.1	58.8	64.0	52.8	59	121.2
Kanred × Minhardi	8031	68.7	64.7	55.8	62.0	52.8	59	119.1
Minhardi × Minturki	8034	67.6	65.3	52.8	61.8	52.8	59	117.0
Beloglina	1543	64.0	65.8	51.4	60.6	52.8	59	114.8
Minhardi × Minturki	8047	.....	67.0	.....	67.0	59.1	21	113.4
Kanred × Minhardi	8040	.....	66.6	.....	66.6	59.1	21	112.7
Kanred	5146	52.4	61.2	45.8	53.3	52.8	59	100.9
Kharkof	1442	50.7	59.1	42.8	52.8	52.8	59	100.0

YIELD

Several of the cooperators who grow the uniform winter-hardiness nurseries have been harvesting the varieties and strains and determining yields. In these nurseries the strains are grown in single rows replicated three times. This does not make possible the elimination of border effect or competition between varieties. This is of considerable importance in winter wheat where strains are winterkilled in varying percentages. The strains in the nurseries are so arranged, however, that the hardier varieties are grown side by side, which would tend to reduce the competition.

Table 18 presents the yield data for the hybrid strains and six standard varieties grown in the winter-hardiness nurseries in 1926, 1927, and 1928. Yields were reported from 14 stations in 1926, from 18 stations in 1927, and from 12 stations in 1928. The varieties are arranged in the table in the order of their percentage of yield as compared with Kharkof. The strain producing the highest yield was Minhardi × Minturki (C. I. No. 8034), followed by Minturki × Beloglina-Buffum (C. I. No. 8033). Minturki showed the highest yield of the standard varieties. Minhardi produced the lowest yield of all the varieties and strains shown.

From the data presented in Tables 17 and 18 it would seem that some of the new hybrid strains have winter hardiness approximating that of Minhardi and Buffum No. 17, and in addition have the ability to yield very much more. The new hybrid strains also have at least equal quality with the leading hard red winter varieties. During the testing, all strains with grain which was soft or appeared to be inferior to that of the hard parents have been discarded, and the appearance of the grain from the new strains has been very good when grown where they are fairly well adapted. This would indicate that the desired combination of winter hardiness, yield, and quality apparently has been obtained.

TABLE 18.—*Yield of winter-wheat hybrids and some standard varieties grown in the uniform winter-hardiness nurseries, 1926–1928*

Name of cross or variety	C. I. No.	Yield per acre					Station years	Yield in terms of Kharkof
		In 1926, at 14 stations	In 1927, at 18 stations	In 1928, at 12 stations	Average (weighted)	Kharkof, same years		
		Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Number*	*Per cent*
Minhardi × Minturki	8034	40.0	34.2	34.8	36.2	32.5	44	111.4
Minturki × Beloglina-Buffum	8033	39.5	33.6	35.3	35.9	32.5	44	110.5
Minturki	6155	40.1	31.2	35.2	35.1	32.5	44	108.0
Minhardi × Minturki	8047	-------	32.2	-------	32.2	30.9	18	104.2
Kanred	5146	33.8	34.2	32.5	33.6	32.5	44	103.4
Eureka × Minhardi	8036	-------	30.7	32.7	31.5	30.5	30	103.3
Kharkof	1442	36.8	30.9	30.0	32.5	32.5	44	100.0
Beloglina	1543	35.2	31.0	28.8	32.1	32.5	44	98.8
Turkey × Minessa	8028	38.1	30.6	27.5	32.1	32.5	44	98.8
Kanred × Buffum No. 17	8030	35.1	30.4	30.7	32.0	32.5	44	98.5
Kanred × Minhardi	8040	-------	28.7	-------	28.7	30.9	18	92.9
Buffum No. 17	3330	29.5	25.8	31.3	28.6	32.5	44	87.7
Kanred × Minhardi	8031	33.5	25.6	25.2	26.0	32.5	44	80.2
Minhardi	5149	32.1	24.4	20.6	27.5	32.5	44	84.6

PLOT EXPERIMENTS

In the fall of 1927 several of the more outstanding strains were increased to plot experiments at Dickinson, N. Dak., and Havre and Moccasin, Mont. At Dickinson four hybrid strains were grown in single 1/10-acre plots. At Havre three strains were grown in duplicate 1/20-acre plots, and at Moccasin the four strains were grown in duplicate 1/10-acre plots. Although none of these tests have run long enough or on a scale extensive enough, they give some indication of the behavior of the new strains in comparison with standard varieties.

The winter-survival and yield results from Dickinson, N. Dak., are presented in Table 19. At this station the new hybrids produced yields better than Minhardi, but were outyielded by Turkey, Minturki, and Beloglina. The survival figures show the hybrids to be hardier than Minhardi.

TABLE 19.—*Yield and percentage of winter survival of some hybrid strains and parent varieties grown in single plots at Dickinson, N. Dak., 1928*

Name of cross or variety	C. I. No.	Survival	Yield per acre	Name of cross or variety	C. I. No.	Survival	Yield per acre
		Per cent	*Bushels*			*Per cent*	*Bushels*
Turkey	1571	76	33.8	Turkey × Minessa	8028	78	22.3
Minturki	6155	77	31.5	Kanred	5146	80	22.1
Beloglina	1543	75	28.0	Buffum No. 17	3330	83	22.1
Kanred × Buffum No. 17	8030	81	26.6	Minhardi × Minturki	8034	87	21.7
Kharkof	1583	78	25.0	Minhardi	5149	76	21.3
Minturki × Beloglina-Buffum	8033	82	24.8				

In the Havre, Mont., experiment, shown in Table 20, the hybrid strains were outyielded by Montana No. 36 and Newturk, while Turkey × Minessa (C. I. No. 8028) yielded slightly more than Karmont. The three strains in this test are probably among the hardiest of the hybrid lines now available.

TABLE 20.—*Average yield of some hybrid strains and standard varieties grown in plot tests at Havre, Mont., 1927–28* [1]

Name of cross or variety	C. I. No.	Average yield	Name of cross or variety	C. I. No.	Average yield
		Bushels			*Bushels*
Montana No. 36	5549	42.9	Karmont	6700	37.8
Newturk	6935	41.2	Kanred × Buffum No. 17	8030	34.4
Turkey × Minessa	8028	38.4	Kanred × Minhardi	8031	33.7

[1] Data from M. A. Bell.

At Moccasin, Mont., the new hybrids were rather outstanding in winter survival and yield, as shown in Table 21. Three of the hybrids greatly outyielded the standard varieties and made fair yields, whereas in most cases the standard varieties were nearly a failure. The survivals of the hybrid strains were very encouraging and indicate that progress has been made. Minturki × Beloglina-Buffum (C. I. No. 8033), which gave the highest yield, has also been found to be very resistant to bunt or stinking smut under conditions at Moccasin.

Milling and baking experiments (conducted in cooperation with the grain division of the Bureau of Agricultural Economics) have been made on the samples, and the data on protein content, flour yield, and loaf volume are shown in Table 21. These data indicate that the quality of the new hybrid selections compares favorably with that of Kharkof, Karmont, and Newturk, the principal commercial varieties of winter wheat grown in the Judith Basin section of Montana.

TABLE 21.—*Average yield per acre, percentage of winter survival, and quality data* [1] *of some hybrid strains and standard varieties of wheat grown in plot tests at Moccasin, Mont., 1928*

Name of cross or variety	C. I. No.	Survival	Yield	Quality		
				Protein content	Flour yield	Loaf volume
		Per cent	*Bushels*	*Per cent*	*Per cent*	*C. c.*
Minturki × Beloglina-Buffum (C. I. No. 5546)	8033	75	18.6	15.0	72.1	2,210
Kanred × Minhardi	8040	88	13.3	15.4	69.6	2,290
Eureka × Minhardi	8036	88	11.9	15.3	71.3	2,080
Kanred × Minessa	8045	55	7.1	16.5	67.7	2,230
Newturk	6935	10	3.6	16.9	69.5	2,200
Kharkof	1583	0	1.8	17.4	65.7	2,120
Karmont	6700	10	1.6	17.7	66.5	2,360

[1] The crude-protein and milling and baking results were obtained in cooperation with the research and milling and baking laboratories, grain division, Bureau of Agricultural Economics.

SUMMARY

The hard red winter wheats, which now occupy about 41 per cent of the total wheat acreage of the United States, are limited in their northward expansion chiefly by winterkilling. Winter wheat is more productive than spring wheat if the former is not injured during the winter.

As a class, the hard red winter wheats are fairly winter hardy, but not hardy enough to be grown in the northern portion of the Great

Plains area. The use of various cultural practices, such as mulching with straw or seeding in furrows or in stubble, offers a partial solution of the problem of winterkilling.

In order to develop hardier, high-quality, and high-yielding wheats, numerous crosses were made between hardy soft wheats (like Minhardi, Buffum No. 17, and Odessa) and high-quality hard wheats, such as Turkey, Kanred, and Kharkof.

Because of the difficulty of studying winter hardiness in the field, the plan used was to grow the hybrid material at several northern stations over a period of years. The material was grown at 11 stations during the period from 1920 to 1928, a total of 26,085 nursery plantings being made.

An attempt was made to study the inheritance of winter hardiness. It was shown that hardiness is inherited, but the character proved to be very complex and probably is controlled by many genetic factors which may be overshadowed by environmental factors.

Laboratory methods are being developed for studying inheritance and testing the cold resistance of parents and hybrids under controlled conditions.

The F_1 plants of about 45 crosses were grown at Manhattan, Kans., and Chico, Calif., in 1919–20. The F_2 generation was grown at Manhattan in 1920–21 and was only slightly killed. The F_3 generation material grown at Dickinson, N. Dak., was seeded both on fallow and on stubble ground. Much more of the material on fallow than of that on stubble ground was killed.

Selections from the surviving F_3 rows at Dickinson were continued into the F_4 at Dickinson, in 1922–23, where partial killing again occurred, the combinations from the hardiest parents in general showing the best survivals.

Selections made in the F_4 generation were continued in the F_5 at Fargo, N. Dak., where killing was severe, and at Dickinson, N. Dak., where there was only about 50 per cent killing.

In addition to the material grown and selected each year, all crosses were grown in bulk at Moccasin, Mont., from 1922 to 1925, inclusive. Yields and winter survivals were recorded on this material. Head selections were then made in the most promising of these crosses.

The most promising F_5 head rows at Dickinson, N. Dak., in 1924, which appeared homozygous for botanical characters, were placed in nursery experiments at Dickinson, N. Dak., and Moccasin, Mont. In these experiments many hybrid selections were discarded on the basis of lack of winter hardiness, yield, and quality.

In the fall of 1925 several hybrid strains which appeared promising were included in the uniform winter-hardiness nurseries, which are seeded at 28 stations in the northern United States and in Canada.

From the results obtained in the nursery experiments at Dickinson, N. Dak., and Moccasin, Mont., covering four years and from the experiments in the uniform winter-hardiness nurseries covering three years, it is concluded that strains have been developed which are approximately as hardy as the hardy soft red winter wheats, Minhardi, Buffum No. 17, and Odessa, in addition to possessing the ability to outyield these varieties and also the hard red winter wheats, Turkey, Kanred, and Minturki, in Montana and North Dakota.

The best of these hybrid strains when tested in Kansas and Nebraska were found to be too late in maturity and therefore of little value for the central and southern sections of the Great Plains area. This seems to indicate that the characters of winter hardiness and late maturity are associated.

The most promising strains have been increased to plot experiments at Dickinson, N. Dak., and at Havre and Moccasin, Mont. From one year's results they appear to have promise for winter hardiness, high yield, and good milling and baking qualities.

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