SURVEY OF WHEAT AND WHEAT RELATIVES FOR RESISTANCE TO *PUCCINIA GRAMINIS TRITICI*, PHYSIOLOGIC RACE 15 B

by

ROBERT PAUL SEIFERT

B. S., Kansas State College
of Agriculture and Applied Science, 1950

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1952

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INTRODUCTION

In recent years, two factors have contributed to the decrease in the frequency and severity of stem rust epiphytotics in the wheat growing regions of North America. According to Hart (1944), one of these factors has been the eradication of barberry, the alternate host of *Puccinia graminis tritici*, a program which began in 1918 and is still in operation (Stakman et al., 1950). Hart (1944) stated that the eradication of many millions of these plants has probably been important in decreasing both the quantity and diversity of early inoculum of wheat stem rust. She also stated that the development and widespread use of resistant varieties is another important factor which has contributed to the decrease in frequency and severity of stem rust epiphytotics in wheat. This is due to the fact that the use of resistant wheat varieties has reduced the chance for rapid multiplication of inoculum.

Although much progress has been made in barberry eradication and in the development and use of resistant varieties, two factors still complicate the stem rust problem in North America. New physiologic races may occur through natural means (Hart, 1944) and the prevalence of the various races may change from year to year (Stakman et al., 1943). Due to changes in race prevalence, varieties resistant to stem rust one year may be susceptible the following year. This greatly complicates the task of maintaining varieties resistant to stem rust.

In 1950, a virulent physiologic race of stem rust, identified as race 15 B, became a new threat to wheat production in North America. This race is a threat to the wheats now grown commercially in the United States and Canada because no varieties available commercially are known to be resistant (Hart, 1944).

It is important, therefore, that wheats being used as parental material in current breeding programs, and new hybrids in the process of being developed, be tested for their reaction to this new race. Such a program may isolate resistant types which can be utilized in breeding projects. This will be necessary if the threat presented by this new race is to be met successfully.

The purpose of the work described in this thesis was to test wheat varieties, un-named selections, and selections from species and generic crosses for their reaction to race 15 B. The practical objective was to find resistant parental material, if any, to utilize in the breeding of hard red winter wheat.

LITERATURE REVIEW

Factors Affecting Stem Rust Epiphytotics

Stakman (1947a) stated that urediospores, and in some cases mycelia, of _P_. _graminis tritici_ may overwinter in Mexico and southern Texas on fall sown wheat. In the spring these urediospores are blown northward by the prevailing southerly winds. If environmental conditions are favorable, secondary cycles result in a build-up of inoculum as the rust progresses northward. In the fall, urediospores are blown back south from the spring wheat area in Canada and the northern United States. As a result, heavy fall infections may develop on volunteer wheat in the main winter wheat belt. Urediospores from these are blown into southern Texas and Mexico, where the rust overwinters on fall sown wheat as previously mentioned.

Hart (1944) stated that the severity of a stem rust epiphytotic depends primarily on the presence of virulent and viable inoculum near the growing wheat, and on the environmental conditions throughout the growing season. She also stated that environmental conditions play as important a part in stem rust epiphytotics as does the presence of abundant inoculum. Even when abundant early inoculum is present, the amount of infection on a variety varies not only from season to season but also within the same season.

Temperature and humidity are two very important environmental factors affecting stem rust epiphytotics. According to Stakman and Piemeisel (1917), a high relative humidity, and moderate temperatures up to about 75 degrees F. seem to be favorable to stem rust development.

Several workers have studied the effects of temperature on the reaction of wheat varieties to stem rust. Johnson and Newton (1941a) tested a number of wheat varieties in the adult plant stage in the greenhouse to races 15, 21, and 56 at three different temperatures. A constant low temperature (about 50 degrees F.), a constant high temperature (about 80 degrees F.), and an intermediate fluctuating temperature (50-85 degrees F.) were the three temperatures used. They found that the reaction of the varieties Gaza, Iumillo, Red Egyptian, Egypt Na 95, Hope, and Bobin-Gaza-Bobin to these races was little influenced by temperature. The reaction to these races of the varieties McMurachy, Kenya R.L. 1373[1], and Eureka was more or less broken down by high temperatures.

Greenhouse tests, in the seedling stage, with races 15, 17, 19, 21, 29, 32, 36, 38, 48, 56, and 152 at a constant low temperature (about 60 degrees F.) and at a constant high temperature (about 83 degrees F.) also were conducted by these workers. In general, the seedling response to temperature was

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[1] R. L.--Dominion Laboratory of Cereal Breeding Accession Number.

very similar to that exhibited in the adult plant stage. At the low temperature the varieties Iumillo, Gaza, Bobin-Gaza-Bobin, Red Egyptian, Kenya R.L. 1373, and McMurachy were immune or highly resistant to all eleven races. The variety Hope was susceptible to races 15, 17, 21, 29, and 32.

Thus it appears that temperature may have an effect on the reaction of some varieties to specific physiologic races in both the seedling and adult plant stages. According to Newton et al. (1940), the breakdown of the resistance of some varieties due to high temperatures is probably not of great significance so far as field resistance is concerned, except in regions where temperatures are excessively high for considerable periods of time.

Physiologic Races of Stem Rust

A physiologic race may be defined as an intraspecific biotype or group of biotypes, not readily distinguishable morphologically but distinguishable physiologically (Stakman, 1928, 1947b). According to Stakman et al. (1944), physiologic races of P. graminis tritici are identified or distinguished, one from the other, by use of a series of twelve differential varieties belonging to the genus Triticum. The process of race identification is accomplished by inoculating a set of these twelve varieties, in the seedling stage, with a given urediospore collection. By comparing the reactions obtained, with a previously prepared key and table which give the known reaction of each differential variety to each race previously identified, the race or races in a collection are determined.

Stakman et al. (1944) stated that the twelve varieties now used to identify physiologic races of P. graminis tritici are Little Club (Triticum compactum); Marquis, Reliance, and Kota (T. vulgare); Einkorn (T. monococcum); and Arnautka, Mindum, Spelmar, Kubanka, and Acme (T. durum). At least 189 physiologic races have been identified using these differential varieties.

It is believed that new physiologic races of P. graminis tritici, such as 15 B, arise by hybridization and recombination through the medium of the barberry (Hart, 1944). Newton and Johnson (1932) selfed eight races of P. graminis tritici and found that only one of the races bred true for pathogenic characters. Thirty different races were found among the progeny of these eight selfed races, and of these 30 races obtained, 12 had not previously been described.

Stakman et al. (1950) conducted some selfing studies on three cultures of the race 15 group. They came to the conclusion from the limited data obtained that

> race 15 is not a unit genotypically, and that aecia derived from it may give rise to a considerable number of races that differ markedly in ability to attack durum wheats, but, for the most part, have in common the ability to attach Vernal emmer.

In crosses between different races of *P. graminis tritici* Newton and Johnson (1932) reported that the F_1 was either pathogenically identical with one or the other of the parent races, or it differed from both. Some of the F_1's appeared to be intermediate in pathogenicity between the two parents. Occasionally an F_1 was found which exhibited greater virulence than either parent on a certain host variety.

Newton and Johnson (1932) also stated that in the F_2 and F_3 generations (obtained by selfing the F_1 and F_2 generations respectively) they found that segregation and recombination for pathogenicity appeared to occur in a Mendelian manner, although several factors appeared to be involved. The results in the F_3 generation indicated that some of the F_2 lines were heterozygous and some were homozygous for pathogenicity. As new races can be produced by selfing and hybridization in the laboratory, it is reasonable to expect this to occur in nature.

There is also evidence to indicate that new races arise by mutation. Stakman et al. (1930) found a new race that probably occurred as a mutation in a uredial culture of race 1, of *P. graminis tritici*. This new race, designated as race 60, remained constant for many years and differed pathogenically from any that had previously been identified. Races 21 and 17 also arose from race 1.

Newton and Johnson (1939) found a mutation in a culture of race 52 of *P. graminis tritici* which had remained stable for almost two years. The mutation occurred during a sixmonth storage period, during which the urediospores of the culture were stored at 8 degrees C. in a refrigerator. The new race was designated as race 178.

Johnson and Newton (1946) reported that mutation in *P. graminis tritici* does not occur with equal frequency in all races. They state that mutation occurs only in a few races which become unstable. These unstable races may produce several different races by mutation, or may mutate to the same race a number of times. There appears to be sufficient evidence that new races may arise by mutation under laboratory conditions, and therefore there seems to be no reason why mutation should not be a factor in the production of new races in nature.

According to Stakman (1947a), the possibility of the introduction of races into an area from another geographical area also exists. Such agencies as wind are especially important in the case of stem rust, as urediospores can germinate after being carried great distances by the wind.

Prevalence, Change, and Distribution of Physiologic Races of Stem Rust

Changes in prevalence among existing physiologic races of stem rust is nothing new, having occurred frequently in the past (Stakman et al., 1943). In some instances an obscure race has in a few years become the most important race in an area, and has severely attacked wheat varieties which were resistant to the races previously prominent in that area (Hart, 1944).

According to Newton and Johnson (1946), races 36, 17, and 21 of P. graminis tritici predominated in the wheat belts of North America until early in the 1930's. The varieties grown in the spring wheat belt of Canada and the northern United States at that time included Hayne's Bluestem, Marquis, Red Fife, and others. These varieties were susceptible to races 36, 17, and 21 and were severely attacked by them in those years when environmental conditions were favorable for stem rust epiphytotics. Stakman (1947c) stated that these varieties were so severely damaged by stem rust, that many farmers began growing the more resistant durums in place of the susceptible bread wheats.

Clark and Quisenberry (1942) reported that Ceres wheat was distributed to farmers in the spring wheat area in 1925. Johnson and Newton (1941b) stated that it appeared to have good resistance to races 21, 34, 36, 38, and 49 of stem rust, which were the prevalent races during the first few years following its release. According to Stakman (1947b), Ceres soon became widely grown, because of its stem rust resistance, and occupied most of the spring wheat acreage in the Dakotas, Minnesota, and a considerable acreage in Canada. It replaced older susceptible varieties such as Marquis and Hayne's Bluestem.

Stakman (1947b) also stated that Ceres was susceptible to race 56, a race which was first identified in 1928, three years after the release of Ceres. With the widespread use of Ceres, race 56 increased in prevalence until in 1934 it became the most prevalent race of wheat stem rust in North America. In the fall of 1934 and spring of 1935, conditions were very favorable for a stem rust epiphytotic. Due to the prevalence of race 56, Ceres was so severely attacked in this epiphytotic that it was soon replaced by other varieties, especially Thatcher, which had been released to farmers in the spring wheat belt in 1934 (Stakman et al., 1943).

Stakman et al. (1943) also stated that Thatcher has good resistance to race 56 and is highly resistant to races 17, 19, 21, and 49. According to Stakman and Loegering (1942), if races 56 and 17 continue to be important, Thatcher should continue to exhibit good stem rust resistance. It is, however, susceptible to several races of stem rust which are unimportant at the present time (Stakman et al., 1943).

Although Thatcher was highly resistant to stem rust, it proved to be very susceptible to leaf rust and therefore has been largely replaced (McFadden, 1949) by other recently released varieties such as Newthatch, Rival, Pilot, Regent, Renown, and Mida. These latter varieties have better leaf rust resistance than Thatcher and are resistant to the most prevalent races of stem rust but are susceptible to race 15 B, as is Thatcher (Goulden et al., 1949). Therefore if race 15 B were to become prevalent, these commercially grown varieties would be severely rusted should environmental conditions favorable to a stem rust epiphytotic occur (Hart, 1944).

The seriousness of the situation is indicated by the fact that race 15 B spread rapidly in 1950. Stakman et al. (1950) stated that more than 25 percent of the stem rust isolates from collections made in 1950 were this race. Stakman et al. (1950) also stated that in 1950 race 15 B was collected in 15 states and caused heavy damage to durum wheats in northern Minnesota and North Dakota.

History of Race 15 B

According to Stakman et al. (1950), race 15 B is the most virulent race of stem rust ever found in North America. Race 15 has been known in the United States since 1918. The virulent biotype B, however, was first identified as such in the United States from a collection taken from barberry near Fort Dodge, Iowa in 1939. Race 15 B probably existed in the United States before 1939 as some collections of race 15 were recorded as being more virulent than others, but no variety capable of distinguishing between the two biotypes of race 15 was known. Loegering and Stakman (1942) stated that Rival is now frequently used to distinguish between these two biotypes.

According to Goulden et al. (1949), race 15 B was not collected in Canada until 1946. Stakman et al. (1950) stated that the designation now denoted as 15 B may include a number of virulent biotypes which are similar to each other in some respects but differ in other respects.

Reaction of Varieties to Race 15 B

Hart (1943) found *Triticum timopheevi* to be susceptible in the seedling stage in the greenhouse and moderately susceptible in the field to race 15 B. She believes that *T. timopheevi* and many of its hybrids might be severely injured if race 15 B should become prevalent.

Johnson 1949 in field experiments found that race 15 B was much more virulent toward the varieties Vernal, Rival, Regent, McMurachy, and Iumillo, and somewhat more virulent on Red Egyptian and *T. timopheevi* than race 15 A. He found that the varieties Hope, Regent, and Redman appeared to possess no seedling resistance to either biotype of race 15, but did possess a degree of adult plant resistance to race 15 A although not to 15 B. He believed that under the conditions at Winnipeg, Canada, the varieties Kenya R.L. 1373, McMurachy, and Red Egyptian might suffer moderate damage from 15 B.

Hart (1944) tested 22 advanced hybrids from the hard red winter wheat area and found all were susceptible in the greenhouse to race 15 B. These hybrids were planted in the field and all were severely rusted. Race 15 B was identified in 14 of 21 uredial collections made from these varieties.

Inheritance of Resistance to Race 15 B

Lejeune (1947) tested 28 named varieties of barley and 41 advanced barley hybrids in the adult stage in the field to race 15 B of *P. graminis tritici*. He found that the reaction of all varieties to race 15 B, as compared to their reaction with a group of other races, was essentially the same. He concluded that the adult plant reaction of the barley varieties studied, to race 15 B, was governed by the same gene or genes as those which control the adult plant reaction of these barley varieties to the other races of stem rust studied.

Shebeski (1946) studied the inheritance of resistance to race 15 B in the F_2 and F_3 generations of various wheat crosses involving eight parental varieties. He concluded that the resistance of each of the varieties Kenya R.L. 1373, McMurachy, and Red Egyptian to race 15 B was governed by one main recessive factor pair. It was also found that in each of these three varieties, one gene governed the resistance both to 15 B and to common races of stem rust. The gene for resistance was found to be allelic and possibly identical in the varieties Kenya, McMurachy, and Red Egyptian.

Shebeski (1946) also studied the resistance of Egypt Na 95 in the F_2 generation and found that in this variety moderate resistance was partially dominant. The varieties Minor and R.L. 1544, although susceptible to race 15 B, were found to have minor factors for resistance complementary to each other and to minor factors in McMurachy and Red Egyptian. Studies in the F_2 generation of crosses involving the susceptible varieties Marquis and H-44-24 indicated that they had no appreciable major or minor factors for resistance complementary to factors for resistance in the other parental varieties studied.

Breeding for Stem Rust Resistance

According to Clark and Quisenberry (1942), Ceres wheat was distributed to farmers in 1925. It was a selection from the cross Kota X Marquis. Johnson and Newton (1941b) stated that it was resistant to races 21, 34, 36, 38, and 49 of *P. graminis tritici* but susceptible to race 56. Ceres was severely attacked in the stem rust epiphytotic of 1935 and was replaced by more resistant varieties (Stakman et al., 1943).

Stakman et al. (1943) stated that Thatcher was a selection from the double cross, (Marquis X Iumillo) X (Marquis X Kanred). It had resistance to several physiologic races derived from its Kanred parent. Thatcher also had considerable adult plant resistance to stem rust derived from its Iumillo durum parent. As Thatcher had good resistance to race 56 and was highly resistant to race 17, the two most prevalent races of stem rust (Stakman and Loegering, 1942), it exhibited good field resistance to this disease. It was, however, susceptible to other less common races including 36 and 15 B (Stakman et al., 1943).

According to Stakman (1947c), there was a decrease in the acreage of Thatcher grown because of its susceptibility to leaf rust and scab. The new hybrids that were developed and released in the spring wheat area derived their stem rust resistance almost exclusively from the varieties Hope or H-44 (McFadden, 1949). Peterson (1940) stated that these two vulgare type wheats were developed by McFadden from a cross made in 1916 between Marquis wheat and Yaroslav emmer. These varieties have been used extensively in breeding programs because of their ability to transmit stem and leaf rust resistance to many of the now prevalent races to their progeny.

Ausemus et al. (1944), stated that Newthatch was produced by backcrossing a selection from the cross Hope X Thatcher to Thatcher twice. It had the good characteristics of Thatcher and in addition leaf rust resistance. According to Newman et al. (1946), many other varieties including Rival, Pilot, Regent, Renown, and Mida have recently been released in the spring wheat area. These varieties all depend on Hope or H-44 for their stem rust resistance. They exhibit resistance to the most prevalent races but are susceptible to race 15 B (Hart, 1944).

Stakman (1947c) stated that attempts are already being made to combine resistance to race 15 B with the desirable characteristics of commercial varieties, and experimental varieties in advanced stages of testing, by crossing these susceptible varieties with varieties resistant to 15 B. As it has been possible in the past to develop varieties resistant to new races, there seems to be reason to believe that this can be done in the case of race 15 B.

MATERIALS AND METHODS

Many selections and varieties in various stages of testing, and parental material currently being used in breeding programs in the hard red winter wheat belt, were obtained from experiment stations in Texas, Oklahoma, Colorado, Kansas, and Nebraska. A group of wheats currently being used in the breeding program of the Rockefeller Foundation in Mexico was obtained from Ignacio Narvaez. This group included selections from crosses involving the varieties Newthatch, Supremo, Kenya, Marroqui, and others. David Ward at Beltsville, Maryland provided a group of plant introductions which also were tested.

Another group of wheats comprised selections from *Triticum* X *Agropyron* crosses, McMurachy-Exchange X Redman crosses, Frontana crosses, Red Egyptian crosses, Bobin-Gaza-Bobin crosses, and Timstein crosses which were obtained from the Kansas Agricultural Experiment Station wheat breeding material. Selections from additional miscellaneous crosses were also obtained from this source.

The reaction in the seedling stage, to race 15 B of stem rust of approximately 1600 varieties and selections was determined in the greenhouse at Manhattan, Kansas, during the winter of 1950-1951. The culture of race 15 B of stem rust was kept isolated as much as possible by growing it in only one section of a greenhouse.

There was considerable variation in air temperature because no temperature control equipment for the greenhouse was available. The temperature as recorded by a thermograph varied between 65 degrees and 85 degrees Fahrenheit. The lower temperatures occurred during the nights while the higher ones were recorded during the middle of warm bright days.

The original uredial culture used in this experiment was obtained from C. O. Johnston. It was checked frequently by him for purity with a set of differential varieties.

As little work was being done with other races of stem rust in other sections of the greenhouses, no difficulty was encountered in keeping the culture of race 15 B free from contamination by other stem rust races. Several races of leaf rust, Puccinia rubigo-vera tritici, were being cultured in other sections of the greenhouses, and consequently trouble was encountered in preventing contamination by them. This was due in large part to the fact that the leaf rust spread naturally in the greenhouses and had a tendency to be more aggressive than the stem rust.

In order to hold leaf rust contamination to a minimum, the variety La Prevision 25 was used as the host on which the inoculum was increased. This variety was selected for this purpose because it was very susceptible to race 15 B of stem rust, but was resistant to most physiologic races of leaf rust. It was hoped that La Prevision 25 would screen out any leaf rust which might be contaminating the culture. It proved effective in accomplishing this purpose, but due to the fact that the seed supply was short, an attempt was made to use winter barley as the host for the stock culture.

A group of winter barley varieties was planted and inoculated with race 15 B, to determine which variety was most susceptible to this race of stem rust. The variety Ludwig was found to be sufficiently susceptible so that this race could be successfully transferred from it, and to be resistant enough to leaf rust to aid in keeping leaf rust from contaminating the culture. By using both Ludwig barley and La Prevision 25 wheat, the culture of race 15 B was kept practically free of contamination by leaf rust.

Twenty-five seeds of each variety or selection to be tested were counted out and planted in a three inch flower pot. The pots were arranged in ten pot X ten pot squares to facilitate inoculation. One-hundred pots (a full ten X ten square) were planted at a time. The varieties Cheyenne, Rival, and Lee were included as checks with each set of 100 pots.

Cheyenne was used as a fully-susceptible check to measure the level of infection. The varieties Rival and Lee were grown to test the purity of inoculum, as they were susceptible to race 15 B but resistant to other races of stem rust and to leaf rust.

After the plants were nine to ten days old, they were considered to be at the proper stage of growth for inoculation. A portable moist chamber, constructed by stretching canvas over a wooden frame, was placed over the plants to maintain a high humidity in the air surrounding them during the time they were being inoculated. It was constructed in such a manner that it just enclosed the 100 pots in each set. The moist chamber was moved from set to set as the plants reached the proper age for inoculation.

Inoculations were made in the evening in order to take advantage of any increase in relative humidity and decrease in temperature that occurred during the night. Before applying the urediospores from the pots of stock culture, the plants being inoculated were sprayed with a fine mist of tap water using an ordinary knapsack sprayer. Rusted seedlings of the stock culture, also growing in three inch pots, were then brushed over the plants being inoculated. The moisture provided by the spray aided the urediospores in adhering to the plants being inoculated. Three pots of rusted stock culture plants were used to inoculate each set of plants. In brushing the seedlings with infected plants, care was taken to see that plants in all parts of the moist chamber were contacted. Brushings were made from front to rear, side to side, and diagonally across the moist chamber.

After the inoculum was applied, the plants were again sprayed with a fine mist of water. The purpose of this spray was to insure an abundance of free moisture, and a high initial humidity in order to facilitate germination of the urediospores. The portable canvas moist chamber was kept damp for 24 hours in order to maintain a high humidity in the air surrounding the inoculated plants. After 24 hours, the moist chamber was removed and the plants left in place on the bench for the infection to develop.

The varieties and selections being tested were classified as to infection type and reaction class 14 days after inoculation. The infection type was determined by observing the pustules on the primary leaves. The following infection types as described by Stakman et al. (1944) were used:

(0)-No uredia developed; hypersensitive flecks sometimes present and designated by a semicolon, thus, 0;

(1)-Uredia minute; surrounded by distinct necrotic areas

(2)-Uredia small to medium; usually in green islands surrounded by a decidedly chlorotic or necrotic border

(3)-Uredia medium in size; coalescence infrequent; no necrosis, but chlorotic areas may be present, especially under unfavorable growing conditions

(4)-Uredia large, and often coalescing; no necrosis, but chlorosis may be present under unfavorable growing conditions

(X)-Uredia variable, sometimes including all infection types and intergradations between them on the same leaf; no mechanical separation possible; on reinoculation small uredia may produce large ones, and vice versa

The three rust reaction classes used were resistant, mesothetic, and susceptible. According to Stakman et al. (1944), the rust reaction class resistant includes infection types 0, 1, and 2; the rust reaction class mesothetic includes the infection type X; and the rust reaction class susceptible includes infection types 3 and 4.

The segregations 1-4 and 2-4 were used to indicate that the plants in a pot were segregating for resistance to race 15 B of stem rust. The designation 1-4 was used to indicate that some of the plants in a pot gave an infection type of 1, while the other plants in the pot gave an infection type 4. The designation 2-4 was used to indicate that some of the plants in a pot gave an infection type of 2, while the other plants in the pot gave an infection type of 4.

EXPERIMENTAL RESULTS

The results obtained with the material tested from the various experiment stations in the hard red winter wheat region and from the Rockefeller Foundation will be discussed first. This will be followed by a discussion of the material tested from the Kansas Experiment Station.

Current Breeding Material in Use in the Hard Red Winter Wheat Region

This group of material, from experiment stations in the hard red winter wheat region, was tested in order to ascertain whether any of the material currently in use in this area was resistant to race 15 B. So far as is known this material had not heretofore been tested with this race.

The results obtained are summarized in Table 1. Resistant selections were found in only two out of the 11 crosses tested from the Colorado Experiment Station. In both crosses the variety Red Egyptian was the source of resistance.

Fifty crosses in advanced generations were tested from the Kansas Experiment Station. This material consisted of the wheats in the 1951 Advanced Rod Row and Uniform Yield Nurseries. These selections have survived for several generations because they exhibited good agronomic characteristics, baking qualities, insect and disease resistance, or a combination of several of these attributes. None of these selections was found to be resistant to race 15 B of stem rust.

Table 1. The seedling reaction of current breeding material in use in the hard red winter wheat region to race 15 B of stem rust.

Kind	Source	No. sel. tested	No. sel. with inf. type and react. indicated: Resistant: 1	1-2	2	1-4	Seg.: 2-4	Susceptible: 3	3-4	4	Meso.: X
Marmin-McMurachy X Hope-Mediterranean X Early Blackhull	Colo.	7	-	-	-	-	-	4	2	-	1
(Marmin X McMurachy) X (Hope-Mediterranean) X (Early Blackhull X Marmin)	Colo.	7	-	-	-	-	-	-	5	1	1
(Marquillo-Oro X Oro-Tenmarq) X (Mediterranean-Hope X Pawnee)	Colo.	5	-	-	-	-	-	2	2	-	1
Red Egyptian X Triumph	Colo.	4	-	-	1	-	-	2	1	-	-
Red Egyptian X Red Chief	Colo.	3	-	-	1	-	2	-	-	-	-
Six other crosses	Colo.	8	-	-	-	-	-	-	3	3	2
IVcl-Comanche X Pawnee-Comanche	Kans.	7	-	-	-	-	-	-	5	2	-
Marquillo-Oro X Pawnee	Kans.	5	-	-	-	-	-	-	-	5	-
(Mediterranear-Hope X Pawnee) X (Oro-Illinois No. 1 X Comanche)	Kans.	8	-	-	-	-	-	-	-	8	-
Forty-seven other crosses	Kans.	63	-	-	-	-	-	-	4	59	-
Cheyenne X _Triticum timopheevi_ hybrid	Nebr.	12	-	-	-	-	-	-	3	7	2
Cheyenne selection X _T. timopheevi_ hybrid	Nebr.	12	-	-	-	-	-	-	-	9	3
T. timopheevi hybrid X Nebred	Nebr.	2	-	-	-	-	-	-	-	-	2
Hope X Timstein	Nebr.	1	-	-	1	-	-	-	-	-	-
IVcl X Comanche	Nebr.	1	-	-	1	-	-	-	-	-	-
Kenya-Florence-Dundee-Early Blackhull	Nebr.	12	-	-	-	-	-	5	7	-	-
Marquillo-Oro X Triunfo	Nebr.	2	-	-	2	-	-	-	-	-	-
Marquillo-Oro-Pawnee X Frontana	Nebr.	16	-	-	5	-	2	4	1	4	-
1750 X Timstein	Nebr.	1	-	-	1	-	-	-	-	-	-
1764 X Timstein	Nebr.	2	-	-	1	-	-	1	-	-	-
1764 X Henry	Nebr.	1	-	-	1	-	-	-	-	-	-
Thirteen other crosses	Nebr.	17	-	-	-	-	-	5	6	5	1
(Chinese-rye X _Agropyron elongatum_) X Forward	Okla.	7	-	-	-	-	-	3	4	-	-
(Kawvale-Marquillo X Tenmarq) X (Kawvale-Marquillo X Kawvale-Tenmarq)	Okla.	6	-	-	-	-	-	1	4	1	-

Table 1. (concl.)

Kind	Source	No. sel. tested	Resistant: 1	1-2	2	Seg.: 1-4	2-4	Susceptible: 3	3-4	4	Meso.: X
			No. sel. with inf. type and react. indicated								
Nebred X (Mediterranean-Hope X Pawnee)	Okla	5	-	-	-	-	-	3	1	-	1
Rye X wheat	Okla.	2	-	-	-	2	-	-	-	-	-
Triticum X Agropyron elongatum	Okla.	1	-	-	1	-	-	-	-	-	-
Triticum-Agropyron elongatum X Pawnee	Okla.	6	-	-	-	-	5	-	1	-	-
Thirty other crosses	Okla.	39	-	-	-	-	-	4	26	9	-
Chiefkan X Marquillo-Oro	Texas	3	-	-	1	-	-	1	1	-	-
(Comanche X Honor-Forward) X (Hope-Mediterranean X Comanche)	Texas	2	-	-	-	-	-	-	2	-	-
Fronteira X Red May[2]	Texas	3	-	-	-	-	-	3	-	-	-
Fronteira X Tenmarq	Texas	3	-	-	1	1	-	1	-	-	-
Hope-Mediterranean X Comanche	Texas	2	-	-	-	-	-	2	-	-	-
(Kenya X Pawnee) X Hope-Turkey	Texas	5	-	-	4	-	-	-	1	-	-
(Kenya X Red Chief) X Hope-Turkey	Texas	1	-	-	1	-	-	-	-	-	-
Quanah	Texas	1	-	-	-	-	-	-	1	-	-
(Selection 29-34-275 X Fronteira) X (selection 29-34-275 X Comanche)	Texas	5	-	-	-	-	2	-	3	-	-
(Sinvalocho X Wichita) X Hope-Cheyenne	Texas	3	-	-	1	-	-	2	-	-	-
Sinvalocho X Wichita) X Hope-Cheyenne) X Wichita	Texas	3	-	-	-	-	-	3	-	-	-
(Triticum dicoccoides X Aegilops speltoides) X Austin[2]	Texas	13	1	8	2	1	1	-	-	-	-
[(T. timopheevi X Aegilops squarrosa) X (Illinois No. 1 X Chinese)] X Newthatch	Texas	8	-	-	-	-	-	-	2	4	2
Cheyenne (check)	-	-	-	-	-	-	-	-	-	1	-
Rival (check)	-	-	-	-	-	-	-	-	1	-	-
Lee (check)	-	-	-	-	-	-	-	-	1	-	-

Selections from 24 crosses from the Nebraska Experiment Station were tested. Resistant selections were found in seven of these crosses. The seven crosses in which resistant selections were found were Hope X Timstein, IVcl X Comanche, Marquillo-Oro X Triunfo, Marquillo-Oro-Pawnee X Frontana, 1750 X Timstein, 1764 X Timstein, and 1764 X Henry.

Resistant selections were found in six of the 13 crosses tested from the Texas Experiment Station. Of particular interest are the crosses Chiefkan X Marquillo-Oro and (Sinvalcho X Wichita) X Hope-Cheyenne. In each of these crosses one resistant selection was found. None of the varieties involved in these two crosses has been found to be resistant to race 15 B. Other resistant selections were found in the crosses Fronteira X Tenmarq, (Kenya X Pawnee) X Hope-Turkey, (Kenya X Red Chief) X Hope-Turkey, and (*Triticum dicoccoides* X *Aegilops speltoides*) X Austin^2. There were more selections with high resistance in the latter cross than in any of the other crosses listed in Table 1.

Wheats From the Rockefeller Foundation

The wheats of this group from the Rockefeller Foundation are adapted to Mexico. They are spring-like in growth habit and somewhat softer in kernel texture than the true hard wheats. They were tested because of the importance to the wheat regions, of the United States and Canada, of the resistance or susceptibility to stem rust of wheats grown in Mexico.

The results obtained with this group of material are summarized in Table 2. Results from seven crosses received from David Ward are included in this table because they also originated in the experiments of the Rockefeller Foundation in Mexico.

The varieties listed in the forepart of Table 2 were included in the material obtained from the Rockefeller Foundation, but it is not known whether or not they are the actual parents involved in the crosses that follow. Three of these varieties were found to be resistant to race 15 B. These were the varieties Candeal, Kenya, and Mentana. Resistant selections were found in many of the crosses involving these varieties as is shown in Table 2. In addition, resistant selections were found in the crosses Egypt 101 X Timstein, Gabo X (Peru-Supremo) X Peru, Maria Escobar X Newthatch-Peru, and (Peru-Supremo)-Peru. Susceptible as well as resistant selections were found in the crosses Kenya X Mentana and (Mentana X Kenya) X Mentana. The one selection tested of the cross (Mentana X Kenya) X $Mentana_2$ was susceptible. The relatively high air temperature in the greenhouse may have been responsible for susceptible selections in these crosses involving only the resistant varieties Kenya and Mentana.

Table 2. Seedling reaction of wheat strains from the Rockefeller Foundation to race 15 B of stem rust.

Kind	No. sel. tested	No. sel. with inf. type and react. indicated								
		Resistant				Seg.	Susceptible			Meso.
		0;-1	1	1-2	2	1-4	3	3-4	4	X
Aquilera 48	1	-	-	-	-	-	-	-	1	-
Candeal	1	-	-	-	1	-	-	-	-	-
Hopings 48	1	-	-	-	-	-	-	-	1	-
Kenya	1	1	-	-	-	-	-	-	-	-
Marroqui	1	-	-	-	-	-	-	-	1	-
Mayo 48	1	-	-	-	-	-	-	-	1	-
Mentana	1	-	-	-	1	-	-	-	-	-
Nazos 48	1	-	-	-	-	-	-	1	-	-
Newthatch	1	-	-	-	-	-	-	-	1	-
Supremo	1	-	-	-	-	-	-	1	-	-
Yaqui 48	1	-	-	-	-	-	-	-	1	-
(Aquilera X Kenya) X Kenya	2	-	-	-	-	-	1	-	-	1
(Aquilera X Kenya) X Newthatch	2	-	-	-	-	-	1	-	1	-
Aquilera-Kenya X Marroqui-Supremo*	1	-	-	-	-	-	-	-	-	1
(Candeal X Newthatch) X Candeal	1	-	-	-	-	-	1	-	-	-
Egypt X Kenya	1	1	-	-	-	-	-	-	-	-
Egypt 101 X Timstein	2	1	-	-	-	-	-	1	-	-
Gabo X (Peru-Supremo) X Peru*	1	-	-	-	1	-	-	-	-	-
Kenya X Marroqui	1	-	-	-	-	-	-	-	1	-
(Kenya X Marroqui) X Marroqui	1	-	-	-	-	-	-	-	1	-
(Kenya-Marroqui^2) X Peru*	1	-	-	-	1	-	-	-	-	-
Kenya X Mentana	5	-	1	1	1	-	1	-	1	-
(Kenya X Mentana) X Mentana	2	-	1	1	-	-	-	-	-	-
Kenya X Peru	1	-	-	-	-	-	-	-	-	1
Kenya X Supremo	1	-	-	-	-	-	-	-	-	1
Kenya-Supremo X Ramona*	1	-	-	-	-	-	-	-	1	-
Maria Escobar X Newthatch-Peru*	1	-	-	-	1	-	-	-	-	-
(Marroqui X Newthatch) X Newthatch	25	-	-	-	-	-	-	-	15	10
(Marroqui X Supremo) X Marroqui	3	-	-	-	-	-	-	-	-	3
(Marroqui$_{588}$ X Supremo) X Marroqui$_{588}$	2	-	-	-	-	1	-	-	1	-

Table 2. (concl.)

Kind	No. sel. tested	No. sel. with inf. type and react. indicated: Resistant 0;-1	Resistant 1	Resistant 1-2	Resistant 2	Seg. 1-4	Susceptible 3	Susceptible 3-4	Susceptible 4	Meso. X
(Marroqui$_{386}$ X Supremo) X Supremo	1	-	-	-	-	-	-	-	-	1
(Marroqui X Supremo) X (Ramona$_3$ X Marroqui)	1	-	-	1	-	-	-	-	-	-
Mayo X (Peru-Supremo) X (Peru-Kenya)*	1	-	-	-	1	-	-	-	-	-
Mentana X Kenya	2	-	2	-	-	-	-	-	-	-
(Mentana X Kenya)X Kenya	3	-	-	-	2	-	-	-	1	-
(Mentana X Kenya) X Mentana	24	-	1	5	3	-	4	6	5	-
(Mentana X Kenya) X Mentana$_2$	1	-	-	-	-	-	-	1	-	-
Mentana X Supremo	2	-	2	-	-	-	-	-	-	-
(Mentana X Supremo) X Mentana	1	1	-	-	-	-	-	-	-	-
Newthatch X Aquilera	3	-	-	-	-	-	-	-	3	-
Newthatch X Candeal	1	-	-	-	-	-	-	1	-	-
Newthatch X Marroqui	33	-	-	-	-	-	1	9	11	12
Newthatch X Marroqui$_{588}$	2	-	-	-	-	-	-	1	1	-
(Newthatch X Marroqui) X Marroqui	2	-	-	-	-	-	-	-	-	2
Newthatch-Marroqui X (Peru-Supremo)-Peru*	1	-	-	-	1	-	-	-	-	-
(Newthatch X Marroqui$_{588}$) X Marroqui$_{588}$	2	-	-	-	-	-	1	1	-	-
(Newthatch X Marroqui) X Newthatch	14	-	-	-	-	-	-	-	7	7
Peru X Supremo	4	-	1	-	-	2	1	-	-	-
Supremo X Baart	1	-	-	-	-	-	1	-	-	-
Supremo X Kenya	7	1	1	1	1	-	1	1	-	1
(Supremo X Marroqui$_{588}$) X Supremo	3	-	-	-	-	1	-	-	-	2
Supremo X Mentana	3	-	1	-	-	-	-	-	-	2
Supremo X Ramona	2	-	-	-	-	-	-	-	-	2
Timstein X Kenya	2	1	-	-	-	-	1	-	-	-
Cheyenne (check)	-	-	-	-	-	-	-	-	1	-
Rival (check)	-	-	-	-	-	-	-	1	-	-
Lee (check)	-	-	-	-	-	-	-	1	-	-

* From David Ward, Beltsville, Maryland.

Miscellaneous Parental Material

This material was a collection of un-named selections, varieties, and species related to wheat, which either had been used in crosses at the Kansas Experiment Station or could be used in crosses if they proved to be sources of resistance to race 15 B. They were tested in order to obtain an indication as to which of the many crosses available should be tested with race 15 B, and to determine which varieties might be used as parents in crosses to obtain new varieties resistant to 15 B.

The results obtained with this material are given in Table 3. The highest type of resistance found in this material was in the three selections from the cross (Chinese-*Agropyron elongatum*) X Chinese. The infection type in all three selections was classified as $0;-1^{-}$.[1] Other lines exhibiting a very high type of resistance were Egyptian Na 95, and the two Kenya selections, K58 and 117A. These three selections were given an infection type of 1. The varieties Red Egyptian and Timstein were only slightly less resistant with an infection type of 1^{+}.

The variety Gaza, and the two species *Aegilops cylindrica* and *Aegilops speltoides* gave a type 2 reaction. Webster exhibited an infection type of $2\text{-}2^{+}$ and Aegilops squarrosa, Gabo, Maria Escobar, McMurachy, and McMurachy-Exchange X Redman R.L. 2325, gave a 2^{+} infection type.

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[1] Plus and minus signs are used to indicate the upper and lower limits of the indicated infection type.

Table 3. Seedling reaction of species related to wheat, interspecific crosses, intergeneric crosses, and miscellaneous wheat varieties to race 15 B of stem rust.

Kind	P.I. or C.I. number	Infection type*	Reaction class**
Aegilops cylindrica	-	2	R
Aegilops squarrosa	-	2+	R-
Aegilops speltoides	-	2	R
Triticum orientale	P.I.135814	4	S
Triticum persicum	P.I.94755	4	S
Triticum pyramidale	P.I.133458	4	S
Triticum sovieticum	-	3	S
Triticum timopheevi	C.I.11802	2-3	R-
Vulgare X timopheevi	C.I.12661	4	S
Vulgare X timopheevi	C.I.12662	4	S
(Chinese-Agropyron elongatum) X Chinese, S-44-2-7	-	0;-1-	R+
(Chinese-A. elongatum) X Chinese, S-44-6	-	0;-1-	R+
(Chinese-A. elongatum) X Chinese, S-49-5	-	0;-1-	R+
Triticum dicoccoides X Aegilops speltoides	-	0;-1	R+
Triticum dicoccoides X Aegilops umbellulata	-	4	S
Triticum timopheevi X Aegilops squarrosa	-	3	S
Austin	-	3	S
Charter	P.I.155430	3	S
Egyptian Na 95	P.I.132107	1	R
Frondoso	C.I.12078	4	S
Frontana	C.I.12470	2-3-	R-
Fronteira	P.I.106503	3-4	S
Gabo	P.I.155431	2+	R-
Gaza	P.I.140959	2	R
Kenya, K58	C.I.12471	1	R
Kenya, 117A	C.I.12568	1	R
Kenya,338A,C.2E.2	P.I.187165	0-1	R+
Maria Escobar	P.I.150604	2+	R-
McMurachy	C.I.11876	2+	R-
Quequen	C.I.12574	4	S
Red Egyptian	C.I.12345	1	R

Table 3. (concl.)

Kind	P.I. or C.I. number	Infection type*	Reaction class**
Sibley 81	-	4	S
Surpreza	P.I.106505	4	S
Timstein	C.I.12345	1+	R
Webster	C.I.3780	2-2+	R
Bobin[2]-Gaza-Premier	-	4	S
Gullen X Gullen-Gaza	P.I.140961	3-4	S
McMurachy-Exchange X Redman,R.L.2325	P.I.187166	2+	R-
McMurachy-Exchange X Redman,R.L.2327	-	3+	S
McMurachy-Exchange X Redman[3],R.L.2535	-	3+	S
McMurachy-Exchange X Redman[3],R.L.2564	-	3	S
Cheyenne (check)	C.I.8885	4	R
Rival (check)	C.I.11708	3-4	R
Lee (check)	-	3-4	R

* Plus and minus signs are used to indicate the upper and lower limits of the indicated infection type.

** R- resistant
S- susceptible
Plus and minus signs are used to indicate the upper and lower limits of the indicated reaction class.

The variety Frontana gave an infection type of 2-3⁻ and *Triticum timopheevi* gave a reading of 2-3. These two lines were considered to be slightly resistant. Twenty other selections, varieties, and species tested were found to be susceptible to race 15 B.

Triticum X *Agropyron* Crosses

As earlier tests had indicated that some *Triticum* X *Agropyron* crosses had promising resistance to race 15 B, it was decided to test a large number of selections from such material that had been collected at the Kansas Agricultural Experiment Station. The results obtained with this material are summarized in Table 4. In the *Agropyron* X wheat cross both the exact *Agropyron* and exact wheat parent are unknown. Fifty-three bulked lines from this cross were tested and of these, 26 were resistant, seven were segregating for resistance, 16 were susceptible, and four gave a mesothetic reaction. Of the 68 individual plant selections tested from this cross, 53 were resistant, four were segregating for resistance, ten were susceptible, and one gave a mesothetic reaction.

Eight crosses involving *Agropyron elongatum* were tested. In the *Agropyron elongatum* X wheat cross, the exact wheat parent is unknown. The 89 individual plant selections tested from the cross (Chinese-*A. elongatum* X Chinese) X Pawnee were in the F_3 generation. Twenty-eight of these selections were

Table 4. The seedling reaction of segregates from *Triticum* X *Agropyron* crosses to race 15 B of stem rust.

Kind	Type of material*	No. lines tested	No. sel. with inf. type and reaction indicated: Resistant 0;-1	Resistant 1	Resistant 1-2	Resistant 2	Seg. 1-4	Seg. 2-4	Susceptible 3	Susceptible 3-4	Susceptible 4	Meso. X
Agropyron X wheat	bulk	53	11	11	2	2	7	-	-	4	12	4
Agropyron X wheat	sel.	68	8	45	-	-	3	1	-	-	10	1
Agropyron elongatum X wheat	bulk	19	2	9	2	1	-	2	1	1	-	1
A. elongatum X wheat	sel.	6	2	2	1	-	1	-	-	-	-	-
Kharkof X *A. elongatum*	bulk	1	-	1	-	-	-	-	-	-	-	-
(Chinese-*A. elongatum* X Chinese) X Pawnee	sel.	89	2	24	1	1	51	1	2	3	4	-
(Wheat-rye X *A. elongatum*) X Cheyenne	bulk	29	-	-	2	1	-	-	-	13	13	-
(Wheat-rye X *A. elongatum*) X Cheyenne	sel.	13	-	7	6	-	-	-	-	-	-	-
Chinese-rye X Chinese-*A. elongatum* X Forward	bulk	19	-	-	-	-	-	-	-	8	7	4
Chinese-rye X Chinese-*A. elongatum* X Forward	sel.	3	-	-	-	-	-	-	-	-	3	-
(Mediterranean-Hope X Pawnee) X (wheat X *A. elongatum*)	bulk	8	-	-	1	-	-	-	4	1	-	2
(Wheat X *A. elongatum* S4-207-8) X (Mediterranean-Hope X Pawnee)	bulk	2	2	-	-	-	-	-	-	-	-	-
Aegilops triuncialis X Peliss X Hard Federation X *A. elongatum* X VPI 131 and/or Harvest Queen	bulk	1	-	1	-	-	-	-	-	-	-	-
Aegilops triuncialis X Peliss X Hard Federation X *A. elongatum* X VPI 131 and/or Harvest Queen	sel.	6	-	2	4	-	-	-	-	-	-	-
White Odessa X *Agropyron glaucum*	bulk	9	2	2	-	-	-	-	-	-	4	1
White Odessa X *A. glaucum*	sel.	26	11	14	-	-	-	-	1	-	-	-
(Minturki X *Agropyron glaucum*) X Minturki	bulk	1	-	-	1	-	-	-	-	-	-	-
(Mindum X *Agropyron trichophorum*) X Red Chief	bulk	3	-	-	-	-	-	-	-	2	1	-
[(Mindum-*A. trichophorum*) X (Mediterranean-Hope X Pawnee)] X (Nebred X Ceres--H-44)	bulk	21	-	-	-	-	-	-	4	11	4	2

Table 4. (concl.)

Kind	Type of material*	No. lines tested	No. sel. with inf. type and reaction indicated: Resistant 0;-1	1	1-2	2	Seg. 1-4	2-4	Susceptible 3	3-4	4	Meso. X
(Mindum-A. trichophorum X Red Chief) X (Mediterranean-Hope X Pawnee)	bulk	2	-	-	-	-	-	-	1	-	1	-
{[(Mindum X A. trichophorum) X Red Chief] X (Mediterranean-Hope X Pawnee)} X (Timstein X Pawnee)	bulk	18	-	-	-	-	-	-	-	9	6	3
[(Mindum X A. trichophorum) X (Sinvalocho X Pawnee)] X (Marquillo-Oro X Hope-Kawvale)	bulk	5	-	-	-	-	-	-	-	5	-	-
Cheyenne (check)	-	-	-	-	-	-	-	-	-	-	1	-
Rival (check)	-	-	-	-	-	-	-	-	-	1	-	-
Lee (check)	-	-	-	-	-	-	-	-	-	1	-	-

* bulk - bulked seed of each line used.
sel. - seed from individual plant selections used.

resistant, 52 were segregating for resistance, and nine were susceptible. Resistant lines were found in all but one of the remaining six crosses involving A. elongatum.

In the cross White Odessa X Agropyron glaucum, nine bulked lines and 26 individual plant selections were tested. The highest type of resistance found in the entire experiment was found in some of the lines of this cross. The infection type of one of these lines was 0; as only flecks and no pustules were found. One bulked line of the cross (Minturki X A. glaucum) X Minturki was tested and found to be resistant.

Forty-nine lines from five crosses involving Agropyron trichophorum were tested. All 49 of these lines were found to be susceptible to race 15 B.

Miscellaneous Crosses

This was a group of miscellaneous crosses which was not classified under any of the other group designations. The results obtained with this material are summarized in Table 5.

Four Bobin-Gaza-Bobin crosses were tested with race 15 B. Of the 65 selections tested from these four crosses, 15 were resistant, four were segregating, and 46 were susceptible. The resistance in these crosses apparently was derived from the durum variety Gaza.

Four selections were tested from the cross Egypt Na 101 X Hope-Cheyenne. Three of these selections were found to be

Table 5. The seedling reaction of miscellaneous wheat crosses to race 15 B of stem rust.

Kind	Generation	No. sel. tested	No. sel. with inf. type and reaction indicated: Resistant 0;-1	1	1-2	2	Seg. 1-4	2-4	Susceptible 3	3-4	4	Meso. X
(Bobin-Gaza-Bobin) X Pawnee	F_6	12	-	-	-	7	-	-	3	2	-	-
(Bobin-Gaza-Bobin) X Pawnee	F_7	16	-	-	5	1	-	-	6	4	-	-
(Bobin-Gaza-Bobin) X Pawnee	F_9	4	1	-	-	-	-	2	1	-	-	-
(Bobin-Gaza-Bobin) X Comanche	F_6	1	-	-	-	-	-	-	1	-	-	-
(Bobin-Gaza-Bobin) X Oro	F_6	7	-	-	-	-	-	1	2	4	-	-
Tenmarq X (Bobin-Gaza-Bobin-Pawnee)	F_3	25	-	-	-	1	-	1	9	13	1	-
Egypt Na 101 X Hope-Cheyenne	F_7	3	1	-	2	-	-	-	-	-	-	-
Egypt Na 101 X Hope-Cheyenne	F_{10}	1	-	-	-	-	1	-	-	-	-	-
Eureka X (Cheyenne-Tenmarq)	F_7	4	-	-	-	-	-	-	3	1	-	-
Eureka X (Cheyenne-Tenmarq)	F_8	1	-	-	-	-	-	-	1	-	-	-
Marquillo-Oro X Eureka	F_7	2	-	-	-	-	-	-	-	2	-	-
Marquillo-Oro X Eureka	F_8	6	-	-	-	-	-	-	-	5	1	-
Eureka X (Hope-Cheyenne)	F_8	3	-	-	-	-	-	-	2	1	-	-
Trumbull X Frondoso	-	11	-	-	-	-	-	-	6	4	1	-
Frontana X (Mediterranean-Hope X Pawnee)	F_3	86	3	6	21	3	7	31	-	4	6	5
Frontana X Pawnee	F_3	73	-	7	8	9	1	33	10	4	-	1
Frontana X Tenmarq	F_3	66	-	-	-	9	-	34	9	13	1	-
Frontana X Cheyenne	F_3	12	-	-	2	3	-	7	-	-	-	-
Langdon 194 X Khapli	-	1	-	-	1	-	-	-	-	-	-	-
Langdon 313 X Langdon 270-Khapli	-	1	1	-	-	-	-	-	-	-	-	-
(Oro X Mediterranean-Hope) X Kenya	F_6	8	-	-	-	1	-	2	1	-	3	1
Kenya X Hope-Turkey	F_6	5	-	-	2	2	-	-	1	-	-	-
Kenya X Nebred	F_6	6	-	-	-	5	-	-	1	-	-	-
Oro-Tenmarq X Kenya	F_8	3	-	-	-	-	-	-	2	-	1	-
Mediterranean-Hope-Tenmarq X Kenya	F_8	7	-	-	-	-	-	-	7	-	-	-
Kenya X Marquillo-Oro	F_{10}	1	-	-	-	-	-	-	1	-	-	-
(McMurachy-Exchange X Redman^3) X Pawnee, R.L. 2564	F_2	6	-	-	-	-	-	-	-	6	-	-

Table 5. (concl.)

Kind	Generation	No. sel. tested	No. sel. with inf. type and reaction indicated									
			Resistant				Seg.		Susceptible			Meso.
			0;-1	1	1-2	2	1-4	2-4	3	3-4	4	X
(McMurachy-Exchange X Redman) X Tenmarq, R.L. 2327	F_4	25	-	-	-	-	-	1	6	17	1	-
(McMurachy-Exchange X Redman) X Comanche, R.L. 2327	F_4	28	-	-	-	-	-	4	3	18	3	-
(Kawvale-Marquillo X Clarkan) X Red Egyptian	F_5	11	-	-	-	2	-	2	5	2	-	-
Timstein X Comanche	F_4	13	-	-	-	1	-	1	9	-	-	2
Pawnee X Timstein	F_4	7	-	-	3	-	-	1	3	-	-	-
(Timstein-Pawnee) X Comanche	F_5	14	-	-	-	2	-	3	9	-	-	-
(Timstein-Pawnee) X Pawnee	F_4	15	-	-	-	1	-	3	4	5	2	-
Timstein X (Marquillo-Oro X Kawvale-Tenmarq)	F_6	12	-	-	-	2	-	4	1	3	2	-
(Mediterranean-Hope X Pawnee) X [(Kawvale-Tenmarq X Comanche) X (94587 X Wea-Hungarian)]	F_4	66	-	-	-	-	-	-	8	31	16	11
(Pawnee X Mediterranean-Hope) X (Pawnee-94587 X Pawnee-Comanche)	F_4	6	-	-	-	-	-	-	2	4	-	-
(Mediterranean-Hope X Pawnee) X (Pawnee-94587 X Pawnee-Comanche)	F_4	6	-	-	-	-	-	-	-	2	4	-
Thirteen <u>Triticum timopheevi</u> crosses	-	48	-	-	-	-	-	5	14	16	10	3
Cheyenne (check)	-	-	-	-	-	-	-	-	-	-	1	-
Rival (check)	-	-	-	-	-	-	-	-	-	1	-	-
Lee (check)	-	-	-	-	-	-	-	-	-	1	-	-

resistant and one was segregating for resistance to race 15 B.

Many resistant selections were found in crosses tested involving the Brazilian variety Frontana. Of the 86 selections tested in the cross Frontana X (Mediterranean-Hope X Pawnee), 33 were resistant, 38 were segregating for resistance, ten were susceptible, and five were mesothetic. Twenty-four selections from the cross Fontana X Pawnee were resistant, 34 were segregating, 14 were susceptible, and one gave a mesothetic reaction. Of 78 selections tested from two other Frontana crosses, 14 were resistant, 41 were segregating for resistance, and 23 were susceptible.

One selection was tested from each of two crosses involving Khapli, an emmer. Both selections were found to be resistant. Six crosses involving Kenya R.L. 1373 were tested. The three of these crosses in which resistant selections were found were (Oro X Mediterranean-Hope) X Kenya, Kenya X Hope-Turkey, and Kenya X Nebred. Nineteen selections from these three crosses were tested and ten were found to be resistant, two were segregating for resistance, six were susceptible, and one gave a mesothetic reaction. No resistant selections were found in the three other Kenya R.L. 1373 crosses tested.

Eleven selections of the cross (Kawvale-Marquillo X Clarkan) X Red Egyptian were tested. Two of these selections were resistant, two were segregating for resistance, and the remainder were susceptible.

Five Timstein crosses were tested. Of the 61 selections tested from these five crosses, nine were resistant, 12 were segregating for resistance, two gave a mesothetic reaction, and the remainder were susceptible.

No resistant selections were found in the crosses involving Durum P.I. 94587, Eureka, Frondoso, McMurachy-Exchange X Redman, McMurachy-Exchange X Redman^3, *Triticum timopheevi*, and Wea-Hungarian. Selections segregating for resistance were, however, found in crosses involving McMurachy-Exchange X Redman and *T. timopheevi*.

In Table 6 the actual infection type and reaction class are given for some of the resistant selections found in some of the crosses tested in the work conducted for this thesis. The list of selections given in Table 6 is a cross-section of the resistant selections found during this survey for resistance to race 15 B.

Table 6. Strains of 21 and 14 chromosome wheats and intergeneric crosses resistant to race 15 B of stem rust in the seedling stage.

Kind	Source	Infection type*	Reaction class**
Aegilops triuncialis X Peliss X Hard Federation X *Agropyron elongatum* X VPI 131 and/or Harvest Queen	1951 Agron.Nus.8722	1	R
Agropyron X wheat	1950 Agron.Nus.6133	0;-1⁻	R+
Agropyron X wheat	1951 Agron.Nus.8565	0;-1⁻	R+
Agropyron elongatum X wheat	1950 Agron.Nus.6026	0;-1	R+
A. elongatum X wheat	1951 Agron.Nus.8464	0;-1⁻	R+
(Bobin-Gaza-Bobin) X Pawnee	1950 Rust Nus.2985	0;-1⁺	R
(Bobin-Gaza-Bobin) X Pawnee	1948 Rust Nus.2333	1-2	R
(Chinese-*A. elongatum* X Chinese) X Pawnee	1951 Agron.Nus.8345	0;-1	R+
(Chinese-*A. elongatum* X Chinese) X Pawnee	1951 Agron.Nus.8426	0;-1	R+
Egypt X Kenya	Rock. Found. 55	0;-1	R+
Egypt Na 101 X Hope-Cheyenne	1947 Rust Nus.1841	0;-1	R+
Egypt Na 101 X Timstein	Rock. Found. 71	0;-1⁻	R+
Frontana X Cheyenne	1950 Rust Nus.223-1	1-2	R
Frontana X (Mediterranean-Hope X Pawnee)	1950 Rust Nus.55-31	0;-1	R+
Frontana X (Mediterranean-Hope X Pawnee)	1950 Rust Nus.55-49	0;-1⁺	R
Frontana X Pawnee	1950 Rust Nus.44-19	1	R
Frontana X Pawnee	1950 Rust Nus.44-20	1	R
Kharkof X *A. elongatum*	1950 Agron.Nus.6075	1	R
Kenya R.L. 1373 X Hope-Turkey	1950 Rust Nus.2282	0;-2+	R
Kenya X Mentana	Rock. Found. 57	1+	R
(Kenya X Mentana) X Mentana	Rock. Found. 135	1	R
Langdon 194 X Khapli	North Dakota	1-2	R
Langdon 313 X Langdon 270-Khapli	North Dakota	0;-1	R
(Marroqui X Supremo) X ($Ramona_3$ X Marroqui)	Rock. Found. 171	1-2	R
Mentana X Kenya	Rock. Found. 92	1	R

Table 6. (concl.)

Kind	Source	Infec-tion type*	Reac-tion class**
(Mentana X Kenya) X Mentana	Rock. Found. 134	1	R
Mentana X Supremo	Rock. Found. 77	1	R
(Mentana X Supremo) X Mentana	Rock. Found. 84	0;-1^{+}	R
(Minturki X *Agropyron glaucum*) X Minturki	1950 Agron.Nus.6078	1+-2	R
Pawnee X Timstein	1950 Rust Nus. 320	1-2	R
Peru X Supremo	Rock. Found. 120	1+	R
Supremo X Kenya	Rock. Found. 169	0;-1	R+
Supremo X Mentana	Rock. Found. 157	1	R
Supremo X Newthatch	Rock. Found. 82	1-2	R
Timstein X Kenya	Rock. Found. 16	0;-1^{-}	R+
(*Triticum dicoccoides* X *Aegilops speltoides*) X Austin[2]	Texas	1-1+	R
(Wheat-rye X *A. elongatum*) X Cheyenne	1950 Agron.Nus.6457	1-2^{-}	R
(Wheat-rye X *A. elongatum*) X Cheyenne	1951 Agron.Nus.8700	1+	R
(Wheat X *A. elongatum*) S4-207-8 X (Mediterranean-Hope X Pawnee)	1949 Rust Nus.2788	0;-1^{+}	R
White Odessa X *Agropyron glaucum*	1949 Agron.Nus.6799	0;	R^{++}
White Odessa X *A. glaucum*	1951 Agron.Nus.8642	0;	R^{++}
Cheyenne (check)	-	4	S
Rival (check)	-	3-4	S
Lee (check)	-	3-4	S

* Plus and minus signs are used to indicate the upper and lower limits of the indicated infection type.

** R resistant
S susceptible
Plus and minus signs are used to indicate the upper and lower limits of the indicated reaction class.

DISCUSSION

The practical application of a survey of breeding material for resistance to a specific race of stem rust, such as the work described with race 15 B in this thesis, lies in the usefulness of the information obtained in setting up a breeding program to develop varieties resistant to the new stem rust race. A knowledge of the sources of resistance to the new race is, however, not in itself sufficient.

A second factor necessary to consider when planning such a breeding program is the mode of inheritance of resistance to the pathogen responsible for the disease. This information is useful in determining the population size necessary to obtain the desired recombinations.

A third factor to be considered, in the case of stem rust, is the geographical location of the area for which the new variety is being developed. The location factor is important because urediospores which the stem rust organism produces may be carried great distances by the wind (Stakman, 1947a), and because the stem rust organism is able to overwinter in some area but not in others. Thus seedling resistance is more important in regions where the pathogen overwinters, than in those regions into which the majority of the inoculum is blown in the spring when the wheat is rapidly approaching the adult stage.

The hard red winter wheat belt in the central portion of the United States occupies a unique location. This is due partly to the fact that teliospores are unable to live through the hot summers in this region, and partly also to the fact that very few urediospores are able to survive the cold winters. In Mexico and central and southern Texas, however, the stem rust fungus is able to survive the mild winters on susceptible fall sown wheats (Stakman, 1947a). Hence, in the hard red winter wheat belt, most of the initial spring inoculum is blown in from Mexico and central and southern Texas where the fungus overwinters. Thus the degree of resistance or susceptibility of the wheats grown in Mexico and central and southern Texas may have a profound influence on the severity of stem rust epiphytotics in the central winter wheat belt of the United States.

According to Stakman et al. (1950), the variety Austin was distributed in Texas in 1941 and has become widely grown in southern Texas. It was a Hope derivative and exhibited the Hope type of stem rust resistance to common stem rust races. Stakman et al. (1950) also stated that the widespread use of Austin in southern Texas has probably been an important factor in protecting the central portion of the hard red winter wheat belt from serious stem rust epiphytotics in recent years.

In the work described in this thesis, Austin was found to be susceptible to race 15 B. Quanah, a variety released for Texas in 1950 (Stakman et al., 1950) was also found to be susceptible to race 15 B. An increase in the prevalence of race 15 B, coincident with the large scale use of these susceptible varieties in a region where the fungus overwinters, could, with the proper environmental conditions, produce enough early spring inoculum to start a serious stem rust epiphytotic.

The results obtained, in the work described in this thesis, with the wheats from the Rockefeller Foundation also are of interest in this connection. The wheats of this group were bred for use in Mexico. The varieties Candeal, Kenya, and Mentana, as well as a number of selections from several of the crosses tested, were found to be resistant to race 15 B. If one or two of these wheats are satisfactory and can be distributed for commercial production relatively soon, they may be of considerable value in suppressing potential stem rust epiphytotics until resistant varieties can be developed for the hard red spring and hard red winter wheat regions farther north. If any of the resistant selections from Texas could be released, they should also be helpful in protecting the wheat regions farther north from stem rust epiphytotics.

In recent years a considerable amount of attention has been placed on developing varieties of wheat for the hard red winter wheat belt, as well as other wheat regions, that not only have good agronomic and baking qualities but also have resistance to several disease and insect pests. There has been an effort not only to concentrate in one variety resistance to stem rust, leaf rust, bunt, loose smut, and Hessian fly, but also the attempt has been made to develop resistance to as many races of each disease pathogen or strains of each insect as possible in each cross.

Although much has been accomplished through these efforts to combine into one variety a large number of desirable characteristics, it has been necessary to use somewhat diverse sources of germ plasm in many cases. As a result, many of the crosses which have been made are complex and involve several parental varieties. Selections from many of these complex crosses are being studied but most of them are not yet ready to be increased for commercial production because of a few undesirable characteristics, such as poor agronomic type and inferior baking quality.

In the work described herein, several selections resistant to race 15 B were found in crosses such as those described above. A list of some of these resistant selections was given in Table 6. These included selections from the crosses *Aegilops triuncialis* X Peliss X Hard Federation X *Agropyron elongatum* X VPI 131 and/or Harvest Queen, *Agropyron* X wheat, (Bobin-Gaza-Bobin) X Pawnee, (Chinese-*A. elongatum* X Chinese) X Pawnee, Egypt Na 101 X Hope-Cheyenne, (wheat-rye X *A. elongatum*) X Cheyenne and others. As these selections possess other desirable characteristics in addition to their resistance to race 15 B, it seems desirable to take advantage of their good germ plasm. This could be accomplished by a crossing program using desirable commercial wheat varieties as the recurrent parents. This type of program should result in recombinations in the segregating generations possessing the desirable agronomic characteristics of the commercial variety, plus resistance to race

15 B of stem rust and possible resistance to other diseases in addition to the ones to which the commercial variety was resistant. The fewer the undesirable characteristics possessed by the selections used as sources of resistance to race 15 B, the fewer the backcrosses which will be necessary.

An established variety could be used as the source of resistance to race 15 B, in this backcrossing program, instead of an un-named, resistant selection from a complex cross such as those described above. In general, however, most of the established varieties possessing resistance to race 15 B of stem rust have several undesirable characteristics and fewer of the desirable characteristics, such as resistance to several diseases, than those possessed by selections from complex crosses. The variety or selection having the most desirable characteristics, such as disease resistance, adaptability, crossability, etc., considering the end result desired, is the one to be used.

CONCLUSIONS AND SUMMARY

The results obtained in a survey for resistance to race 15 B of stem rust among the breeding material being used in the hard red winter wheat region, as well as that being used by the Rockefeller Foundation in Mexico, are reported. Approximately 1600 varieties and selections were tested in the seedling stage with this race. The work was conducted in the greenhouse at Manhattan, Kansas during the winter of 1950-1951.

The results obtained indicated that some selections from several crosses already in the breeding programs of experiment stations in the hard red winter wheat region, as well as material from the Rockefeller Foundation in Mexico, possessed some resistance to race 15 B. Many of these crosses are complex because they represent an attempt to combine in one variety, resistance to a number of disease and insect pests as well as desirable agronomic and baking characteristics. Selections from most of these crosses would not be acceptable as commercial varieties, as they now exist, due in many cases to only a few undesirable characteristics.

The crosses *Agropyron* X wheat, *Agropyron elongatum* X wheat, (Bobin-Gaza-Bobin) X Pawnee, (Chinese-*A. elongatum* X Chinese) X Pawnee, Egypt Na 101 X Hope-Cheyenne, Frontana X (Mediterranean-Hope X Pawnee), Kenya R.L. 1373 X Hope-Turkey, (Mentana X Kenya) X Mentana, (Minturki X *Agropyron glaucum*) X Minturki, Pawnee X Timstein, (wheat-rye X *A. elongatum*) X Cheyenne, and White Odessa X *A. glaucum* were among those found to contain resistant selections.

The suggestion was made that the breeding program to develop varieties resistant to race 15 B of stem rust should involve the use of backcrossing. By backcrossing desirable commercial wheat varieties to selections resistant to race 15 B, segregates possessing desirable agronomic and baking characteristics as well as resistance to race 15 B of stem rust and other diseases should be obtained. The commercial varieties should be used as the recurrent parents.

Resistant selections were found in some of the crosses tested from the Rockefeller Foundation in Mexico and the Texas Experiment Station. If any of these selections resistant to race 15 B are satisfactory for commercial distribution, their use in Mexico and southern Texas, where the organism over-winters, might help protect the regions farther north from severe stem rust epiphytotics. This would give the wheat breeders in regions north of Mexico and central Texas more time to develop resistant varieties for their areas.

ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to his major instructor, Professor E. G. Heyne, for his many helpful suggestions and guidance in the preparation of the thesis, and for the use of the greenhouse space in which the work was conducted; to Mr. C. O. Johnston, Pathologist, Bureau of Plant Industry, for providing the pure culture of urediospores of physiologic race 15 B of stem rust used, for periodically checking the culture for purity, and for his many helpful suggestions during the investigation and preparation of the thesis; and to Mrs. Norma L. Seifert, wife of the writer, for her inspiration throughout the study, and for her help with the clerical work.

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SURVEY OF WHEAT AND WHEAT RELATIVES
FOR RESISTANCE TO *PUCCINIA GRAMINIS TRITICI*,
PHYSIOLOGIC RACE 15 B

by

ROBERT PAUL SEIFERT

B. S., Kansas State College
of Agriculture and Applied Science, 1950

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1952

The purpose of this problem was to make a survey of wheat varieties, un-named selections, and selections from species and generic crosses currently in use in breeding programs in the hard red winter wheat region, in order to determine their reaction to race 15 B of stem rust, *Puccinia graminis tritici*. The practical objective was to find resistant parental material, if any, to utilize in the breeding of hard red winter wheat.

In order to accomplish this objective, approximately 1600 varieties and selections were tested in the seedling stage for their reaction to race 15 B. The material tested was obtained from various experiment stations in the hard red winter wheat region, including the Kansas Experiment Station, and from the Rockefeller Foundation in Mexico. The investigation was conducted in the greenhouse at Manhattan, Kansas during the winter of 1950-1951.

The reaction of each variety or selection, to race 15 B of stem rust, was determined by growing approximately 25 plants of each in a three inch pot. Ten days after planting, the plants were inoculated by brushing them, after they had been moistened, with rusted stock culture plants which had previously been infected with a pure culture of race 15 B. A portable moist chamber was used to facilitate testing large numbers of selections with a minimum expenditure of labor. After the infection had developed 14 days, the plants were classified as to infection type and reaction class by observing the infection on the primary leaves.

The results obtained indicated that some selections from several crosses already in the breeding programs of experiment stations in the hard red winter wheat region, as well as material from the Rockefeller Foundation in Mexico, possessed some resistance to race 15 B of stem rust. Selections from most of these crosses would not be acceptable as commercial varieties, as they now exist, due in many cases to only a few undesirable characteristics.

The crosses *Agropyron* X wheat, *Agropyron elongatum* X wheat, (Bobin-Gaza-Bobin) X Pawnee, (Chinese-*A. elongatum* X Chinese) X Pawnee, Egypt Na 101 X Hope-Cheyenne, Frontana X (Mediterranean-Hope X Pawnee), Kenya R.L. 1373 X Hope-Turkey, (Mentana X Kenya) X Mentana, (Minturki X *Agropyron glaucum*) X Minturki, Pawnee X Timstein, (wheat-rye X *A. elongatum*) X Cheyenne, and White Odessa X *A. glaucum* were among those found to contain resistant selections.

The suggestion was made that the breeding program to develop varieties resistant to race 15 B of stem rust should involve backcrossing desirable commercial varieties to selections resistant to race 15 B, such as those mentioned above. The commercial varieties should be used as the recurrent parents. Such a program should result in segregates that possess desirable agronomic and baking characteristics in addition to resistance to race 15 B of stem rust and other diseases.