A FIELD STUDY OF THE EFFECTS OF LEAF RUST AND STEM RUST ON SISTER LINES OF A HARD RED WINTER WHEAT

by

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INTRODUCTION

The importance of a plant disease is determined by the amount of economic damage it produces. It is a function of both frequency and severity of destructiveness. Economic damage may differ from plant to plant. For example, an organism's unsightly blemish upon a flower will be of major importance in floriculture but not necessarily so in wheat production. In a wheat crop the grain is of prime importance. Thus the major criteria for evaluating a wheat pathogen's importance is the effect upon yield, seed quality, and harvestibility.

According to Chester (1946), man has recognized the damage resulting from rust infections since ancient times. Prior to the nineteenth century all rust diseases were considered one disease. By the last part of the nineteenth century the fungus-host relationships had been discovered and different rust species were recognized. After stem rust and leaf rust were recognized as separate diseases, evaluations of the importance of each were made. The damage caused by stem rust was much more striking. Stem rust attacks the wheat crop in the later stages of development, spreads rapidly, brings sudden defoliation, and results in severely shriveled kernels. On the other hand leaf rust occurs earlier in plant development and the plant seems to withstand the attack and produce normal kernels. Several early investigators concluded that leaf rust was of only minor importance. Since then, numerous researchers have shown conclusively that leaf rust causes major damage.

In this study an attempt was made to estimate damage produced by the leaf rust organism Puccinia recondita Rob. ex Desm. f. sp. tritici Erikss. (Cald) and the stem rust organism Puccinia graminis Pers. tritici Erikss. and E. Henn. ( ) using resistant-susceptible sister lines of hard red winter wheat. Since this approach, using nearly isogenic lines differing in rust reaction, has not been published in America to date, an evaluation of this method was one objective of this research. In other words, this study was set up to evaluate the benefit derived from rust resistance under certain varied conditions.

REVIEW OF LITERATURE

Early in the 20th century the use of sulfur dust as a fungicide enabled researchers to make direct comparisons between rusted and non-rusted plants. Kightlinger (1925) found that uredeospore germination was reduced from 72.9 to 18.8 percent when microscopic slides were dusted with 90-10 sulfur-lead arsenate dust. In a subsequent field trial, stem rust on oats was reduced from 90 percent to below 1 percent by repeated applications of sulfur. Greaney (1928) found that dusting after inoculation failed to control rust. Kightlinger and Whetzel (1926) studied the effect of sulfur treatment on wheat and oats. A wheat yield increase of 18.5 percent was attributed to the reduction of leaf rust by sulfur treatment. Oats protected from both stem rust and leaf rust showed an increase in yield of 19.6 percent. Bailey and Greaney (1928) protected wheat plots from both stem rust and leaf rust with tri-weekly applications at different rates. Yields under all rates tested were over three times the average of the untreated check plots. Lambert and

Stakman (1929) found that at least three applications of sulfur were necessary during a growing season to control stem rust. Yields were increased approximatley 30 percent but the cost was greater than the value of the increased yield.

Other workers set up experiments to determine the direct effect of rust diseases. Murphy (1935) found that the effect of crown rust of oats varied with the degree and type of infection, growth stage of the host, and duration of infection. In further studies Murphy and others (1940) ran correlations between crown rust readings and yields. Correlation coefficients between amount of infection and yield were found to be highly significant and ranged between -.75 and -.80.

In greenhouse comparison, Johnston (1931) measured a 55.71 percent reduction in yield of a leaf-rusted, susceptible variety of wheat as compared to non-infected checks. Severe flecking necrosis reduced yield of a resistant variety 22.05 percent. Johnston and Miller (1934) found that susceptible plant yields were reduced 42.8 to 93.8 percent and the maximum yield reduction of the resistant plants was 15.2 percent. Mains (1927) found yields reduced 15 to 25 percent with severe greenhouse infections lasting from the beginning of heading to maturity. Mains (1930) reduced yields of susceptible, greenhouse plants up to 94.7 percent when infested throughout the growing period. He found that the amount of yield reduction was dependent upon the stage of host development at the time of inoculation and upon level of resistance or susceptibility of the host.

Hayes, et al., (1927) correlated yielding ability with disease reactions and other characters of spring and winter wheats grown in rod row trials in Minnesota. They found that leaf rust reaction was an important contributing factor to yielding ability but that the negative correlation was greater between stem rust and yield than between leaf rust and yield. In winter wheats over 50 percent of the yield variability was attributed to winterkilling.

Sulfur has been widely used in setting up field experiments specifically designed to evaluate the effects of rust. Goulden and Greaney (1930) varied the amount of stem rust infection with different rates and intervals of sulfur applications. A 10 percent increase in infection was accompanied by a 6.8 percent reduction in yield in one experiment and a 9.7 percent reduction in another. Regressions in yield were said to be linear. From late studies, Greaney _et al._, (1941) stated that yield reduction ranged from 6.7 to 9.2 percent for each 10 percent increase in stem rust infection. In 1937 an increase in stem rust severity from 5 to 90 percent reduced yield 84 percent.

Johnston (1931) compared leaf rust infected plots with sulfur treated plots and calculated the reduction in yield due to leaf rust to be 8.13 percent and 7.77 percent for the two years studied. Caldwell and others (1934) found that leaf rust was responsible for decreases in yield of 14.8 to 28.4 percent. In Canada Peturson and Newton (1939) found a maximum yield reduction due to leaf rust of over 50 percent. Late planting, which produced younger plants at the time of infection, resulted in a heavier reduction in yield. Peturson _et al._, (1945) showed that even moderately resistant varieties of spring wheats may suffer a considerable reduction in yield when infected with leaf rust. Yields of susceptible varieties were reduced as much as 56.3 percent.

Yields of susceptible varieties were reduced as much as 56.3 percent. Yields of the varieties Renown and Regent were reduced 22.7 and 16.1 percent, respectively, in 1940 although both had rust readings of only 15 percent. A statistically significant difference was found between the treated and untreated plots of all varieties tested in the 1940, 1941, and 1943 trials. The same workers (1948) continued the study for three more years and obtained similar results. However, in 1946, when rust infections were lighter and later in getting established, yield differences due to infection were not significant. In Australia Phipps (1938) controlled leaf rust with colloidal sulfur and calculated that leaf rust reduced the yield of a susceptible variety 14.5 percent. Martinez (1951) reported a significant difference between protected and rust plots. He stated that a 10 percent increase in infection of leaf rust caused a 4 to 5 percent reduction in yield.

Newton _et al._, (1945) found significantly different yields, kernel weights and test weights between artificially leaf rust-inoculated barley varieties and their sulfur treated checks.

Levins and Geddes (1957) measured the intensities of leaf rust and stem rust infections in a percent average rust load. Duration as well as pustule cover was taken into account. Seasonal leaf rust loads were found to be consistently heavier than seasonal stem rust loads. However, an increase of 65.0 percent in the average leaf rust load reduced yield only 33 percent, while an increase of 31.7 percent in the average stem rust load reduced yield 45 percent. Later infections were accompanied by lesser reductions in yield.

Certain detailed studies have been made into the nature of the yield reduction caused by rusts. Weiss (1924) found that plants infested with stem rust had a significantly higher water requirement than non-infected plants. Johnston and Miller (1934) found that the water requirement of wheat was greatly increased by leaf rust infection. It was also noted that the roots of heavily infected plants were discolored and stunted. Murphy (1935) stated that crown rust of oats reduced water economy and the ratio of roots to tops. Mains (1930) and Johnston (1931) reported that yield reduction could be chiefly attributed to a reduction in kernel number per head. Peturson and Newton (1939) concluded that reduced kernel weight was the most important component of yield reduction. Greaney et al., (1941) concluded that kernel weight gives the truest measure of stem rust damage.

MATERIALS AND METHODS

This study utilized sister lines of wheat from a Sinvalocho-Pawnee[2] x Mediterranean-Hope-Pawnee[3] cross made in 1952 (Cross No. X 52V). Resistant and susceptible plants were selected in the F_3 generation in segregating families. Each family represents the progeny of an individual F_2 plant that was heterozygous for leaf rust reaction.

1958 Procedures

Leaf Rust. In 1958 there were 323 lines from 29 families grown at the Ashland agronomy farm. A composite of leaf rust races was inoculated into spreader rows. Readings of rust percentages were made according to a modified Cobb scale by Peterson et al., (1948). At harvest time four heads were picked randomly from each row, tagged, and boxed for kernel counts to be made later. The rows were harvested individually. Relative test weights and 100-kernel weights were determined from this grain.

Only data from families with both resistant and susceptible lines were used in making kernel weight, test weight, and kernel count comparisons between resistant and susceptible lines. Segregating lines were discarded.

The heads used for kernel counts were threshed by hand. The procedure consisted of rolling the heads inside a piece of flexible rubber hose, then blowing the chaff away from the grain in a small pan. The test weights were taken by measuring out samples of grain in a small cylinder and weighing them. The cylinder used was approximately 2.3 gm. in diameter and 7.1 cm. in height. In calculating 100-kernel weights, kernels were counted by hand and weighed to the nearest 0.01 of a gram.

When the kernel weight, test weight and kernel count data were collected, analyses of variance to test the effects of resistance removing the variation due to families were planned. Accordingly data were collected from the non-segregating rows within families which contained both resistant and susceptible lines. The sub-class numbers were so uneven that the planned F-test was unusable. Analyses of variance were run on these data testing the test weight and kernel weight differences due to family variation among resistant and among susceptible lines. Concerning the same rows, nested analyses of variance were used to test the significance of both family and lines within families variation on the number of kernels per head.

Since the data were not statistically suited to making group comparisons between resistant and susceptible lines within families, t-tests were used to evaluate differences between resistant and susceptible pair members within families. According to the 1958 rust readings, the resistant member of a leaf rust pair represented the highest level of leaf rust resistance present in a family and the susceptible member the lowest. In cases where there were more than one high or low rust reading per family, the lines analyzed were chosen randomly.

Stem Rust. The same 323 lines which were grown at Ashland in 1958 were also planted in the stem rust nursery on the Kansas State University agronomy farm at Manhattan. The rows were artificially infected with race 56 of stem rust. Plants in spreader rows between ranges were inoculated using a hypodermic needle to insert spores under the leaf sheaths. Stem rust readings were taken and the rows were harvested in the rows in the leaf rust nursery. Five heads were randomly picked from each row for kernel number determination. As in the leaf rust trial, only data from families having both resistant and susceptible lines were used. Since there seemed to be only a slight difference between the 30 and 40 percent stem rust readings, rows with the 40 percent readings as well as those segregating for stem rust reaction were discarded. Kernel number per head and 100-kernel weight determination followed the same procedure used in the leaf rust trial. Because more grain was available, cylinder, 2.3 cm. in diameter and 14.2 cm. high, was used for test weight determinations.

Test weights were determined from all the rows in the stem rust nursery. Stem rust percentages were correlated with test weights.

As in the leaf rust trial, the effects of family differences upon test weight and kernel weight were tested with analyses of variance. Again kernel count variations due to both family and lines within families were tested.

Stem rust data also were not suited to evaluating resistant-susceptible lines and removing family differences with analyses of variance. Resistant-susceptible test weight, kernel weight and kernel count differences were analyzed with t-tests as in the leaf rust trial. Paired comparisons were made between the most resistant and the most susceptible rows within families. Stem rust pairs were taken from families in which at least 30 percentage points difference occurred between resistant and susceptible lines.

1959 Procedures

In the fall of 1958, four experiments were planted at three locations --- one on the Hutchinson experiment field, one on the Ashland agronomy farm, and two on the university agronomy farm at Manhattan. Each experiment was composed of two parts, paired single rows and paired, thrice-replicated, four row plots. The paired single rows were planted side by side and the paired plots were planted end to end. The rows were eight feet long.

Seed for the single rows was taken from the study grown at Ashland. Both stem rust and leaf rust pairs were chosen by selecting one resistant and one susceptible line from each family, referring to rust readings made in 1957 and 1958. Resistant lines with the lowest rust readings were used. An attempt was made to equal the stem rust reactions within leaf rust pairs and the leaf rust readings within stem rust pairs. Pairs were selected only from those families that had both resistant and susceptible lines.

There were 72 paired single rows planted in each experiment in the 1959 trials. Of these 16 pairs were planted to show different leaf rust reactions, 14 were planted to show different stem rust reactions and the members of the remaining 6 pairs differed in both stem rust and leaf rust reactions in 1958.

Seed for the replicated plots was obtained from increase plots of part of the lines grown in the 1958 rust effect study. Corresponding rust readings were referred to in making the selections. Pairs were picked within families as they were for the single row trials. There were no distinct stem rust pairs in the increase plots, therefore only leaf rust pairs were tested in the replicated plots.

The study was planned to give four different rust-host relationships. At Hutchinson the experiment was subjected to a natural rust infection. A composite of leaf rust races was inoculated into spreader rows at Ashland to insure heavy leaf rust infection. Stem rust was inoculated into spreader rows in the stem rust nursery at Manhattan. In the second experiment at Manhattan sulfur was used to minimize rust infection. The sulfur treatment was comprised of fifteen applications, each of approximately sixty pounds of commercial dusting sulfur per acre. Dusting was begun just before jointing stage (May 23) and was continued until kernels were formed. Intervals between dustings varied from one to four days depending upon weather conditions.

Field notes were taken on the date of half bloom and height at maturity at both experiments at Manhattan. Leaf rust readings were taken on all four experiments following a modified Cobb scale (Peterson et al., (1948)). In the stem rust nursery, stem rust readings were made at the telia stage of rust development.

The yields for both the paired single rows and the inner rows of the four row plots were weighed in grams. The single row yields, in grams, may be converted to bushels per acre by multiplying by 0.2 and the plot yields by multiplying by 0.1. Relative test weights were taken using a glass, flat-bottomed tube, 9.4 cm. high and 2.2 cm. in diameter, as a standard measure. The weights were taken in grams. The 500-kernel counts were taken with a mechanical counting device and were weighed to the nearest 0.01 of a gram.

Leaf Rust Evaluation. Yields, test weights, and 500-kernel weights were determined for the leaf rust pairs at all experiments. The pairs used contained clear-cut differences between the resistant and the susceptible members. Paired rows were discarded if one member was segregating for leaf rust reaction. Yield, test weight, and kernel weight differences between resistant and susceptible paired rows were statistically analyzed using one-tailed t-tests. There were 16 leaf rust pairs used at Hutchinson and 17 at the other experiments.

One pair of entries in the replicated yield trials were discarded because its members were both susceptible. The resistant member of another pair contained a few susceptible plants but that pair was retained. Thus data from five pairs of sister lines were subjected to split plot analysis of variance to determine if leaf rust reaction significantly affected yield, test weight and kernel weight in each of the four experiments.

Stem Rust Evaluation. Stem rust was found only in the stem rust nursery experiment. Yield, test weight and kernel weight differences between stem rust resistant and susceptible members of 14 single-row pairs in the stem rust nursery were analyzed with one-tailed t-tests. The 1959 rust readings were consulted in picking the pairs to be analyzed. Pairs were chosen with a minimum of 20 percentage points between members.

EXPERIMENTAL RESULTS

The bulk of the data collected in the 1958 and 1959 rust effect studies makes it advisable to present most of the data in tabular form in an appendix. Accordingly, this section of the thesis is limited to a summarization of various trial results with references to the proper tables in the appendix.

1958 Results

Leaf Rust. In the 1958 trials, leaf rust readings were made in the leaf rust nursery at Ashland. Leaf rust infection resulted in rust percentage readings of 80 to 90 percent for the susceptible rows. Trace amounts of leaf rust were found on the resistant rows. These data are recorded in Table 1 in the appendix. Although leaf rust built up heavy levels of infection at Ashland it was late in getting established.

Test weight, kernel weight and kernel count data from the 1958 non-segregating rows which were from families showing both leaf rust resistance and susceptibility are presented in Table 3 in the appendix. From each of those families, two rows were picked out to represent the highest and lowest levels of resistance among sister lines. Test weight, kernel weight and kernel number per head differences between pairs were tested with one-tailed t-tests. Appendix Table 5 contains the data tested. It was found that test weight and kernel weight differences between leaf rust pair members were significant to the .05 level. Leaf rust did not significantly affect the number of kernels per head in the 1958 trial.

Analysis of variance indicated there were highly significant kernel number and test weight differences between families among both leaf rust resistant and leaf rust susceptible rows grown at Ashland in 1958. The families source of kernel weight variation was statistically significant among the resistant rows but not among the susceptible rows. Kernel number was significantly influenced by lines within families among both resistant and susceptible lines.

Stem Rust. Inoculation gave good stem rust infection at Manhattan in 1958. Stem rust readings ranged from trace to 30 percent for the resistant rows and from 40 to 60 percent for the susceptible rows. The stem rust percentages are listed in Table 1 of the appendix.

Test weights of the grain produced by 320 rows in the stem rust nursery in 1958 were correlated with the stem rust percentage reading of those rows. A correlation coefficient of -.6446 was found. It is significant to the .001 level. The test weights are included in Table 2 of the appendix.

Test weight, kernel weight and kernel count data from families having both resistant and susceptible rows are shown in Table 4 in the appendix. Susceptible rows with 40 percent rust readings were not included.

As in the leaf rust trial, stem rust pairs were picked from families to represent the highest and lowest resistance levels present. One-tailed t-tests evaluated test weight, kernel weight and kernel number differences between pair members. The data used are shown in Table 6 in the appendix. Test weight and kernel weight differences between stem rust resistant and susceptible pair members were both significant to the .001 level. The number of kernels per head was not significantly influenced by stem rust infection.

At the Manhattan stem rust nursery family kernel weight variation was significant among both resistant and susceptible rows. Families had a significant effect upon test weight among the resistant rows but not among the susceptible rows. Family kernel number differences were not significant among either the resistant or susceptible rows, but the lines within families differences were significant among both.

1959 Results

Leaf Rust. In 1959 leaf rust readings were made at all the experiments of this study. These data are presented in Tables 7 and 9 in the appendix. In general, leaf rust infection was heaviest at Ashland, somewhat lighter at the stem rust nursery, much lighter at Hutchinson, and was reduced by sulfur in the treated experiment to the lowest level. The leaf rust developed earlier in the experiments that had the higher levels of infection; therefore, the amount of the rust at the different experiments varied more than percentage values indicate.

The leaf rust percentage data was examined and pairs were checked. It was found that of 22 pairs of single rows planted to show a difference between leaf rust resistance and susceptibility, 17 pairs showed clear-cut differences with neither row segregating. The readings at the different experiments were not conflicting except for one row at Hutchinson. A check with the planting list showed that another seed source had been used for that row. As a consequence the row was discarded so that there were only 16 paired single row comparisons made at Hutchinson. In the replicated plots 5 pairs were divided on leaf rust resistance. The readings at the different experiments supported each other.

Height and maturity data for the leaf rust pairs are recorded in Tables 11 and 12 in the appendix. Leaf rust had no appreciable effect upon height and date of half bloom.

Lodging did not occur in any rows at any of the experiments.

As stated in the introduction, the chief objective of this study was to evaluate the effect of genetic resistance by comparing resistant with susceptible lines. Such comparisons were made using yield, test weight and kernel weight data concerning leaf rust reaction. Two general observations were made: when the inoculum provided for early, heavy infection, grain production was somewhat higher in the leaf rust resistant as compared to the susceptible rows. A significant difference in kernel weight and in test weight was detected within pairs even when yield differences were not significant.

Table 1 gives a condensation of the results expressed as percentage ratios of leaf rust resistant lines compared with susceptible lines.

Whether the difference is significant is also indicated.

Table 1. Yield, test weight, and kernel weight R/S ratios and levels of significance of the differences from the 1959 leaf rust effect study.

Experiment	Trial	Yield		Test Weight		Kernel weight	
		% R/S	t or F	% R/S	t or F	% R/S	t or F
Manhattan-SRN							
	Single rows	108	n.s.	102	**	110	***
	Replicated plots	127	***	103	***	111	***
Manhattan-sulfur							
	Single rows	112	*	100	n.s.	101	n.s.
	Replicated plots	98	n.s.	99	*	98	***
Ashland-LRN							
	Single rows	117	**	102	**	116	***
	Replicated plots	105	n.s.	101	n.s.	105	*
Hutchinson							
	Single rows	95	n.s.	100	n.s.	103	n.s.
	Replicated plots	106	n.s.	99	*	102	*

The resistance x family interactions were tested in the split plot trials in 1959. This interaction had significant effects upon kernel weight at all experiments. Its effect upon yield was significant at Ashland and test weight was significantly influenced at both Manhattan experiments.

Detailed yield, test weight and kernel weight data are presented in the appendix. Tables 13 through 16 give the yields, test weights, and 500-kernel weights of the paired single rows at each of the four experiments. The yields, test weights, and kernel weights of the replicated plots are recorded in separate tables. Tables 17, 18 and 19 contain yield, test weight and kernel weight data, respectively, from the Manhattan, stem rust nursery. In a like manner Tables 20, 21 and 22 contain data from the sulfur treated experiment. Tables 23, 24 and 25 list the Hutchinson results and the Ashland replicated plot results are shown in Tables 26, 27 and 28.

Stem Rust. Although stem rust infection occurred too late in the season to cause great damage, stem rust readings were taken and 14 stem rust pairs were studied at the stem rust nursery at Manhattan. The rust readings are listed in Table 29 in the appendix. Stem rust did not occur at the other experiments.

Yields, test weights, and kernel weights of lightly infected rows were compared with those of more heavily infected rows. Resistant plants showed a 2.8 percent yield advantage. The average test weight was 1.2 percent higher for resistant rows than for susceptible rows. The average kernel weight was 5.2 percent higher from the resistant rows than from the susceptible rows. The data were analyzed with t-tests and resistant-susceptible differences were found to be significant for kernel weight and test weight but not for yield.

Single-row yields, test weights, and kernel weights of the 1959 stem rust pairs are listed in Table 29 in the appendix.

DISCUSSION AND CONCLUSIONS

For purposes of discussion the 1958 and 1959 data will be handled separately. The trials during both years are preliminary. Ideally, yield results are the best criteria for evaluating wheat disease damage; however, when yield results are scanty or unobtainable, the study of disease effects upon components of yield gives useful information.

The use of t-tests showed test weight and kernel weight to be significantly different between lines highly resistant and susceptible to both leaf rust and stem rust. The number of kernels per head was not significantly affected by either rust. These results are in disagreement with the findings of Johnston (1931) and Mains (1927) who found that a reduction in kernel number was the chief component of leaf rust yield reduction. However, Peturson's and Newton's statement (1939) that kernel number per head is dependent upon the stage of host development at the time of leaf rust infection offers an explanation. Leaf rust infection was later than usual in getting established in 1958.

The significance of the family sources of variation in test weight and kernel weight among leaf rust and stem rust resistant and/or susceptible lines indicate that other factors besides resistance levels differ from family to family and affect those components of yield. The significance of the lines within families source of variation among both leaf rust resistant and susceptible rows gives indication that the lines are not as nearly iso-genic as would be desirable.

The 1959 results concerning stem rust showed that a light, late infection reduced test weight and kernel weight slightly but had no measurable effect on yield.

The 1959 leaf rust results showed that leaf rust resistance was accompanied by increases in test weight and kernel weight in the presence of a moderate to heavy leaf rust infection. Since neither test weights nor kernel weights were higher for resistant than for susceptible lines under sulfur treatment, it may be assumed that the increases were functions of leaf rust reactions and not some genetically linked but unrelated phenomenon. It was noted that test weight and kernel weight differences between resistant and susceptible lines were greater at the experiments where rust infection was higher. The effect of leaf rust on kernel weight was greater than its effect on test weight.

Yield data were inconclusive. At Ashland, differences between resistant and susceptible yields and test weights were not found in the replicated plots. On the other hand these differences at the Manhattan stem rust nursery were highly significant. The results may be partially explained by the soil variation at Ashland. Although the variance between replications was removed in analyzing the effect of resistance in the split plot design, the replications extremely high F value was indicative of a large amount of soil variation. Uneven water supply may have provided additional variation in the Ashland plots. Ranges were laid out parallel to the irrigation sprinkler pipes. The second range yielded 13 percent more than the first. Variation between ranges was important because paired comparisons were made between ranges. An unnamed head blight was also present and could have caused additional variation although the pairs appeared to be equally infected.

Concerning the single row trials it was realized that the yield results would be subject to some error because the rows were in direct competition with each other. The significant difference in yield between the resistant and susceptible rows and the Manhattan sulfur treated block may be questioned. It was the only trial in which leaf rust affected yield and not kernel weight or test weight. Furthermore, it is strange that leaf rust would affect yield in the trial in which the leaf rust level was by far the lowest in any trial and not in trials with higher infection levels. As a consequence the author feels that all the single row yield data must be viewed with utmost skepticism.

Both years' data provide evidence that test weights and kernel weights increase with both leaf rust and stem rust resistance. The 1959 yield data were inconclusive but indicated that a leaf rust resistant-susceptible yield difference could be detected using this method of disease evaluation. For usable yield results larger tests are needed and soil and/or water variation such as was present at Ashland should be avoided.

SUMMARY

In this study leaf rust and stem rust damage was evaluated by comparing resistant and susceptible sister lines of wheat. This method of disease evaluation gives a direct measurement of the benefit derived from rust resistance.

In 1958, test weight, kernel weight, and kernel count data from sister line pairs differing in leaf rust and stem rust reactions showed that there were significant differences between sister pairs for that weight and kernel weight. No rust influence upon kernel number was detected. Analysis of variance of the data from both resistant and susceptible rows at both the leaf rust and the stem rust nurseries showed that families significantly influenced test weight and kernel weight differences among lines. Lines within families were found to significantly influence kernel count variation among heads. A correlation between stem rust infection percentage and test weight in the 1958 stem rust nursery trial produced a correlation coefficient of -.6446 which was significant to the .001 level.

In 1959, infection levels, yields, and rust effects varied between locations. Leaf rust had highly significant effects upon yield, test weight, and kernel weight in the stem rust nursery split plot trial at Manhattan, In the single row trials at that location test weight and kernel weight differences were significant but yield differences were not.

At Ashland in the single row comparisons leaf rust resistant and susceptible differences were statistically significant for yield, test weight and kernel weight. In the replicated plot trial only kernel weight differences were significant.

At Hutchinson the only statistically detected effect of leaf rust was upon kernel weight in the replicated plot trial.

Under sulfur treatment a significant difference in yield was detected between resistant and susceptible yields in the paired single rows. Other differences were not detected.

In paired single row comparisons in the stem rust nursery in 1958, test weights and kernel weights were significantly affected by stem rust but yields were not.

It was concluded that this approach to disease evaluation needs further study. Test weight and kernel weight were shown to be influenced by both leaf rust and stem rust reaction. Yield data were inconclusive but showed that significant differences could be detected between resistant and susceptible sister lines.

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APPENDIX

Table 1. Leaf rust percentage readings taken at Ashland and stem rust percentage readings taken at Manhattan on the rust effect study on wheat in 1958.

Entry No.	Family No.	Leaf rust %	Stem rust %	Entry No.	Family No.	Leaf rust %	Stem rust %
601	10293	90	T	641	10297	T-90	10
602		90	60	642		T	10
603		90	20	643		T	5
604		90	seg	644		T	10
605		90	seg	645		90	10
606		T	40	646		90	15
607		90	20	647		T	10
608		90	50	648		90	10
609	10294	T-90	15	649		T	20
610		T	20	650		T	20
611		80	30	651		T	20
612		T	30	652		T	20
613		T-5	30	653		T	30
614		80	40	654		T	30
615		90	30	655	10298	T-90	30
616		T	30	656		T-80	40
617		T	5	657		T	50
618		T	30	658		T	40
619	10295	T-90	50	659		T	30
620		T	30	660		T	20
621		T	15	661		90	50
622		T-80	30	662		T	30
623		T	10	663		90	40
624		T-80	30	664		T	30
625		80	20	665	10299	90	40
626		T	15	666		T	40
627		90	30	667		90	50
628		T-90	30	668		T	40
629	10296	90	40	669		90	40
630		90	40	670		T	40
631		T-90	40	671		90	60
632		T-90	40	672		90	50
633		T-80	30	673		T	40
634		T-80	15	674		90	40
635		90	30	675		90	50
636		90	30	676		T-90	30
637		T-80	40	677		T	40
638		T-80	40	678	10300	80	20
639		T-80	40	679		90	30
640		90	30	680		90	40

Table 1. (Continued)

Entry No.	Family No.	Leaf rust %	Stem rust %	Entry No.	Family No.	Leaf rust %	Stem rust %
681	10300	90	30	721	10305	T	30
682		90	30	722		T	40
683		90	30	723		T	40
684		90	40	724		T	30
685	10301	T	50	725		T	30
686		T	40	726		T	20
687		T	40	727		T	30
688		T	30	728	10306	T	20
689		T	40	729		90	30
690		T	40	730		T	30
691		T	40	731		90	30
692		T	50	732		T	20
693	10302	T	30	733		90	30
694		90	40	734		80	30
695		90	40	735		T	30
696		T	40	736	10307	T	30
697		90	30	737		80	40
698		T	40	738		80	30
699		T-90	30	739		T	30
700		90	30	740		T	30
701	10303	90	30	741		T-80	30
702		90	30	742		90	40
703		90	30	743		80	50
704		90	30	744		T-80	40
705		T-90	30	745		T	30
706		T-90	40	746		90	40
707		T-90	40	747		T	40
708		90	40	748	10308	T	30
709	10304	T	40	749		T	40
710		T	50	750		T	40
711		T	50	751		T	20
712		T	40	752		T	30
713		T	30	753		T	15
714		T	30	754		T	15
715		T	30	755		T	20
716		T	40	756		T	30
717		T	40	757	10309	T	30
718	10305	T	40	758		T	20
719		T	40	759		T	30
720		T	30	760		T	30

Table 1. (Continued)

Entry No.	Family No.	Leaf rust %	Stem rust %	Entry No.	Family No.	Leaf rust %	Stem rust %
761	10309	T	30	801	10312	T	40
762		90	30	802		80	30
763		T	20	803		T	30
764		T	30	804	10313	T	20
765		T	15	805		T	20
766		T	15	806		90	30
767		T	20	807		T	40
768	10310	T-80	20	808		T	40
769		90	20	809		90	50
770		T	20	810		T	40
771		T	15	811		T	30
772		80	15	812		T-80	20
773		90	20	813		80	30
774		T	30	814		T	30
775		T-80	30	815		T	30
776		T	30	816	10314	90	30
777		T	20	817		T-80	20
778		90	20	818		80	20
779		T-90	40	819		T	20
780	10311	T	50	820		T	20
781		T	50	821		80	30
782		T	50	822		T-80	40
783		T	50	823		T	20
784		T	40	824		T-80	30
785		T	40	825		80	30
786		T-60	40	826		80	30
787		T	30	827	10315	80	15
788		T	60	828		90	15
789		T	50	829		90	30
790		T	50	830		90	30
791		T	40	831		90	20
792		T	40	832		80	20
793	10312	90	30	833		90	30
794		90	30	834		80	30
795		90	40	835		80	20
796		90	30	836		80	20
797		90	30	837		80	30
798		90	30	838		80	20
799		90	40	839		80	20
800		90	40	840	10316	70	30

Table 1. (Continued)

Entry No.	Family No.	Leaf rust %	Stem rust %	Entry No.	Family No.	Leaf rust %	Stem rust %
841	10316	T		881	10319	T	30
842		T		882		T	30
843		T-80		883		80	40
844		T-80		884		T	20
845		T-90		885		T	30
846		T		886		90	40
847		T		887		T	30
848	10317	80		888	10320	T-90	40
849		T-90		889		T	30
850		90		890		90	40
851		T		891		T	40
852		T-80		892		90	60
853		T		893		T	50
854		T		894		T	40
855		90		895		90	50
856		T-80		896		90	40
857		90		897		90	40
858		90		898		T	30
859		90		899		T	30
860		T		900	10321	T-80	20
861		90		901		T	30
862	10318	T		902		T	40
863		T-80		903		T	30
864		90		904		T-80	30
865		T-80		905		T	30
866		T		906		T	30
867		T		907		T-80	30
868		90		908		T-80	30
869		T-80		909		90	20
870		T		910		T	30
871		T-90		911		90	20
872		90		912	10322	T	20
873		T		913		T	20
874	10319	T		914		T	30
875		T-5		915		T	20
876		T		916		T	20
877		T-80		917		T	20
878		80		918		T	30
879		T		919		T	20
880		T		920		T	30
				921		T	30
				922		T	20
				923		T	20

Table 2. Relative test weights of single rows grown in the stem rust nursery rust effect study in 1958.

Entry No.	T.W.	Entry No.	T.W.	Entry No.	T.W.
601	22.1	641	22.6	681	22.8
602	19.0	642	23.0	682	20.0
603	22.7	643	23.1	683	23.5
604	19.6	644	23.4	684	22.0
605	20.3	645	21.5	685	18.8
606	22.0	646	22.9	686	22.5
607	21.8	647	22.6	687	23.8
608	21.5	648	22.4	688	20.4
609	22.8	649	22.8	689	19.9
610	22.1	650	23.4	690	21.1
611	21.0	651	22.6	691	19.9
612	22.5	652	24.0	692	19.4
613	21.5	653	22.4	693	21.5
614	19.7	654	23.6	694	21.4
615	21.0	655	23.5	695	20.0
616	22.6	656	19.8	696	20.6
617	23.1	657	20.3	697	20.6
618	22.2	658	23.0	698	20.3
619	22.1	659	23.1	699	23.1
620	22.2	660	23.4	700	21.4
621	22.0	661	19.5	701	21.6
622	22.2	662	23.0	702	20.7
623	21.7	663	20.9	703	20.9
624	21.9	664	23.0	704	21.2
625	22.4	665	18.6	705	21.6
626	22.5	666	21.5	706	21.5
627	22.2	667	missing	707	20.7
628	21.8	668	21.9	708	22.0
629	21.3	669	20.4	709	21.2
630	19.6	670	22.0	710	18.4
631	21.2	671	18.0	711	18.0
632	20.9	672	17.0	712	18.7
633	22.4	673	22.2	713	20.6
634	23.5	674	22.0	714	21.8
635	19.4	675	18.8	715	21.2
636	20.6	676	20.6	716	22.0
637	20.2	677	21.7	717	17.9
638	23.0	678	23.3	718	20.5
639	19.5	679	23.6	719	20.4
640	20.3	680	20.0	720	21.1

Table 2. (Continued)

Entry No.	T.W.	Entry No.	T.W.	Entry No.	T.W.
721	20.3	761	23.7	801	21.8
722	18.9	762	20.6	802	21.6
723	20.2	763	23.1	803	22.0
724	23.9	764	20.8	804	22.2
725	23.0	765	21.8	805	22.9
726	24.0	766	23.0	806	22.0
727	23.3	767	21.5	807	22.0
728	23.4	768	22.0	808	19.0
729	22.7	769	22.7	809	22.1
730	24.0	770	22.4	810	19.1
731	23.0	771	23.0	811	22.9
732	23.7	772	23.4	812	22.8
733	23.0	773	23.6	813	21.5
734	22.8	774	23.9	814	22.1
735	22.9	775	22.9	815	21.8
736	22.6	776	21.2	816	22.0
737	20.9	777	23.1	817	23.0
738	22.2	778	22.6	818	23.0
739	22.1	779	21.7	819	23.8
740	22.7	780	19.7	820	22.9
741	21.9	781	18.2	821	22.0
742	18.4	782	19.6	822	22.0
743	18.0	783	19.0	823	23.8
744	21.0	784	20.0	824	23.3
745	22.1	785	22.0	825	21.7
746	19.0	786	19.4	826	23.1
747	18.7	787	23.3	827	23.1
748	23.0	788	21.1	828	22.7
749	22.5	789	20.1	829	21.9
750	22.8	790	18.9	830	23.0
751	23.5	791	21.9	831	22.9
752	22.4	792	22.6	832	22.5
753	22.3	793	22.0	833	20.7
754	23.0	794	21.7	834	23.1
755	21.8	795	18.5	835	24.2
756	21.3	796	20.6	836	24.3
757	20.1	797	22.9	837	21.8
758	22.3	798	21.4	838	23.9
759	21.5	799	20.4	839	23.6
760	21.9	800	20.8	840	23.4

Table 2. (Continued)

Entry No.	T.W.	Entry No.	T.W.	Entry No.	T.W.
841	25.0	871	23.3	901	23.8
842	24.8	872	21.2	902	23.9
843	22.5	873	21.7	903	24.3
844	22.0	874	22.5	904	24.0
845	22.1	875	22.0	905	24.5
846	22.5	876	22.6	906	23.6
847	23.9	877	22.5	907	24.1
848	22.8	878	22.2	908	23.4
849	22.4	879	22.0	909	24.6
850	19.0	880	22.9	910	24.5
851	21.2	881	23.4	911	24.1
852	19.5	882	23.0	912	24.0
853	22.8	883	22.7	913	24.3
854	21.5	884	23.9	914	23.9
855	17.7	885	22.8	915	23.9
856	21.9	886	22.9	916	23.6
857	18.5	887	23.0	917	23.7
858	20.6	888	21.0	918	23.1
859	21.4	889	23.1	919	23.9
860	22.6	890	20.9	920	23.6
861	21.4	891	21.8	921	24.0
862	23.9	892	20.4	922	24.0
863	20.2	893	19.0	923	24.1
864	21.0	894	22.6		
865	23.0	895	20.1		
866	22.7	896	23.3		
867	22.3	897	22.5		
868	22.2	898	23.3		
869	23.4	899	23.0		
870	24.5	900	24.4		

Table 3. Relative test weights and 100-kernel weights in grams and average number of kernels per head for rows grown in the leaf rust nursery at Ashland in 1958 which came from families containing both resistant and susceptible lines and were not segregating for leaf rust reaction.

Entry No.	% L.R.	Test weight*		100-kernel weight*		Average kernels* per head	
		R	S	R	S	R	S
601	90		10.9		2.62		22.5
602	90		11.3		2.88		29.0
603	90		11.2		2.85		33.0
604	90		11.4		2.80		39.8
605	90		11.5		2.54		26.5
606	T	11.1		2.99		2.42	
607	90		11.1	Missing			25.5
608	90		11.5		3.29		26.2
610	T	11.2		3.46		31.0	
611	80		11.2		3.18		35.2
612	T	11.3		3.26		28.5	
613	T-5	11.5		3.32		28.2	
614	80		11.0		2.91		24.2
615	90		11.3		3.12		25.8
616	T	11.4		3.26		Missing	
617	T	11.2		3.30		24.8	
618	T	11.4		3.59		29.2	
620	T	11.4		3.26		18.0	
621	T	11.5		3.63		24.5	
623	T	11.3		3.60		24.2	
625	80		11.0		2.92		27.8
626	T	11.6		3.42		27.8	
627	90		11.3		3.10		24.0
642	T	11.2		3.25		25.0	
643	T	11.3		3.48		28.2	
644	T	11.1		3.56		Missing	
645	90		10.6		2.60		23.5
646	90		11.6		2.82		27.0
647	T	11.3		3.32		27.0	
648	90		11.1		3.04		28.2
649	T	11.2		3.22		Missing	
650	T	11.2		3.26		26.0	
651	T	10.9		3.19		31.8	
652	T	11.5		3.26		23.5	
653	T	11.1		3.23		30.2	
654	T	11.5		3.23		27.8	

Table 3. (Continued)

Entry No.	% L.R.	Test weight*		100-kernel weight*		Average kernels* per head	
		R	S	R	S	R	S
657	T	11.1		3.48		28.0	
658	T	11.2		3.72		23.5	
659	T	11.4		3.67		20.2	
660	T	11.4		3.63		25.0	
661	90		11.0		3.07		18.0
662	T	11.1		3.65		23.0	
663	90		11.0		3.21		29.0
664	T	11.5		3.44		Missing	
665	90		11.1		2.95		31.2
666	T	11.2		3.16		27.5	
667	90		11.3		2.88		29.2
668	T	11.5		3.05		28.2	
669	90		11.1		2.96		31.2
670	T	11.3		3.12		Missing	
671	90		11.0		2.87		33.0
672	90		11.0		3.08		25.8
673	T	11.5		3.42		32.5	
674	90		10.9		2.99		29.8
675	90		11.0		2.74		39.8
677	T	11.4		3.50		2[illegible].8	
693	T	11.4		3.38		Missing	
694	90		11.2		2.70		28.5
695	90		11.5		2.86		23.0
696	T	11.4		3.47		25.8	
697	90		11.1		3.29		29.8
698	T	11.2		3.40		34.2	
700	90		11.1		3.15		29.2
728	T	11.2		3.32		Missing	
729	90		11.1		3.18		18.2
730	T	11.2		3.33		20.0	
731	90		11.2		3.18		18.0
732	T	11.4		3.27		Missing	
733	90		11.0		3.06		22.5
734	80		10.8		2.88		23.0
735	T	10.6		2.86		27.2	

Table 3. (Continued)

Entry No.	% L.R.	Test weight*		100-kernel weight*		Average kernels* per head	
		R	S	R	S	R	S
736	T	10.8		3.18		20.2	
737	80		Missing		2.83		20.2
738	80		10.9		2.81		21.0
739	T	11.3		3.21		24.0	
740	T	11.1		3.59		25.0	
742	90		Missing		3.16		23.0
743	80		11.1		3.16		20.2
745	T	11.2		3.35		20.2	
746	90		10.9		3.18		27.8
747	T	11.5		3.44		29.0	
757	T	11.0		3.12		27.5	
758	T	11.5		3.23		33.8	
759	T	10.8		3.29		31.5	
760	T	11.2		2.99		35.0	
761	T	11.0		3.30		28.8	
762	90		10.7		2.84		25.2
763	T	Missing		2.67		31.2	
764	T	11.0		3.32		36.0	
765	T	11.0		3.07		33.2	
766	T	11.0		3.31		31.5	
767	T	11.0		3.23		30.2	
769	90		11.0		3.20		28.5
770	T	11.0		3.14		31.0	
771	T	10.9		2.80		29.2	
772	80		10.7		2.99		25.8
773	90		10.5		2.71		30.5
774	T	11.4		3.38		29.5	
776	T	11.3		3.30		27.5	
777	T	11.3		3.58		Missing	
778	90		Missing		Missing		26.8

Table 3. (Continued)

Entry No.	% L.R.	Test weight* R	Test weight* S	100-kernel weight* R	100-kernel weight* S	Average kernels* per head R	Average kernels* per head S
793	90		11.4		2.96		34.8
794	90		11.1		2.87		35.8
795	90		10.8		2.57		32.0
796	90		10.9		2.92		27.8
797	90		10.8		3.04		29.0
798	90		10.9		2.78		32.8
799	90		10.8		3.23		31.2
800	80		11.1		3.09		31.2
801	T	11.4		3.29		37.2	
802	80		11.0		3.00		30.0
803	T	11.5		3.15		35.2	
804	T	11.1		3.70		28.5	
805	T	11.6		3.33		24.8	
806	90		11.1		34.9		27.2
807	T	11.3		3.11		32.2	
808	T	11.1		3.51		31.5	
809	90		11.0		2.82		30.2
810	T	11.1		3.42		35.5	
811	T	11.4		3.47		30.2	
813	80		11.1		3.25		26.8
814	T	11.4		3.74		32.5	
815	T	11.2		3.24		29.8	
816	90		11.2		2.95		33.5
818	80		11.1		3.07		34.2
819	T	11.0		3.50		23.8	
820	T	11.4		3.18		34.0	
821	80		10.0		3.23		30.2
823	T	10.9		3.39		29.8	
825	80		11.0		3.48		28.8
826	80		11.0		2.98		29.2
840	70		11.2		2.90		29.0
841	T	10.9		3.38		33.0	
842	T	11.0		3.25		27.8	
846	T	11.1		3.05		38.2	
847	T	10.8		3.10		29.2	

Table 3. (Continued)

Entry No.	% L.R.	Test weight* R	Test weight* S	100-kernel weight* R	100-kernel weight* S	Average kernels* per head R	Average kernels* per head S
848	80		10.9		3.80		24.8
850	90		11.0		2.89		33.5
851	T	11.0		3.50		25.5	
853	T	11.3		3.54		34.2	
854	T	11.0		3.94		Missing	
857	90		10.5		2.87		32.2
858	90		10.6		3.37		24.2
859	90		10.6		3.66		29.0
860	T	11.0		3.35		29.8	
861	90		10.6		3.33		42.0
862	T	11.0		3.22		31.8	
864	90		11.0		2.95		29.2
866	T	11.4		3.43		25.5	
867	T	11.0		3.47		32.2	
868	90		10.9		3.09		28.8
870	T	11.2		3.36		29.5	
872	90		11.1		3.23		27.5
873	T	11.2		3.27		33.8	
874	T	11.0		3.54		28.8	
875	T-5	11.0		3.19		31.5	
876	T	10.9		3.54		33.2	
878	80		10.8		2.85		27.5
879	T	11.0		3.67		33.5	
880	T	11.0		3.04		41.5	
881	T	11.2		3.06		33.2	
882	T	10.8		3.14		33.5	
883	80		10.9		3.27		30.5
884	T	11.4		3.19		37.2	
885	T	10.9		3.60		24.2	
886	90		10.9		3.26		28.5
887	T	11.0		3.63		32.3	
889	T	11.0		3.21		45.5	
890	90		11.0		3.00		34.8
891	T	11.0		3.31		33.8	
892	90		10.8		2.84		38.0
893	T	11.0		3.04		38.8	
894	T	11.0		3.21		36.2	
895	90		11.0		2.93		29.0
896	90		11.0		3.20		32.8
897	90		11.0		3.22		33.5
898	T	11.4		3.41		26.5	
899	T	11.1		3.40		37.2	

Table 3. (Continued)

Entry No.	% L.R.	Test weight* R	Test weight* S	100-kernel weight* R	100-kernel weight* S	Average kernels* per head R	Average kernels* per head S
901	T	Missing		Missing		35.8	
902	T	11.2		3.03		36.8	
903	T	11.4		3.03		31.0	
904	T	11.3		3.50		23.8	
905	T	11.5		3.51		38.5	
906	T	11.0		3.06		28.5	
909	90		11.1		3.47		29.5
910	T	11.0		2.73		Missing	
911	90		11.1		2.97		40.0

* Double columns are used to facilitate comparisons between resistant and susceptible row data.

Table 4. Relative test weights and 100-kernel weights in grams and average number of kernels per head for rows grown in the stem rust nursery in 1958 which came from families containing both resistant and susceptible lines and were either resistant or susceptible with a stem rust reading of 50 percent or higher.

Entry No.	% Stem rust	Test weight R	Test weight S	100-kernel weight R	100-kernel weight S	Average kernels per head R	Average kernels per head S
601	T	22.1		1.76		25.0	
602	60		19.0		1.37		19.8
603	20	22.7		1.66		25.4	
607	20	21.8		1.52		25.2	
608	50		21.5		1.52		22.4
619	50		21.1		1.53		23.8
620	30	22.2		2.00		23.6	
621	15	22.[illegible]		1.94		23.6	
622	30	22.2		1.74		24.6	
623	10	21.7		1.76		25.2	
624	30	21.9		1.67		20.4	
625	20	22.4		1.88		21.4	
626	15	22.5		1.77		20.6	
627	30	22.2		1.86		23.2	
628	30	21.8		1.87		28.2	
655	30	23.5		2.18		28.8	
657	50		20.3		1.68		25.6
659	30	23.1		2.14		26.6	
660	20	23.4		2.08		20.8	
661	50		19.5		1.44		23.2
662	30	23.0		2.19		26.2	
664	30	23.0		2.09		26.8	
667	50		Missing		1.16		31.6
671	60		18.0		1.19		30.6
672	50		17.0		1.13		26.8
675	50		18.8		1.24		26.8
676	30	20.6		1.82			Missing
685	50		18.8		1.25		25.0
688	30	20.4		1.53		24.6	
692	50		19.4		1.35		23.6
710	50		18.4		1.28		22.4
711	50		18.0		1.21		19.8
713	30	20.6		1.49		24.6	
714	30	21.8		1.96		29.6	
715	30	21.2		1.85		28.8	

Table 4. (Continued)

Entry No.	Stem rust	Test weight R	Test weight S	100-kernel weight R	100-kernel weight S	Average kernels per head* R	Average kernels per head* S
736	30	22.6		1.96		30.6	
738	30	22.2		1.85		27.2	
739	30	22.1		2.00		26.0	
740	30	22.7		2.07		23.4	
741	30	21.9		1.90		22.4	
743	50		18.0		1.38		25.4
745	30	22.1		1.83		18.6	
780	50		19.7		1.59		29.2
781	50		18.2		1.30		18.6
782	50		19.6		1.54		23.8
783	50		19.0		1.40		21.2
787	30	23.3		2.26		24.2	
788	60		20.1		1.52		24.6
789	50		18.9		1.42		Missing
790	50		21.1		1.82		25.6
804	20	22.2		2.02		21.6	
805	20	22.9		2.16		26.0	
806	30	22.0		2.02		20.0	
811	50		21.1		1.87		21.6
812	30	22.9		1.98		20.8	
813	20	22.8		2.06		22.8	
814	30	21.5		1.84		27.0	
815	30	21.8		1.72		20.8	
848	30	22.8		1.94		22.0	
850	60		19.0		1.43		18.0
851	50		21.2		1.69		24.6
852	60		19.5		1.53		22.4
853	30	22.8		2.16		24.0	
855	50		17.7		1.25		22.8
862	20	23.9		2.15		32.0	
863	50		20.9		1.39		21.8
867	30	22.3		2.00		21.2	
869	30	23.4		2.20		24.2	
870	20	24.5		2.24		22.6	
871	30	23.3		1.86		22.0	
889	30	23.1		2.26		25.0	
892	60		20.4		1.55		18.0
893	50		19.0		1.44		21.8
895	50		20.1		1.62		21.6
898	30	23.3		2.55		23.6	
899	30	23.0		2.43		28.6	

*Double columns are used to facilitate comparisons between resistant and susceptible row data.

Table 5. Test weight, kernel weight and kernel count data used in t-tests evaluating the differences between the most resistant and the most susceptible lines grown in the rust nursery in 1958.

Entry No.*	% L.R.	Test weight	100-kernel weight	Number of kernels per four heads
602	90	11.3	2.88	116
603	T	11.2	2.99	97
616-618	T	11.4	3.26	117
615	90	11.3	3.12	103
623	T	11.3	3.60	97
627	90	11.3	3.10	96
646	90	11.6	2.82	108
652	T	11.5	3.26	94
661	90	11.0	3.07	72
662	T	11.1	3.65	92
672	90	11.0	3.08	103
670-673	T	11.3	3.12	130
700	90	11.1	3.15	117
696	T	11.4	3.40	103
732-735	T	11.4	3.27	109
729	90	11.1	3.18	73
747	T	11.5	3.44	116
746	90	10.9	3.18	111
764	T	11.0	3.32	144
762	90	10.7	2.84	101
769	90	11.0	3.20	114
770	T	11.0	2.80	124
797	90	10.8	3.04	116
803	T	11.5	3.15	141
805	T	11.6	3.33	99
806	90	11.5	3.49	109
816	90	11.2	2.95	134
819	T	11.0	3.50	95

Table 5. (Continued)

Entry No.*	% L.R.	Test weight	100-kernel weight	Number of kernels per four heads
840	70	11.2	2.90	116
842	T	11.0	3.25	111
851	T	11.0	3.50	102
857	90	10.5	2.87	129
872	90	11.1	3.23	110
873	T	11.2	3.27	135
880	T	11.0	3.04	166
886	90	10.9	3.26	114
893	T	11.0	3.04	155
896	90	11.0	3.20	131
911	90	11.2	2.97	160
910-913	T	11.[illegible]	2.73	124
		Analysis		
N		20	20	20
S		3.2	3.39	68
SS		1.92	2.3347	13550
Sa		1.408	1.7601	13318.8
$\bar{x}$		.16	.1695	3.4
s		.08608	.60806	5.92026
t		1.858*	2.490*	0.5742 n.s.

* Two entry numbers are listed for pair members on which the kernels per head data was missing for the first lines chosen. In those cases the second entry number refers to the kernel count data only.

Table 6. Test weight, kernel weight, and kernel count data used in t-tests evaluating the differences between the most resistant and the most susceptible lines grown in the stem rust nursery in 1958.

Entry No.	% R S	Test weight	100-kernel weight	No. of kernels in five heads
601	T	22.1	1.76	125
602	60	19.0	1.37	99
619	50	21.1	1.53	119
623	10	21.7	1.76	126
660	20	23.4	2.08	104
657	50	20.3	1.68	128
671	60	18.0	1.19	No pairs
676	30	20.6	1.82	
787	30	23.3	2.26	121
788	60	21.1	1.82	128
809	50	22.1	1.87	108
812	20	22.8	2.06	114
852	60	19.5	1.53	112
848	30	22.8	1.94	110
863	50	20.9	1.39	109
862	20	23.9	2.15	160
892	60	20.4	1.55	90
899	30	23.0	2.43	143

Analysis

	Test weight	100-kernel weight	No. of kernels in five heads
N	9	9	8
S	21.2	4.33	110
SS	58.32	2.5117	6800
Ss	8.383	.4285	5287.5
$\bar{x}$	2.35	.4811	13.75
s	.3412	.07714	9.7169
t	6.887***	6.236***	1.415 n.s.

Table 7. Leaf rust percentage readings of the paired single rows taken at Hutchinson, Ashland, Manhattan stem-rust nursery, and Manhattan sulfur nursery in 1959.

Entry No.	% Leaf Rust* Hutchinson	Ashland	SRN	Sulful	Entry No.	% Leaf Rust Hutchinson	Ashland	SRN	Sulfur
921	50	80	60	20	957	0-50	T-70	T-80	5
922	60	80	70	20	958	50	80	80	10
923	0	T	T	0	959	T	T	T	0
924	50	80	70	20	960	50	80	80	5
925	50	80	60	20	961	T	T	T	0
926	0	T	T	T	962	T	T	T	0
927	50	T	T	T	963	50	80	70	20
928	50	80	80	10	964	0	T	T	0
929	0	T	T	T	965	0	T	T	0
930	30	80	50	10	966	50	90	80	30
931	40	80	60	10	967	40	80	70	10
932	0	T	T	T	968	0	T	T	T
933	0	T-80	T-	5	969	50	80	70	10
934	0	T	T	T	970	0	T	T	T
935	0	T	T	0	971	30	80	70	10
936	50	80	60	10	972	0	T	T	T
937	50	80	40-70	10	973	40	80	70	10
938	0	T	T	0	974	0	T	T	T
939	40	80	70	10	975	40	80	70	5
940	50	80	60	10	976	0-50	T-80	T-	5
941	0	T	T	T	977	40	80	70	5
942	0	T	T	0	978	0	T	T	0
943	0	T	T	0	979	0	T-90	T-80	5
944	50	80	70	10	980	30	80	5-70	5
945	0	T	T	0	981	0	T	T	T
946	0	T	T	T	982	0	T	T	T
947	0	T	T	T	983	0-50	T-80	T	T
948	0	T	T	T	984	0	T	T	T
949	40	T	T	10	985	0	T	T-	0
950	40	80	80	10	986	0	T	T	T
951	0	T	T	T	987	0-50	T-70	T-80	10
952	0	T	T	T	988	0	T-80	T-80	T
953	50	80	80	20	989	0-50	T-	T-60	10
954	0-50	T-80	70	20	990	0-	T	T	T
955	50	T-80	80	30	991	0	T	T	T
956	0-50	T-80	T-[illegible]	10	992	0	T	T	T

* Two readings are listed for rows segregating for leaf rust reaction. The underline indicates the predominent reading in the segregating row. The dash indicates that a few susceptible plants were present.

Table 8. Stem rust percentage readings of the paired single rows in the stem rust nursery at Manhattan, 1959.

Entry No.	% Stem Rust	Entry No.	% Stem Rust	Entry No.	% Stem Rust
921	30	945	70	969	40
922	70	946	70	970	50
923	30	947	30	971	50
924	40	948	20	972	30
925	70	949	15	973	50
926	20	950	30	974	30
927	30	951	30	975	40
928	50	952	30	976	20
929	10	953	40	977	15
930	15	954	20	978	10
931	10	955	30	979	30
932	5	956	30	980	30
933	30	957	15	981	50
934	15	958	20	982	15
935	10	959	20	983	10
936	40	960	20	984	60
937	60	961	50	985	20
938	30	962	70	986	5
939	20	963	70	987	50
940	50	964	60	988	20
941	30	965	30	989	5
942	70	966	40	990	T
943	50	967	20	991	T
944	50	968	20	992	5

Table 9. Average leaf rust percentage readings of the replicated plots taken at Hutchinson, Ashland, Manhattan stem rust nursery, and Manhattan sulfur nursery in 1959.

Entry No.	% Leaf Rust			
	Hutchinson	Ashland	SRN	Sulfur
901	47	83	70	13
902	T	T	7	T
903	57	87	83	27
904	53	77	77	23
905	50	80	73	27
906	0	T	T	T
907	53	90	80	40
908	T-50	T-77	T-80	8
909	0	T	T	T
910	53	83	73	27
911	50	80	57	13
912	T	2	T	T

Table 10. Average stem rust percentage readings of the replicated plots at the Manhattan stem rust nursery in 1959.

Entry No.	% Stem Rust	Entry No.	% Stem Rust
901	17	907	27
902	17	908	13
903	33	909	30
904	37	910	30
905	30	911	33
906	22	912	37

Table 11. Height of the leaf rust pairs in both the paired rows and replicated plots in the stem-rust nursery and the sulful nursery in 1959.

Entry No.	Ht. in inches SRN	Sulfur	Entry No.	Ht. in inches SRN	Sulfur
901	38	41	937	37	39
902	38	40	938	36	38
905	36	38	943	36	37
906	36	37	944	37	39
907	37	38	949	37	38
908	37	38	950	36	39
909	36	38	959	35	36
910	35	38	960	36	36
911	36	39	963	36	37
912	36	40	964	37	38
			965	37	36
			966	36	37
923	36	37	967	36	37
924	36	38	968	36	36
925	36	37	969	37	37
926	37	37	970	37	37
927	37	37	971	36	35
928	35	36	972	38	38
929	38	40	973	37	37
930	36	39	974	37	38
931	37	41	977	39	40
932	37	40	978	37	38
935	37	39			
936	36	37			

Table 12. Dates of ½ bloom of the leaf rust pairs in both the paired rows and replicated plots in the stem rust nursery and the sulfur nursery in 1959.

Entry No.	Date in May SRN	Date in May Sulfur	Entry No.	Date in May SRN	Date in May Sulfur
901	22	23	937	22	22
902	22	23	938	22	22
905	22	22	943	22	22
906	22	23	944	22	22
907	23	22	949	22	22
908	22	22	950	22	22
910	22	21	959	22	22
909	22	21	960	22	22
911	22	21	963	22	21
912	22	21	964	23	21
923	22	21	965	22	21
924	22	23	966	22	21
925	22	23	967	22	21
926	22	21	968	22	21
927	22	21	969	22	21
928	22	21	970	22	21
929	22	22	971	22	21
930	22	22	972	22	21
931	22	22	973	22	21
932	22	22	974	22	20
935	22	22	977	23	21
936	22	22	978	23	22

Table 13. Yields, test weights, and 500 kernel weights of paired single rows at Hutchinson in 1959.

Entry No.	% Leaf Rust	Yield Grams	Yield R-S	Test Weight Grams	Test Weight R-S	Kernel Weight Grams	Kernel Weight R-S
923	0	135		26.9		13.70	
924	50	155	-20	26.6	.3	13.37	.33
925	50	171		26.8		13.67	
926	0	116	-55	26.9	-.1	14.73	1.06
927	0	141		26.8		14.15	
928	50	104	37	26.6	.2	12.88	1.27
929	0	119		27.0		14.63	
930	30	123	- 4	27.1	-.1	12.69	1.94
931	40	180		26.6		14.23	
932	0	93	-87	26.3	-.3	13.06	-1.17
935	0	150		26.7		15.02	
936	50	92	58	26.9	-.2	13.84	1.18
937	50	159		26.8		12.95	
938	0	104	-55	26.5	-.3	14.06	1.11
943	0	153		27.0		14.88	
944	50	149	4	27.4	-.4	15.57	-.69
959	0	115		27.2		14.53	
960	50	123	-8	26.1	1.1	14.78	-.25
963	50	121		27.0		12.97	
964	0	151	30	27.1	.1	14.72	1.75
965	0	112		26.0		14.13	
966	50	117	- 5	27.4	-1.4	12.67	1.46
967	40	141		26.7		15.01	
968	0	106	-35	26.0	-.7	13.73	-1.28
969	50	131		27.0		14.16	
970	0	95	-36	27.0	0	15.66	1.50
971	30	148		26.9		13.59	
972	0	157	9	27.0	.1	14.19	.60
973	40	72		26.1		13.98	
974	0	143	71	26.9	.8	12.71	-1.27
977	40	146		27.8		14.02	
978	0	133	-13	27.0	-.8	14.00	-.02

Table 14. Yields, test weight, and 500 kernel weights of paired single rows under sulfur treatment at Manhattan in 1959.

Entry No.	% Leaf Rust	Yield Grams	Yield R-S	Test Weight Grams	Test Weight R-S	Kernel Weight Grams	Kernel Weight R-S
923	0	219		26.6	-.9	14.59	
924	20	203	16	27.5		14.54	.05
925	20	161		26.1		14.12	
926	T	215	54	26.8	.7	14.77	.65
927	T	229		27.0		15.66	
928	10	238	- 9	27.1	-.1	15.36	.30
929	T	221		27.5		16.12	
930	10	222	- 1	26.9	.6	14.07	2.05
931	10	188		27.0		14.42	
932	T	246	58	27.4	.4	14.54	.12
935	0	192		27.8		16.17	
936	10	241	-49	27.0	.8	15.58	.59
937	10	187		27.9		15.07	
938	0	305	118	27.9	0	15.14	.07
943	0	223		27.5		16.15	
944	10	199	24	27.2	.3	16.30	-.15
949	10	195		26.9		15.50	
950	10	256	-61	27.4	-.5	16.24	-.74
959	T	208		27.4		15.39	
960	5	258	-50	27.5	-.1	15.51	-.12
963	20	259		27.5		14.41	
964	0	230	-29	27.2	-.3	15.58	1.17
965	0	277		27.4		15.57	
966	30	230	47	27.5	-.1	14.93	.64
967	10	166		26.9		16.46	
968	T	243	77	27.3	.4	15.87	-.59
969	10	186		27.4		15.68	
970	T	260	74	27.7	.3	15.76	.08
971	10	214		27.7		16.00	
972	T	266	52	27.0	-.7	16.69	.69

Table 14. (Continued)

Entry No.	% Leaf Rust	Yield Grams	Yield R-S	Test Weight Grams	Test Weight R-S	Kernel Weight Grams	Kernel Weight R-S
973	10	247		27.6		17.10	
974	T	290	43	27.1	-.5	14.39	-2.71
977	5	193		27.8		14.92	
978	0	275	82	27.5	.3	16.22	1.30

Table 15. Yields, test weights, and 500 kernel weights of paired single rows with natural leaf rust infection at Manhattan in 1959.

Entry No.	% Leaf Rust	Yield Grams	Yield R-S	Test weight Grams	Test weight R-S	Kernel weight Grams	Kernel weight R-S
923	T	221		26.9		15.00	
924	70	166	55	25.8	1.1	12.81	2.19
925	60	168		26.0		12.36	
926	T	159	- 9	26.9	.9	13.83	1.47
927	T	256		26.5		16.90	
928	80	189	67	26.1	.4	14.37	2.53
929	T	190		27.0		16.87	
930	50	214	-24	26.3	.7	14.01	2.86
931	60	196		26.8		14.45	
932	T	178	-18	26.5	-.3	14.83	.38
935	T	213		26.9		15.04	
936	60	170	43	26.0	.9	13.05	1.99
937	40-70	155		26.6		13.11	
938	T	161	6	26.4	-.2	14.14	1.03
943	T	169		26.5		15.25	
944	70	120	49	26.1	.4	14.49	.76
949	T	165		27.1		14.71	
950	80	139	26	26.1	1.0	14.26	.45
959	T	129		26.6		14.33	
960	80	167	-38	26.4	-.2	13.45	.88
963	70	188		25.1		12.19	
964	T	140	48	25.8	.7	14.25	2.06
965	T	190		26.8		15.47	
966	80	193	- 3	26.9	-.1	13.95	1.52
967	70	150		26.7		16.17	
968	T	180	30	25.9	-.8	15.45	-.72
969	70	176		26.6		14.24	
970	T	178	2	26.2	-.4	15.63	1.39
971	70	152		25.6		13.30	
972	T	150	- 2	26.2	.6	14.56	1.26
973	70	153		25.6		13.59	
974	T	127	-26	25.6	0	13.57	-.02
977	70	117		25.0		13.31	
978	T	130	13	26.0	1.0	15.60	2.29

Table 16. Yields, test weights and 500 kernel weights of paired single rows at Ashland in 1959.

Entry	%	Yield		Test weight		Kernel weight	
No.	Leaf Rust	Grams	R-S	Grams	R-S	Grams	R-S
923	T	242		27.3		12.55	
924	80	125	117	26.2	1.1	10.00	2.55
925	80	137		25.9		9.52	
926	T	150	13	27.0	1.1	11.37	1.85
927	T	150		27.1		12.33	
928	80	123	27	26.7	.4	10.87	1.46
929	T	148		26.6		11.99	
930	80	112	36	25.2	1.4	8.90	3.09
931	80	145		25.6		10.07	
932	T	189	44	27.2	1.6	11.90	1.83
935	T	152		26.7		12.71	
936	80	144	8	25.9	.8	10.75	1.96
937	80	173		27.5		11.07	
938	T	204	31	27.0	-.5	12.21	1.14
943	T	146		26.4		11.73	
944	80	124	22	26.1	.3	10.56	1.17
949	T	186		26.4		11.40	
950	80	144	42	25.0	1.4	10.39	1.01
959	T	207		27.9		13.98	
960	80	175	32	27.4	.5	11.69	2.29
963	80	168		27.2		11.15	
964	T	142	-26	27.0	-.2	12.58	1.43
965	T	235		27.7		14.41	
966	90	166	69	27.0	.7	11.83	2.58
967	80	172		27.2		13.00	
968	T	209	37	28.1	.9	14.71	1.71
969	80	192		27.1		11.24	
970	T	165	-27	27.8	.7	14.57	3.33
971	80	191		27.4		11.24	
972	T	225	34	27.7	.3	14.35	3.11
973	80	201		27.9		13.06	
974	T	189	-12	27.9	0	13.32	.26
977	80	146		27.5		12.05	
978	T	148	2	26.8	-.7	11.89	-.16

Table 17. Yields in grams of the replicated plots in the stem rust nursery at Manhattan in 1959.

Entry No.	Rep. I		Rep. II		Rep. III		Average	
	R	S	R	S	R	S	R	S
901		301		233		336		290.0
902	427		386		453		422.0	
905		282		316		268		288.6
906	298		396		431		375.0	
907		370		315		269		318.0
908	315		357		350		340.6	
909	418		394		455		455.6	
910		328		303		405		345.3
911		289		353		298		313.3
912	425		343		373		380.3	

Table 18. Relative test weights from the replicated plots in the stem rust nursery at Manhattan, Kansas in 1959.

Entry No.	Rep. I		Rep. II		Rep. III		Average	
	R	S	R	S	R	S	R	S
901		24.8		25.0		26.0		25.26
902	26.4		26.6		27.0		26.66	
905		25.0		25.0		26.0		25.23
906	27.0		26.8		26.6		26.80	
907		25.9		26.0		26.0		25.96
908	25.9		26.6		25.8		26.10	
909	27.0		26.3		26.1		26.46	
910		26.1		26.3		25.8		26.06
911		26.1		26.5		25.7		26.10
912	27.0		26.5		26.1		26.53	

Table 19. 500-kernel weights in grams from the replicated plots at the stem rust nursery in Manhattan, 1959.

Entry No.	Rep. I R	Rep. I S	Rep. II R	Rep. II S	Rep. III R	Rep. III S	Average R	Average S
901		11.87		12.04		13.51		458.3
902	13.87		14.45		14.36		504.3	
905		12.67		14.16		12.36		13.06
906	14.51		14.52		14.47		14.50	
907		13.40		13.31		12.98		13.23
908	12.61		12.49		12.89		12.66	
909	15.81		15.55		14.61		15.32	
910		13.29		13.26		13.25		13.27
911		14.34		14.02		12.10		13.49
912	16.55		15.35		15.24		15.71	

Table 20. Yields in grams of the replicated plots in the sulfur nursery at Manhattan, 1959.

Entry No.	Rep. I R	Rep. I S	Rep. II R	Rep. II S	Rep. III R	Rep. III S	Average R	Average S
901		487		443		445		458.3
902	486		499		528		504.3	
905		423		437		449		436.3
906	344		413		470		409.0	
907		529		444		442		471.6
908	496		496		432		465.6	
909	427		441		397		421.6	
910		412		488		431		443.6
911		424		531		583		512.6
912	414		510		488		470.6	

Table 21. Relative test weights from the replicated plots in the sulfur nursery at Manhattan in 1959.

Entry No.	Rep. I R	Rep. I S	Rep. II R	Rep. II S	Rep. III R	Rep. III S	Average R	Average S
901		27.3		27.1		27.3		27.23
902	27.4		27.6		27.6		27.53	
905		27.4		27.5		27.5		27.46
906	26.8		27.7		27.5		27.33	
907		27.5		27.5		27.6		27.60
908	27.5		27.7		27.6		27.56	
909	26.8		26.5		27.2		26.83	
910		27.4		27.2		27.4		27.33
911		27.4		27.8		27.7		27.63
912	27.1		27.1		27.3		27.16	

Table 22. 500-kernel weights from the replicated plots in the sulfur nursery at Manhattan in 1959.

Entry No.	Rep. I R	Rep. I S	Rep. II R	Rep. II S	Rep. III R	Rep. III S	Average R	Average S
901		14.97		14.78		14.82		14.86
902	14.73		14.70		14.80		14.74	
905		15.47		15.73		15.69		15.63
906	14.01		14.23		14.15		14.13	
907		14.59		14.49		14.81		14.63
908	14.16		13.88		13.85		13.96	
909	14.30		14.46		14.63		14.46	
910		14.64		15.04		14.72		14.80
911		15.18		15.12		15.05		15.12
912	16.12		15.69		15.80		15.87	

Table 23. Yields in grams of replicated plots at Hutchinson in 1959.

Entry no.	Rep. I R	Rep. I S	Rep. II R	Rep. II S	Rep. III R	Rep. III S	Average R	Average S
901		216		249		266		243.7
902	303		218		233		251.3	
905		149		205		245		199.7
906	238		243		247		242.7	
907		265		236		191		230.7
908	240		238		256		244.7	
909	244		228		261		244.3	
910		211		214		232		219.0
911		296		265		231		264.0
912	273		253		221		249.0	

Table 24. Relative test weights from replicated plots at Hutchinson in 1959.

Entry no.	Rep. I R	Rep. I S	Rep. II R	Rep. II S	Rep. III R	Rep. III S	Average R	Average S
901		27.0		26.1		26.8		26.63
902	26.8		26.6		27.0		26.80	
905		26.6		27.0		26.7		26.77
906	27.2		27.0		27.0		27.07	
907		27.0		26.5		26.4		26.63
908	27.2		27.0		27.4		27.20	
909	26.8		26.6		26.9		26.77	
910		26.1		26.8		26.2		26.37
911		27.0		26.9		26.8		26.90
912	26.5		27.0		27.1		26.87	

Table 25. 500-kernel weights in grams from replicated plots at Hutchinson in 1959.

Entry no.	Rep. I R	Rep. I S	Rep. II R	Rep. II S	Rep. III R	Rep. III S	Average R	Average S
901		14.22		14.00		13.40		13.87
902	13.82		13.95		13.72		13.83	
905		14.14		14.53		15.56		14.74
906	14.35		14.54		14.42		14.44	
907		13.54		13.89		13.45		13.63
908	13.63		13.38		13.53		13.51	
909	14.22		14.19		14.36		14.26	
910		13.81		13.19		13.81		13.60
911		13.86		13.56		13.86		13.76
912	15.20		15.37		15.20		15.26	

Table 26. Yields in grams of the replicated plots in the leaf nursery at Ashland in 1959.

Entry No.	Rep. I R	Rep. I S	Rep. II R	Rep. II S	Rep. III R	Rep. III S	Average R	Average S
901		213		260		235		236.0
902	256		368		370		331.3	
905		217		276		232		241.6
906	270		320		278		289.3	
907		260		283		266		269.6
908	231		345		205		260.3	
909	316		311		318		315.0	
910		262		303		285		283.3
911		370		433		360		387.6
912	226		327		322		291.6	

Table 27. Relative test weights from the replicated plots in the leaf rust nursery at Ashland in 1959.

Entry No.	Rep. I R	Rep. I S	Rep. II R	Rep. II S	Rep. III R	Rep. III S	Average R	Average S
901		24.6		25.3		26.0		25.30
902	26.3		25.8		26.3		26.13	
905		25.4		26.3		25.5		25.73
906	25.4		26.6		25.8		25.73	
907		26.6		26.0		26.8		26.47
908	26.4		27.2		25.8		26.47	
909	26.5		27.4		26.9		26.93	
910		26.5		26.2		25.5		26.07
911		26.9		27.2		26.6		26.90
912	26.8		26.8		26.2		26.60	

Table 28. 500-kernel weights in grams from the replicated plots in the leaf rust nursery at Ashland.

Entry No.	Rep. I R	Rep. I S	Rep. II R	Rep. II S	Rep. III R	Rep. III S	Average R	Average S
901		9.43		10.78		9.57		9.93
902	11.54		12.41		12.41		12.12	
905		10.80		11.74		11.53		11.36
906	10.55		12.44		10.46		11.15	
907		10.48		10.44		10.73		10.55
908	10.42		11.47		9.39		10.43	
909	12.00		12.14		12.69		12.28	
910		11.66		12.09		10.64		11.46
911		12.38		12.39		11.70		12.16
912	12.34		12.96		12.25		12.52	

Table 29. Yield, test weight and 500-kernel weight of stem rust paired single rows in the stem rust nursery at Manhattan in 1959.

Entry No.	Stem Rust %	Yield	Test weight	500-kernel weight
921	30	173	26.5	13.90
922	70	175	26.0	13.32
925	70	168	26.0	12.36
926	20	159	26.9	13.83
927	30	256	26.5	16.90
928	50	189	26.1	14.37
935	10	213	26.9	15.04
936	40	170	26.0	13.05
937	60	155	26.6	13.11
938	30	161	26.4	14.14
939	20	127	25.8	12.86
940	50	160	27.2	13.76
941	30	196	27.1	14.54
942	70	237	27.0	14.59
953	40	117	26.2	13.42
954	20	142	26.5	12.99
971	50	152	25.6	13.30
972	30	150	26.5	14.56
973	50	153	25.6	13.59
974	30	127	25.6	13.57
975	40	136	25.0	12.60
976	20	173	26.0	14.10
981	50	142	25.8	14.75
982	15	161	26.8	14.84
983	10	178	26.2	13.97
984	60	166	26.1	15.01
987	50	158	26.4	12.93
988	20	128	26.5	14.91

Table 30. Split-plot analyses of variance on data from Hutchinson, Ashland and Manhattan in 1959.

Source of Variation	d.f.	Ss	Ms	F	Sig
Hutchinson Yield Evaluation					
Whole Plot:					
Replications	2	375.20	187.60		
Family	4	4512.20	1128.05		
Error (a)	8	8078.80	1009.85		
Sub-plots:					
Resistance	1	1687.50	1687.50	1.89	n.s.
Resistance x family	4	2768.33	692.08	.78	n.s.
Error (b)	10	8914.67	891.47		
Test weight Evaluation					
Whole Plot:					
Replications	2	.04	.02		
Family	4	.57	.14		
Error (a)	8	.63	.08		
Sub-plots:					
Resistance	1	59	.59	7.38	*
Resistance x family	4	31	.08	1.00	n.s.
Error (b)	10	82	.08		
Kernel weight Evaluation					
Whole Plot:					
Replications	2	.0270	.0135		
Family	4	4.6668	1.1667		
Error (a)	8	.9994	.1249		
Sub-plots:					
Resistance	1	.8535	.8535	9.01	*
Resistance x family	4	3.3099	.8275	8.74	**
Error (b)	10	.9472	.0947		

Table 30. (Continued)

Source of Variation	d.f.	Ss	Ms	F	Sig
Ashland Yield Evaluation					
Whole Plot:					
Replications	2	18,485.00	9242.50	11.25	***
Family	4	22,886.20	5721.55		
Error (a)	8	6,573.00	821.62		
Sub-plots:					
Resistance	1	1,442.13	1442.13	1.48	n.s.
Resistance x family	4	31,057.54	7764.38	7.97	**
Error (b)	10	9,745.33	974.53		
Test weight Evaluation					
Whole Plot:					
Replications	2	.78	.39		
Family	4	4.91	1.23		
Error (a)	8	1.84	.23		
Sub-plot:					
Resistance	1	.77	.77	3.21	n.s.
Resistance x family	4	1.59	.40	1.67	n.s.
Error (b)	10	2.45	.24		
Kernel weight Evaluation					
Whole Plot:					
Replications	2	3.6286	1.8142		
Family	4	12.5556	3.1389		
Error (a)	8	1.3136	.1642		
Sub-plot:					
Resistance	1	2.7664	2.7664	7.18	
Resistance x family	4	5.7232	1.4308	3.72	
Error (b)	10	3.8513	.3851		
Stem Rust Nursery Yield Evaluation					
Whole Plot:					
Replications	2	3,201.27	1600.64		
Family	4	11,681.54	2920.38		
Error (a)	8	18,191.06	2273.88		
Sub-plot:					
Resistance	1	44,467.50	44467.50	26.77	***
Resistance x family	4	9,246.33	2311.58	1.39	n.s.
Error (b)	10	16,611.67	1661.17		

Table 30. (Continued)

Source of Variation	d.f.	Ss	Ms	F	Sig
		Test weight Evaluation			
Whole Plot:					
Replications	2	.01	.005		
Family	4	.56	.14		
Error (a)	8	2.16	.27		
Sub-plots:					
Resistance	1	4.41	4.41	33.92	***
Resistance x family	4	2.31	.58	4.46	*
Error (b)	10	1.27	.13		
		Kernel weight Evaluation			
Whole Plot:					
Replications	2	.7133	.3566		
Family	4	10.8953	2.7238		
Error (a)	8	5.0243	.6280		
Sub-plots:					
Resistance	1	14.3106	14.3106	49.19	***
Resistance x family	4	7.6602	1.9150	6.58	**
Error (b)	10	2.9088	.2909		
		Sulfur block Yield Evaluation			
Whole Plot:					
Replications	2	3470.60	1735.30		
Family	4	22032.53	5508.13		
Error (a)	8	27923.07	3490.38		
Sub-plots:					
Resistance	1	790.53	790.53	.94	n.s.
Resistance x family	4	6930.14	1732.54	2.06	n.s.
Error (b)	10	8406.33	840.63		
		Test weight Evaluation			
Whole Plot:		.22			
Replications	2		.11		
Family	4	.74	.18		
Error (a)	8	.36	.04		
Sub-plots:					
Resistance	1	.16	.16	5.33	*
Resistance x family	4	.71	.18	6.00	**
Error (b)	10	.34	.03		

Table 30. (Continued)

Source of Variation	d.f.	Ss	Ms	F	Sig
		Kernel weight			
Whole Plot:					
Replications	2	.0022	.0011		
Family	4	4.6004	1.1501		
Error (a)	8	.2700	.0338		
Sub-plots:					
Resistance	1	.8036	.8036	24.13	***
Resistance x family	4	4.1268	1.0317	20.98	***
Error (b)	10	.3333	.0333		

A FIELD STUDY OF THE EFFECTS OF LEAF RUST AND STEM RUST ON SISTER LINES OF A HARD RED WINTER WHEAT

by

JOHN LEWIS BIEBER

B. S., Purdue University, 1958

AN ABSTRACT OF A THESIS

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This study was an attempt to evaluate the effect of stem rust and the effect of leaf rust using sister lines of a Pawnee-type wheat. Although this method of disease evaluation tends to underestimate damage, it gives a direct measurement of the benefit of genetic rust resistance available for disease control.

Comparisons were made between rust resistant and susceptible sister lines that had been selected as heads from segregating plant rows in the F_3 generation.

In 1958 there were 323 lines representing 29 families grown in single rows at both the leaf rust nursery at Ashland and the stem rust nursery at Manhattan. Stem rust and leaf rust readings were made, heads were picked from each row, and the rows were harvested individually. Relative test weights, 100-kernel weights and average numbers of kernels per head were determined. Data from families with both resistant and susceptible lines was collected. Resistant-susceptible differences in the above mentioned components of yield were tested with t-tests. Pairs used in the tests represented the highest and the lowest levels present in the same families. Test weight and kernel weight were both significantly increased by both stem rust and leaf rust resistance. A correlation coefficient of -.6446 was found between stem rust reaction and test weight in the stem rust nursery.

In 1959 the rust effect study was comprised of four experiments; at Hutchinson under natural infection, at Ashland with artificial leaf rust infection, at Manhattan with artificial stem rust infection, and another at Manhattan in which sulfur treatments minimized rust infection. Each experiment was made up of two parts--paired single rows and paired replicated plots.

Rust percentages were taken and the trials were harvested. Yields, test weights, and 500-kernel weights were determined. The 1959 rust readings were used to pick the pairs used in statistically analyzing yield, test weight, and kernel weight differences between resistant and susceptible lines. Only pairs with clear-cut resistant level differences were analyzed. Stem rust occurred only at the Manhattan stem rust nursery trials in 1959. Leaf rust damage was evaluated at all the experiments.

Yield, test weight, and 500-kernel weight differences were statistically evaluated using t-tests for the single row data and split plot analyses of variance for the replicated plot data.

The 1959 results showed that test weight and kernel weight were significantly affected by rust reaction. Yield data were inconclusive but indicated that an effect upon yield could be detected by this method.

From this study it appears that sister lines of wheat are adaptable to the evaluation of leaf rust and stem rust damage; however, further study is needed before comparisons can be made between this and other methods of disease damage evaluation.