EFFECTS OF GREENBUG RESISTANCE OF WHEAT ON SEVERAL AGRONOMIC AND QUALITY CHARACTERS

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CHAPTER I

INTRODUCTION

The incorporation of pest resistance into wheat varieties has been a major contribution to the increase and stabilization of wheat production. Resistance to greenbugs (Schizaphis graminum Rond.) has been eagerly sought by wheat breeders in the winter wheat area where this destructive pest is of great economic importance. With the discovery of greenbug resistant germ plasm in common wheat in 1952 (16) and the subsequent development of a test for the rapid identification of greenbug resistance in breeding material the tools for development of greenbug resistant varieties were available. Although the resistant wheats were spring-type and of poor quality, it seemed likely that the incorporation of resistance with satisfactory agronomic and quality characters of hard red winter wheat would be a simple process.

The known existence of simply inherited greenbug resistance in common wheat for 13 years without its incorporation into a suitable genotype for release as a commercial variety suggested the possibility of an association between this gene and factors for inferior agronomic or quality characters. The purpose of this study was to determine, by the use of near-isogenic lines, if a strong association existed between the gene conditioning greenbug resistance in wheat (gb) and several important agronomic and quality characters.

CHAPTER II

REVIEW OF LITERATURE

Inheritance of Greenbug Resistance in Wheat

Dickinson Selection 28A (DS28A), a common wheat line with spring habit selected by Dahms et al. (16), exhibits a tolerance type resistance to greenbugs (15). Results obtained by Painter and Peters (30) using this greenbug resistant strain in crosses with the winter wheat varieties, Concho, Bison, and Pawnee, indicate a single gene difference between susceptible and resistant strains with susceptibility being dominant to resistance. Daniels and Porter (17) obtained similar results from crosses of DS28A with Crockett, Blue Jacket, Westar, and Kanred. The latter authors suggested that modifying factors may be involved.

Curtis et al. (15) studied F_1, F_2, F_3, and backcross hybrids of the greenbug resistant varieties DS28A and C.I. 9058 crossed with the susceptible varieties, Concho, Ponca, and Crockett. C.I. 9058 is a spring type Russian introduction. All F_1 plants were susceptible. The F_2 data of DS28A and C.I. 9058 crossed with the susceptible varieties fitted very closely a 3:1 ratio of susceptible to resistant plants. F_3 lines of DS28A/Ponca segregated very near a 1:2:1 ratio of susceptible: segregating: resistant. Backcrosses of F_1's of DS28A and C.I. 9058 to susceptible parents proved to be susceptible in all populations tested. They concluded from this and other data that resistance of both parents was controlled by a single recessive gene pair. However, they found that F_1 hybrids of DS28A and C.I. 9058 with susceptible wheats lived 7.6 and 13.9 days longer, respectively, than the average of the susceptible varieties. They interpreted these F_1 data as indication of a lack of complete dominance of susceptibility.

Similar reactions were obtained from F_1, F_2, F_3, and backcross hybrids of DS28A and C.I. 9058 when crossed with the same susceptible varieties and when crossed to each other. Hybrids of DS28A X C.I. 9058 showed no susceptible plants in F_1 and backcrosses to both parents. These results suggested that the same gene pair for resistance was present in both DS28A and C.I. 9058.

Chada et al. (8) concluded, on the basis of F_2, F_3, and BC data, that resistance could be monogenic. However, they stated that enough conflicting evidence was obtained to suggest the possibility of modifying genes in certain genetic backgrounds. Their report that resistance appeared to be dominant conflicted with previous published reports (15, 17, 30). They also suggested that differences in testing methods might account for this conflict.

Porter and Daniels (32) studied backcross, F_1, F_2, F_3, and F_4, generations of DS28A/Concho crosses. They reported pronounced environmental influences which precluded a definite conclusion of the mode of inheritance. In any event, the distribution of greenbug reaction of plants in segregating populations suggested that more than a single factor pair was involved.

An attempt by Curtis et al. (15) to locate the chromosome carrying the Gb/gb locus by monosomic analysis was unsuccessful. These workers crossed DS28A with 2 to 3 plants of each of the 21 Chinese Spring monosomics. They reported that no F_1 plants were resistant and suggested from these data that resistance is hemizygous-ineffective.

Although a monogenic inheritance of greenbug resistance has not been conclusively shown, data indicate that it can quickly and easily be transferred to other strains of wheat (15, 32).

Genetic Association of Plant Characters

There are numerous cases where well-defined physiological or morphological characters are controlled largely by single genes and are little affected by either the genetic or physical environment. These familiar qualitative genes of classical genetics can, however, have more than a single-phenotypic manifestation. A case of particular interest to plant breeders has been described by Suneson, et al. (35). They found that the removal of awns from Baart wheat by backcrossing reduced the yield by 7% and the bushel weight by approximately 1 pound. Comparable increases attended the addition of awns to Onas wheat by a similar process.

Atkins and Mangelsdorf (2) suggested the use of isogenic lines as a means of measuring the influence of a simply inherited character on yield and other plant characters. Isogenic awned and awnless lines were selected from the F_{10} of the cross Kanred/Clarkan by Atkins and Norris (3). Although they reported the lines to be phenotypically identical except for the awned condition the awned lines had significantly higher yields, heavier kernels, and higher test weight than awnless lines. Similar results were reported by Patterson et al. (29). In the latter study a specific isogenic pair X awnedness interaction indicated that awns were more advantageous to certain genotypes than others. Awn length has also been found to affect moisture retention of wheat spikes in the field (31) and response to photoperiod (20).

Lofgren et al. (25) found high flour yield of wheat to be associated with the awnleted condition in isogenic lines selected from a Tenmark/Chiefkan backcross series. However, their data indicated no difference for mixing time between awnleted and awned lines.

Chowdhry and Allen (9) studied the effect of culm length on the development of three foliar leaves on near-isogenic wheat lines. Five lines were developed from a cross between the standard-height winter wheat variety, Burt, and semidwarf variety, Norin 10/Brever 14, followed by four generations of backcrossing to the variety Burt. The near-isogenic selections represented five distinct culm length groups, averaging 30.00, 34.50, 49.02, 53.45, and 64.98 centimeters in height. Differential development of the corresponding leaves of these selections was generally positively related to culm length expression. Indirect evidence suggested that the genetic mechanism which controls culm length also controls leaf development or that closely linked systems are involved.

An association between stem rust resistance and powdery mildew resistance was found by Allard and Shands (1). They reported that two of the three genes controlling resistance to race 5 of powdery mildew in the common wheat strain C.I. 12633 were either the same two genes which governed stem rust resistance or were closely linked to them. Nyquest (28) found no association between mildew reaction controlled by the Mlx gene and stem rust resistance in C.I. 12633. However, he found that mildew resistance on the leaf blade, apart from mildew resistance due to the Mlx gene, was linked closely to stem rust resistance.

Other character associations in wheat include an association between stem rust resistance and amount of reducing sugars (26), resistance to powdery mildew and the gene for hairy glume (5), resistance to powdery mildew and a factor for long-time vernalization requirement (39), and a positive relationship between purple straw and kernel weight (27).

Suneson et al. (36) reported a yield increase resulting from the transfer of a chromosome segment containing the locus conditioning awn barbing in barley. Backcross-derived semismooth-awn composites outyielded rough-awned composites each of six years tested. Everson and Schaller (21) later showed this association to be a result of closely linked genes rather than pleiotropic action.

Qualset et al. (33) studied four backcross-derived isogenic lines of barley having awns of different length in order to assess the role of the awn in contributing to yield. They found the kernel number per spike in half- and quarter-awned to be higher than full-awned and awnless. Increased yields of 16.3, 23.0, and 8.4% were observed for full-, half-, and quarter-awned, respectively. This compared with increased kernel weight of 22.4, 11.6, and 3.4%, respectively. These data did not permit distinction between linkage and pleiotropy as the cause of the genetic variability in these isogenic lines.

A study designed to ascertain the effect of short segments of chromosomes on Sr-89 accumulation in barley was conducted by Rasmusson and Kleese (34). Twenty-two isogenic pairs were used. The members of each pair differed by chromosome segments estimated to be less than 6 recombination units in length. Three different segments, each identified by a marker gene, had a significant effect on Sr-89 accumulation.

The three genes were those that controlled two vs six rows of kernels, black vs white lemma and pericarp and purple vs no-purple lemma and pericarp.

Gardenhire (22) found no association between the gene for greenbug resistance in barley and the genes conditioning powdery mildew resistance, leaf rust resistance, green seedling and orange lemma.

Hadley et al. (24) reported that the dominant or recessive state at a single Dw locus (presumably Dw_3) in 3-dwarf and 2-dwarf isogenic lines of sorghum influenced yield of grain and tillering but not days to bloom. Casady (6) using isogenic lines has shown that taller lines produce significantly more grain than shorter lines when the lines differed genetically at the Dw_3 locus. Based on environment X height interactions he suggested that environment had a differential effect on the relative performance of tall and short lines for the plant characters: kernel weight, test weight, number of heads per plant and yield. Later studies by Casady (7) provided evidence that differences observed in culm diameter, peduncle length, leaf blade width, length and area between the 3-dwarf and 2-dwarf lines were the direct effects of the dw_3 and Dw_3 alleles.

Data reported by Graham and Lessman (23) indicate that the recessive or dominant state at the Dw_2 locus in 2-dwarf or 3-dwarf isogenic lines influenced total yield, seed weight, main head yield and panicle length but not tillers per plant, days to bloom or leaves per plant.

An association between seed coat color, conditioned by the b_1 gene, and agronomic characters in paired F_{10} isogenic lines of flax was reported by Culbertson and Kommedahl (14). They found yellow seed coat color to be negatively associated with seed yield and test weight and positively associated with percentage of damaged seed, weight per 100 seeds, oil content, and iodine number. This material was carried to the F_{20} where paired lines with yellow vs brown seed coat color were again selected (13). Seed color was significantly associated with each of the 13 agronomic characters studied except lodging score and days to last bloom.

A positive association of yellow seed color, conditioned by the g allele, with oil percentage and iodine value has been reported in flax (12). However, there was no association of seed yield with the g locus.

A simply inherited chlorophyll mutant character has been shown to be associated with agronomic and seed characters of flax (12). Loci that condition anther color and petal color did not show association with several important quantitative traits, but did exhibit small but significant association with time of bloom (10, 11). The gene conditioning anther color also showed an association with iodine value.

Associations have been noted between cotyledon color and emergence percentage in certain varieties of lima beans (37); and between leaf width and reaction to the root-knot nematode in tobacco (38). Dean (18) found an association between the yg gene which determines leaf color in tobacco and several quantitative characters.

CHAPTER III

MATERIALS AND METHODS

Parents and Lines

Twelve pairs of lines of hard red winter wheat nearly isogenic except for reaction to greenbugs were used in this study. By near-isogenic pairs is meant two lines having similar genotypes, except for the gb locus and genes closely linked to it. Near-isogenic pairs were obtained from DS28A/Ponca 2/5 Kaw F_2 rows segregating for the gb locus.

The parents used were Kaw and a DS28A/Ponca selection, Stw. 598874. The former variety, which was the recurrent parent in the backcrossing scheme, is susceptible to both known strains of greenbugs while the latter parent is resistant to the strain A. Although only two greenbug strains have been identified, recent studies indicate that several biotypes may exist.[1]

DS28A was originally found as a mixture in a variety of *Triticum durum*, Dickinson No. 485, C.I. 3707 (16). The seed of C.I. 3707 was obtained from the World Wheat collection and originally came from the North Dakota Agricultural Experiment Station at Fargo. DS28A is a hexaploid and has all the characteristics of *T. aestivum*. Where this hexaploid originated and how it became a mixture in C.I. 3707 is not known.

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[1]Personal communication with E. A. Wood, Jr., USDA Entomologist.

DS28A has a spring growth habit but appears to have some degree of cold hardiness. The spike is lax, awned, fusifom to oblong and contains red seed. The chaff color varies from light black underlain by brown to a dark chocolate color. DS28A is highly susceptible to the leaf rust races prevalent in Oklahoma.

The pedigree and detailed description of Kaw and Ponca are given by Briggle and Reitz (4). The general characteristics of Kaw and DS28A/Ponca (Stw. 598874) are given in Table I.

Testing Procedures

The development of near-isogenic lines used in this study required three separate greenbug reaction tests. F_2's of DS28A/Ponca 2/4 Kaw (BC^3 F_2's) were tested to identify the DS28A/Ponca 2/5 Kaw F_1's (BC^4 F_1's) which contained the gb gene. BC^4 F_2's were tested to identify the susceptible (GbGb) and resistant (gbgb) F_2 plants and BC^4 F_3's were tested to confirm their classification.

Greenbug reaction tests of BC^3 F_2 and BC^4 F_3 populations were seeded in the greenhouse in galvanized iron flats having inside dimensions of approximately 13 X 20 X 3.5 inches. Seeds from BC^4 F_1 plants were seeded in 1.5 X 1.5 X 2.5 inch plant bands contained in wooden flats, 130 bands per flat. Kaw and DS28A/Ponca (Stw. 598874) were included in each flat as checks. The flats were filled with a soil mixture consisting of 4 parts silt loam soil, 1 part peat moss and 1 part washed river sand. Each galvanized iron flat was divided into 10 rows, 13 inches long, 2 inches apart and 0.5 inches deep with a corrugated row marker that fitted the inside dimensions of the flat.

TABLE I

MEANS FOR SIX CHARACTERS FROM GREENBUG SUSCEPTIBLE AND RESISTANT PARENTS GROWN IN THREE ENVIRONMENTS

Characters	Kaw Susceptible	DS28A/Ponca (Stw. 598874) Resistant
Plant Height (cm)	90.9	78.6
Days to Heading[a]	21.2	18.5
Number Heads/Ft.^{2}	36.4	27.0
Number Seed/Head	19.1	20.7
Seed Weight (g/1000)	26.49	20.56
Grain Yield/Ft.^{2} (g)	18.4	11.5

[a]Days to heading from March 31.

Except for a few cases where seed supply was limited, 15 seeds from BC^3 F_1 plants or 10 seeds from BC^4 F_2 plants were evenly spaced in each row. The flats were filled to the top with sand and watered. The temperature was maintained at approximately 70° F.

Approximately 1000 greenbugs which had been increased on cultures of Rogers barley were distributed uniformly on each flat of BC^3 F_2 and BC^4 F_3 seedlings as soon as most of the seedlings had emerged. BC^4 F_2 seedlings were vernalized, in plant bands, for 34 days at approximately 34° F. before infestation. BC^4 F_2 seedlings were rated as susceptible (GbGb) if they exhibited damage similar to the susceptible variety, Kaw, six to nine days after infestation. Plants which appeared as healthy as the resistant check 25 days after infestation were rated resistant (gbgb). Plants which survived more than nine days but less than 25 days were classified heterozygous susceptible (Gbgb).

Progeny tests were carried out on BC^3 F_2 and BC^4 F_3 populations in October 1964 and September 1965, respectively. Survival of the plants in these tests was not necessary so a different rating system was used. If the plants were dead or appeared beyond recovery thirty days after infestation they were rated as susceptible. The point beyond recovery may be described as the stage when the entire seedling appeared to be dead except for a slight yellowish green area near the soil surface.

Development of Near-Isogenic Lines

The near-isogenic pairs used in this study were selected from a population of 50 F_1 plants following the last backcross to Kaw. The pedigree of these F_1's was: DS28A/Ponca 2/5 Kaw. This material was obtained from the Small Grains Section of the Oklahoma Agricultural

Experiment Station. Greenbug reaction tests were conducted on the F_2 progeny of each nonrecurrent parent plant to identify those with Gbgb genotypes. These tests indicated that 22 of the aforementioned 50 plants carried the gb gene. Five F_0 seeds from each of these 22 populations were seeded in five-inch pots in the greenhouse in the fall of 1964. A greenbug reaction test was conducted on all available F_2 seedlings from each of the 22 families in the spring of 1965.

Six of the families failed to produce any segregating F_2 lines. This failure could have resulted from the absence of the gb gene in the nonrecurrent parents from which their families were derived or from the chance failure to obtain plants of the Gbgb genotype among the five F_1's selected from each backcross; both factors probably contributed.

The remaining sixteen groups of F_1 produced a total of 33 segregating F_2 lines. On the basis of seedling reaction to the greenbugs 83 resistant and 77 susceptible F_2 plants were selected, treated with an insecticide to kill greenbugs and transplanted to five-inch clay pots. They were then placed in a growth chamber and grown to maturity.

Each of the 75 resistant and 68 susceptible plants producing seed were progeny tested in October, 1965. Nine susceptible F_2's produced segregating F_3 lines and six resistant and four susceptible lines could not be properly classified due to poor emergence.

Six families failed to produce enough resistant and/or susceptible plants for inclusion in replicated yield trials in 1965. These were placed in an increase nursery to permit their use in the 1966-67 tests. As a result of poor seed emergence one family was discontinued from the study. Adequate seed of nine pairs of near-isogenic F_3 lines was produced for planting in 1965.

Because of an apparent genetic lethal or sublethal factor, two of the families could not be used for this study. In both the resistant and susceptible lines of these families the older leaves began to die, from the tip toward the base, about one month after emergence. This continued until maturity and resulted in stunted plants. The same condition was noted in one of the six lines being grown in an increase nursery for inclusion in the 1966-67 study. The loss of these three families left seven pairs of near-isogenic lines for the 1965-66 study and 12 in the 1966-67 tests.

Experimental Procedure

BC^4 F_3 and parent seedlings were established under greenhouse conditions in October 1965 by planting the seeds in plant bands contained in flats. In November the seedlings were transplanted in the field on the Stillwater Agronomy Research Station in a randomized complete block design with a split plot arrangement of treatments. Main plots were pairs consisting of a resistant and a susceptible line originating from the F_0 seed of a single DS28A/Ponca 2/5 Kaw plant or parents. Subplots were one greenbug susceptible or one greenbug resistant near-isogenic line or parent.

Plots in 1965-66 consisted of two 10-foot rows each of which included ten plants. All plants from which data were collected were spaced at one-foot intervals both within and between rows. Where necessary, dead or weak plants were replaced with healthy plants to maintain uniform competition. Plants at the end of the plots were not included in the sampling. In each plot ten plants selected at random were pulled at maturity and bagged to prevent loss of seed.

All plots received supplemental irrigation in March 1966. The presence of a light greenbug infestation necessitated the application of an insecticide to prevent possible damage to the susceptible lines.

The 1966-67 study consisted of a nursery with the same planting rate and plot size as the 1965-66 study and an additional nursery which was densely seeded. The latter nursery consisted of four 10-foot rows spaced one foot apart and seeded at the rate of 60 pounds per acre. The plots in both seeding rates were arranged in the same type of design as that used in 1965-66. Both nurseries were seeded in October 1966. Despite a moderately severe spring drought the plots were not irrigated; however, the presence of greenbugs necessitated two insecticide applications in the spring.

On May 14 hail and high winds damaged the plants, subsequently reducing the yield of all plots. On close examination the damage appeared to be uniformly distributed and the spaced planted material was harvested as in the preceding year.

In June, shortly before maturity, the two center rows of all thickly seeded plots were shortened to a length of eight feet. As the plants matured, samples consisting of all spikes within a linear foot of row were harvested to facilitate collection of yield and yield component data on a unit area basis. Two samples in tandem were taken randomly from each row making a total of four samples per plot. The spikes of plants cut in this manner were bagged to prevent seed loss during storage; the remainder of each plot was not harvested.

Agronomic Characters

In 1965-66 all pre- and post-harvest observations were recorded on a per plant basis. The following characters were studied:

Maturity

Heading date was used as a measure of the relative maturity of the parents and lines, and was recorded as the number of days from March 31 until the first spike of each plant was completely visible.

Plant Height

Measurements were taken in centimeters from the soil surface to the tip of the tallest spike of each plant, exclusive of awns.

Tiller Number

This character was determined on the basis of a direct count of the number of fertile tillers on each plant ($foot^2$) and expressed as number of tillers per plot (ten plants).

Kernel Weight

This was obtained by counting 100 kernels from each plant and was expressed in grams per 1000 kernels.

Kernel Number

The number of kernels per spike was calculated as:

$$\frac{\text{Number of kernels per gram X grams of grain per plot}}{\text{Number of heads per plot}}$$

Yield

Yield observations were expressed as grams of threshed and cleaned grain per plot.

The same characters observed in 1965-66 were studied in both tests in 1966-67. Sampling techniques differed only for those plots planted at the 60 pound per acre rate. The procedure used in sampling from these plots for the various characters was as follows:

Maturity

Heading date observations were made on the entire plot, and were expressed as number of days after March 31 until emergence of approximately 75 per cent of the main spikes of each plot.

Plant Height

Measurements were taken in centimeters from the soil level to the tips of several adjacent plants, excluding awns. The average of five observations per plot was recorded.

Tiller Number

Tiller counts were based on a direct count of the number of spikes in each one-foot sample and expressed as the total heads in four $foot^2$.

Kernel Weight

Kernel weight was obtained by counting 250 kernels from each of four 1-foot samples and was expressed in grams per 1000 kernels.

Kernel Number per Spike

This was calculated from the same formula used in 1965-66.

Yield

Yield observations were expressed as grams of threshed and cleaned grain per four $foot^2$.

Quality Tests

Micromillings were performed on 150-gram samples of grain from each near-isogenic line and their parents from each of the three tests. These quality tests were conducted by personnel of the Oklahoma Agriculture Experimental Wheat Quality Laboratory. After determination of moisture content each sample was tempered to 15 per cent moisture in glass jars prior to milling.

Wheat and flour protein determinations were made by standard Kjeldahl analysis. Sedimentation tests were run on milled flour as an indication of dough-mixing tolerance and general bread baking strength of the lines (19, 40). Mixogram mixing time was obtained from 35 grams of flour and recorded in minutes.

Analyses of Variance

Standard analyses of variances were conducted on data from the populations grown in 1965-66 and 1966-67 for each of the agronomic characters studied. Analyses of the 1966-67 spaced planted data are based on only three of the four replications grown since approximately one-fourth of the plants in one replication were visibly stunted. The cause of the stunting was undetermined. It was not the genetic factors which affected three lines the previous year. It was restricted to one replication and also affected the parents. Quality characters were not analyzed statistically due to the necessity of compositing replications to obtain sufficient seed for quality tests.

LSD values were used to test each resistant-susceptible line contrast within each pair. Duncan's new multiple range test was used to determine significance of differences among means of pairs of lines and parents for each of the studies.

Analyses of variance were conducted on a whole plot basis. Number of heads and grain yield were converted to a yield per $foot^2$ basis before the LSD and multiple range tests were conducted. Factors used in converting the mean squares were obtained by squaring the factors used to convert the variable itself, i.e., $(0.10)^2$ and $(0.25)^2$ for spaced and solid seeded tests, respectively.

CHAPTER IV

RESULTS AND DISCUSSION

Agronomic Data

Mean squares from the analyses of variance conducted on the agronomic data of near-isogenic pairs and their parents are given in Tables II - IV. A significant line X pair interaction occurred for most characters. No significant interaction occurred for number of seed per head in any of the three tests. The resistant and susceptible parents were included in the study and for the purpose of statistical analysis were considered paired near-isogenic lines. Thus the line X pair interaction would be expected if (1) there was no association between greenbug resistance and the character under consideration and (2) the parents differed for this character.

Differences between line means within pairs for agronomic characters in which a line X pair interaction was significant are presented in Tables V - IX. A significant difference between lines occurred in eight of 155 comparisons. This heterogeneity might be due to genetic segregation, to sampling error, or to a combination of these causes. In four of the cases the means of the resistant lines were closer to the susceptible (recurrent parent) than were those of the susceptible line. The character and pairs for which this occurred were: plant height within pair 18 in 1966 and pair two in 1967, number of heads for pair six in 1966, and weight per 1000 kernels in pair five at the dense

TABLE II

MEAN SQUARES FROM ANALYSES OF VARIANCE OF DATA FROM NEAR-ISOGENIC LINES AND PARENTS GROWN IN 1965-66

Source of Variation	d.f.	Days to Head	Plant Height	Number of Kernels	Weight per 1000 Kernels	Number of Heads	Yield
Pairs	7	14.94**	117.89**	4.10	9.99	1,472.46	1,112.63
Error (a)	21	0.69	12.70	3.03	6.19	1,036.10	1,505.43
Lines	1	3.90	25.25*	0.14	9.31	22.56	146.11
Lines X Pairs	7	5.97**	131.87**	3.76	4.32	2,539.78**	1,976.85*
Error (b)	24	0.73	5.60	2.33	2.37	626.42	612.92

*Exceeds the 5% level of significance.

**Exceeds the 1% level of significance.

TABLE III

MEAN SQUARES FROM ANALYSES OF VARIANCE OF DATA FROM NEAR-ISOGENIC LINES AND PARENTS GROWN IN 1966-67 (SPACED SEEDING)

Source of Variation	d.f.	Days to Head	Plant Height	Number of Kernels	Weight per 1000 Kernels	Number of Heads	Yield
Pairs	12	4.94**	49.31**	9.69	20.59	1,609.29	1,052.00
Errors (a)	24	0.65	11.36	8.61	10.33	1,467.29	858.7
Lines	1	1.70	31.79**	10.36	3.71	5,357.55*	1,739.04*
Lines X Pairs	12	1.71**	31.48**	6.81	6.32*	2,147.91*	493.1
Error (b)	26	0.51	3.73	3.49	2.51	971.38	376.2

*Exceeds the 5% level of significance.

**Exceeds the 1% level of significance.

TABLE IV

MEAN SQUARES FROM ANALYSES OF VARIANCE OF DATA FROM NEAR-ISOGENIC LINES AND PARENTS GROWN IN 1966-67 (DENSE SEEDING)

Source of Variation	d.f.	Days to Head	Plant Height	Number of Kernels	Weight per 1000 Kernels	Number of Heads	Yield
Pairs	12	10.36**	39.45**	4.39	3.53	972.44	161.37
Error (a)	36	1.11	13.36	3.90	2.54	780.98	197.33
Lines	1	0.92	0.04	3.40	6.30*	1,137.85	601.45**
Lines X Pairs	12	0.68*	5.31*	3.65	9.30**	626.66*	214.18*
Error (b)	36	0.28	2.55	3.94	1.14	288.04	57.55

*Exceeds the 5% level of significance.

**Exceeds the 1% level of significance.

TABLE V

MEANS AND DIFFERENCES FOR DAYS TO HEADING WITHIN PAIRS OF WHEAT LINES NEARLY ISOGENIC EXCEPT FOR SUSCEPTIBILITY AND RESISTANCE TO GREENBUGS

Pair Number	1966			1967 (Spaced)			1967 (Dense)		
	Susc.	Res.	Diff. S-R	Susc.	Res.	Diff. S-R	Susc.	Res.	Diff. S-R
	Days to Head[a]			Days to Head[a]			Days to Head[a]		
3	32.90	33.75	-0.85	15.40	14.86	0.54	17.50	18.25	-0.75
6	33.65	33.85	-0.20	14.77	15.27	-0.50	16.50	17.25	-0.75
8	33.85	33.93	-0.08	16.00	15.01	0.99	18.50	18.75	-0.25
9	34.23	33.93	0.30	15.80	16.80	-1.00	18.50	18.50	0.00
11	33.25	33.28	0.03	16.03	13.40	2.63**	18.00	17.25	0.75
18	32.83	33.30	-0.47	14.87	14.03	0.84	17.25	16.25	1.00*
19	33.40	33.30	0.10	15.47	15.83	-0.36	19.00	18.50	-0.50
5	-	-		15.50	16.17	-0.67	18.75	19.00	-0.25
23	-	-		14.03	13.97	0.06	17.00	16.75	0.75
14	-	-		13.30	13.30	0.00	15.75	15.25	0.50
16	-	-		15.23	15.50	-0.27	18.75	18.75	0.00
2	-	-		15.53	15.90	-0.37	19.00	18.25	0.75
Parents	32.58	27.40	5.18**	14.63	12.63	2.00**	16.50	15.75	0.75
LSD	t=.05		1.24			1.12			0.75
	t=.01		1.67			1.51			1.02

*Exceeds the 5% level of significance.
**Exceeds the 1% level of significance.
[a]Days to heading from March 31.

TABLE VI

MEANS AND DIFFERENCES FOR PLANT HEIGHT WITHIN PAIRS OF WHEAT LINES NEARLY ISOGENIC EXCEPT FOR SUSCEPTIBILITY AND RESISTANCE TO GREENBUGS

Pair Number	1966 Susc.	1966 Res.	1966 Diff. S-R	1967 (Spaced) Susc.	1967 (Spaced) Res.	1967 (Spaced) Diff. S-R	1967 (Dense) Susc.	1967 (Dense) Res.	1967 (Dense) Diff. S-R
	Centimeters			Centimeters			Centimeters		
3	108.6	108.2	0.4	94.7	95.4	-0.7	78.3	80.3	-2.0
6	100.5	103.1	-2.6	91.9	90.3	1.6	74.8	75.3	-0.5
8	104.8	104.3	0.5	92.1	91.3	0.8	74.8	75.3	-0.5
9	104.1	104.7	-0.6	94.3	92.7	1.6	77.3	78.5	-1.2
11	103.3	103.7	-0.4	92.0	92.6	-0.6	76.0	75.8	0.2
18	101.6	107.7	-6.1**	92.1	89.4	2.7	73.3	73.5	-0.2
19	105.8	107.7	-1.9	95.4	94.1	1.3	75.3	76.3	-1.0
5	-	-		93.5	96.3	-2.8	77.3	77.8	-0.5
23	-	-		93.6	92.8	0.8	73.8	73.5	-0.3
14	-	-		88.2	88.8	-0.6	71.7	73.5	-1.8
16	-	-		89.4	88.7	0.7	73.3	71.8	1.5
2	-	-		90.4	93.8	-3.4*	75.3	75.8	-0.5
Parents	105.9	85.2	20.7**	92.8	77.4	15.4**	74.3	70.0	4.3**
LSD	t=.05		3.5			3.2			2.6
	t=.01		4.7			4.4			3.5

*Exceeds the 5% level of significance.

**Exceeds the 1% level of significance.

TABLE VII

MEANS AND DIFFERENCES FOR 1000 KERNEL WEIGHT WITHIN PAIRS OF WHEAT LINES NEARLY ISOGENIC EXCEPT FOR SUSCEPTIBILITY AND RESISTANCE TO GREENBUGS

Pair Number	1966			1967 (Spaced)			1967 (Dense)		
	Susc.	Res.	Diff. S-R	Susc.	Res.	Diff. S-R	Susc.	Res.	Diff. S-R
	Grams			Grams			Grams		
3	28.90	28.99	-0.09	24.96	25.23	-0.27	29.03	28.55	0.48
6	26.82	25.82	1.00	21.03	21.83	-0.80	26.69	27.55	-0.86
8	27.41	27.05	0.36	20.40	20.66	-0.26	27.03	28.48	-1.45
9	26.45	25.38	1.07	22.56	22.06	0.51	28.45	28.03	0.42
11	27.02	27.87	-0.85	23.43	23.33	0.10	27.90	26.58	1.32
18	27.59	27.96	-0.37	22.96	22.53	0.43	28.48	27.60	0.88
19	26.80	25.78	1.02	23.56	24.20	-0.64	27.88	28.50	-0.62
5	-	-		22.60	22.73	-0.13	26.48	28.10	-1.62*
23	-	-		25.03	24.86	0.17	28.90	28.70	0.20
14	-	-		22.36	22.26	0.10	28.35	28.43	-0.08
16	-	-		23.10	21.76	1.34	28.35	28.30	0.05
2	-	-		20.93	22.63	-1.70	27.38	26.70	0.68
Parents	27.57	23.62	3.95**	21.43	14.60	6.83**	30.48	23.45	7.03**
LSD, t=.05			2.24			2.66			1.53
t=.01			3.04			3.59			2.04

*Exceeds the 5% level of significance.

**Exceeds the 1% level of significance.

TABLE VIII

MEANS AND DIFFERENCES FOR NUMBER OF HEADS WITHIN PAIRS OF WHEAT LINES NEARLY ISOGENIC EXCEPT FOR SUSCEPTIBILITY AND RESISTANCE TO GREENBUGS

Pair Number	1966			1967 (Spaced)			1967 (Dense)		
	Susc.	Res.	Diff. S-R	Susc.	Res.	Diff. S-R	Susc.	Res.	Diff. S-R
	Heads/ft.^{2}			Heads/ft.^{2}			Heads/ft.^{2}		
3	31.3	30.6	0.7	36.2	31.4	4.8	35.0	34.6	0.4
6	26.6	31.1	-5.5**	30.2	31.5	-1.3	39.5	36.5	3.0
8	30.4	31.1	-0.7	34.4	34.5	-0.1	32.1	32.0	0.1
9	29.4	29.2	0.2	32.3	36.2	-3.9	35.0	34.2	0.8
11	32.7	31.3	1.4	30.6	31.9	-1.3	35.0	36.3	-1.3
18	30.7	32.6	-1.9	34.9	32.7	2.2	36.5	34.4	2.1
19	30.3	33.7	3.4	34.2	30.0	4.2	36.8	38.0	-1.2
5	-	-		37.3	28.4	8.9**	39.6	34.2	5.4
23	-	-		36.9	35.7	1.2	30.6	31.2	-0.6
14	-	-		31.8	34.1	-2.3	29.1	32.7	-3.6
16	-	-		36.1	34.4	1.7	37.4	34.9	2.5
2	-	-		31.2	32.6	-1.4	29.0	29.3	-0.3
Parents	32.5	25.3	7.2**	34.9	28.2	6.7*	41.8	27.6	14.2**
LSD,	t=.05		3.7			5.2			6.1
	t=.01		5.0			7.1			8.1

*Exceeds the 5% level of significance.

**Exceeds the 1% level of significance.

TABLE IX

MEANS AND DIFFERENCES FOR YIELD WITHIN PAIRS OF WHEAT LINES NEARLY ISOGENIC EXCEPT FOR SUSCEPTIBILITY AND RESISTANCE TO GREENBUGS

Pair Number	1966			1967 (Spaced)			1967 (Dense)		
	Susc.	Res.	Diff. S-R	Susc.	Res.	Diff. S-R	Susc.	Res.	Diff. S-R
	Grams/ft.^{2}			Grams/ft.^{2}			Grams/ft.^{2}		
3	20.7	20.6	0.1	16.8	15.6	1.2	15.7	14.7	1.0
6	17.5	17.6	-0.1	15.0	14.4	0.6	14.4	13.5	0.9
8	17.8	19.0	-1.2	14.6	14.1	0.5	12.8	11.8	1.0
9	17.5	16.4	1.1	15.6	14.1	1.5	14.2	12.9	1.3
11	19.3	19.5	-0.2	13.7	16.3	-2.6	14.3	15.4	-1.1
18	17.3	20.3	-3.0	15.8	14.3	1.5	14.6	13.7	0.9
19	18.8	19.3	-0.5	15.9	14.6	1.3	14.3	13.9	0.4
5	-	-		15.4	10.5	4.9**	15.3	12.4	2.9
23	-	-		18.2	17.3	0.9	12.7	12.6	0.1
14	-	-		14.5	14.6	-0.1	12.5	13.5	-1.0
16	-	-		15.3	13.4	1.9	13.7	13.6	0.1
2	-	-		12.7	14.3	-1.6	11.0	11.3	-0.3
Parents	21.6	14.4	7.2**	14.4	9.8	4.6**	19.3	10.2	9.1**
LSD,	t=.05		3.61			3.23			3.6
	t=.01		4.90			4.40			4.9

*Exceeds the 5% level of significance.

**Exceeds the 1% level of significance.

seeding rate. The similarities of resistant lines to the susceptible parent precludes the possibility of an association of factors for the expression of these characters with the gb locus as a cause of these differences.

The resistant line of pairs 11 and 18 were significantly earlier in heading than their susceptible counterparts in the 1967 spaced and dense seeding, respectively (Table V). Heading dates of lines in these pairs were very similar in 1966. This is in contrast to the heading dates for the parents where the heading dates were closer in 1967 than in 1966, presumably a result of the spring drought. In view of the reaction of the parents across environments and the similarity of lines in pair 11 in the other two tests the significant difference in pair 11 is apparently a result of sampling error.

Heading dates for the parents did not differ significantly when densely seeded; however, differences between parents and between lines within several of the pairs approached significance. Heading dates for the dense seeding rate were determined on a whole plot basis rather than on individual plants. The former method leaves a great deal to the evaluator's judgment and is not considered to be as accurate as the latter method. This probably contributed to the small difference between parent means and the significance between line means in pair 18, although a differential response to seeding rate cannot be ruled out.

Significant differences between line means for number of heads and grain yield occurred in pair 5 under spaced-planted conditions and approached significance in the dense seeded test (Tables VIII and IX). This is the response expected if greenbug resistance and factors for inferior yield were associated. However, failure of this type of response from any other pair suggests genetic segregation for yield factors in the BC^4F_1 plants, from which this pair was selected, as the most probable explanation for the lack of similarity of these means. Parents differed significantly for height, 1000 kernel weight, number of heads and grain yield in all environments and for heading date in two of the three environments. Thus, the majority of the line X pair interaction occurred as a result of differences between parents. Comparisons of means for resistant and susceptible near-isogenic lines averaged over all pairs, excluding parents, show small differences which are not consistent over environments (Tables X - XII) and are almost identical when averaged over pairs and environments (Table XIII). These data indicate no strong association of the agronomic characters studied with the gb locus.

Multiple range tests were used to test differences among pairs for each of the five characters in which significant line X pair interaction occurred (Tables XIV - XVIII). Significant differences among paired near-isogenic lines occurred for heading date and number of heads in 1967 but not in 1966 and for plant height and yield in all three tests. There was no significant difference among pairs for 1000 kernel weight. As would be expected from F_3's and F_4's derived from material with four backcrosses most pairs did not differ significantly. However, some differences among pairs for plant height, heading date, number of heads and yield indicate that dominant and recessive alleles of the Gb/gb locus were compared in diverse genetic backgrounds.

The gb gene has been reported only in DS28A and C.I. 9058, both spring-type wheats. This seemed to warrant observation of the material

TABLE X

MEANS AND AVERAGE DIFFERENCES BETWEEN SEVEN PAIRED GREENBUG RESISTANT AND SUSCEPTIBLE NEAR-ISOGENIC LINES OF WHEAT, FOR PLANT AND YIELD CHARACTERS, 1965-66

Character	Near-Isogenic Lines		Difference
	Susceptible(GbGb)	Resistant(gbgb)	
Plant Height (cm)	104.1	105.6	-1.5
Days to Heading[a]	33.4	33.6	-0.2
Head Number/Ft.^{2}	30.2	31.4	-1.2
Seeds/Head	22.2	22.4	-0.2
Seed Weight (g/1000)	27.28	26.97	0.31
Grain Yield/Ft.^{2} (g)	18.4	19.1	-0.7

[a]Days to heading from March 31.

TABLE XI

MEANS AND AVERAGE DIFFERENCES BETWEEN TWELVE PAIRED GREENBUG RESISTANT AND SUSCEPTIBLE NEAR-ISOGENIC LINES OF WHEAT FOR PLANT AND YIELD CHARACTERS, 1966-67 SPACED PLANTED

Character	Near-Isogenic Lines		Difference
	Susceptible(GbGb)	Resistant(gbgb)	
Plant Height (cm)	100.0	98.6	1.4
Days to Heading[a]	15.2	15.0	0.2
Head Number/Ft.^{2}	36.6	35.3	1.3
Seeds/Head	19.9	19.7	0.2
Seed Weight (g/1000)	22.74	22.84	-0.10
Grain Yield/Ft.^{2} (g)	15.3	14.7	0.6

[a]Days to heading from March 31.

TABLE XII

MEANS AND AVERAGE DIFFERENCES BETWEEN TWELVE PAIRED GREENBUG RESISTANT AND SUSCEPTIBLE NEAR-ISOGENIC LINES OF WHEAT FOR PLANT AND YIELD CHARACTERS, 1966-67 DENSELY SEEDED

Character	Near-Isogenic Lines		Difference
	Susceptible(GbGb)	Resistant(gbgb)	
Plant Height (cm)	75.2	75.6	-0.4
Days to Heading[a]	17.9	17.7	0.2
Head Number/Ft.^{2}	34.6	34.0	0.6
Seeds/Head	14.5	14.1	0.4
Seed Weight (g/1000)	27.91	27.96	-0.05
Grain Yield/Ft.^{2}	13.8	13.3	0.5

[a]Days to heading from March 31.

TABLE XIII

MEANS AND DIFFERENCES BETWEEN PAIRED GREENBUG RESISTANT AND SUSCEPTIBLE NEAR-ISOGENIC LINES OF WHEAT AVERAGED OVER PAIRS AND ENVIRONMENTS

Character	Near-Isogenic Lines		Difference
	Susceptible(GbGb)	Resistant(gbgb)	
Plant Height (cm)	93.1	93.3	-0.2
Days to Heading[a]	22.2	22.1	0.1
Head Number/Ft.^{2}	33.8	33.6	0.2
Seeds/Head	18.9	18.6	0.3
Seed Weight (g/1000)	25.98	25.92	0.06
Grain Yield/Ft.^{2} (g)	15.8	15.7	0.1

[a]Days to heading from March 31.

TABLE XIV

MULTIPLE RANGE TEST OF THE AVERAGE HEADING DATE (NUMBER OF DAYS AFTER MARCH 31) FOR PAIRS OF NEAR-ISOGENIC WHEAT LINES AND THEIR PARENTS GROWN IN THREE ENVIRONMENTS

1966		1967 (Spaced)		1967 (Dense)	
Pair Number	Days to Head	Pair Number	Days to Head	Pair Number	Days to Head
9	34.02	9	16.30	5	18.88
8	33.89	5	15.83	19	18.75
6	33.75	2	15.72	16	18.75
19	33.35	19	15.65	8	18.63
3	33.33	8	15.53	2	18.62
11	33.26	16	15.37	9	18.50
18	33.06	3	15.13	3	17.88
Parents	29.99	6	15.02	11	17.62
		11	14.72	6	16.88
		18	14.45	23	16.88
		23	14.00	18	16.75
		Parents	13.63	Parents	16.13
		14	13.30	14	15.50

NOTE: Any two means connected by the same line are not significantly different at the 5% level.

TABLE XV

MULTIPLE RANGE TESTS OF THE AVERAGE PLANT HEIGHT FOR PAIRS OF NEAR-ISOGENIC WHEAT LINES AND THEIR PARENTS GROWN IN THREE ENVIRONMENTS

1966		1967 (Spaced)		1967 (Dense)	
Pair Number	Height (cm)	Pair Number	Height (cm)	Pair Number	Height (cm)
3	108.4	3	95.0	3	79.3
19	106.7	5	94.9	9	77.9
18	104.6	19	94.7	5	77.5
8	104.5	9	93.5	11	75.9
9	104.4	11	92.3	19	75.8
11	103.5	23	92.2	8	75.8
6	101.8	2	92.1	2	75.5
Parents	95.6	8	91.7	6	75.1
		6	91.1	23	73.6
		18	90.7	18	73.4
		16	89.1	14	72.6
		14	88.5	16	72.5
		Parents	85.1	Parents	72.1

NOTE: Any two means connected by the same line are not significantly different at the 5% level.

TABLE XVI

MULTIPLE RANGE TEST OF THE AVERAGE 1000 KERNEL WEIGHT FOR PAIRS OF NEAR-ISOGENIC WHEAT LINES AND THEIR PARENTS GROWN IN THREE ENVIRONMENTS

1966		1967 (Spaced)		1967 (Dense)	
Pair Number	Grams	Pair Number	Grams	Pair Number	Grams
3	28.95	3	25.10	23	28.80
18	27.77	23	24.95	3	28.78
11	27.45	19	23.88	14	28.39
8	27.23	11	23.38	16	28.33
19	26.92	18	22.75	9	28.24
6	26.32	5	22.67	19	28.19
9	25.91	16	22.43	18	28.04
Parents	25.60	9	22.32	8	27.75
		14	22.32	5	27.29
		2	21.78	11	27.24
		6	21.43	6	27.11
		8	20.53	2	27.04
		Parents	18.02	Parents	26.96

NOTE: Any two means connected by the same line are not significantly different at the 5% level.

TABLE XVII

MULTIPLE RANGE TESTS OF THE AVERAGE NUMBER OF HEADS FOR PAIRS OF NEAR-ISOGENIC WHEAT LINES AND THEIR PARENTS GROWN IN THREE ENVIRONMENTS

1966		1967 (Spaced)		1967 (Dense)	
Pair Number	Heads/Ft.^{2}	Pair Number	Heads/Ft.^{2}	Pair Number	Heads/Ft.^{2}
19	32.0	23	36.3	6	37.9
11	32.0	16	35.3	19	37.4
18	31.7	8	34.5	5	36.9
3	30.9	9	34.2	16	36.1
8	30.7	18	33.8	11	35.6
9	29.3	3	33.8	18	35.4
6	28.9	14	32.9	3	34.8
Parents	28.9	5	32.8	Parents	34.7
		19	32.1	9	34.6
		2	31.9	8	32.1
		Parents	31.6	23	30.9
		11	31.3	14	30.9
		6	30.9	2	29.2

NOTE: Any two means connected by the same line are not significantly different at the 5% level.

TABLE XVIII

MULTIPLE RANGE TESTS OF THE AVERAGE YIELD FOR PAIRS OF NEAR-ISOGENIC WHEAT LINES AND THEIR PARENTS GROWN IN THREE ENVIRONMENTS

1966		1967 (Spaced)		1967 (Dense)	
Pair Number	Grams/Ft.^{2}	Pair Number	Grams/Ft.^{2}	Pair Number	Grams/Ft.^{2}
3	20.7	23	17.7	3	15.2
11	19.4	3	16.2	11	14.9
18	19.3	19	15.3	Parents	14.8
19	19.0	18	15.0	18	14.2
8	18.4	11	15.0	19	14.1
Parents	18.0	9	14.9	6	14.0
6	17.6	6	14.7	5	13.8
9	17.0	14	14.6	16	13.6
		16	14.4	9	13.5
		8	14.3	16	13.0
		5	14.1	23	12.7
		2	13.5	8	12.3
		Parents	12.1	2	11.2

NOTE: Any two means connected by the same line are not significantly different at the 5% level.

to determine if resistant lines lacked winterhardiness. No differences between resistant and susceptible near-isogenic lines were noted for plant or leaf injury in any of the three environments. Thus, no attempt was made to rate the "leaf-burn" that occurred in both tests in 1966-67. The resistant parent (Stw. 598874) suffered considerably more leaf damage than Kaw in 1966-67 but neither was damaged in 1965-66. Observations during these years, which can be classified as "mild winters", do not indicate an association of greenbug resistance and a lack of winterhardiness.

Quality Characters

Quality data of four characters for pairs of near-isogenic lines and their parents are presented in Appendix Tables XXI and XXII. There was essentially no difference between susceptible and resistant lines for per cent wheat and flour protein (Table XIX). Within pairs, six resistant lines were higher in wheat protein and four were lower than their susceptible counterpart. Protein content of flour followed the same trend between lines in pairs as that observed for protein content of the wheat.

Specific sedimentation scores were very similar between lines within pairs and when averaged over pairs (Table XX). Susceptible lines had a longer average mixing requirement than resistant lines; however, similarity of several lines within pairs and the occurrence of two pairs in which resistant exceeded susceptible lines indicate no strong association between the gb gene and factors for short mixing time. Mixing time for lines was unusually high in 1966 (Appendix Table XXII) when all lines exceeded the time of both parents. Most of these

TABLE XIX

MEANS AND DIFFERENCES FOR WHEAT AND FLOUR PROTEIN CONTENT FROM GREENBUG RESISTANT AND SUSCEPTIBLE NEAR-ISOGENIC WHEAT LINES AND THEIR PARENTS GROWN IN THREE ENVIRONMENTS

Pair Number	Wheat Protein (%)			Flour Protein (%)		
	Susc.	Res.	Diff.	Susc.	Res.	Diff.
8	15.7	15.2	0.5	14.2	13.6	0.6
9	15.3	15.1	0.2	14.0	13.7	0.3
11	15.2	14.9	0.3	14.0	13.8	0.2
3	15.1	14.9	0.2	13.6	13.3	0.3
19	15.1	15.1	0.0	13.5	13.6	-0.1
6	15.0	14.9	-0.1	13.6	13.4	0.2
18	14.6	15.2	-0.6	13.5	13.6	-0.1
16	15.3	15.7	-0.4[a]	14.1	14.6	-0.5[a]
2	15.2	15.6	-0.4[a]	14.0	14.2	-0.2[a]
5	15.0	15.0	0.0[a]	13.9	14.0	-0.1[a]
23	14.9	15.2	-0.3[a]	13.5	13.6	-0.1[a]
14	14.2	14.7	-0.5[a]	12.8	13.6	-0.8[a]
Line Means	15.1	15.1	0.0	13.8	13.7	0.1
Parents	15.3	16.0	-0.7	13.9	14.4	-0.5
Parents	15.2	15.5	-0.3[a]	13.9	14.2	-0.3[a]

[a]Mean of two environments only.

TABLE XX

MEANS AND DIFFERENCES FOR TWO QUALITY CHARACTERS FROM GREENBUG RESISTANT AND SUSCEPTIBLE NEAR-ISOGENIC WHEAT LINES AND THEIR PARENTS GROWN IN THREE ENVIRONMENTS

Pair Number	Specific Sedimentation (Units)			Mixing Time (Minutes)		
	Susc.	Res.	Diff.	Susc.	Res.	Diff.
3	2.30	2.46	-0.16	4.4	4.9	-0.5
6	2.43	2.54	-0.11	5.3	4.5	0.8
8	2.39	2.47	-0.08	5.0	4.7	0.3
9	2.39	2.38	-0.01	5.1	4.5	0.6
11	2.48	2.44	0.04	4.6	4.5	0.1
18	2.40	2.23	0.17	4.7	4.6	0.1
19	2.44	2.33	0.11	5.3	4.6	0.7
5	2.26	2.22	0.04[a]	3.8	3.6	0.2[a]
23	2.29	2.24	0.05[a]	3.5	3.5	0.0[a]
14	2.27	2.17	0.10[a]	3.5	4.0	-0.5[a]
16	2.14	2.20	-0.06[a]	3.5	3.2	0.3[a]
2	2.29	2.36	-0.07[a]	3.5	3.0	0.5[a]
Line Means	2.43	2.35	0.08	4.5	4.2	0.3
Parents	2.40	2.31	0.09	3.9	2.8	1.1
Parents	2.29	2.25	0.04[a]	3.5	2.4	1.1[a]

[a]Mean of two environments only.

lines exceeded the parents at both planting rates in 1967, although the differences were not as great as in 1966. It may be that there is no real difference between the mixing times of Kaw and the isogenic lines for the 1967 tests since some lines are lower than Kaw and the difference is usually less than one minute. However, no logical explanation for the high mixing requirements of the lines in 1966 is readily available in view of the low mixing requirements of the resistant parent.

These data do not indicate an association between the gb locus and mixing time or protein content of wheat and flour. Sedimentation values of the two parents did not differ to the extent that an association could be detected.

CHAPTER V

Summary and Conclusions

Possible genetic association between greenbug resistance conditioned by the recessive gb locus and certain agronomic and quality characters was studied in near-isogenic lines derived from the wheat cross DS28A/Ponca 2/5 Kaw. Parents and BC^4 F_3 pairs of near-isogenic lines were grown as spaced plants in 1965-66, and BC^4 F_4 pairs and parents were grown both as spaced plants and normal stands in 1966-67. A randomized complete block design with a split-plot arrangement of treatments was used. The main plots were pairs, a resistant (gbgb) and a susceptible (GbGb) line, obtained from BC^4 F_2 rows segregating for the gb locus or parents. Sub plots were individual lines or a parent.

Agronomic characters studied were heading date, plant height, number of heads, number of seed per head, seed weight, and yield. Wheat and flour protein content, mixing time, and specific sedimentation scores were determined as an indication of baking quality. The quality data were not analyzed statistically.

A significant line X pair interaction occurred for all agronomic characters, except number of seed per head. This suggests a failure of resistant and susceptible lines to react the same in all pairs. Tests for significant differences between resistant and susceptible plants in the same pair indicated that most of the interaction was a result of differences between parents. Significant differences between near-isogenic lines within pairs occurred in eight of 155 comparisons. These did not occur for the same character and in the same pair in more than one environment. These differences might be due to sampling error, to genetic segregation or to a combination of these causes. Differences between resistant and susceptible lines averaged over all pairs were small and not consistent over environments.

Association among genetic characters can result from pleiotrophy or linkage. No evidence was obtained for any strong association of greenbug resistance with heading date, plant height, seed weight, number of heads or yield. When averaged over all pairs and environments the resistant lines were 0.2 centimeter taller than their susceptible counterparts. Susceptible lines were 0.1 day earlier in heading, produced 0.2 head/foot^2, 0.3 seed/head, and 0.1 gram of seed/foot^2 more than the resistant lines. The 1000 kernel weight of susceptible lines was 0.06 gram heavier than resistant lines. Although the yield and yield component data were more desirable in the susceptible lines the differences were small. Lines differed significantly in only one pair for weight of kernels and yield and in two pairs for number of heads, height, and heading date. Each of these differences occurred in only one environment.

Although statistical analyses of quality data were not conducted, data from individual pairs and means for three environments do not indicate pleiotropic effect upon or linkage with the gb locus and factors for these characters. When averaged over environments protein content of wheat and flour were very similar for lines within pairs and almost identical when averaged over all pairs and environments. Mixing times of susceptible lines averaged 0.3 minute longer than their resistant counterparts. The occurrence of resistant lines with longer mixing times than susceptible lines in two pairs and the similarity of lines in three other pairs show that no strong association exists between mixing time and greenbug resistance.

The gb locus apparently does not have a pleiotropic effect upon the above eight characters. It is possible that genes closely linked to the gb locus do affect these characters but were not segregating in the cross DS28A/Ponca 2/5 Kaw.

Due to the similarity of parents for specific sedimentation values and number of seeds/head no conclusions can be drawn as to the possible association of greenbug resistance with these characters. In view of the good yield and quality of Kaw, the similarity of this variety and Stw. 598874 for these characters indicate the presence of adequate specific sedimentation value and number of seeds/head in the resistant parent.

The lack of any strong association of important quantitative traits with greenbug resistance indicates that the gb gene does not contribute towards undesirable agronomic and quality characters. Consequently, there do not seem to be any genetic barriers which would prevent the incorporation of greenbug resistance, conditioned by the gb gene, and desirable agronomic and quality traits in a single genotype.

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APPENDIX

TABLE XXI

PERCENT OF WHEAT AND FLOUR PROTEIN FOR PAIRS OF NEAR-ISOGENIC GREENBUG RESISTANT AND SUSCEPTIBLE LINES AND THEIR PARENTS, GROWN IN THREE ENVIRONMENTS

	Wheat Protein %						Flour Protein %					
	1966		1967(Spaced)		1967(Dense)		1966		1967(Spaced)		1967(Dense)	
Pair Number	Susc.	Res.	Susc.	Res.	Susc.	Res.	Susc.	Res.	Susc.	Res.	Susc.	Res.
3	16.1	15.4	14.9	14.6	14.3	14.6	14.0	13.3	13.8	13.7	13.0	13.5
6	16.2	16.1	14.2	14.0	14.7	14.5	14.0	14.2	13.0	12.9	13.8	13.2
8	15.7	15.6	14.7	14.8	16.6	15.6	13.8	13.4	13.2	13.5	15.5	14.0
9	16.0	16.0	14.6	14.0	15.4	15.3	14.1	14.1	13.3	13.0	14.5	14.1
11	15.6	14.9	14.4	14.2	15.6	15.5	14.2	13.9	13.4	13.1	14.4	14.3
18	14.7	15.7	14.3	14.8	14.7	15.0	13.9	13.2	13.1	13.8	13.5	13.8
19	15.5	16.2	14.9	14.4	15.0	14.7	13.4	14.2	13.5	13.0	13.6	13.5
5	-	-	14.8	15.0	15.2	14.0	-		13.7	13.9	14.0	14.1
23	-	-	14.3	14.8	15.5	15.5	-		13.1	12.9	14.3	14.1
14	-	-	13.8	14.3	14.5	15.0	-		12.5	13.2	13.1	14.0
16	-	-	14.8	14.9	15.7	16.5	-		13.7	14.0	14.4	15.1
2	-	-	14.8	14.7	15.5	16.4	-		13.7	13.5	14.2	14.9
Parents	15.5	16.9	14.8	15.0	15.6	16.0	14.0	14.8	13.2	13.6	14.5	14.7

TABLE XXII

SPECIFIC SEDIMENTATION VALUES AND MIXING TIME FOR PAIRS OF NEAR-ISOGENIC GREENBUG RESISTANT AND SUSCEPTIBLE LINES AND THEIR PARENTS GROWN IN THREE ENVIRONMENTS

Pair Number	Specific Sedimentation (Units)						Mixing Time (Minutes)					
	1966		1967 (Spaced)		1967 (Dense)		1966		1967 (Spaced)		1967 (Dense)	
	Susc.	Res.	Susc.	Res.	Susc.	Res.	Susc.	Res.	Susc.	Res.	Susc.	Res.
3	2.41	2.71	2.26	2.34	2.23	2.34	6.2	7.0	3.0	3.7	4.0	4.0
6	2.60	2.65	2.42	2.48	2.28	2.50	7.3	6.4	4.0	3.3	4.5	3.7
8	2.43	2.54	2.42	2.31	2.32	2.57	6.2	6.5	3.7	3.2	5.0	4.5
9	2.55	2.44	2.18	2.23	2.44	2.48	7.2	6.4	3.8	3.0	4.3	4.0
11	2.59	2.66	2.36	2.29	2.50	2.37	6.2	6.3	3.5	3.3	4.2	4.0
18	2.52	2.33	2.35	2.17	2.34	2.20	6.6	6.4	3.3	3.3	4.3	4.0
19	2.54	2.46	2.22	2.08	2.35	2.46	7.0	7.2	4.5	3.0	4.3	3.3
5	-	-	2.23	2.24	2.29	2.20	-		3.5	3.3	4.0	4.2
23	-	-	2.20	2.20	2.38	2.28	-		3.3	3.5	3.7	3.5
14	-	-	2.22	2.12	2.31	2.21	-		3.7	3.7	3.3	4.2
16	-	-	2.19	2.10	2.08	2.29	-		3.2	2.8	3.8	3.5
2	-	-	2.19	2.30	2.39	2.42	-		3.0	4.0	3.0	3.0
Parents	2.61	2.44	2.44	2.32	2.14	2.18	4.8	3.5	3.2	2.3	3.7	2.5

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