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# Newthatch Wheat

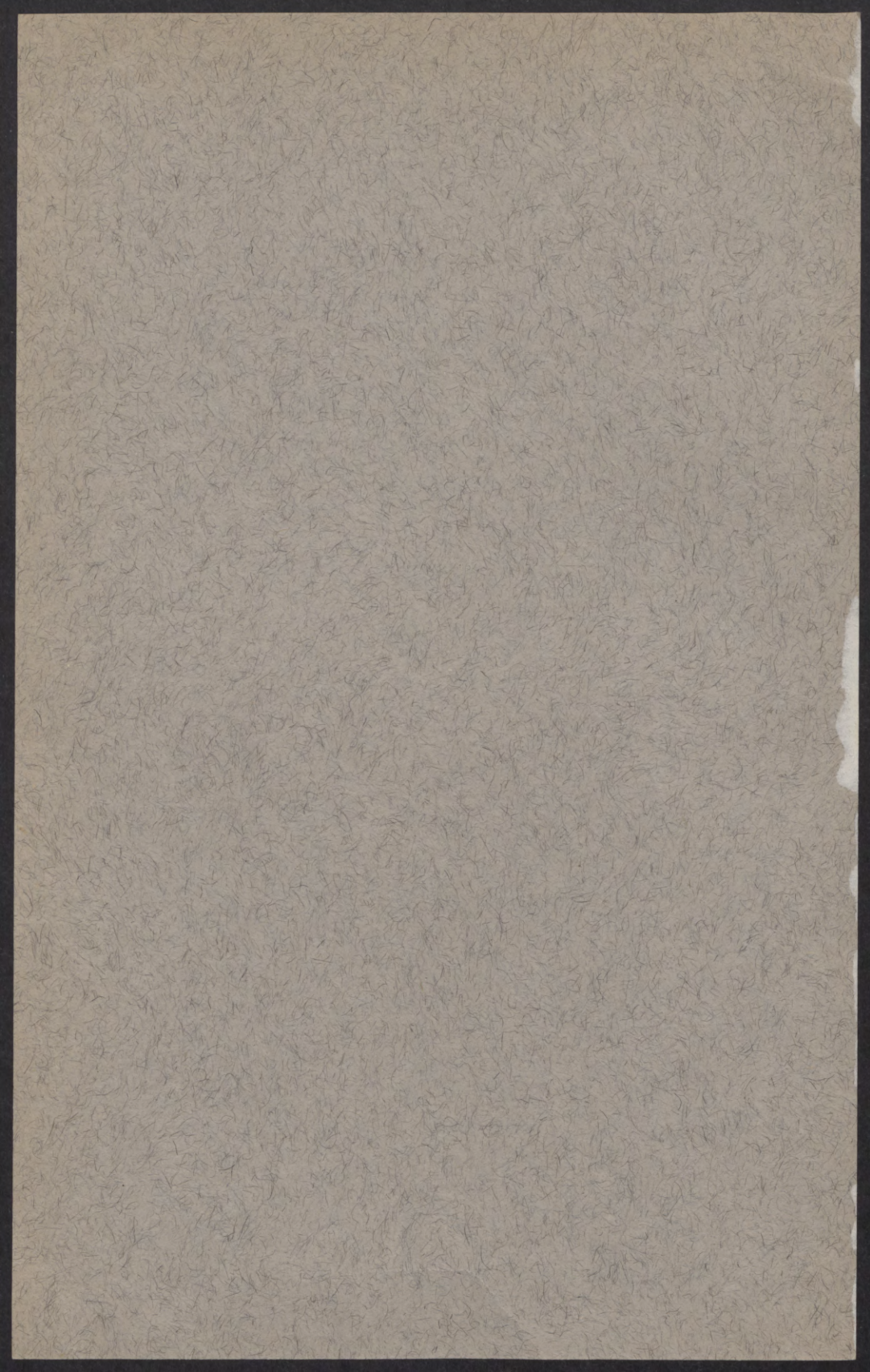
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and Division of Agricultural Biochemistry

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# Newthatch Wheat<sup>1</sup>

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BECAUSE of the destructiveness of stem rust in certain years, the selection and breeding of varieties resistant to stem rust were begun at the Minnesota, South Dakota, and North Dakota Agricultural Experiment stations during the early years of the century in cooperation with the United States Department of Agriculture (1)<sup>3</sup>. During the early years of the breeding program no highly resistant varieties of *Triticum vulgare* L. were available. Studies were made of all available material and crosses were made between varieties of *T. vulgare* wheats and crosses between *T. vulgare* and rust resistant varieties of *T. durum* and *T. dicoccum*. About 20 years ago, two varieties of common wheats, Kota C.I. 5878<sup>4</sup> (13) and Ceres C.I. 6900 (12), were developed at the North Dakota Agricultural Experiment Station. Both of these wheats had considerable resistance to stem rust and were grown extensively in the spring wheat area, but they later became heavily rusted and were replaced with varieties having more resistance.

Marquillo, Minn. No. 2202, C.I. 6887 (5), developed from Marquis x Iumillo (*durum*), was the first hard red spring wheat commercially grown in which the stem rust resistance of the *durum* parent was transferred to a common hard red spring wheat. It was released to farmers in 1928. This wheat proved to be unsatisfactory because of too much yellow pigment in the flour and has never been grown extensively.

Thatcher, Minn. No. 2303, C.I. 10003 (4), distributed in 1934, was a selection from the double cross (Marquis x Iumillo) (a sister selection of Marquillo) x (Marquis x Kanred) and combined

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<sup>3</sup> Italicized figure in parentheses refers to Literature Cited.

<sup>4</sup> Accession record number, Division of Cereal Crops and Diseases.

the field resistance to stem rust from heading to maturity from the Lumillo parent and resistance to several races of rust in both the seedling and adult plant stages obtained from the Kanred parent. Thatcher, because of its wide adaptability, good milling and baking qualities, and stem rust resistance in the adult stage, has been grown extensively, about 14 million acres being grown in the spring wheat area of the United States and Canada in 1941. The acreage has decreased in recent years because of its susceptibility to leaf rust.

Hope, C.I. 8178 (6), is a vulgare type of wheat, selected from a cross of Marquis with Yaroslav (emmer) that is highly resistant to both leaf and stem rust in the adult stage in the field, and to loose and stinking smut. Hope has not been grown extensively because of its rather low-yielding ability, weak straw, and grayish color of flour. However, it has been used extensively as a parent in hybridization with other *T. vulgare* wheats.

No hard red spring wheats of the vulgare group were available prior to the development of Hope and H-44, C.I. 8177 (a sister selection), with high resistance to leaf rust. Recently, however, four new varieties have been released which so far have been resistant to both leaf and stem rust, and have Hope or H-44 as one of their parents. These wheats, Pilot C.I. 11428 (2), Rival C.I. 11708 (11), Regent C.I. 11867, and Renown C.I. 11947 (8), are replacing Thatcher in areas where leaf rust is a problem and where they are adapted.

This bulletin contains a summary of (a) the major steps in the breeding of Newthatch, a variety of wheat resistant to both leaf and stem rust, (b) a description of the botanical characters of the new variety, and (c) data on agronomic characters, disease reaction, and milling and baking quality in comparison with Thatcher and other varieties which are now being grown commercially in the state.

## The Breeding of Newthatch Wheat

In order to understand better the methods used in the development of Newthatch wheat, it seems desirable to review briefly some of the problems solved that have led to the present viewpoint in the breeding program for disease resistance.

The wheat stem rust pathogen, *Puccinia graminis tritici* E. and H., comprises numerous physiologic races which are differentiated by their parasitic effect on seedling plants of about a dozen varieties of common wheats, durums, emmers, and einkorn, known as

differential varieties (9). Seedlings of the same variety of wheat may be resistant to one race of rust and susceptible to another. A wheat variety that is resistant to a given race in the seedling stage is resistant to that race in the adult stage also. There is a type of resistance, however, from heading to maturity that is not correlated with seedling reaction. A variety may be susceptible in the seedling stage to one or more races and resistant in the adult stage to these races or to all prevalent races. The knowledge that new races develop from hybridization on the barberry and the fact that over 200 parasitic or physiologic races have been identified makes the problem of breeding for resistance continuous. This is particularly true because it is known that the relative prevalence of these rust races varies greatly with seasons and regions.

The reaction to stem rust in wheat is dependent upon genetic factors located in both the host and pathogen. The mode of inheritance of a particular type of reaction to stem rust has been studied both in the seedling and on the adult plants in the field. Resistance to a number of races as the plants approach maturity may be dependent upon one or a few genetic factors. Knowing the complexity of inheritance aids in deciding the number of progeny desirable for a particular cross.

It is now known that the causes of resistance may be due to physiological, morphological, and functional differences, and the genetic differences and their manner of inheritance. Knowledge of the genetic factors involved in the inheritance of resistance and susceptibility is important even though the nature of the resistance is not known. The adult or mature plant type of resistance of certain resistant varieties such as Hope and H-44, which have been used widely in the hybridization program, is relatively simply inherited. There is not a close relationship between the presence of genetic factors for resistance and known causes of resistance in hybrids of any of the three types of resistance, physiological, morphological, and functional, except in the case of physiological resistance.

Environmental conditions may modify rust reaction of a variety. Plants genotypically rust resistant may be susceptible if severely affected by loose smut. Variations in temperature and light or date of planting have been shown to cause considerable fluctuation in rust reaction. The manner of reaction under a particular set of conditions is inherited rather than the character itself.

Thatcher early in the breeding program was found to be susceptible to leaf rust, although it was resistant to stem rust and

had desirable agronomic and milling and baking quality. Since Thatcher was susceptible to leaf rust, it was decided to use the backcross method, suggested by Harlan and Pope (3), to add leaf rust resistance. The principle of backcrossing is that of adding one or two characters that are lacking to a variety that in most respects is rather highly satisfactory. In this case, Thatcher has good yielding ability, stem rust resistance, and excellent milling and baking qualities. It therefore was used as the recurring parent and Hope as the nonrecurring parent. Hope is more resistant to leaf and stem rust than Thatcher, so the purpose of using this method was to add greater leaf and stem rust resistance to a variety similar in other characters to Thatcher.

The history of a series of crosses and backcrosses used in the development of Newthatch is shown in table 1.

The early generations of the backcrosses were grown on a plant basis in special disease gardens at the central station under artificially induced epidemic disease conditions. Single rows in which 25 seeds were spaced, three inches apart within the row, of each plant progeny were tested for reaction to leaf rust, *Puccinia triticina* Eriks., and stem rust, *P. graminis tritici* Eriks. and Henn., in the rust nursery; and for reaction to bunt, *Tilletia tritici* (Bjerk.) and *T. levis* (Kuhn), loose smut, *Ustilago tritici* (Pers.) Rostv., black chaff, *Bacterium undulosum translucens*, Smith, Jones, and Reddy, scab and root rot, *Gibberella saubinetii* (Mont.) Sacc. or *G. zeae* (Schw.) Petch, *Fusarium* sp. and *Alternaria* sp., in the disease garden. Selections were made for stem and leaf rust resistance in the early generations; in the F<sub>4</sub> and later generations, these selections were also tested for their reaction to bunt, scab, foot rots, and black chaff. When the progeny of individual plants appeared homozygous and relatively desirable for all characters, they were bulked and put into comparative yield trials.

Table 1. History of Newthatch

Year	Plan	Place grown
1930	Hope x Thatcher	Field
1930-31	F <sub>1</sub> x Thatcher (first backcross)	Greenhouse
1931	1st backcross x Thatcher (2nd backcross)	Field
1932-35*	Pedigree selection	Field
1936-41	Rod-row trials	Field
1941-43	1/40 acre trials	Field

\* Leaf rust epidemics were obtained only in 1932, 1935, 1940, and 1942. Stem rust epidemics obtained each year.



The first comparative yield trials were made in rod rows. Three replications of three rows each were grown at each of the four stations, University Farm, Waseca, Morris, and Crookston, Minnesota, in randomized blocks. Three replications of the 1/40 acre plots were grown at University Farm, Waseca, Morris, Crookston, Grand Rapids, and Duluth.

In addition to the yield trials, studies were made during the same years of reaction to diseases in the disease gardens. One planting was made for studies of the reaction of the hybrids to stem and leaf rust, the reaction to bunt, root rots, scab, and black chaff being tested in a separate disease garden.

Twelve lines were selected in the  $F_5$  generation for the yield tests. After testing these strains in rod-row and 1/40 acre plot trials, and disease gardens, seven of the strains, Minnesota Nursery Stock Nos. II-31-3, -6, -8, -9, -10, -13, and -14, appeared so nearly alike in all characteristics and were all derived from a single  $F_2$  plant that they were bulked and called Newthatch. The similarity is not unexpected since all strains trace back to a single  $F_2$  plant from the second backcross.

The seven backcross strains making up Newthatch were first grown in rod-row trials in 1939, and in 1/40 acre plot trials in 1941. Data on all characters for each of these strains were summarized in comparison with Thatcher for the years and stations where they were grown. The data obtained on yield per acre are given in table 2. These data show the strains to be very similar in yielding ability. Similar comparisons were made on other agronomic characters, disease reaction, and milling and baking properties.

Although the parents, Hope and Thatcher, and the lines composited into Newthatch were resistant in the adult plant stage in the field, they were tested for reaction to 18 races of stem rust in the seedling stages to determine whether the lines reacted similarly to the various races. The results obtained for the individual races are given in table 3. These results show that the seedling resistance of Thatcher to races 17 and 24 was retained in the hybrid lines and that resistance to races N.R., 40, 39, 38, 56, 147, 55, 36, and 53 had been obtained from the Hope parent. Both parents and Newthatch were resistant to races 59, 49, and 69, and to 14 and 19 that are controlled by the factor for immunity of Kanred. The lines had very similar reactions to the races in the seedling stage, which was further evidence that they were of similar genetic constitution.

Table 2. Comparison of Backcross Strains Used in Newhatch with Thatcher for Yield When Grown in Rod-row and 1/40 Acre Plot Trials at University Farm, Waseca, Morris, and Crookston, During 1939-42

Nursery stock number of strains or variety	Number trials Rod rows	Average yield	Least significant difference	Number trials 1/40 acre	Average yield	Least significant difference	Total number trials	Average yield	Least significant difference	Per cent of Thatcher
		bushels			bushels			bushels		
II-31-6 (2692)	14 (1939-42)	28.6	1.29	8 (1941-42)	34.5	2.21	22 (1939-42)	30.7	1.28	131
Thatcher	14 (1939-42)	22.9	1.29	8 (1941-42)	24.4	2.21	22 (1939-42)	23.4	1.28	100
II-31-14 (2691)	10 (1939-41)	28.4	1.42	8 (1941-42)	35.4	2.21	18 (1939-42)	31.5	1.32	144
Thatcher	10 (1939-41)	21.9	1.42	8 (1941-42)	24.4	2.21	18 (1939-42)	21.8	1.32	100
					Per cent of Thatcher					
II-31-8	10 (1939-41)	27.5	1.42		126					
II-31-9	10 (1935-41)	28.1	1.42		128					
Thatcher	10 (1939-41)	21.9	1.42		100					
II-31-10	9 (1939-41)	28.0	1.50		128					
II-31-3	9 (1939-41)	26.7	1.50		118					
Thatcher	9 (1939-41)	22.7	1.50		100					
II-31-13	6 (1939-41)	24.7	1.94		136					
Thatcher	6 (1939-41)	18.1	1.94		100					

Table 3. Seedling Reaction of Parents and Backcross Lines Used in Newthatch to 18 Physiologic Races of Stem Rust, Grown in the Greenhouse at University Farm

Variety or backcross line	Reaction of parents or lines to race*																		
	Race No.	17	10	N.R. 40 39 38	38	56	147	55	14	34	59	53	40	24	15	69	49	19	36
Hope (parent) .....	S	R	R	R	R	R	R	R	R	S	R	R	S	S	S	R	R	R	R
Thatcher (parent) .....	R	S	S	S	X	S	X	R	S	R	S	S	R	S	R	R	R	R	S
Nursery stock number of backcross lines																			
II-31-3 .....	R	S	R	S	R	R	R	R	S	R	R	S	R	S	R	R	R	R	X
II-31-6 .....	R	S	R	S	R	R	R	R	S	R	.....	S	R	X	R	R	R	R	X
II-31-8 .....	R	S	R	S	R	R	R	R	S	R	R	S	R	S	R	R	R	R	X
II-31-9 .....	R	S	R	S	R	R	R	R	S	R	.....	S	R	X	R	R	R	R	X
II-31-10 .....	R	S	R	X	R	R	R	R	S	R	R	S	R	S	R	R	R	R	X
II-31-13 .....	R	S	R	S	R	R	R	R	S	R	.....	S	R	S	R	R	R	R	X
II-31-14 .....	R	S	R	X	R	R	R	R	S	R	R	S	R	X	R	R	R	R	R

\* S = susceptible type of pustule.

R = resistant type of pustule.

X = resistant and susceptible types of pustule on same plant.

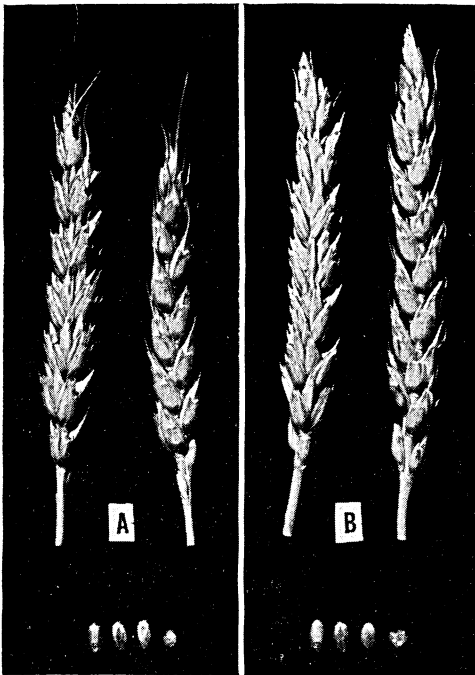


FIG. 1. Comparable spikes and kernels of Thatcher and Newthatch  
A, Thatcher; B, Newthatch

to angular; brush mid-sized and mid-long. The weight of 1,000 seeds is higher than that of Thatcher. Spikes and kernels of Newthatch and Thatcher are shown in figure 1.

### Yield Trials

One or more of the strains composing Newthatch were grown in rod-row trials during 1939 to 1942 and in 1/40 acre field plots in 1941 to 1943, inclusive. Two of the strains, Nursery Nos. II-31-6 and 14, Minn. Nos. 2692 and 2691, respectively, were grown in 1/40 acre field plots in 1941 and 1942. Since these two strains were used in the Newthatch composite, the results obtained from them were used to compute averages for these two years.

**Yield in Bushels per Acre**—The average yields of six varieties grown at the six stations during two or more of the three years, 1941 to 1943, inclusive, are given in table 4.

Before discussing the yielding ability in detail, it seems desirable to consider the relation between yielding ability and leaf rust reaction for each of the years and stations.

### Botanical Characters of Newthatch

Newthatch is a hard red spring wheat. It is very similar to Thatcher in appearance. It matures about the same time as Thatcher and is moderately resistant to leaf and stem rust under field conditions. The plant has spring habit, short to mid-tall, strong stem; spike awnletted, fusiform, mid-dense, erect; glumes glabrous, white, short; beaks mid-wide, acute triangular 0.5-1.0 m.m., long; awnlets few, 1 to 15 m.m. in length.

The grain is red, short, hard, ovate; germ mid-sized; crease mid-wide and mid-deep, rounding

Table 4. Average Yields of Varieties of Hard Red Spring Wheats Grown in Field Plots at the Six Stations in Minnesota, During Two or More of the Three Years, 1941-1943, Inclusive

Location	Years tested	Yield in bushels per acre						L.S.*
		Thatcher	Newthatch	Pilot	Rival	Re-gent	Re-nown	
University Farm .....	1941-43	23.9	35.0	33.7	31.2	28.2	29.3	3.6
Waseca .....	1941-43	19.3	25.2	28.4	24.8	23.7	23.9	3.1
Morris .....	1941-43	27.9	33.1	34.8	34.6	30.9	29.2	3.5
Crookston .....	1941-43	29.1	37.2	34.9	34.2	34.8	33.9	3.1
Grand Rapids .....	1942-43	15.3	21.8	27.0	26.7	24.9	25.3	5.3
Duluth .....	1942-43	21.0	26.4	34.0	32.2	27.0	25.6	5.3

\* Level of significance 5 per cent point.

Figure 2 gives the average yields in 1/40 acre plot trials and leaf rust reaction of Newthatch and Thatcher at the two stations, Morris and Crookston, which are located in the wheat growing region. There were heavy epidemics of leaf rust at these stations as shown by the susceptibility of Thatcher, the heaviest infection being at Crookston in 1941.

Leaf rust infection will be discussed more fully later but data are given here to show that leaf rust infection caused a marked reduction in the yield of Thatcher:

The yields given in table 4 show Newthatch to be a high-yielding variety under all conditions in Minnesota. Pilot, Rival, and Regent have been grown for longer periods at the stations and have been moderately to highly resistant to both leaf and stem rust, outyielding Thatcher in all tests made in Minnesota.

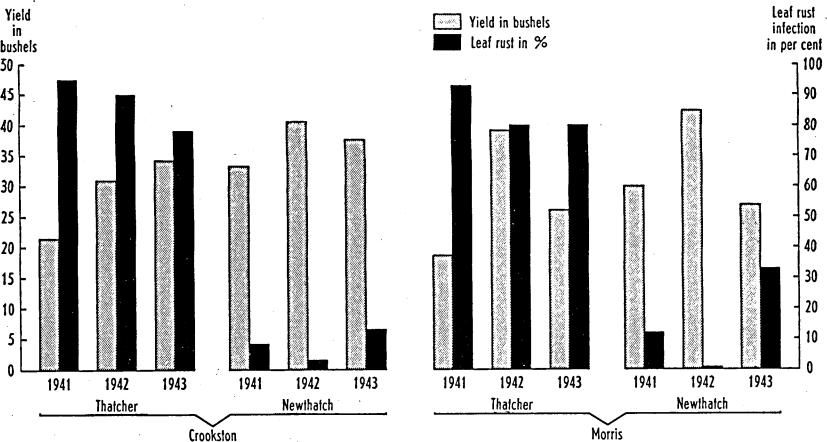


FIG. 2. Comparison of yield and leaf rust infection of Thatcher and Newthatch in the 1/40 acre plot trials at Crookston and Morris, Minnesota, during 1941-1943

Newthatch has been a high-yielding variety in the spring wheat growing region of the state. At the Crookston station, located in the northwestern part of the state, Newthatch out-yielded Thatcher, on the average, 8.1 bushels, Pilot by 2.3 bushels, Rival by 3.0 bushels, Regent by 2.4 bushels, and Renown by 3.3 bushels.

At Morris, Newthatch yielded less than Pilot and Rival by 1.7 bushels and 1.5 bushels, respectively, but it yielded 5.2 bushels more than Thatcher and 2.2 and 3.9 bushels more than Regent and Renown, respectively. Rival and Pilot are both bearded wheats, while the other varieties are awnleted.

Waseca is in the winter wheat growing section of the state, and here Newthatch was outyielded by Pilot by 3.2 bushels per acre, while it exceeded the yield of Thatcher by 5.9 bushels, Rival by 0.4 bushel, Regent by 1.5 bushels, and Renown by 1.3 bushels.

At University Farm, Newthatch was the highest-yielding variety, outyielding Pilot by 1.3 bushels per acre, Rival by 3.8 bushels, Regent by 6.8 bushels, Renown by 5.7 bushels, and Thatcher by 11.1 bushels.

Yields of these varieties are available at the Grand Rapids and Duluth stations for two years only. At these stations Newthatch did not yield as well as some of the other varieties.

Newthatch wheat appears to be well adapted to the region where spring wheat is best adapted, being the highest-yielding wheat at Crookston and not significantly different from the best-yielding variety at Morris. It does not appear to be adapted to the north central and northeastern part of the state, although there are not sufficient data to draw definite conclusions.

**Test Weight per Bushel**—High test weight is usually associated with high flour yield; hence bushel weight is an important index of the value of a variety of wheat. Environmental or climatic conditions may affect the test weight, although there are inherent differences within the varieties themselves. The average weights per bushel of the six wheats are given in table 5.

In general, Newthatch exceeded Thatcher in bushel weight at all stations, except at Waseca, although the difference was very small at Morris. The other four varieties, Pilot, Rival, Regent, and Renown, had test weights equal or superior to Newthatch at all the stations. A higher test weight would be desirable in Newthatch, since the lower test weight may result in a lower grade when it is grown under environmental conditions which favor low test weight, whereas other varieties of inherently high

Table 5. Average Weight per Bushel of Hard Red Spring Wheat Varieties Grown at the Six Stations in Minnesota, During 1941 to 1943

Location	Years tested	Weight per bushel in pounds					
		Thatcher	New-thatch	Pilot	Rival	Regent	Renown
Crookston .....	1941-43	55.9	57.9	57.6	58.0	59.0	59.6
Morris .....	1941-43	56.1	56.4	57.0	58.2	57.0	58.0
Waseca .....	1941-43	55.5	55.1	56.5	57.3	55.8	57.0
University Farm .....	1941-43	53.9	55.8	57.4	57.8	56.4	58.0
Grand Rapids .....	1942-43	55.6	56.0	57.9	58.0	57.6	59.0
Duluth .....	1942-43	58.0	59.0	59.1	60.2	59.9	60.4
Average .....		55.8	56.7	57.6	58.2	57.6	58.7

test weight might still be eligible for a higher grade when grown under the same conditions.

**Reaction to Stem Rust**—Stem rust has not caused any marked damage during the years 1941 to 1943, inclusive, the varieties grown all being moderately resistant to this disease. Average percentages of stem rust infection obtained on these varieties in the 1/40 acre plot trials at the six stations are given in table 6.

Table 6. Average Stem Rust Infection of Varieties in 1941-1943

Location	Years tested	Percentage of stem rust infection					
		Thatcher	New-thatch	Pilot	Rival	Regent	Renown
Crookston .....	1941-43	0	0	0	0	0	0
Morris .....	1941-43	T*	T	T	T	T	T
Waseca .....	1941-43	T	T	T	T	T	T
University Farm .....	1941-43	T	T	2	1	T	T
Grand Rapids .....	1942-43	T	T	T	T	0	T
Duluth .....	1942-43	21	16	14	10	9	20
Average .....		3	3	3	2	1	3

\* T = trace.

**Reaction to Leaf Rust**—Average percentages of leaf rust infection of the six varieties grown at the six stations are given in table 7.

Table 7. Average Leaf Rust Infection of Varieties in 1941-1943

Location	Years tested	Percentage of leaf rust infection					
		Thatcher	New-thatch	Pilot	Rival	Regent	Renown
Crookston .....	1941-43	88	8	10	28	4	13
Morris .....	1941-43	84	15	18	13	10	26
Waseca .....	1941-43	75	9	10	4	1	22
University Farm .....	1941-43	79	5	6	20	2	6
Grand Rapids .....	1942-43	T	T	T	T	0	0
Duluth .....	1942-43	23	17	16	10	17	21
Average .....		58	9	10	12	6	15

Table 8. Average Leaf Rust Infection in the Rust Nursery at University Farm, 1939-1943

Year	Percentage of leaf rust infection					
	Thatcher	Newthatch	Pilot	Rival	Regent	Renown
1939 .....	80	13	30	25	T	15
1940 .....	80	10	2	10	25	20
1941 .....	80	T	T	5	1	T
1942 .....	75	T	T	10	T	T
1943 .....	60	T	1	20	T	T
Average .....	62	4	5	12	4	6

The data given show that leaf rust infection of Thatcher was severe during recent years at Crookston, Morris, Waseca, and University Farm. Leaf rust damage as shown by reductions in yield and test weight per bushel was highest in 1941. The other varieties showed a rather high degree of resistance to leaf rust infection when an epidemic occurred.

The percentages of leaf rust infection occurring on these six varieties in the Rust Nursery at University Farm are given in table 8.

These results show Newthatch and the four other varieties to be highly resistant to leaf rust, while Thatcher was highly susceptible. Under these artificially induced epidemics Newthatch was as resistant as any other variety.<sup>5</sup>

**Reaction to Other Diseases**—The varieties were tested for their reaction to bunt, scab, root rot, and black chaff, in five-foot rows in the Disease Garden, under artificially induced epidemic conditions (using several races of each pathogen). Infection with bunt is induced by dusting a small sample of the wheat kernels before planting with spores from a mixture of collections of bunt, made up from collections of bunt obtained from the entire spring wheat area. Percentages of infection were determined by dividing the number of bunt-infected heads in a row by the total number of heads in a five-foot row. The results are given in table 9. None of the varieties were heavily infected but Newthatch had a slightly heavier infection than the other five varieties.

Scab reactions were obtained and the results are given in table 10. The plants were inoculated in the field by spraying with a water suspension of spores of a mixture of scab-producing organisms. Scab percentages were taken by estimating the percent-

<sup>5</sup> Although considerable leaf rust has been observed on these varieties in certain tests in previous years, conditions were very favorable for the rusts in 1944, and an unusual amount of leaf rust developed on all the varieties listed in table 8. It is known, also, that there are races of leaf rust that can attack these varieties and they may have been more prevalent in 1944 than in other years in which tests were made.



Table 9. Bunt-Infected Heads in the Disease Garden at University Farm, 1939-1943

Year	Percentage of bunt-infected heads					
	Thatcher	Newthatch	Pilot	Rival	Regent	Renown
1939	0	2	0	0	0	0
1940	0	4	3	0	1	0
1941	1	6	0	0	7	0
1942	3	6	3	0	2	0
1943	4	10	0	4	0	0
Average	2	7	2	1	2	0

Table 10. Scab Infection in the Field in the Disease Garden, 1939-1943

Year	Percentage of scab infection						
	Thatcher	Newthatch	Pilot	Rival	Regent	Renown	Hope
1939	35	50	T+	2	65	65	10
1941*	55	65	10	15	50	80	15
1942	15	20	10	2	30	25	20
1943	65	80	60	60	80	80	40
Average	42	54	21	22	56	62	21

\* No scab infection in 1940.

Table 11. Root Rot Infection in the Disease Garden at University Farm, 1939-1943

Year	Thatcher	Newthatch	Pilot	Rival	Regent	Renown
1939	T++	T++	L	T++	T++	H
1940	T+	T+	L++	T++	T++	L+
1941	L-	T++	T+	T+	M+	T+
1942	M-	M	M-	M-	M-	M+
1943	T++	T++	L	L	T++	T++

age of florets infected in the wheat heads, then estimating the percentage of heads infected within the row. The multiplication of these two percentages together gives the percentage of infection for a row.

Regent, Renown, and Newthatch were the three most susceptible varieties. Thatcher was slightly less susceptible while Pilot, Hope, and Rival were the most resistant.

Root rot infection notes were taken on short rows in the Disease Garden. Four classes were used, T = trace, L = light, M = medium, and H = heavy. The notes obtained on the varieties are given in table 11. Differences in root rot reaction were not very great, but it does appear that Thatcher and Pilot were slightly more resistant than the other varieties.

Varietal reactions to black chaff are given in table 12. Infections were light in most years. Thatcher had the least infection while Newthatch and Rival had a heavier average infection than the other four varieties. No attempt was made in these investiga-

Table 12. Black Chaff Infection in the Disease Garden at University Farm, 1939-1943

Year	Thatcher	Newthatch	Pilot	Rival	Regent	Renown
1939	—	T+	T+	T++	T+	M
1940	0	0	0	T—	0	0
1941	0	L	0	M—	L	T
1942	0	T	0	0	0	T
1943	0	T+	T—	T++	L—	L—

tions to distinguish between true black chaff and brown necrosis as described by McFadden (7).

**Lodging**—Lodging notes were taken on the 1/40 acre plots whenever lodging occurred. Two notes were taken: (1) percentage of plot lodged, (2) average degree or the angle of the lodged stems in the plots. For the average degree of lodging of the three replications of a variety the per cent of lodging was multiplied by the degree of lodging and the product divided by the total percentage of lodging. The lodging notes obtained in the years and at the stations are given in table 13.

Table 13. Comparative Lodging Notes on Varieties Grown in the 1/40 Acre Plots at the Four Stations in Minnesota, 1941-1943

Station and variety	Lodging						Averages	
	1941		1942		1943		Per cent	Degree
<b>University Farm</b>	Per cent	Degree	Per cent	Degree	Per cent	Degree	Per cent	Degree
Thatcher	0	0	0	0	0	0	0	0
Newthatch	0	0	0	0	0	0	0	0
Pilot	27	40	33	5	70	38	43	30
Rival	0	0	67	10	67	33	45	21
Regent	0	0	0	0	0	0	0	0
Renown	0	0	0	0	17	30	6	30
<b>Waseca</b>								
Thatcher	10	35	0	0	0	0	3	35
Newthatch	2	30	0	0	0	0	1	30
Pilot	60	45	100	23	0	0	53	31
Rival	30	28	40	22	0	0	23	25
Regent	18	34	0	0	0	0	6	34
Renown	0	0	17	20	0	0	6	20
<b>Morris</b>								
Thatcher	10	10	0	0	0	0	3	10
Newthatch	0	0	0	0	0	0	0	0
Pilot	30	26	70	28	0	0	33	27
Rival	22	27	53	40	0	0	26	35
Regent	5	10	0	0	0	0	2	10
Renown	0	0	0	0	0	0	0	0
<b>Crookston</b>								
Thatcher	63	45	18	45	17	45	33	45
Newthatch	53	20	12	68	36	49	34	36
Pilot	5	45	80	71	92	79	59	74
Rival	13	45	92	90	50	45	52	72
Regent	75	22	38	45	40	23	51	28
Renown	58	36	17	45	25	25	33	35

The results show that Newthatch is outstanding in its ability to withstand lodging, being in this respect far superior to Rival and Pilot. Regent and Renown also have good ability to withstand lodging.

**Milling and Baking**—Samples of the varieties from University Farm, Waseca, Morris, and Crookston were milled to patent flours (about 85 per cent patent) on an experimental mill of the Division of Agricultural Biochemistry of the Minnesota Experiment Station. Baking tests were made from the samples of flour obtained. The flours were baked by the baking formula of the American Association of Cereal Chemists (Cereal Laboratory Methods, 4th ed., 1941) with the exception that one milligram of potassium bromate was added. Each flour was baked by this formula, using two mixing times (two and four minutes in a Hobart Swanson mixer) and two fermentation periods (two and three hours). The loaf volumes were measured by seed displacement, and the loaves scored for three characters, crumb color, crumb grain, and crumb texture, on the basis of 10 as an ideal score. In addition to the milling and baking tests, the protein content of the wheat and carotinoid or yellow pigment of the flours was determined. Protein content is expressed on a 15 per cent moisture basis. The pigments were extracted with water-saturated butanol and their concentration determined spectrophotometrically, in terms of carotene, as outlined in Cereal Laboratory Methods (4th ed., 1941).

Three-year averages for the varieties grown at University Farm, Waseca, Morris, and Crookston are given in table 14. Newthatch had the highest average protein content, was one of the three highest in flour yield, and was highest in average loaf volume. The carotinoid pigment of Newthatch was lower than that of Thatcher but was higher than that of the other varieties. The crumb color of loaves baked from Newthatch was somewhat superior to that of Thatcher. On the basis of all the analytical milling and baking data, Newthatch may be regarded as superior to Thatcher in milling and baking value.

Table 14. Average Analytical Milling and Baking Data Obtained on Varieties of Spring Wheat Grown in the 1/40 Acre Plots, at University Farm, Waseca, Morris, and Crookston During the Three-Year Period, 1941-1943

Variety	Minn. No.	Wheat protein					Flour yield					Loaf volume				
		U.F.	W.	M.	C.	Av.	U.F.	W.	M.	C.	Av.	U.F.	W.	M.	C.	Av.
		Per cent					Per cent					Cubic centimeters				
Thatcher .....	2303	13.2	13.6	13.5	14.1	13.6	74.2	75.0	74.0	73.5	74.2	790	749	778	887	801
Pilot .....	2687	13.2	13.6	14.1	13.0	13.5	73.4	72.5	71.5	71.9	72.3	740	764	829	773	777
Renown .....	2675	14.5	14.0	15.0	14.6	14.5	74.0	75.0	75.6	74.5	74.8	832	785	810	844	818
Rival .....	2670	13.8	14.1	14.5	14.9	14.3	73.8	74.1	73.5	74.4	74.0	747	762	822	848	795
Regent .....	2688	14.9	14.5	15.4	13.7	14.6	73.9	75.1	75.0	75.1	74.8	834	821	825	797	819
Newthatch .....	2752	14.8	14.8	15.3	14.8	14.9	75.4	74.9	74.4	73.1	74.8	843	814	832	861	838
Average .....		14.1	14.1	14.6	14.2	14.2	74.1	74.4	74.0	73.8	74.2	798	783	816	835	808

Variety	Minn. No.	Carotinoid pigments					Crumb color					Crumb grain					Crumb texture				
		U.F.	W.	M.	C.	Av.	U.F.	W.	M.	C.	Av.	U.F.	W.	M.	C.	Av.	U.F.	W.	M.	C.	Av.
		Ppm.					Ideal score = 10					Ideal score = 10					Ideal score = 10				
Thatcher .....	2303	3.09	3.14	3.02	3.48	3.18	7.8	7.7	8.0	7.9	7.8	7.3	7.8	8.0	7.3	7.6	8.5	8.7	9.0	8.9	8.8
Pilot .....	2687	2.51	2.55	2.50	2.61	2.54	7.9	7.9	8.5	8.3	8.2	7.3	7.6	7.3	7.5	7.4	8.4	8.5	8.6	8.5	8.5
Renown .....	2675	2.65	2.67	2.55	2.68	2.64	7.6	7.6	8.1	7.9	7.9	7.3	7.4	7.6	7.4	7.4	8.5	8.7	8.6	8.5	8.6
Rival .....	2670	2.43	2.53	2.45	2.74	2.54	7.8	7.8	8.4	7.8	8.1	7.6	7.4	7.5	7.5	7.5	8.6	8.5	8.8	8.5	8.6
Regent .....	2688	2.52	2.58	2.44	2.55	2.52	7.8	7.8	8.2	7.7	8.0	7.3	7.5	7.6	7.7	7.5	8.3	8.5	8.6	8.5	8.5
Newthatch .....	2752	2.57	3.01	2.61	2.96	2.86	8.1	8.0	8.3	8.0	8.1	7.2	7.5	7.4	7.4	7.4	8.5	8.7	8.8	8.6	8.7
Average .....		2.63	2.75	2.60	2.84	2.71	7.8	8.0	8.3	7.9	8.0	7.3	7.5	7.6	7.5	7.5	8.5	8.6	8.7	8.6	8.6

## Summary

Newthatch is being distributed to approved seed growers in 1944. It is the result of cooperative experiments conducted in Minnesota since 1907 by the Bureau of Plant Industry, Soils, and Agricultural Engineering of the United States Department of Agriculture and the Minnesota Agricultural Experiment stations. These experiments were made for the purpose of developing stem and leaf rust resistant varieties having desirable agronomic characters and excelling in milling and baking qualities.

Newthatch was produced by crossing Hope with Thatcher and backcrossing to Thatcher twice.

Newthatch is a hard red spring wheat which resembles Thatcher in appearance, having approximately the same date of heading and maturity, height, seed characters, and ability to withstand lodging as Thatcher.

During the three-year period 1941-1943, yield trials at the four experiment stations, University Farm, Waseca, Morris, and Crookston, show that Newthatch has been outstanding in yield, being highest at University Farm and Crookston, second at Waseca, and third at Morris. It has not yielded as well as other varieties in the two-year trials at Grand Rapids and Duluth.

In weight per bushel, Newthatch is higher than Thatcher but lower than Pilot, Rival, Regent, and Renown.

Newthatch has been resistant in these studies under field conditions to both leaf and stem rusts. In the seedling stage, it proved to be resistant to 13 of the 18 races of stem rust to which it was tested.

In milling and baking characteristics, Newthatch has been superior to all other varieties in protein content and loaf volume, and equal to the other varieties in yield of flour, in crumb color, grain, and crumb texture. It has a lower carotinoid pigment than Thatcher but a higher pigment content than the other varieties in the trials at the four stations, University Farm, Waseca, Morris, and Crookston. The color of the crumb of the bread has been satisfactory.

## Literature Cited

1. CARLETON, M. A. Lessons from the grain-rust epidemic of 1904. U. S. Dept. Agr. Farmers' Bul. 219. 1905.
2. CLARK, J. A. Registration of improved wheat varieties, XII. Amer. Soc. Agron. Jour. 30:1037-1042. 1938.
3. HARLAN, H. V., and POPE, M. N. The use and value of back-crosses in small-grain breeding. Jour. Hered. 13:319-322. 1922.
4. HAYES, H. K., AUSEMUS, E. R., STAKMAN, E. C., BAILEY, C. H., WILSON, H. K., BAMBERG, R. H., MARKLEY, M. C., CRIM, R. F., LEVINE, M. N. Thatcher wheat. Minn. Agr. Expt. Sta. Bul. 325. 1936.
5. ——— PARKER, J. H., and KURTZWELL, C. Genetics of rust resistance in crosses of varieties of *Triticum vulgare* with varieties of *T. durum* and *T. dicoccum*. Jour. Agr. Res. 19:523-542. 1920.
6. McFADDEN, E. S. A successful transfer of emmer characters to *vulgare* wheat. Amer. Soc. Agron. Jour. 22:1020-1034. 1930.
7. ——— Brown necrosis, a discoloration associated with rust infection in certain rust-resistant wheats. Jour. Agr. Res. 58:805-819. 1939.
8. NEWMAN, L. H., FRASER, J. G. C., and WHITESIDE, A. G. O. Handbook of Canadian spring wheat varieties. Canad. Dept. Agr. Pub. 538. 1939.
9. STAKMAN, E. C., LEVINE, M. N., and LOEGERING, W. Q. Identification of physiologic races of *Puccinia graminis tritici*. U. S. Dept. Agr., Bur. Ent. and Pl. Quar. E-617, 26 pp. (multigraphed). 1944.
10. ——— LOEGERING, W. Q., CASSELL, R. C., and HINES, LEE. Population trends of physiologic races of *Puccinia graminis tritici* in the United States for the period 1930 to 1941. Phytopath. 33:884-898. 1943.
11. STOA, T. E., HARRIS, RAE H., and SIBBITT, L. D. The comparative performance of some new varieties of hard red spring wheat. N. Dak. Agr. Expt. Bimo. Bul. 2(3):3-8. 1940.
12. WALDRON, L. R. Hybrid selections of Marquis and Kota. N. Dak. Agr. Expt. Sta. Bul. 200. 1926.
13. ——— and CLARK, J. A. Kota, a rust-resisting variety of common spring wheat. Amer. Soc. Agron. Jour. 11:187-195. 1919.