

UNIVERSITY OF MINNESOTA
AGRICULTURAL EXPERIMENT STATION
In Cooperation With
UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PLANT INDUSTRY

THATCHER WHEAT



Thatcher Wheat at the Crookston Station, 1935

UNIVERSITY FARM, ST. PAUL

FOREWORD

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The Minnesota Agricultural Experiment Station and the Division of Cereal Crops and Diseases of the United States Department of Agriculture have for many years cooperated in attempts to breed wheats resistant to black stem rust (*Puccinia graminis tritici*). With this announcement, they present to the public one of the outstanding results of that breeding program, a new hard spring wheat named "Thatcher." Thatcher wheat at the present time exhibits considerable resistance to black stem rust, and it has many other desirable qualities of the best wheats suitable for the spring wheat region.

Thatcher is, in a real sense, a cooperative institutional product, involving not only a long period of investigation supported by state and federal appropriations but also numerous investigators who have each contributed to the final result. A complete list of contributors would be difficult, if not impossible, to compile. As in all such worthwhile cooperative enterprises, certain leaders of the various phases of the investigation merit special recognition. The authors of the present publication are preeminently in this class.

Thatcher wheat is a great step forward in spring wheat breeding, but, because it is a biological product, it is by no means the final solution of the important problem of black stem rust in wheat. As environment changes, as new diseases or pests appear, it may be succeeded by newer and still better varieties. Thatcher, however, is an evidence of progress, abundantly justifying the time, effort, and money necessary to produce it. It is a landmark in a continuous and permanent program of improvement of wheats and other crops to meet the changing demands of time—a program essential to the future prosperity of agriculture.

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THATCHER WHEAT¹

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Stem rust of wheat is one of the most important diseases in the spring wheat area. Severe infection occurred in 1916, 1919, 1920, and 1935, causing great reduction in yield and severe shriveling of the wheat kernels. This shriveling of the grain markedly reduces the weight per bushel and results in a correspondingly lower price per bushel. It is important, therefore, to find some practical method of controlling stem rust.

The breeding of a wheat resistant to stem rust, of desirable agronomic type, and with the milling and baking qualities that characterize desirable hard red spring wheats has been a major project of the Minnesota Agricultural Experiment Station for more than 25 years. The work has been carried on cooperatively by the Station and the Division of Cereal Crops and Diseases of the United States Department of Agriculture. Plant breeders, plant pathologists, agronomists, and cereal technologists have all done their part in solving the problems involved.

This bulletin contains a short summary of (1) the major steps taken in the breeding of Thatcher wheat, a moderately rust-resistant variety that was introduced commercially in the spring of 1934, (2) a description of the botanical characters of the new variety, and (3) comparative data on Thatcher, Marquis, Ceres, Reward, and Hope for such important characteristics as yielding ability, agronomic habit, disease reaction with particular reference to stem rust, and milling and baking quality.

THE BREEDING OF THATCHER WHEAT

The spring-wheat breeding project with special reference to stem rust has been under way since 1907. While much still remains to be learned about various phases of stem-rust resistance in wheat, many problems have been solved and each of these has played a part in de-

¹ Joint contribution of the Minnesota Agricultural Experiment Station and the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture.

Work on breeding wheat for rust resistance was started by E. M. Freeman in 1907.

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The following persons have at various times contributed to this investigation: R. O. Bridgford, R. S. Dunham, R. E. Hodgson, O. W. Swenson, and M. J. Thompson, variety testing, for the Minnesota Agricultural Experiment Station; O. S. Aamodt, Carl Kurtzweil, L. W. Melander, John H. Parker, and Karl Quisenberry, breeding program, for the U. S. Department of Agriculture.

veloping logical breeding principles. Some of the steps that have led to our present viewpoint are:

1. The mode of inheritance of particular types of reaction to stem rust has been determined, both in the seedling stage in the greenhouse and in older plants in the field. The results of these studies show that reaction to stem rust is dependent upon genetical factors located both in the host organism and in the pathogene. An important practical conclusion from these studies is that resistance to all forms of rust, as the plant approaches maturity, may be dependent upon one or few genetic factors. This enables the breeder to combine this resistance with other desirable characters by hybridization and selection.
2. The pathogene, *Puccinia graminis tritici*, E. and H., causing the disease comprises numerous parasitic strains or physiologic races that can be differentiated by their parasitic effect on seedling plants of about a dozen varieties of common wheats, durumms, emmers, and einkorn, known as differential hosts. Seedlings of the same variety may be immune from one form of rust and susceptible to another. A variety that is physiologically resistant to a particular form of rust in the seedling stage is usually resistant in the mature plant stage to the same form but may be highly susceptible to other forms. The large number of parasitic strains (physiologic races) and the development of new ones by hybridization on the barberry makes the problem of breeding a variety with physiological resistance to all forms not only difficult but continuous.
3. A knowledge of the causes of resistance has helped in an understanding of the problem. This includes resistance due to physiological, morphological, and functional differences and the genotypic differences and their manner of inheritance. It is of value for the breeder to know the genetic factors involved in resistance and susceptibility, even tho the exact nature of resistance is unknown. So-called "mature plant" resistance, which enables a plant to be resistant to many or possibly all parasitic strains, is a result in some cases of morphological or functional characters in the host plants. In some varieties of wheat the bundles of collenchyma-like cells in the stems are small, few in number, and often separated from one another by thick-walled schlerenchymatous tissues in which rust cannot develop. The size of the rust pustules is therefore limited by the size of the collenchyma bundles. In some varieties of wheat the time of opening of the stomata in the early morning also may reduce the amount of rust infection under certain conditions.

Mature plant resistance is inherited in a simple Mendelian manner in some cases. This is true especially where the resistant varieties

used as parents are Hope and H44. While morphological, physiological, and functional causes of resistance are known, no one has succeeded in particular hybrids, where mature plant resistance is involved, in demonstrating an exact correlation between the presence of genetic factors for resistance and known causes of resistance, except in the case of physiological resistance.

4. Environmental differences may cause a modification in the type of rust reaction. Thus, a plant genotypically rust resistant is often severely infected by rust if it has been infected previously by loose smut. Growing conditions apparently may sometimes cause considerable change in rust reaction. For example, in 1935 Ceres, a variety that had been less affected with rust than Marquis in previous years, became heavily rusted throughout most of the spring wheat region. Knowledge of the extent and frequency to which the resistance of particular varieties can be modified by conditions is of great importance, but too little is known. It is important to appreciate the fact that what is inherited is the manner of reaction under particular conditions and not the character itself.

In the early years of these studies no highly stem-rust-resistant varieties of *Triticum vulgare*, which includes hard red spring wheat, were available. Accordingly, crosses were made between common wheats and rust-resistant varieties of *T. durum*. The resistant durum variety, Iumillo, is one of the ancestors of Thatcher, from which it inherited some of its resistance. Iumillo is a red-kernel durum variety highly resistant to rust under both greenhouse and field conditions. It was one of the resistant varieties which stood out in the great epidemic of 1904, noted by Carleton in commenting on lessons to be gained from the epidemic. In 1915 Iumillo was crossed with Marquis and over a thousand F_2 plants were grown in the summer of 1917 under rust epidemic conditions in the field. As no common wheats with the required resistance were obtained from this generation, the progeny of all F_2 plants from the cross were grown in 1918. In one F_3 line a few plants appeared with the head type of common wheat and with a considerable degree of rust resistance. The progeny of these plants were grown in the rust nursery through the F_6 generation, and four lines were finally selected and given yield trials. One of these four lines was named Marquillo, and one, grown under the designation N.S.N. II-15-51, was one of the parents of Thatcher.

In 1918 Kanred winter wheat was crossed with Marquis, the purpose being to combine the rust resistance of Kanred with the spring habit of growth and other characters of Marquis. Kanred was immune from 11 physiological forms of stem rust in both the seedling and mature plant stages, and the immunity of Kanred was dominant to the susceptibility of

Marquis, the reaction to the 11 forms being controlled by a single genetic factor pair. The F_2 crosses were grown in 1920 in individual plant plots, the progeny of individual plants being harvested separately. Rust reaction was determined by sowing a few seeds of many individual F_2 plants in the greenhouse and inoculating the seedlings with an individual rust form from which Kanred was immune. In this way many F_2 plants were selected that were known to be homozygous for the Kanred type of immunity. These were tested in the field under rust epidemic conditions for rust reaction and examined for purity of type in another nursery not infected with rust.

At the time the Kanred-Marquis crosses were made it was hoped that the Kanred type of resistance would have considerable value in the spring wheat area, as several of the physiological forms from which Kanred is immune are common in the Northwest. The Kanred type of resistance was transferred easily to spring wheats, but extensive field trials proved conclusively that this type of resistance was of little value in Minnesota because rust strains that attack Kanred are often present. Some of the Kanred-Marquis hybrids with spring wheat habit appeared very vigorous in the field nurseries, and in 1921 an F_3 hybrid from this cross was selected because of its uniform habit of growth, desirable field appearance, and resistance to the strains of rust from which Kanred is immune. Many of these hybrids appeared to be rather resistant to root rots also.

The particular hybrid that was used as one of the parents of Thatcher was grown in 1921 as row number 3001 in the nurseries. This Kanred x Marquis hybrid was crossed with N.S.N. II-15-51 selected from the Iumillo x Marquis hybrid for the purpose of combining the mature plant resistance of the Marquis x Iumillo parent to many parasitic strains with the physiological immunity of Kanred from 11 parasitic strains and with desirable seed type, vigor of growth, resistance to root rots, and desirable agronomic type.

In this double cross (Marquis x Iumillo) x (Kanred x Marquis), selection for field resistance to many strains of rust was made in the rust nurseries. Those lines that gave evidence of resistance under field conditions were tested in the seedling stage for immunity of the Kanred type. Approximately one line in 16 bred true in F_3 for field resistance, altho there was some evidence of minor modifying factors. The Kanred type of resistance was inherited in the same manner as in previous crosses and was independent in inheritance of field reaction. From these double crosses many selections were made that had both field resistance to many forms and seedling immunity from certain forms.

In general, selection in each of these crosses was made in the field

each year, individual plants that were vigorous, rust resistant, and that produced plump seeds of good texture being chosen. When the progeny of individual plants appeared homozygous for all characters, they were bulked and given comparative yield trials.

Thatcher was first grown in rod-row trials as N.S.N. II-21-28 in 1927 and given Minnesota No. 2303 when first placed in 1/40-acre plot trials in 1929.

BOTANICAL CHARACTERS OF THATCHER

Thatcher is a hard red spring wheat. It closely resembles Marquis in appearance, but the head is slightly shorter and more compact and sometimes slightly crooked. Thatcher matures one or two days earlier and is moderately resistant to stem rust under field conditions. The plant has spring habit, short to mid-tall, strong stem; spike awnleted, fusiform, mid-dense, erect; glumes glabrous, white, short, mid-wide; beaks mid-wide, acute, triangular, 0.5-1.0 mm. long; awnlets few, 1 to 15 mm. long.

The grain is red, short, hard, ovate, germ mid-sized, crease mid-wide and mid-deep, cheeks rounding to angular, brush mid-sized and mid-long. In general, under favorable conditions weight of a thousand kernels of Thatcher is somewhat less than that of Marquis. Figure 1 shows comparable spikes and kernels of Thatcher and Marquis. The photograph on the cover shows an increase field of Thatcher at the Crookston Station in 1935.

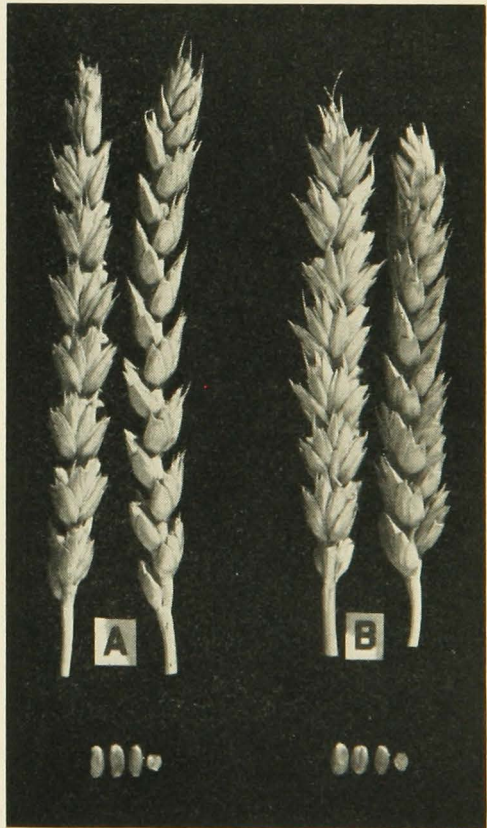


Fig. 1. Comparable Spikes and Kernels of Marquis and Thatcher
A, Marquis; B, Thatcher

COMPARATIVE TRIALS AT THE CENTRAL AND BRANCH STATIONS

Methods.—When particular hybrid lines in the field appeared homozygous, rust resistant, and desirable, they were harvested by the individual plant method, threshed individually, and examined for uniformity and desirability of seed characters. If they appeared uniform and desirable, the seed of individual plants for each line was bulked and the line placed in yield trials.

Three replications were used in all yield trials. The first comparative yield trial was made in rod rows. Three-row plots were used, the rows being spaced one foot apart and sown at the same rate per acre as in the 1/40-acre plot tests, 16.8 grams of seed being used for each 18-foot row. About a week before harvest, the end foot from each row was cut off and only the central row of each plot was harvested for the yield trial. In recent years yield tests have been made in randomized blocks, rod-row trials being conducted at Crookston, Morris, Waseca, and University Farm, while 1/40-acre plot trials are made also at these same four stations and at the branch stations located at Duluth and Grand Rapids.

The 1/40-acre plots are sown with a grain drill. They are 132 feet long by 8 feet wide. In recent years they have been harvested by the square yard method, the yield of each plot being estimated by harvesting and threshing 6 square yard samples from each plot. A systematic method of replication was used in 1929 and 1930, errors being calculated by the deviation of the mean method. Since 1931 randomized blocks have been used and the standard errors computed by the analysis of variance.

**Table 1.—Standard Errors in Percentage for a Mean of Three Plots
Computed from Yields Obtained During the Period 1929 to
1935, Inclusive, at Six Stations in Minnesota**

Location	Standard errors for different years						
	1929	1930	1931	1932	1933	1934	1935
Crookston	7.3	9.2	5.0	15.6	9.6	6.2	8.5
Morris	6.1	11.4	1.6	5.6	.....	22.9	5.4
University Farm	6.1	5.2	6.4	5.6	6.1	5.0	6.5
Waseca	16.8	5.5	5.2	4.7	6.4	6.8	6.6
Grand Rapids	16.8	5.6	6.4	10.1	15.1	11.6	6.7
Duluth	13.0	4.4	5.6	13.3	15.9	6.5	6.3

Yields are analyzed on the basis of standard errors computed separately for each year and location. When conditions are normal, leading to the production of a good crop, computed errors are generally small. While it seems unnecessary in the present bulletin to analyze the results on the basis of these computed standard errors, they are included here

in order to give the technical reader an opportunity to compare differences on the standard error basis when this seems desirable. They are of advantage, also, in giving a measure of the reliability of differences.

In addition to yield trials, studies of reaction to diseases were made in specially prepared disease gardens, where artificial epidemics of particular diseases were induced, one planting being made for studies of stem and leaf rust resistance, other tests being made of reaction to root rots, black chaff, bunt, and scab.

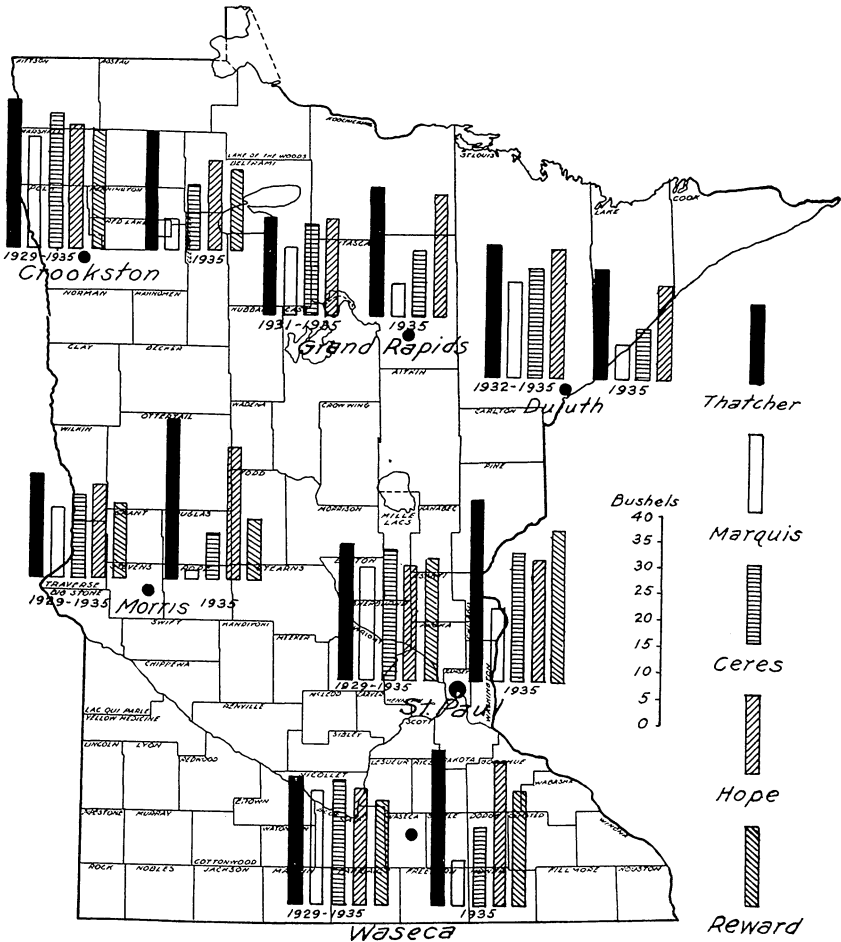


Fig. 2. Comparative Average Yields of Five Varieties of Spring Wheat at the Four Stations, Morris, Crookston, University Farm, and Waseca, 1929-35, Inclusive; Grand Rapids, 1931-35, Inclusive; Duluth, 1932-35, Inclusive, and the Yields at All Six Stations in 1935

Comparative yields.—Thatcher wheat was grown in the nursery plot trials at the four Minnesota experiment stations, located at University Farm, Waseca, Morris, and Crookston, in the years 1927 and 1928. The selection appeared so promising that it was placed in the varietal field plot trials at these stations in 1929. It continued to be promising and was placed in the field plot trials at the Grand Rapids Branch Experiment Station in 1931 and at the Duluth Station in 1932. The average yields of five hard red spring wheat varieties that have been grown at the six stations during four or more years of the period 1929 to 1935, inclusive, and the yields of all the stations for 1935 are given in Table 2 and expressed diagrammatically in Figure 2. The annual yields for each of the varieties and stations are given in Table 26 of the appendix.

Table 2.—Average Yields of Varieties of Hard Red Spring Wheats Grown in Field Plots at the Six Agricultural Experiment Stations in Minnesota for Four or More of the Seven Years, 1929-35, Inclusive, and Yields at These Stations for 1935

Location	Years tested	Yield in bushels per acre				
		Thatcher	Ceres	Marquis	Hope	Reward
Crookston	1929-35	28.1	25.9	21.6	23.7	23.0
Morris	1929-35	20.0	15.7	13.3	17.6	14.2
University Farm	1929-35	25.9	24.9	21.5	21.7	23.2
Waseca	1929-35	24.1	23.5	21.4	21.9	19.9
Grand Rapids	1931-35	18.4	17.5	13.0	18.7	.....
Duluth	1932-35	25.6	20.8	18.4	24.5	.....
Crookston	1935	22.9	12.6	5.9	17.1	15.9
Morris	1935	31.1	8.9	1.7	25.2	11.6
University Farm	1935	34.7	24.5	13.3	23.2	29.1
Waseca	1935	29.6	14.8	8.2	27.4	21.9
Grand Rapids	1935	24.4	12.9	6.3	23.4	.....
Duluth	1935	20.8	9.8	6.9	18.3	.....

The severe stem rust epidemic of 1935 greatly modified yields, the largest effect of rust being at Morris and Crookston and the least damage, on the average, occurring at University Farm. Hope is a highly rust-resistant variety, but Thatcher was sufficiently resistant in 1935 so that it yielded well at all stations, giving a higher yield in 1935 at each location than any other variety in the test.

Before analyzing yielding ability in detail, it seems of interest to point out the relation between yielding ability and rust reaction for each of the seven years at Crookston and Morris, representing those sections of the state where spring wheat is grown extensively and to the greatest advantage.

Figures 3 and 4 give diagrams of the yields and rust reaction of Ceres, Thatcher, and Marquis at the Crookston and Morris stations. There was moderate rust infection at Crookston on the susceptible varieties in 1929, 1930, 1931, 1934, and a heavy epidemic in 1935, with

light infection in 1932 and 1933 when drouth was severe. Thatcher was outstanding in yielding ability in rust years and was intermediate in yielding ability in 1932 and 1933 when drouth was most severe, yielding more than Marquis each of these two years but less than Ceres.

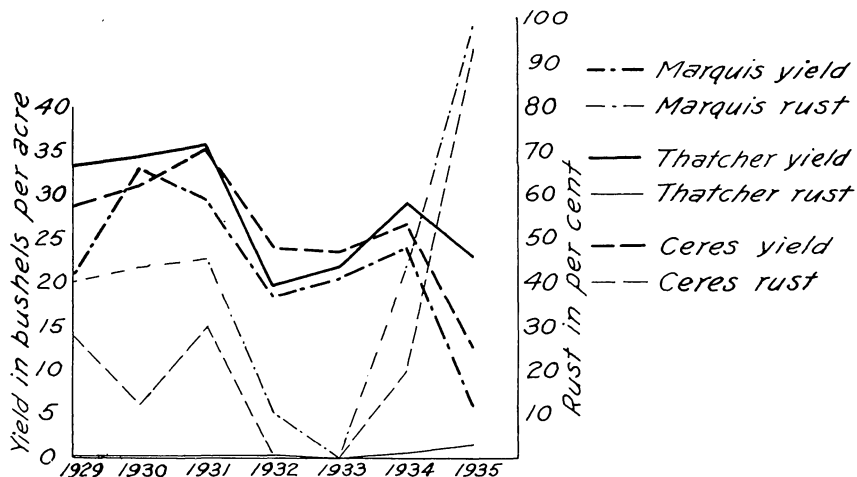


Fig. 3. Comparison of Yield and Stem Rust Infection of Thatcher, Ceres, and Marquis in 1/40-Acre Plots at Crookston, 1929-35

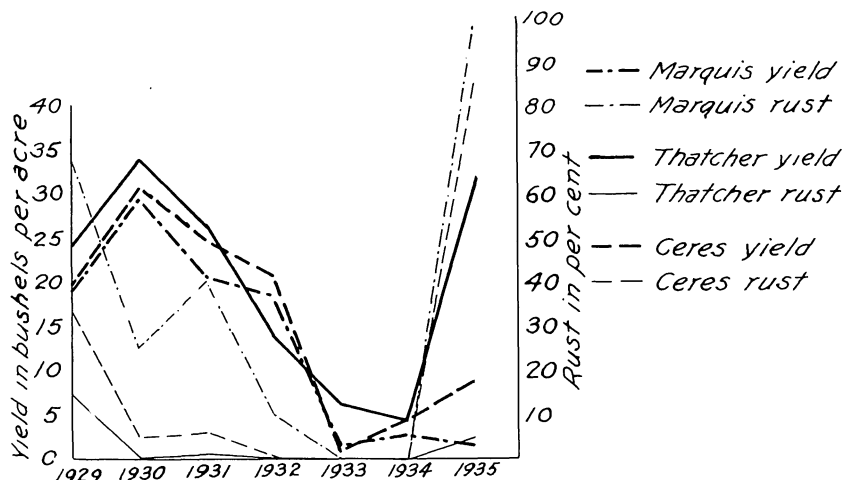


Fig. 4. Comparison of Yield and Stem Rust Infection of Thatcher, Ceres, and Marquis in 1/40-Acre Plots at Morris, 1929-35

Similar results were obtained at Morris; the only year in which Thatcher did not yield more than either Marquis or Ceres was 1932. In 1933 and 1934, when yields were very low as a result of drouth,

Thatcher gave higher average yields than either Ceres or Marquis. These facts regarding stem rust infection and differences in resistance to stem rust will be discussed more fully later. They are introduced here in order that the reader may have a picture of the extent to which stem rust is of major importance.

The yields recorded in Table 2 show Thatcher to be well adapted to many of the varying conditions in Minnesota. At the Crookston Station, in the northwestern part of the state, Thatcher, during the years 1929-35, inclusive, outyielded Marquis, on the average, by 6.5 bushels, Ceres by 2.2 bushels, Hope by 4.4 bushels, and Reward by 5.1 bushels. Thatcher exceeded the other four varieties in yield four out of the seven years. In 1935 Thatcher greatly exceeded each of the other four varieties in yield.

At Morris, in west central Minnesota and in the center of the spring wheat growing region of this state, Thatcher outyielded Marquis by an average of 6.7 bushels, Ceres by 4.3 bushels, Hope by 2.4 bushels, and Reward by 5.8 bushels per acre.

Drouth was so severe in west central Minnesota in 1933 and 1934 that the crop was almost a total failure and only a small crop was harvested. During these two years Thatcher yielded more than any other variety. In 1935, Thatcher, because of its rust resistance, produced 31.1 bushels per acre, while Hope yielded 25.2 bushels. Hope, altho very resistant to stem rust, is susceptible to heat injury, which occurred during the ripening period. The more susceptible varieties, Marquis, Ceres, and Reward, were killed by the early and severe epidemic of stem rust, giving low yields of badly shriveled grain. It is of interest to note that Ceres yielded 8.9 bushels at Morris in 1935, while Marquis yielded only 1.7 bushels.

At University Farm, in the east central part of the state, Thatcher has outyielded Marquis, Ceres, Hope, and Reward by 4.4, 1.0, 4.2, and 2.7 bushels, respectively, during the seven-year period 1929-35, inclusive. There was less injury from stem rust at University Farm in 1935 than at any of the other stations. Thatcher, however, produced a significantly higher yield than Marquis, Ceres, Hope, or Reward, yielding 11.2 bushels more than Ceres and 21.4 bushels more than Marquis.

At Waseca, in the winter wheat growing region in the south central part of Minnesota, Thatcher has outyielded Ceres on the average by 0.6 bushels, Marquis by 2.7 bushels, Hope by 2.2 bushels, and Reward by 4.2 bushels, for the years 1929 to 1935, inclusive. At this station, Ceres appears to be a desirable variety except in seasons like 1935, when stem rust was the determining factor. The yields of Thatcher and Hope in 1935, as compared with Marquis and Ceres, show the value of a more rust-resistant wheat. Reward, being an early-maturing variety, partly escaped damage by stem rust and yielded 21.9 bushels.

Yields of four wheat varieties are available at the Grand Rapids Station, in the north central part of the state, for the five-year period 1931 to 1935, inclusive. Wheat is a minor crop in this section, being used primarily for feed. Thatcher exceeded Marquis by 5.4 bushels and Ceres by 0.9 bushel. Hope has outyielded the other three varieties, altho on an average it exceeded Thatcher by only 0.3 bushel per acre. Stem rust was a factor in 1935, as shown by the yields of the two more rust-resistant varieties. Thatcher yielded 24.4 bushels and Hope 23.4 bushels, as compared with 6.3 bushels for Marquis and 12.9 bushels for Ceres.

In the four-year period, 1932-35, inclusive, Thatcher outyielded Marquis by 7.2 bushels, Ceres by 4.8 bushels, and Hope by 1.1 bushels, at the Duluth Station, in northeastern Minnesota. The same condition prevailed at Duluth as at the Grand Rapids Station, spring wheat being a minor crop. The effect of stem rust as a determining factor on yield of spring wheat in 1935 is shown here again, Thatcher exceeding Marquis by 13.9 bushels per acre and Ceres by 11 bushels. Thatcher and Hope gave similar yields at Duluth, the four-year average yields being 25.6 and 24.5 bushels per acre, respectively.

Thatcher wheat has produced the highest average yield at five of the six stations and has not been significantly different at the other one, Grand Rapids, during the period of years it has been grown. It shows itself well adapted to the varying conditions occurring at the experiment stations in the various parts of the state.

Test weight per bushel.—Weight per bushel is an important index of the value of a wheat variety, since high test weight is usually associated with high flour yield, and thus wheat with a higher test weight brings the higher price on the market. The conditions under which a crop matures may cause a variation in the bushel weight from season to season. A deficiency of plant nutrients, moisture, sunlight, excessive temperatures, or the presence of some disease, may reduce the test weight of a variety.

Varieties have different inherent abilities to withstand abnormal climatic conditions or vary in their resistance to certain diseases which attack the plant. The average weight per bushel for the varieties of hard red spring wheats grown at the six stations in Minnesota for four or more years of the seven-year period 1929 to 1935, inclusive, and for 1935 at all of the stations is given in Table 3. The annual test weights for all of the years and stations are given in Table 27 of the appendix.

The average weight per bushel of Thatcher at Crookston during the seven-year period was 59.4 pounds. During the same period, Ceres averaged 59.1 pounds; Reward, 61.0 pounds; Marquis, 56.3 pounds, and Hope, 55.9 pounds. Reward gave higher test weights than other va-

rieties, while Marquis and Hope gave distinctly lower test weights than other varieties.

Table 3.—Average Weight per Bushel of Varieties of Hard Red Spring Wheats Grown in Field Plots at the Six Agricultural Experiment Stations in Minnesota for Four or More of the Years 1929-35, Inclusive, and at These Stations for 1935 When a Heavy Infection of Stem Rust Was Obtained

Location	Years tested	Weight per bushel in pounds				
		Thatcher	Ceres	Marquis	Hope	Reward
Crookston	1929-35	59.4	59.1	56.3	55.9	61.0
Morris	1929-35	57.6	57.7	56.0	55.7	59.1
University Farm	1929-35	55.9	57.6	55.8	53.8	59.9
Waseca	1929-35	57.1	58.2	56.4	54.9	59.4
Grand Rapids	1931-35	56.9	55.6	52.7	55.3	.....
Duluth	1932-35	57.6	57.0	55.2	55.7	.....
Crookston	1935	57.9	49.0	42.0	52.0	52.8
Morris	1935	56.3	47.3	41.9	51.7	52.9
University Farm	1935	56.9	54.4	49.6	50.6	59.0
Waseca	1935	56.1	52.6	47.6	54.2	56.1
Grand Rapids	1935	54.8	45.0	39.9	53.9	.....
Duluth	1935	58.5	57.0	55.2	55.8	.....

At Morris the seasons have not been as favorable for spring wheat as at Crookston, but bushel weights were not reduced to as great an extent as yields. Thatcher averaged 57.6 pounds; Ceres, 57.7 pounds; Marquis, 56.0 pounds; Hope, 55.7 pounds, and Reward 59.1 pounds per bushel.

The average test weight of Thatcher at University Farm was 55.9 pounds per bushel. This exceeded Hope by 2.1 pounds, was equalled by Marquis with 55.8 pounds, and was exceeded by Ceres with 57.6 pounds, and Reward with 59.9 pounds. There was relatively less injury from stem rust at University Farm than at any of the other stations in 1935, resulting in higher seven-year average test weights of the Ceres and Reward varieties. Some injury from heat occurred during the maturing period and Reward, being a very early-maturing variety, apparently escaped heat injury.

At Waseca, Thatcher had an average test weight of 57.1 pounds but was exceeded by Ceres with 58.2 pounds and Reward with 59.4 pounds. Marquis had an average test weight of 56.4 pounds and Hope 54.9 pounds.

Thatcher has given a higher average test weight than any of the other three varieties, Marquis, Ceres, or Hope, at Grand Rapids and Duluth. There is not a significant difference, however, between the average weight per bushel of Ceres with 57.0 pounds, at Duluth, and Thatcher with 57.6 pounds.

Thatcher exceeded all varieties in test weight per bushel at all the stations in 1935, except Reward which had a higher test weight at University Farm, where injury from stem rust was less severe than in other parts of the state, and at Waseca, where Reward equaled Thatcher in test weight. In general, the test weight of Thatcher has been about equal to that of Marquis and has been exceeded by Ceres and Reward in years in which climatic conditions were favorable for the growth of spring wheats, but in years of severe rust damage Thatcher has had a higher test weight than the more susceptible varieties. It should also be pointed out that these varieties have been grown under unfavorable climatic conditions for the growing of spring wheat four of the seven years tested and under severe epidemic stem-rust conditions in 1935. There was a deficiency of moisture in most parts of the state from 1930 to 1934, inclusive, which was more favorable to the more drought-resistant varieties like Ceres and to an early-maturing variety like Reward. Severe heat damage occurred at various times during the period from heading to ripening and resulted in lower test weights, depending on the ability of the variety to resist heat. Thatcher has yielded more than Marquis under these conditions, but the test weight of Thatcher appears to be a little lower than that of Marquis when drought is severe.

Reaction to stem rust.—Stem rust is commonly considered the most destructive disease of wheat in the spring wheat area. This disease causes losses which vary from year to year and depend on the amount of inoculum present, time of infection, stage of maturity of the plant, and the climatic conditions. Average percentage of stem rust infection in the 1/40-acre plots is given in Table 4, in the seasons when rust occurred, at each of the five stations, Crookston, Morris, University Farm, Waseca, and Grand Rapids, together with rust reaction for 1935.

Table 4.—Average Infection of Stem Rust in Percentage for Seasons When Rust Was Prevalent and in 1935 When Infection Was Most Severe

Location	Years	Percentage of stem rust infection				
		Thatcher	Ceres	Marquis	Hope	Reward
Crookston	1929-31, '34, '35	1	31	54	T	48
Morris	1929-32, '35	4	25	48	T	45
University Farm	1929, '35	T	20	53	T	47
Waseca	1929-33, '35	2	12	40	T	37
Grand Rapids	1931, '32, '35	13	50	75	T	.....
Duluth	1935	5	70	87	T	.....
Crookston	1935	3	93	98	T	98
Morris	1935	5	83	98	T	95
University Farm	1935	T	40	63	T	50
Waseca	1935	2	43	68	T	75
Grand Rapids	1935	20	100	100	T	.....
Duluth	1935	5	70	87	T	.....

The percentages of infection given in the tables were determined by the aid of the "Scale for Estimating Rust" adopted and generally used by the Office of Cereal Crops and Diseases of the U. S. Department of Agriculture (see Fig. 5).

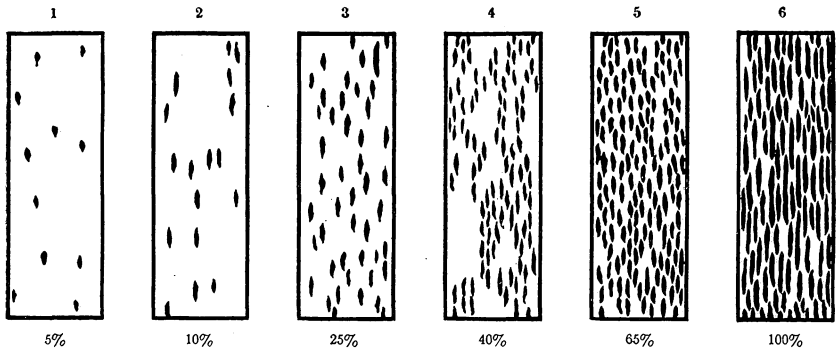


Fig. 5. Scale for Estimating Rust

Six degrees of rustiness, which may be used in estimating the percentage of rust infection on leaf or stem. The shaded spots represent rust, and the figures represent approximately the rust percentages computed on the basis of the maximum amount of surface covered by rust as shown in the 100 per cent figure. This figure (No. 6 in the diagram) represents 37 per cent of actual surface and is arbitrarily selected as 100 per cent. Other percentages are in terms of No. 6.

Hope wheat showed only a trace of rust in the 1/40-acre plots and is one of the most resistant varieties of common wheat available. Thatcher proved more resistant, on the average, than Ceres, altho much less resistant than Hope. Similar results were obtained in 1935 when infection was most severe. Under these conditions Ceres appeared highly susceptible, while the highest infection that occurred in Thatcher was 20 per cent, the average reading obtained at Grand Rapids in 1935.

The annual infection of stem rust in the 1/40-acre plots for the years in which it occurred is given in Table 28 of the appendix. In general, Ceres has been much more resistant than Marquis and Reward over the seven-year period. Variations in the amount of injury from rust may occur as a result of earliness, the early varieties escaping rust to some extent.

The five varieties have been grown in the Rust Nursery at University Farm where an epidemic of stem rust is artificially induced each year. Collections of available physiological forms are used to induce such artificial epidemics of stem rust. These individual forms are cultured in the greenhouse on seedling plants and the infection is induced in the field by hypodermically inoculating susceptible plants in the border rows of the

nursery with a water suspension of urediniospores and by transplanting infected plants from the greenhouse to the field. Seventeen to 31 physiological forms of stem rust have been used in the field in various years. Conditions are made as favorable as possible for the development of rust on the plants. Results under artificially induced epidemic conditions are given in Table 5 for each of the years from 1929 to 1935, inclusive.

Table 5.—Stem Rust Infection on Five Varieties of Wheat Under Artificial Rust Epidemic Conditions at University Farm

Variety	Percentage of stem rust infection in							7-yr. av.
	1929	1930	1931	1932	1933	1934	1935	
Thatcher	5	15	5	10	10	10	5	9
Ceres	5	40	25	25	35	55	50	34
Marquis	25	60	40	40	60	80	70	54
Hope	0	5	T*	T	5	T	T	1
Reward	30	50	40	30	40	80	60	47

* Trace.

Hope gave as high as 5 per cent infection in 1930 and 1933. The highest infection for Thatcher was 15 per cent in 1930. Ceres showed considerable resistance but was much more severely infected than Thatcher, while Reward and Marquis were very susceptible.

Leaf rust.—Percentage of leaf rust infection was taken in the 1/40-acre plots for those years and seasons when leaf rust was prevalent. Data presented in Table 6 give averages for the three years out of six when there was considerable infection in the trials at Crookston, Morris, and University Farm, for a five-year period at Waseca, and a four-year period at Grand Rapids. Data are included also for 1935, when infection was severe in most sections of Minnesota. In 1935 the leaves on Marquis and Reward dried up before leaf rust notes were taken.

Table 6.—Percentage of Leaf Rust Infection in 1/40-Acre Plot Trials

Station	Years tested	Percentage of leaf rust infection				
		Thatcher	Ceres	Marquis	Hope	Reward
Crookston	1929, '30, '35	44	30	10	5	44
Morris	1930, '31, '35	29	40	32	3	31
University Farm	1929, '30, '35	51	42	43	T	57
Waseca	1929-32, '35	40	35	50	5	41
Grand Rapids	1931-33, '35	34	39	40	2	.....
Crookston	1935	46	21	.....	T	.....
Morris	1935	60	47	57	2	53
University Farm	1935	47	47	53	T	80
Waseca	1935	37	40	50	T	67
Grand Rapids	1935	97	92	100	5	.....
Duluth	1935	53	47	10	T	.....

Hope was the only variety that showed marked resistance. Thatcher was susceptible in all trials. Data were taken also at University Farm in the rust nursery and the results are given in Table 7.

Table 7.—Percentage of Infection of Leaf Rust in the Rust Nursery at University Farm

Year	Percentage of leaf rust infection				
	Thatcher	Ceres	Marquis	Hope	Reward
1929	75	45	45	T	100
1930	50	60	80	15	80
1932	60	80	80	T	80
1935	50	40	50	T	60
Average, 4 years.....	59	56	64	4	80

These results also show that all of the four varieties, Thatcher, Ceres, Marquis, and Reward, are highly susceptible, while Hope again proved to be resistant.

Other diseases.—Studies were made in the disease gardens at University Farm from 1929 to 1935, inclusive, on the percentage of bunt or stinking smut infection, on scab infection for a three-year period, on root rot infection for a similar length of time, and black chaff infection in 1935 when there was a severe epidemic in the disease nurseries.

The percentages of bunt were determined by dividing the number of bunted spikes by the total number of spikes in a five-foot row. For this test a small sample of seed of each variety was inoculated by dusting with a mixture of collections of bunt, just before sowing. This inoculum was made up of collections obtained from a large number of different locations in the spring wheat area. Results are given in Table 8.

Table 8.—Percentage of Bunted Heads for a Seven-Year Period, 1929-35, Inclusive, in the Disease Garden at University Farm

Year	Percentage of bunted heads				
	Thatcher	Ceres	Marquis	Hope	Reward
1929	1	38	2	1	38
1930	15	45	6	0	41
1931	6	28	10	1	28
1932	8	26	1	1	33
1933	0	3	0	0	6
1934	5	44	6	1	25
1935	1	11	10	0	19
Average	5	28	5	1—	27

Under these conditions Ceres and Reward were about equally susceptible, with average infections of 28 and 27 per cent, respectively. Marquis and Thatcher were moderately resistant, with an average infection of 5 per cent, in both cases, while Hope was highly resistant.

Percentages of scab infection were taken under artificially induced

epidemic conditions in a specially prepared disease garden from 1933 to 1935, inclusive. Short rows of each variety were covered with muslin tents at heading time. The plants were inoculated by spraying with a water suspension of spores of a mixture of scab-producing organisms. Satisfactory conditions for the development of the disease in the tests were maintained by watering whenever necessary. Scab percentages were computed from the approximate per cent of heads infected and the average type of infection. Infection types ranged from (1) to (4) and may be described as: (1) less than one-fourth of the spikelets on the diseased heads infected; (2) one-fourth to one-half infected; (3) one-half to three-fourths infected, and (4) more than three-fourths of the spikelets infected. Percentages were computed by multiplying the per cent of heads attacked by type of infection and dividing the product by four. Results are given in Table 9.

Table 9.—Percentages of Scab Infection in the Disease Nursery at University Farm, 1933-35

Year	Thatcher	Ceres	Marquis	Hope	Reward
1933	4	10	11	10	19
1934	14	24	19	15	63
1935	13	23	15	8	5
Average	10	19	15	11	29

Thatcher and Hope were least infected, averaging 10 and 11 per cent of infection, respectively, while Marquis, Ceres, and Reward had averages of 15, 19, and 29 per cent, respectively.

Notes on root rot were taken in the disease garden, in a nursery continuously used for this purpose, and the readings placed in four classes on the basis of average infection. These were T, trace; L, light; M, medium; and H, heavy. Plus and minus signs were used to denote heavier or lighter degrees of infection in each of the four classes. Notes on black chaff were taken for 1935. Data on root rot and black chaff are included in Table 10.

Table 10.—Notes on Root Rot and Black Chaff Infection in the Disease Garden at University Farm

Year	Disease	Thatcher	Ceres	Marquis	Hope	Reward
1929	Root rot	M	M-	L+	M	M
1930	“ “	M-	L+	T	M-	T
1931	“ “	M-	M	L	M	M-
1933	“ “	M	H	H	H	M+
1935	Black chaff	T	L+	L	M	L

Differences in root rot infection were not very great. Thatcher was placed in the medium group each of the four years, while Hope gave

three readings of M and one of H. Marquis, Hope, and Ceres were heavily infected in 1933.

Hope was moderately infected with black chaff in 1935 and Ceres, Marquis, and Reward had light infection, while Thatcher was least infected of the five varieties.

Lodging studies.—Whenever lodging occurred in the 1/40-acre plots, notes were taken on the percentage of the plot that was lodged and the average degree of lodging, i.e., the angle that the lodged stem deviated from the normal upright habit. Plants that were flat on the ground were considered to have a lodging degree of 90. Averages for per cent lodging are obtained arithmetically. For average degree of lodging the per cent of lodging is multiplied by degree and the product divided by the total per cent of lodging. The data given in Table 11 are for the locations and years when there was considerable lodging.

Table 11.—Percentage and Degree of Lodging of Five Varieties of Spring Wheat in 1/40-Acre Plot Trials

Location	Year	Thatcher		Ceres		Marquis		Hope		Reward	
		Per cent	De-gree	Per cent	De-gree	Per cent	De-gree	Per cent	De-gree	Per cent	De-gree
University Farm	1932	0	0	100	15	33	25	100	22	100	7
“	1935	30	44	63	48	77	25	100	72	7	28
“	Average	15	44	82	28	55	25	100	47	54	8
Waseca	1932	0	0	50	43	3	30	70	44	60	15
“	1935	0	0	8	20	7	20	55	43	0	0
“	Average	0	0	29	40	5	23	63	44	30	15
Morris	1930	0	0	4	28	3	45	12	45	2	32
“	1935	10	20	45	37	97	59	67	28	20	22
“	Average	5	20	25	36	50	55	40	31	11	23

The results of these studies show Thatcher to have marked ability to withstand lodging. In these trials it was superior to any other variety in this respect. Figure 6 shows a plot of Thatcher at University Farm in the summer of 1935.

Table 12.—Average Height in Inches of Five Varieties of Spring Wheat Grown at University Farm, Waseca, and Crookston, 1929-35, Inclusive; Morris 1929-33, 1935; Grand Rapids 1931-35, and Duluth 1935

Location	Average height in inches				
	Thatcher	Ceres	Marquis	Hope	Reward
University Farm	31	33	34	33	33
Waseca	35	37	37	37	35
Crookston	31	32	32	30	32
Morris	31	33	32	32	33
Grand Rapids	30	35	35	33	.....
Duluth	35	36	38	35	.....

Height of plant.—Average height of plant was taken in inches from the ground level to the tip of the upper spikelet of the central spike. These averages are given in Table 12.

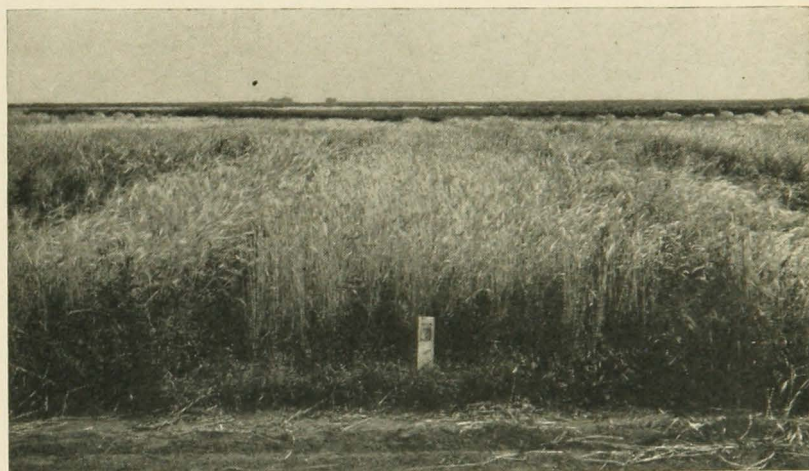


Fig. 6. One-Fortieth Acre Plot of Thatcher Wheat at University Farm, 1935
Thatcher has unusual ability to withstand lodging.

Differences were small. On the average, Thatcher produced straw that was slightly shorter than that of Marquis and Ceres.

Period of maturity.—Two estimates were made of time of maturity. Date of heading was taken when more than half of the spikes were out of the boot and date of maturity was taken when the crop appeared to be sufficiently mature to be harvested by the binder. Date of maturity is influenced to a much greater extent by environmental conditions than date of heading. When the weather is hot and dry from heading until maturity, two varieties may head several days apart and yet appear to mature at the same time. Averages for date of heading are given in Table 13.

Table 13.—Average Date of Heading of Five Varieties of Spring Wheat at Crookston, Morris, University Farm, and Waseca, 1929-35; Grand Rapids 1931-35; and Duluth 1935

Location	Average date of heading				
	Thatcher	Ceres	Marquis	Hope	Reward
Crookston	6-30	7-2	7-4	7-3	6-27
Morris	6-24	6-26	6-26	6-27	6-21
University Farm	6-19	6-21	6-23	6-23	6-15
Waseca	6-20	6-22	6-25	6-26	6-16
Grand Rapids	6-30	7-1	7-1	7-2	
Duluth	7-7	7-10	7-12	7-10	

Reward headed nearly a week earlier than Marquis, Hope headed about the same day as Marquis, Ceres was slightly earlier than Marquis on an average, while Thatcher headed from one to five days earlier than Marquis at all stations. Time of maturity is summarized in Table 14.

Table 14.—Average Time of Maturity of Five Varieties of Spring Wheat at Crookston, Morris, University Farm, and Waseca, 1929-35; Grand Rapids 1931-35

Location	Average date of maturity				
	Thatcher	Ceres	Marquis	Hope	Reward
Crookston	7-30	7-31	8-1	8-1	7-27
Morris	7-24	7-22	7-22	7-23	7-20
University Farm	7-18	7-20	7-21	7-22	7-15
Waseca	7-21	7-21	7-23	7-23	7-18
Grand Rapids	7-30	7-30	8-1	8-2	

The average dates of maturity for the five varieties show differences similar to those given for their dates of heading. Marquis and Hope matured at about the same time, Ceres about a day earlier than Marquis. Thatcher matured three days earlier than Marquis at University Farm, two days earlier at Crookston, on the same day as Ceres at Waseca and Grand Rapids, and two days later than Ceres and Marquis at Morris. Reward on the average matured several days earlier than Marquis.

Milling and baking studies.—A good variety of wheat not only must have desirable agronomic characters, but must also produce a flour of high quality. Samples of all wheats having desirable agronomic characters were milled and baked in the experimental mill of the Biochemistry Division of the Minnesota Experiment Station, as a part of the cooperative wheat breeding project.

Samples of each variety from each station were milled and baked each year. Table 15 gives a summary of the averages obtained on each character at the three individual stations, Crookston, University Farm, and Waseca, during the years 1929 to 1934, inclusive, for Morris during 1929-32, inclusive, and the grand average for all four stations and years. No tests were made in 1933 and 1934 from Morris because of low yields of grain of poor quality, so the Morris average includes only the data obtained in 1929 to 1932. Samples from Grand Rapids and Duluth have not been milled.

In 1930 and 1931, three per cent of the flour made from wheat malt was added to each variety to increase the diastatic activity of the dough. Loaves of bread baked from Thatcher, Marquis, Ceres, and Reward are shown in Figure 7.

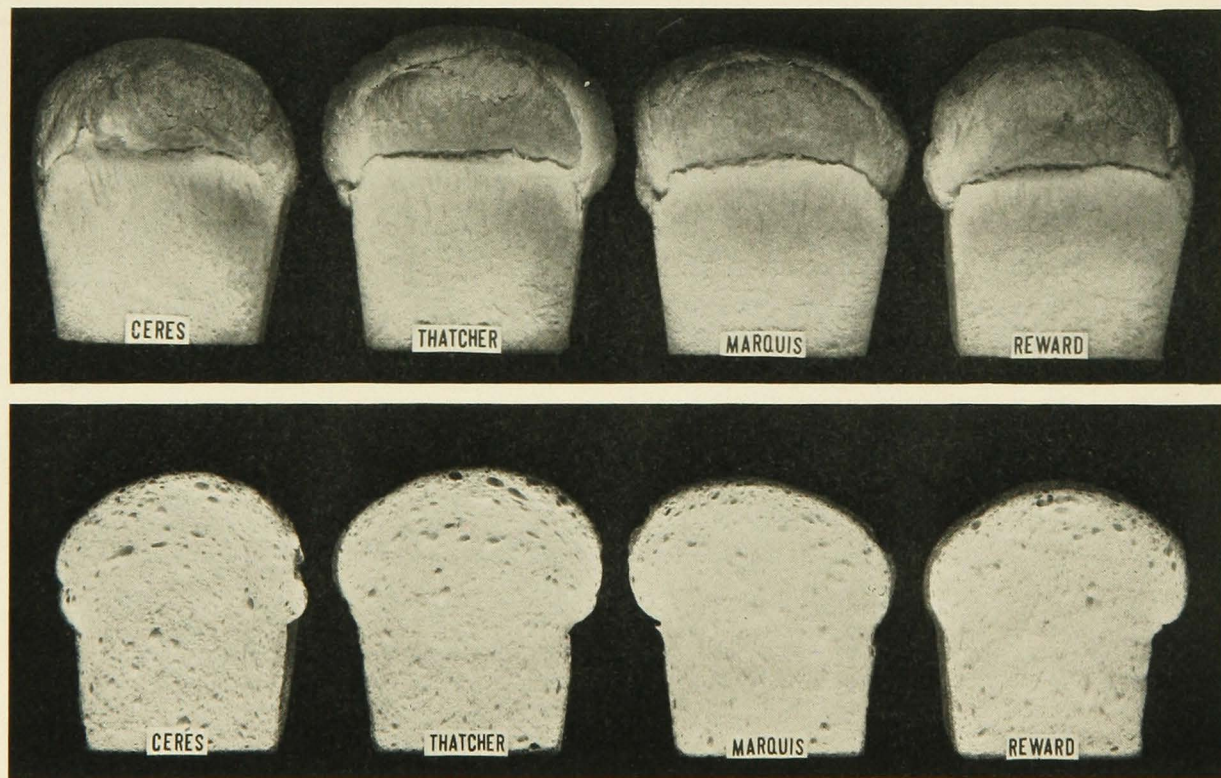


Fig. 7. Comparable Loaves of Four Varieties of Wheat from Composite Samples of 1934 Crop

Table 15.—Summary of Studies of Milling and Baking Qualities of Five Varieties of Spring Wheat at Four Stations 1929-34*

Variety	Crookston 1929-34	Morris 1929-32	University Farm 1929-34	Waseca 1929-34	Average	Crookston 1929-34	Morris 1929-32	University Farm 1929-34	Waseca 1929-34	Average
Crude protein per cent (N × 5.7)						Crumb texture score				
Thatcher	14.2	14.8	16.6	14.9	15.2	98.3	99.7	99.6	99.2	99.1
Ceres	13.6	14.4	15.3	13.9	14.3	98.2	99.4	99.4	97.9	98.7
Marquis	13.9	14.1	15.7	13.9	14.4	97.5	98.4	98.7	97.4	98.0
Hope	14.6	14.8	15.5	14.5	14.9	97.2	98.1	98.2	97.7	97.7
Reward	14.5	15.6	16.3	15.9	15.4	98.8	99.1	100.1	99.3	99.3
Flour yield per cent						Color score				
Thatcher	73.5	74.5	71.9	73.7	73.3	97.9	98.5	98.1	98.7	98.2
Ceres	74.8	72.5	71.7	73.4	73.1	98.1	97.0	97.6	97.4	97.6
Marquis	73.1	72.5	70.9	72.7	72.2	98.1	97.8	97.7	97.6	97.8
Hope	75.6	77.0	73.4	75.3	75.2	97.9	97.9	96.2	96.9	96.9
Reward	73.7	72.0	71.7	71.5	72.3	97.6	97.8	99.1	99.0	98.2
Loaf volume, cc.						Grain of crumb score				
Thatcher	518	555	567	564	551	97.1	97.2	97.2	96.3	96.3
Ceres	517	521	540	533	528	96.8	96.3	96.0	95.9	95.9
Marquis	491	468	518	505	498	97.0	97.4	96.5	96.3	96.3
Hope	514	512	519	516	516	96.2	96.8	96.4	95.7	95.7
Reward	538	505	590	584	559	96.3	96.6	96.3	95.0	95.0

* In 1930 and 1931 three per cent of flour milled from wheat malt was added to increase diastatic action in baking tests.

According to the results given in Table 15, Reward had the highest average crude protein percentage, 15.4 per cent, followed by Thatcher, Hope, Marquis, and Ceres, with percentages of 15.2, 14.9, 14.4, and 14.3, respectively. In yield of flour, Hope had the highest average, 75.2 per cent, followed by Thatcher, Ceres, Reward, and Marquis, with percentages of 73.3, 73.1, 72.3, and 72.2, respectively.

Four of the more important characters used in describing baking quality of wheats are: loaf volume, measured in cubic centimeters, and color, texture, and grain scores of the crumb or freshly cut interior of the loaf, scored by an arbitrary scoring method.

On an average, Thatcher has been about equal to or better than the other four varieties in all of these baking characters. In some of the tests, Hope has been slightly lower in color score because of a grayish color appearing in loaves baked from this variety.

As studies at Morris were made for only four years, while six years' results are available at the three other stations, there are 22 comparisons in all. It is of interest to determine the relative rankings of the five varieties in these trials, each variety being placed in group 1 to 5 according to its position in each individual trial. Results for protein content are given in Table 16.

Table 16.—Relative Rank in Percentage of Crude Protein of Five Varieties of Wheat in 22 Trials

Variety	Number times placed					Average
	1st	2nd	3rd	4th	5th	
Thatcher	6	8	7	0	1	2.2
Ceres	0	0	3	14	5	4.1
Marquis	1	2	5	6	8	3.8
Hope	6	7	6	1	2	2.4
Reward	11	4	5	1	1	2.0

In some cases two varieties gave the same value and when this occurred both were placed in the same group. For example, at University Farm in 1930 the protein percentages were as follows: Thatcher 12.3, Reward 12.1, Hope 11.7, Marquis 11.7, and Ceres 11.6. Thatcher was placed first, Reward second, Hope and Marquis each third, and Ceres fifth.

Reward gave somewhat higher average protein content and was placed in group 1 eleven times in the 22 trials, altho in one trial it was placed in group 5. Thatcher was a close second and Hope third. Marquis and Ceres had average placings of 3.8 and 4.1, respectively. In no case out of the 22 was Ceres placed first or second, and in only one comparison in the 22 was Thatcher placed lower than third.

Placings for flour yield percentage are given in Table 17.

Table 17.—Relative Rank in Flour Yield Percentage of Five Varieties of Wheat in 22 Trials

Variety	Number times placed					Average
	1st	2nd	3rd	4th	5th	
Thatcher	2	11	4	3	2	2.6
Ceres	2	6	8	4	2	2.9
Marquis	3	0	3	7	9	3.9
Hope	16	2	2	1	2	1.8
Reward	1	5	3	6	7	3.6

Hope was superior, on the average, in flour percentage, taking 16 first places; Thatcher was next, with two first and 11 second places; Ceres was a close third, and Reward and Marquis had distinctly lower flour percentages, on an average.

Loaf volume is of outstanding importance. The relative placings are given in Table 18.

Table 18.—Relative Rank in Loaf Volume of Five Varieties of Wheat in 22 Trials

Variety	Number times placed					Average
	1st	2nd	3rd	4th	5th	
Thatcher	8	7	4	2	1	2.1
Ceres	2	5	7	7	1	3.0
Marquis	0	0	5	5	12	4.3
Hope	0	7	5	5	5	3.4
Reward	13	2	3	2	2	2.0

Reward took 13 first places, with 8 for Thatcher and 2 for Ceres. Reward had an average position of 2.0, and Thatcher, 2.1. The other wheats had, on the average, distinctly lower placings, with Ceres averaging 3.0, Hope 3.4, and Marquis 4.3.

Texture and grain of crumb are two measures of high quality and may be considered together, results of placings appearing in Tables 19 and 20.

Table 19.—Relative Rank in Texture of Crumb of Five Varieties of Wheat in 22 Trials

Variety	Number times placed					Average
	1st	2nd	3rd	4th	5th	
Thatcher	12	6	2	0	2	1.8
Ceres	3	7	6	5	1	2.7
Marquis	0	4	6	6	6	3.6
Hope	2	2	2	7	9	3.9
Reward	12	5	3	1	1	1.8

Thatcher and Reward excelled in texture of crumb, each receiving 12 first places and having average positions of 1.8. Ceres, Marquis, and Hope were distinctly inferior to Thatcher and Reward, on the average, in texture of crumb, altho the differences were not very great. Thatcher

Table 20.—Relative Rank in Grain of Crumb of Five Varieties of Wheat in 22 Trials

Variety	Number times placed					Average
	1st	2nd	3rd	4th	5th	
Thatcher	10	6	3	1	2	2.0
Ceres	4	1	7	9	1	3.1
Marquis	7	7	7	1	0	2.1
Hope	4	6	3	1	8	3.1
Reward	3	2	4	5	8	3.6

and Marquis excelled in grain of crumb, appearing superior to other varieties in this respect. Ceres and Hope averaged the same, 3.1, with Reward having the lowest rank, 3.6. Relative positions for color of crumb are given in Table 21.

Table 21.—Relative Ranks for Color of Crumb of Five Varieties of Wheat in 21 Trials*

Variety	Number times placed					Average
	1st	2nd	3rd	4th	5th	
Thatcher	8	6	1	3	3	2.3
Ceres	2	9	4	4	2	2.6
Marquis	5	4	6	5	1	2.5
Hope	1	3	5	2	10	3.6
Reward	7	7	0	4	2	2.1

* No data on crumb color for Morris 1931.

Differences were not very great. Thatcher had eight first places, Reward seven, followed by Marquis with five, Ceres with two, and Hope with one. These same four varieties had six placings each in the fourth and fifth positions combined. Hope was distinctly inferior, with 10 out of 21 placings in the fifth position. In general, the results of the baking test show that Thatcher is equal to Marquis.

LARGE-SCALE TESTING OF THATCHER WHEAT

Thatcher wheat was subjected to extensive milling tests on a large scale during the five crop years of 1931 to 1934, inclusive. The work during 1931 and 1932 was a cooperative project between the Minnesota Agricultural Experiment Station, the Northwest Crop Improvement Association, the Minnesota State Testing Mill, and 12 commercial milling organizations of Minnesota. Thatcher and Marquis wheats were seeded side by side upon farmers' fields in typical localities in the spring wheat area of Minnesota. After threshing, lots of from 60 to 120 bushels of each variety were brought into the Minnesota State Testing Mill. The varieties were grown at two locations in 1931 and at four in 1932. The Minnesota State Testing Mill is a commercial flour mill of 150 barrels daily capacity, having the additional special equipment for han-

dling test runs of approximately 60 bushels of wheat each. The flour from each lot was given a variety of bleaching and maturing treatments. The various lots of flour were subdivided and subjected to chemical and baking tests in the laboratories of the 12 commercial milling organizations and the Minnesota Agricultural Experiment Station.

In 1931 Thatcher was rated favorably in general baking quality in comparison with Marquis by a majority of the collaborating baking technicians. The two varieties reacted similarly to various commercial flour-bleaching agents. Unfortunately samples were available from only two localities, and, moreover, there was some variability among the pairs of samples as well as in the judgment of the various baking technicians. The tests were repeated in 1932 with samples from four localities and with essentially similar results.

The testing was expanded in 1933 by forming a cooperative regional project including the same 12 milling organizations, the Minnesota Agricultural Experiment Station, the Northwest Crop Improvement Association, the United States Department of Agriculture, and the agricultural experiment stations of North Dakota, Montana, and Kansas. The last-named station reported baking test results in 1933, but not in 1934. In 1933 Thatcher and Marquis wheats were grown on four sites in Minnesota, one in North Dakota and one in Montana. Lots of from 10 to 50 bushels were milled in the 50-barrel capacity testing mill of the Pillsbury Flour Mills Company. In the opinion of the authors these tests indicate that the consensus of opinion in rating general baking quality was that Thatcher was to be preferred over Marquis, altho there was a 0.4 point (on a scale of 100) difference in crumb color score in favor of Marquis.

Table 22.—Results of Four Crop Seasons of Commercial Testing of Marquis and Thatcher Wheats, 1931-34, Inclusive

	Marquis	Thatcher	No. of pairs	No. of baking tests
Weight per bushel, lb.	57.7	57.0	18	.....
Protein in wheat, per cent	15.0	16.0	19	.....
Milling yield	100.0	102.7	19	.....
Ash in flour, per cent.....	.417	.415	19	.....
Loaf volume	100.0	104.2	19	530
Crumb color	100.0	99.7	19	498*

* While the crumb color was observed in each of the 530 baking tests, it was not always recorded in terms that permitted mathematical expression and hence in 32 cases could not be included in the average.

In 1934 Thatcher, Marquis, Ceres, and Reward wheat were harvested at one location in Minnesota, three in North Dakota, and one in Montana. Seedings were made in South Dakota, but the crop was abandoned because of extreme drouth. Comet wheat was substituted for Reward at two Montana stations. In general baking quality rating

Thatcher was placed first, Reward second, Marquis third, and Ceres fourth. Marquis was again given a somewhat higher color score, about a half point in a scale of 100.

In Table 22 the weight per bushel of Thatcher is shown to be less than that of Marquis by 0.7 pound. This characteristic of Thatcher is only apparent in years of low rust incidence. The protein content of

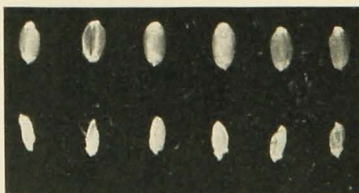
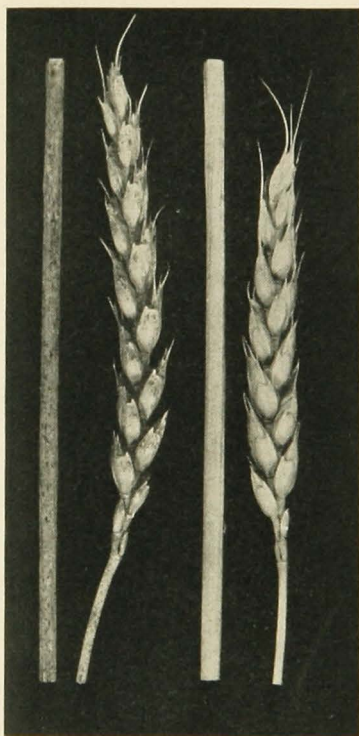


Fig. 8. Comparable Heads, Stem Rust Infection, and Kernels of Thatcher and Marquis in Saskatchewan (Photo by J. B. Harrington)

Above: left to right, stem and spike of Marquis and Thatcher, respectively; below, top row, kernels of Thatcher, bottom row, kernels of Marquis.

Under rust epidemic conditions at Saltcoats and Kelso, Thatcher weighed 65.4 and 62.3 pounds per bushel, and Marquis weighed 45 and 35 pounds, respectively.

Thatcher wheat was found to average one per cent higher than that of comparable Marquis. In spite of its slightly lower test weight, Thatcher in the commercial milling tests yielded about two per cent more flour than Marquis. This flour is of equal grade to that produced from Marquis wheat as is shown by the essentially equal average ash content. The volume of the loaves baked from the Thatcher wheat flours averaged four per cent greater than those from comparable Marquis flours. In crumb color the loaves from Thatcher wheat were on the average very slightly inferior to those from the comparable Marquis samples. When the test weight of the wheat and the protein content of the flour are taken into consideration, the differences between Thatcher and Marquis in both loaf volume and crumb color tend to disappear. The higher protein content of the flour milled from Thatcher wheat is enough to account for its greater loaf volume. Crumb color has been found to be primarily due to carotenoid pigments. A negative correlation has been established between the carotenoid pigment content of flour and the test weight of the wheat used in making the flour. This correlation is enough to account for the observed differences in crumb color between the varieties. Under conditions such as rust incidence, when the test weight of Thatcher was greater

than that of Marquis the crumb color of Thatcher was found by the majority of the collaborating technicians to be superior to that of Marquis.

In summing up these large-scale milling and baking trials, it appears that Thatcher wheat is superior to Marquis in milling yield and is approximately equal in baking properties.

The Northwest Crop Improvement Association, through its officers and committees, has cooperated with other agencies and institutions in certain studies of the milling and baking qualities of Thatcher wheat during recent years. In consequence of its interest, it prepared and issued the following statement late in 1935:

"Thatcher wheat has not been received and milled in carload quantities so it is difficult to make any predictions relative to its commercial reception in the years to come. However, the Association has conducted 60 bushel milling and baking tests of Thatcher for the season of 1932-33-34 and the information gained from those tests plus the findings made by federal and state authorities make it possible for the Association to state that Thatcher has shown satisfactory milling and baking qualities and that unless something unforeseen happens we anticipate it will be rated as a good commercial variety. The results of the milling and baking trials on the 1935 crop may make possible a further or more definite statement by the Association."

Demonstration trials.—New crop varieties frequently are tested on farmers' fields through cooperation between the Division of Agronomy and Plant Genetics of the Experiment Station, the Agricultural Extension Division, the county agents, and farmer cooperators. Twenty pounds of seed are furnished individual cooperators who sow a strip of the new crop in the center of their commercial field. At maturity 10 square yard samples are harvested from the farmer's variety and the new variety in nearby positions and under comparable conditions and sent to University Farm where they are threshed and yields are computed. Fortunately, a considerable number of such trials were carried out during 1935 when stem rust was most severe. Comparisons of results from Thatcher and Marquis are given in Table 23.

Thatcher gave an average yield of 27.3 bushels, whereas Marquis averaged only 6.5 bushels in 1935. Weight per bushel of Thatcher averaged 55.5 pounds, whereas Marquis averaged only 43.4 pounds. The reason for these marked differences can be attributed to stem rust infection, for Marquis had an average percentage infection of 86 and Thatcher had an average of only 5. These results substantiate those at the experiment stations and show Thatcher to be sufficiently resistant to rust so that good yields were obtained under conditions that favor rust injury. The major cause of the rather low weight per bushel of Thatcher is probably dry, hot weather during the stage from heading to maturity, particularly about a week before maturity, which caused some shriveling of the seed.

Table 23.—Comparative Trials of Thatcher and Marquis on Farmers' Fields in 1935

County	No. trials	Thatcher			Marquis		
		Yield in bushels	Bushel weight, pounds	Stem rust, per cent	Yield in bushels	Bushel weight, pounds	Stem rust, per cent
Kittson	3	27.4	55.8	2	7.3	44.8	80
Roseau	3	34.3	55.9	2	9.3	39.3	90
West Polk*	3	33.1	57.3	7	3.6	39.2	97
Norman	3	27.3	53.3	8	6.6	39.5	90
Mahnomen	1	27.9	53.0	5	9.0	42.5	80
Clay	1	27.1	54.5	2	5.3	45.0	90
Wilkin	1	30.3	57.0	5	13.3	47.5	80
Grant	4	28.8	56.3	2	9.6	48.5	65
Douglas	1	27.6	56.5	10	6.2	45.0	90
Traverse	1	18.9	52.6	5	2.1	39.0	90
Bigstone	2	28.2	54.0	20	7.6	42.0	80
Stevens	1	22.7	54.7	T	10.4	46.5	60
Pope	1	27.2	58.0	2	3.9	44.0	90
Swift	2	19.8	56.5	10	.9	45.3	95
Kandiyohi†	2	21.3	55.8	4	6.3	45.3	70
Renville	2	24.0	57.0	1	3.0	43.5	90
Average	31	27.3	55.5	5	6.5	43.4	86

* Marquis yield based on one square yard in each test.

† In one trial the farmer's variety was Quality instead of Marquis.

Thatcher and Ceres are compared in Table 24. In these trials Thatcher gave an average yield of 24.1 bushels under conditions under which Ceres yielded only 9.1 bushels. Weights per bushel of Thatcher

Table 24.—Comparative Trials of Thatcher and Ceres in Farmers' Fields in 1935

County	No. trials	Thatcher			Ceres		
		Yield in bushels	Bushel weight, pounds	Stem rust, per cent	Yield in bushels	Bushel weight, pounds	Stem rust, per cent
Kittson	1	28.4	57.0	20	8.0	44.0	90
Marshall	1	32.3	53.6	10	23.3	47.9	75
Roseau	1	21.2	55.0	3	6.9	43.5	70
Koochiching	1	15.2	52.7	3	2.9	41.5	60
West Polk*	1	34.6	57.0	1	16.2	51.0	70
East Polk†	1	32.8	55.5	2	16.1	49.0	67
Norman	6	22.8	52.1	5	8.9	44.5	75
Mahnomen	3	21.1	54.4	8	10.9	47.3	80
Clay	1	22.9	53.0	15	7.9	48.0	60
Wilkin	2	21.1	51.8	6	5.8	47.3	65
Grant	1	26.0	51.0	1	7.2	48.0	70
Douglas	1	29.0	57.0	10	6.0	50.5	80
Traverse	3	16.8	51.2	5	5.3	41.8	80
Pope	1	24.1	58.0	5	8.4	54.0	70
Renville	1	31.0	56.0	1	10.3	51.0	60
Lyon	1	27.5	53.7	3	8.0	40.0	90
Average	26	24.1	53.5	6	9.1	46.0	70

* Ceres yields on one square yard only.

† Three tests of three square yards each.

and Ceres were 53.5 pounds and 46.0 pounds, respectively. These differences were due primarily to differences in rust infection, the percentage of infection of Thatcher averaging 6 per cent, while Ceres averaged 70 per cent.

The relative susceptibility of Thatcher to stem rust, as compared with Marquis and Ceres grown in adjacent plots in county demonstration trials in 1935, is illustrated in Figure 9.

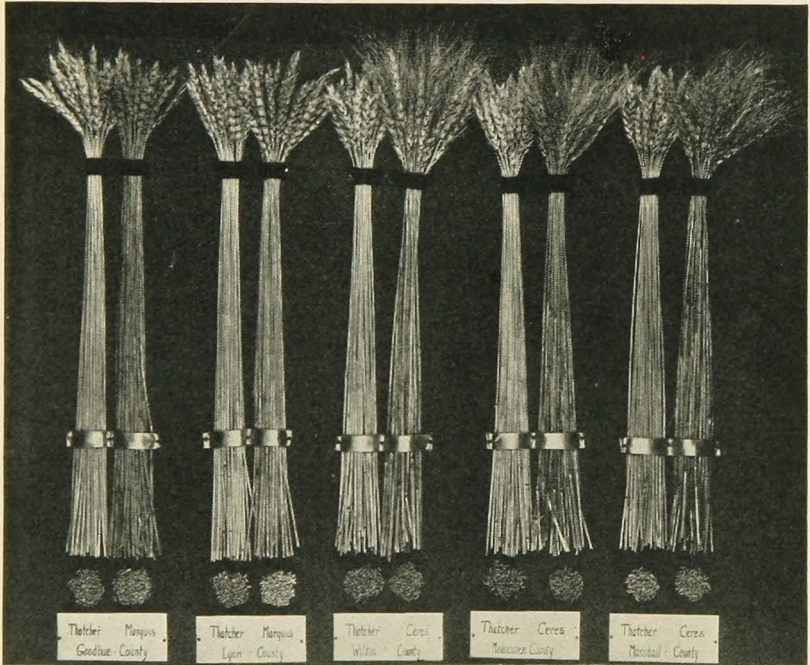


Fig. 9. Comparable Samples of Thatcher and Marquis or Ceres in County Demonstration Trials in 1935

In the description of the parentage of Thatcher, it was stated that Thatcher has a combination of the field resistance of its Marquis x Jumillo parent, which is a sister of Marquillo, and immunity to a considerable number of physiological forms of stem rust from a spring wheat segregate of its Kanred x Marquis parent. Marquillo has in general yielded well in Minnesota under rust epidemic conditions. It is of considerable interest to compare Thatcher and Marquillo under farm trials. Results of 12 such comparable trials are given in Table 25.

Thatcher gave an average yield of 26.8 bushels, while Marquillo yielded 22.0 bushels under comparable conditions. In weight per bushel Thatcher averaged 55.1 pounds and Marquillo 53.4 pounds. Marquillo

had an average percentage rust infection of 11, while Thatcher averaged only 3 per cent under similar conditions.

Table 25.—Comparative Trials of Thatcher and Marquillo in Farmers' Fields in 1935

County	No. trials	Thatcher			Marquillo		
		Yield in bushels	Bushel weight, pounds	Stem rust, per cent	Yield in bushels	Bushel weight, pounds	Stem rust, per cent
Roseau	1	24.4	51.4	5	17.5	48.3	20
Mahnomen	1	27.9	55.7	1	15.1	51.4	20
Traverse	1	28.2	51.9	5	21.6	48.8	5
Bigstone	1	19.8	52.0	1	18.2	51.0	10
Stevens	2	23.0	53.2	2	17.7	52.4	15
Pope	1	25.6	58.5	2	24.8	57.5	5
Kandiyohi	3	26.9	57.2	5	24.1	56.5	10
Renville	1	37.0	58.0	1	34.0	57.0	5
Yellow Medicine	1	31.5	55.5	5	25.2	52.5	20
Average	12	26.8	55.1	3	22.0	53.4	11

SUMMARY

1. Thatcher wheat was introduced in the spring of 1934 as a result of cooperative experiments conducted in Minnesota since 1907 by the Bureau of Plant Industry of the United States Department of Agriculture and the Minnesota agricultural experiment stations, the primary purpose being to obtain a spring wheat resistant to stem rust, of desirable agronomic type, and of high quality for milling and baking purposes.

2. Thatcher is a hard, red, spring wheat that resembles Marquis in appearance, but the head is slightly shorter and more compact than Marquis and sometimes slightly crooked. It matures a day or two earlier than Marquis under comparable conditions and excels all varieties with which it has been compared in ability to withstand lodging.

3. Thatcher was produced by a series of crosses. From a cross of Marquis x Iumillo (durum) several selections were obtained of bread wheat type and with considerable resistance to stem rust under field conditions. From a cross of Kanred winter wheat with Marquis, spring types were selected with the immunity to several forms of stem rust inherited from the Kanred parent. Thatcher is a selection from a double cross of (Iumillo x Marquis) x (Kanred x Marquis) and combines field resistance to stem rust from heading to maturity inherited from the Iumillo parent with immunity from several forms of rust in both the seedling and mature plant stage obtained from the Kanred parent. Selection for rust resistance was made possible by culturing rust in the greenhouse and creating an artificial epidemic of rust in the field in a specially prepared rust nursery.

4. Yield trials were made at University Farm, St. Paul, and at the Waseca, Morris, and Crookston branch stations from 1929 to 1935, inclusive, at Grand Rapids 1931-35, and at Duluth 1932-35, each variety at each station being grown in three 1/40-acre plots. Thatcher was outstanding in yielding ability in seasons when stem rust infection caused severe shriveling of the seed of susceptible varieties. It yielded well also when rust was not a factor.

5. Thatcher produces somewhat smaller kernels, on the average, than either Ceres or Marquis. When conditions are favorable for all varieties, the weight per bushel of Thatcher is slightly lower than that of Marquis or Ceres. When rust is prevalent, Thatcher greatly exceeds Marquis and Ceres in bushel weight.

6. Thatcher is susceptible to leaf rust, giving about the same percentage of bunt as Marquis in trials at University Farm, being distinctly superior to Ceres and Reward. It is resistant to black chaff.

7. Thatcher was tested for milling and baking qualities from 1929 to 1932, inclusive, from grain harvested in the varietal plots at Morris, Crookston, Waseca, and University Farm. It was outstanding in most respects, on the average, equalling or exceeding Marquis and Ceres in crude protein percentage, flour percentage, loaf volume, crumb texture, grain of crumb, and crumb color score. Studies of individual rank in each of the 22 trials show Thatcher to be no more variable in these important characters than the standard high-quality spring wheats, Ceres and Marquis.

8. Demonstration trials were made in 1935 when samples of Thatcher were grown in 69 trials in 21 counties in the spring wheat area of Minnesota. Twenty pounds of seed were furnished farmer co-operators who sowed a strip of Thatcher in the center of their commercial field. Opportunities were available for comparisons of Thatcher with Marquis, Ceres, and Marquillo. Thatcher gave good yields and little rust infection under conditions under which Ceres and Marquis were severely injured. Thatcher was somewhat more resistant than Marquillo, altho Marquillo also excelled Ceres and Marquis in yielding ability and rust resistance under the rust epidemic conditions of 1935.

Table 26.—Yields in Bushels per Acre of 1/40-Acre Plots at the Central and Branch Stations 1929-35

Variety	Minn. No.	1929	1930	1931	1932	1933	1934	1935	Average 1929-35	1929	1930	1931	1932	1933	1934	1935	Average 1929-35
University Farm										Waseca							
Thatcher	2303	31.1	26.8	18.9	34.1	26.4	9.6	34.7	25.9	25.5	27.7	28.9	22.3	23.3	11.3	29.6	24.1
Ceres	2223	33.2	26.8	18.4	31.8	27.9	11.4	24.5	24.9	25.4	27.3	29.2	25.7	25.6	16.4	14.8	23.5
Marquis	1239	34.3	22.2	18.2	29.3	23.3	10.0	13.5	21.5	27.7	25.8	26.1	26.0	22.1	13.9	8.2	21.4
Hope	2297	29.6	22.3	18.5	28.3	24.2	5.8	23.2	21.7	21.9	22.1	22.6	23.7	22.2	13.4	27.4	21.9
Reward	2204	28.8	20.8	22.0	26.9	28.3	6.5	29.1	23.2	20.3	22.4	21.5	25.6	19.8	7.6	21.9	19.9
Morris										Crookston							
Thatcher	2303	24.2	33.9	26.3	13.6	6.3	4.5	31.1	20.0	33.3	34.4	35.7	19.7	21.7	29.0	22.9	28.1
Ceres	2223	19.7	30.6	24.8	20.6	.9	4.2	8.9	15.7	28.6	31.0	35.2	23.8	23.3	26.5	12.6	25.9
Marquis	1239	19.0	29.5	20.7	18.4	1.4	2.7	1.7	13.3	20.5	33.0	29.4	18.3	20.3	23.8	5.9	21.6
Hope	2297	24.3	25.8	18.9	20.9	2.1	5.8	25.2	17.6	26.3	29.6	29.3	21.8	19.6	21.9	17.1	23.7
Reward	2204	19.5	23.2	21.3	16.2	4.3	3.1	11.6	14.2	25.4	27.4	31.2	21.9	17.7	21.6	15.9	23.0
Grand Rapids										Duluth							
Thatcher	2303			13.3	15.3	9.3	29.5	24.4	18.4				17.5	26.7	37.5	20.8	25.6
Ceres	2223			15.4	16.7	10.7	31.7	12.9	17.5				18.5	15.9	38.8	9.8	20.8
Marquis	1239			11.4	15.5	9.2	22.8	6.3	13.0				18.5	16.6	31.6	6.9	18.4
Hope	2297			11.1	14.9	10.7	33.6	23.4	18.7				19.3	20.9	39.3	18.3	24.5

Table 27.—Weight in Pounds per Bushel of Five Varieties of Spring Wheat 1929-35

Variety	Minn. No.	1929	1930	1931	1932	1933	1934	1935	Average 1929-35	1929	1930	1931	1932	1933	1934	1935	Average 1929-35		
		University Farm									Waseca								
Thatcher	2303	58.8	59.6	50.6	59.9	50.7	55.2	56.9	55.9	57.8	55.8	58.4	56.1	58.8	56.8	56.1	57.1		
Ceres	2223	60.2	60.6	53.5	60.2	56.6	58.0	54.4	57.6	59.9	57.8	59.5	57.8	60.8	59.1	52.6	58.2		
Marquis	1239	57.1	59.5	53.2	60.2	54.4	56.6	49.6	55.8	58.4	55.5	58.6	57.9	58.7	57.8	47.6	56.4		
Hope	2297	57.5	56.3	53.2	57.1	51.5	50.3	50.6	53.8	54.9	52.9	56.7	54.5	56.9	54.3	54.2	54.9		
Reward	2204	61.4	62.8	57.2	62.3	59.2	57.7	59.0	59.9	60.3	57.0	61.2	61.1	60.6	59.5	56.1	59.4		
		Morris									Crookston								
Thatcher	2303	58.0	60.1	57.6	58.2	59.0	54.2	56.3	57.6	60.0	62.1	60.3	55.4	60.4	59.6	57.9	59.4		
Ceres	2223	59.0	61.2	59.7	60.2	58.8	57.5	47.3	57.7	61.3	62.4	61.0	57.6	61.5	60.7	49.0	59.1		
Marquis	1239	58.0	59.7	59.3	58.6	60.5	54.3	41.9	56.0	55.0	62.8	58.7	56.7	60.4	58.7	42.0	56.3		
Hope	2297	58.0	56.6	55.7	56.4	59.0	52.3	51.7	55.7	56.0	60.1	56.3	53.4	56.9	56.3	52.0	55.9		
Reward	2204	61.0	63.0	60.3	62.0	60.0	54.6	52.9	59.1	62.0	64.0	62.5	61.1	62.6	62.2	52.8	61.0		
		Grand Rapids								Average 1931-35	Duluth								Average 1932-35
Thatcher	2303			56.6	56.0	60.1	57.2	54.8	56.9				59.1	59.6	60.4	55.8	58.5		
Ceres	2223			56.4	58.3	58.0	60.2	45.0	55.6				61.0	60.5	59.9	46.6	57.0		
Marquis	1239			53.9	56.6	57.4	55.6	39.9	52.7				58.9	59.4	59.4	43.0	55.2		
Hope	2297			53.6	54.5	54.6	59.7	53.9	55.3				58.5	58.9	58.6	51.0	55.8		

Table 28.—Stem Rust Infection in Percentage in 1/40-Acre Plots of Spring Wheat

Variety	Morris						Crookston							University Farm		
	1929	1930	1931	1932	1935	Av.	1929	1930	1931	1932	1934	1935	Av.	1929	1935	Av.
Thatcher	15	T	1	T	5	4	T	T	T	T	1	3	1	T	T	T
Ceres	33	5	6	T	83	25	28	12	30	T	20	93	37	T	40	20
Marquis	67	25	40	10	98	48	40	43	45	10	43	98	47	43	63	53
Hope	T	T	T	0	T	T	0	0	0	0	T	T	T	0	T	T
Reward	63	10	53	5	95	45	63	7	35	5	38	98	41	43	50	47

Variety	Waseca							Grand Rapids			Duluth
	1929	1930	1931	1932	1933	1935	Av.	1931	1932	1935	1935
Thatcher	T	T	T	T	10	2	2	8	12	20	5
Ceres	3	17	8	T	T	43	12	42	8	100	70
Marquis	15	47	48	20	40	68	40	57	67	100	87
Hope	0	T	0	0	0	T	T	0	0	T	T
Reward	55	47	27	10	5	75	37				