A STUDY OF GREENBUG RESISTANCE IN A PROGENY FROM "BLOOMLESS" SORGHUM

By

IRAJ AMINI

Licentiate Degree
Tehran University
Karadj, Iran
1968

Above Licentiate Degree
Tehran University
Karadj, Iran
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A STUDY OF GREENBUG RESISTANCE IN A PROGENY FROM "BLOOMLESS" SORGHUM

Thesis Approved:

Lewis H. Edwards
Thesis Advisor

Lester W. Reed

Kenneth J. Starks

N. N. Durham
Dean of Graduate College

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CHAPTER I

INTRODUCTION

The greenbug, Schizaphis graminum (Rondani), was first considered as a serious pest of sorghum in 1962 in Romania (11). In the summer of 1968 grain and forage sorghums in the Midwest and Southwest areas of the United States were severely damaged by greenbugs. Grain yields of sorghum in Kansas, Texas and Oklahoma were reduced up to 45%.

Because of frequent phytotoxicity of sorghum to insecticides, the cost of application, and losses from damage, breeders have been challenged to transfer greenbug resistance to cultivars of sorghum. One of the characters that indicates resistance to greenbugs in sorghum is the absence of the waxy material from the surface of the stems and leaves of bloomless sorghum. Bloomless sorghums showed fewer greenbugs and little or no damage in the field as compared to normal plants.

The purpose of this investigation was to study the nature of the resistance of bloomless sorghum to greenbugs and to determine the feasibility of combining the normal greenbug resistance with the bloomless form of resistance.

CHAPTER II

LITERATURE REVIEW

Biotypes of the Greenbug

Wood (27) studied the effect of two strains of greenbug, Schizaphis graminum (Rondani), on resistant and susceptible wheat lines. He reported that the strains were similar morphologically. The only method for distinguishing the two strains was their differential reaction on resistant and susceptible wheat lines. The new strain (greenhouse strain) attacked lines of wheat that the old strain (field strain) could not. These were later designated as Biotype A for the field strain and Biotype B for the greenhouse strain.

Harvey and Hackerott (10) recognized a biotype of the greenbug that was injurious to sorghum and sudangrass as well as small grains. This strain of greenbug which caused the outbreak on sorghum in 1968 was later designated as Biotype C. Wood (26) studied the reaction of these three different biotypes of greenbugs on resistant and susceptible selections of sorghum. He evaluated preference, fecundity and longevity, and found a significant difference in the reaction of the biotypes on the different sorghum selections. He indicated that these marked differences in the reaction of the biotypes to resistant and susceptible sorghum can, therefore, be used to separate the three biotypes.

Saxena and Chada (18) studied the feeding habits and mouth

parts of greenbugs (Biotypes A and B) and found that Biotype A made intercellular pentration of its stylets into plant tissue and fed in the phloem tissue while Biotype B penetrated both intra- and intercellularly and fed in the mesophyll parenchyma of the leaf.

Wood, Chada and Saxena (28) described morphological differences among Biotypes C, A, and B. They reported that there was no morphological or ecological differences between Biotypes A and B but both differed from Biotype C. Also, Biotypes C and A had similar habits in feeding in leaf tissue. Biotype A can infest only small grains while Biotype C can destroy both small grains and sorghum.

Harvey and Hackerott (9) compared the effectiveness of resistance to Biotypes B and C of the greenbug in wheat, barley, rye and sudangrass. They reported that 'Piper' sudangrass, 'Caribou Selection' rye and 'CI 9058/7 Bison' wheat were resistant to Biotype B and susceptible to Biotype C. 'Insave F.A.' rye and 'Dicktoo' barley were resistant to both biotypes.

Greenbug Resistance in Sorghum

Hackerott and Harvey (7) studied 'Combine Kafir-60' as a susceptible sorghum and 'KS 30' as a resistant sorghum in the field. It was found that Biotype C of the greenbug reduced the yield of the Combine Kafir-60 more than KS 30, but grain quality was not reduced as much as grain yield.

Schuster and Starks (19) used nonpreference, antibiosis, and tolerance to measure resistance to the greenbug. Five entries ('PI 229828', 'IS 809', 'Shallu Grain', 'PI 302178' and 'PI 226096') had a high degree of resistance in all three resistance components.

Teetes, Schaefer, and Johnson (22) studied nonpreference and antibiosis of resistant and susceptible sorghums in the laboratory. They found that resistant lines 'PI 264453', IS 809 and Shallu Grain had more nonpreference than susceptible lines 'TX 2536' and 'TX 7000'. The F_1 hybrids of susceptible x resistant lines showed a response similar to the resistant parent, only in a lesser degree. In this study, the effect of susceptible and resistant sorghums on fecundity and longevity of greenbugs was used to evaluate antibiosis. The greenbugs on the resistant sorghum had fewer progeny per adult and less longevity than on the susceptible sorghum.

Starks and Wood (21) studied greenbug damage in different growth stages of susceptible and resistant sorghum. They indicated that growth of IS 809 was not affected by the greenbugs, but susceptible Wheatland showed damage. The greenbugs did not decrease the grain yield of IS 809 but significantly decreased the grain yield of Wheatland.

Teetes, et al. (24) in their field studies indicated that since leaf damage by greenbugs to resistance types was not severe, tolerance was the primary mechanism of resistance. The test for antibiosis and nonpreference in the field showed that these mechanisms played a lesser role than the tolerance mechanism.

Johnson, Rosenow, and Teetes (12) studied a greenbug resistant line, a susceptible line and their hybrid in the field under a natural infestation. They reported that infestation of seedlings by greenbugs in susceptible Combine Kafir-60 reduced grain yield, tillering, plant height and delayed maturity more than in resistant 'H 39'. The F_1 (Combine Kafir-60 x H 39) appeared to be more resistant than Combine Kafir-60 and less resistant than H 39.

Maunder, Lambright, and McNeely (16) indicated that the infestation of plants at 2.5 cm of height did not result in any significant difference in height between resistant and susceptible sorghums after 16 days, but the percent of survival in resistant was more than in susceptible plants.

Juneja, et al. (13) indicated that benzyl alcohol was associated with resistance to the greenbug in barley. They reported that the addition of benzyl alcohol to growing plants decreased the number of greenbug progeny produced on susceptible barley but did not effect the number on the resistant line.

Weibel, et al. (24) studied the resistant sorghums, Shallu Grain, PI 264453 and IS 809, susceptible sorghums and the F_1 and F_2 of their crosses to determine the inheritance of resistance. They found that the F_1 plant had intermediate resistance. The study of F_2 populations indicated that the inheritance of resistance was controlled by a single gene with incomplete dominance. Weibel, Starks, and Buajarern (25) compared resistant lines of sorghum and the F_1 and F_2 of their crosses. They concluded that the resistant factor in Shallu Grain and IS 809 was controlled by a single incompletely dominant gene but the resistance of PI 264453 was slightly different.

Gardenhire (5) concluded that resistance to greenbug in oats ('Russian 77') was controlled by a single dominant gene pair. Curtis, Schlehuber, and Wood (4) found that resistance to greenbugs in wheat (CI 9058 and 'DS 28A') was controlled by a single recessive gene and susceptibility was not completely dominant. According to a study of the inheritance of greenbug resistance in barley by Gardenhire and Chada (6), resistance was controlled by a single completely dominant gene. Smith,

Schlehuber, and Curtis (20) reported that the greenbug resistance of the barleys 'Omugi' (C.I. 5144), 'Dobaku' (C.I. 5238), and 'Kearney' (C.I. 7580) appeared to be controlled by a common single completely dominant gene.

Bloom and Bloomless Sorghum

Martin (15) compared corn with sorghum for drought resistance. It was reported that the waxy cuticle in sorghum was one of the important factors that was responsible for drought resistance. Lambright and Maunder (14) indicated that the bloom or normal type exhibited a higher resistance to stomatal diffusion.

Cummins (2) studied the silage yield of bloom and bloomless types of sorghum. He reported that there was only a small difference between bloom and bloomless types in silage yield. Cummins and Dobson (3) examined three pairs of bloom and bloomless isogenic lines of sorghum, by the "in vitro dry matter digestibility" technique to determine the digestibility of these lines. They found that the green leaf segments of the bloomless sorghum were more digestible than the bloom type. Hanna, Monson, and Burton (8) in their study with the same technique reached the same conclusion.

Ayyangar and Ponnaiya (1) reported on crosses between bloomless and heavy bloom and between bloomless and sparse bloom types. In the first cross the F_1 had heavy bloom, and in the F_2 the ratio of heavy bloom to bloomless was 3:1. The gene 'Bm' was designated for the heavy bloom and 'bm' for the bloomless type. In the second cross, the F_1 had a heavy bloom. The F_2 segregated into heavy bloom, sparse bloom, and bloomless types in the ratio 9:3:4.

CHAPTER III

MATERIALS AND METHODS

Sorghum Entries

The sorghum entries in this study (Table I) included IS 809 (Resistant), RWD3-Weskan-4-3-1-1-2 (Bloomless), RS 610 Hybrid of Combine Kafir-60 x Comb. 7078 (Susceptible), and the F_1 and F_2 generations from the cross of IS 809 x RWD3-Weskan. The experiment included four replications, of which two were grown in the Agronomy greenhouse and two were grown in the Entomology greenhouse. Each replication occupied one greenhouse table and included: IS 809 (10 pots), RWD3-Weskan (10 pots), RS 610 (10 pots), F_1 (10 pots), and F_2 (25 pots). The pots were assigned to each table at random. Four to five seeds were planted in each pot, and 20 days after germination the plants were thinned keeping two plants per pot. All pots were fertilized uniformly and irrigated as needed. Biotype C of the greenbug was cultured on susceptible sorghum in the greenhouse. Resistance to greenbugs in sorghum was measured in three different tests: tolerance, antibiosis, and nonpreference.

Tolerance to Damage

One of the two plants in each pot was selected at random for this study. Damage readings were obtained at two different ages of the plants. Plastic cages 2.5 cm on each side were utilized in this study

TABLE I

SORGHUM ENTRIES AND THEIR CHARACTERISTICS

Identification	Entry Characteristic
IS 809	Greenbug resistant - bloom type
RWD 3-Weskan	Greenbug susceptible in seedling stage - bloomless
F_1	Intermediate resistance - bloom type
F_2	Segregating
RS 610	Greenbug susceptible - bloom type

to confine greenbugs on leaf blades. Each cage had a hole in the top and in the bottom that was covered with cloth. Ten adult apterous greenbugs were put in each cage, and the cage was closed over a blade of sorghum leaf. The cages were supported by a wire and rubber band.

Each cage was checked on alternate days to replace dead or missing adults and to remove the offspring in order to maintain a constant number of greenbugs on the leaf and eliminate the effect of antibiosis. At the end of 17 days the plants were rated for visual damage by using a scale of 1 to 6 with 1 representing no damage and 6 a dead or dying leaf blade.

In the first analysis of damage readings, the experimental design was a randomized complete block with four replications in a split plot arrangement. The main plots were the entries IS 809, RWD3-Weskan, F_1, bloom type sorghum in F_2, bloomless sorghum in F_2, and RS 610, and the sub-plots were the two different times of infestation (30 and 50 days after germination).

In the second analysis of damage readings, only data from the F_2 populations were used. The experimental design was simialr to the first analysis but the main plots were bloom type and bloomless and the sub-plots were the times of infestation (30 and 50 days after germination). In both analyses because of missing individual plants and unequal sub-samples, the analysis of variance by the method of fitting constants was applied.

The damage readings of the parents, F_1, and F_2 populations were used to study the inheritance of tolerance to damage from greenbugs. For calculating the expected distributions in the F_2 populations, the partitioning method of genetic analysis was applied. Powers (17) stated

that if the character is determined by one major effective factor pair, the theoretical mean and frequency distribution of F_2 is obtained by the following equation:

$$F_2(P_1 \times P_2) = \tfrac{1}{4}(P_1 + P_2) + \tfrac{1}{2}F_1(P_1 \times P_2)$$

The distribution of different damage readings in the populations of parents, F_1, F_2, and RS 610 was calculated on the basis of 100 and was called the relative frequency distribution.

Antibiosis

In this study the experimental design was the same as the one used for the tolerance study. However, the F_2 population was eliminated because of missing data. Similar cages and the same plants were used as in the tolerance study. The tests were made to compare the ability of the greenbugs to live and reproduce on the four sorghum entries. In this case, five adult apterous greenbugs were caged on one individual leaf blade of each experimental plant.

The adult greenbugs were removed after four days and only five nymphs were retained in each cage. The nymphs were examined at the end of four days, and the first nymph to mature and reproduce was selected for the test specimen. All other adults were removed from the cage.

The progeny of the adult in each cage was counted and removed at two to three day intervals for the life of the adult. Because of the early death of some of the adult greenbugs, or the occurance of winged forms in the cages, the numbers of nymphs per day was counted for 12-16 days during the highest reproductive period of their lives. The

antibiosis study was conducted at two different ages of the plants. The first was initiated when the plants were 30 days of age and the second when the plants were 50 days of age. The analysis of variance for antibiosis was calculated in a manner similar to the one for damage readings.

Nonpreference

Two methods were used to evaluate the degree of nonpreference of the entries.

Method 1

IS 809, RWD3—Weskan, the F_1, and RS 610 were utilized for this study. The entries were planted at random in a circular pattern with equal distance between them in eight 10-inch pots. Plants were thinned to one plant of each entry per pot five days after germination.

The experiment was initiated by placing 80 adult apterous greenbugs (20/plant) in the center of each pot seven days following emergence. Infested pots were covered with circular clear plastic cages with cloth covered holes on both sides and top. The number of adult greenbugs on each plant was counted after five days and was calculated in percentage of adults per plant. The experimental design was completely randomized with eight replications.

Method 2

Plants 50 and 70 days old were utilized in this study. IS 809, RWD 3-Weskan, and the F_1 were studied at 50 days of age, while RS 610 was added for the study at 70 days of age. Plastic cages 12.5 x 12.5 x

5 cm with a hole on the top covered with cloth were used. One leaf of each entry was enclosed in each of six cages equally spaced and in random order. The cages were infested by placing 30 adult apterous greenbugs (10 per leaf) in the center of each cage. The cages were opened after four days and the number of adult greenbugs on each leaf was counted. The experimental design was completely randomized with six replications.

Study of Bloom and Bloomless Sorghum

All the plants were classified for bloom and bloomless segregation. The Chi-Square Test was used to test the F_2 plant ratio of three bloom to one bloomless.

CHAPTER IV

RESULTS AND DISCUSSION

Segregation of Bloom and Bloomless

The production of bloom began at 25 days after planting. All the entries were examined for the bloom and bloomless characteristic at 30 days of age. The RS 610, IS 809, and F_1 showed the presence of bloom, and there were no apparent differences in the degree of the bloom characteristic among all plants.

All of the F_1 plants contained bloom. The F_2 population contained 146 bloom and 52 bloomless which fit the ratio of 3:1 of bloom to bloomless plants with a probability of 70 to 90%. Therefore the bloom and bloomless characteristic appears to be determined by a single completely dominant and completely recessive gene, respectively. Ayyangar and Ponnaiya (1) reached the same conclusion in their study of bloom and bloomless sorghum.

Tolerance to Damage

Figures 1 to 10 show the relative frequency distributions of entries for damage readings in the first and second set of readings on the basis of the sum of the four replications.

Figures 1 and 2 show that IS 809 had more plants in the lower end of the scale in the second set than in the first set of readings. Since all the plants in this entry had bloom, the reduction in the rate

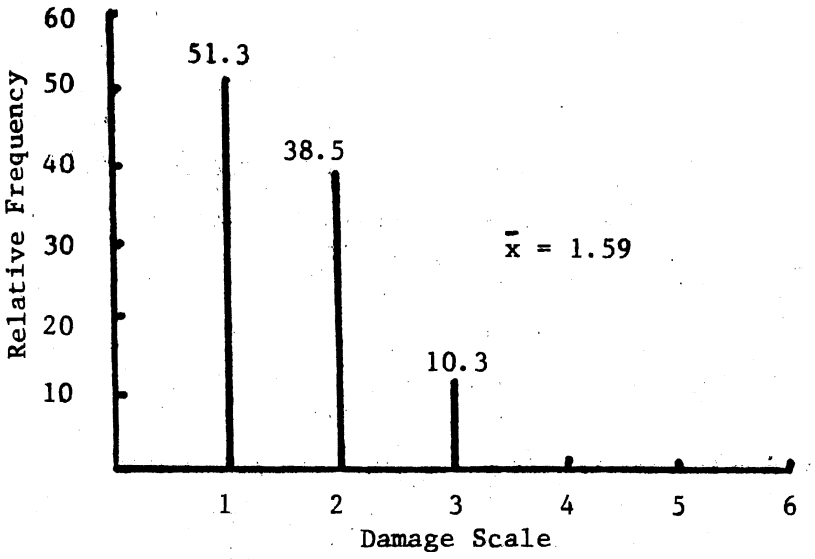

Figure 1. Relative Frequency Distribution of IS 809 for Damage Readings in the First Set of Readings.

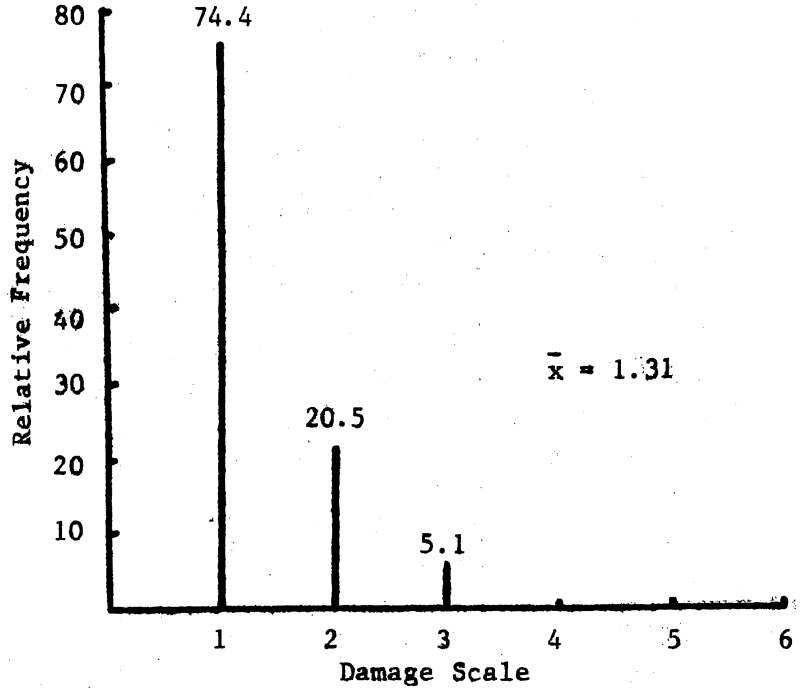

Figure 2. Relative Frequency Distribution of IS 809 for Damage Readings in the Second Set of Readings.

of damage in the second set of readings was probably due to the increased age of the plants, or to an increase in the leaf tissue in the cage for the greenbugs to damage.

Figures 3 and 4 show that RWD3-Weskan had more plants in the upper end of the scale in the first set than in the second set of readings. These figures show that the older plants had more resistance to greenbugs. This increase of resistance might be caused by the effect of the bloomless character or by the increased age of the plant or by the increased amount of leaf tissue in the cage. When these figures are compared with Figures 1, 2, 5, 6, 7 and 8 that also come from homozygous populations (IS 809, F_1, and RS 610), it would appear that the increase of resistance in RWD3-Weskan was similar to the others and was caused only by the increased age of the plants. On the other hand, the distribution of RWD3-Weskan shows more resistance to greenbugs than does RS 610.

Figures 5 and 6 show that the distribution of the F_1 plants was intermediate between the parental distributions and that the second set of readings showed more resistant plants than the first set.

Figures 7 and 8 show that the distribution of plants of RS 610 for damage readings in the first set of data had more plants in the higher end of the scale than the second set, but in general, RS 610 gave a susceptible reaction to greenbugs.

Figures 9 and 10 show that the F_2 population in the first set of readings gave a normal bell-shaped distribution while in the second set the distribution was skewed to the left indicating a higher frequency of resistant plants than expected.

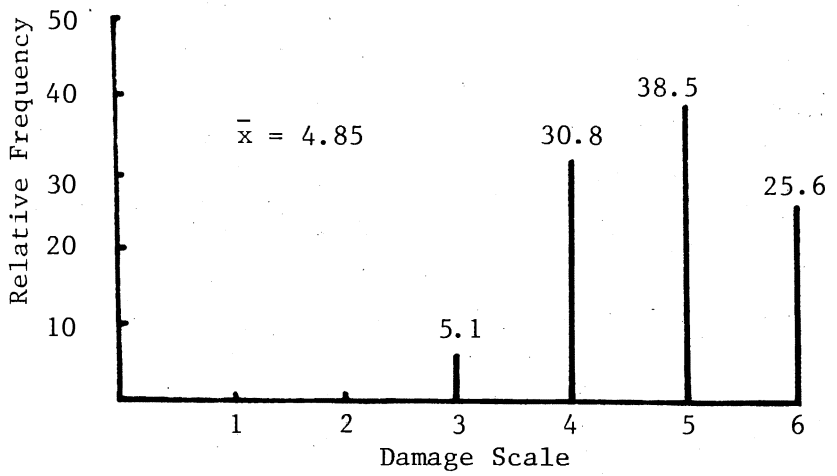

Figure 3. Relative Frequency Distribution of RWD3-Weskan for Damage Readings in the First Set of Readings.

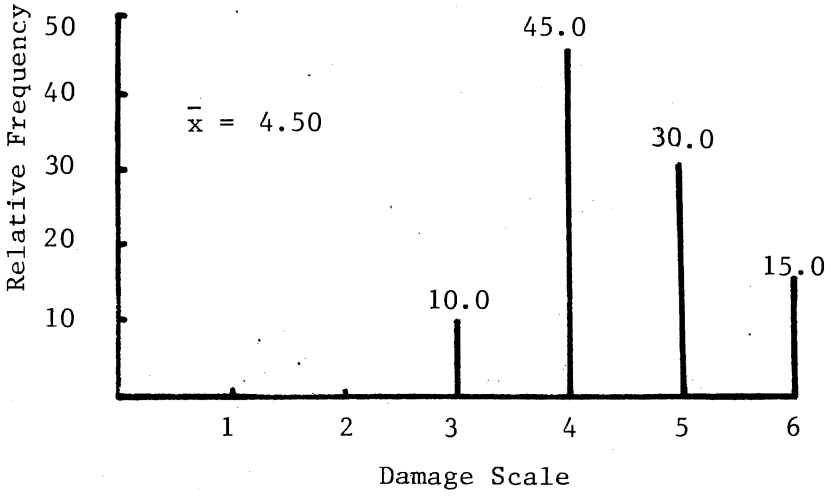

Figure 4. Relative Frequency Distribution of RWD3-Weskan for Damage Readings in the Second Set of Readings.

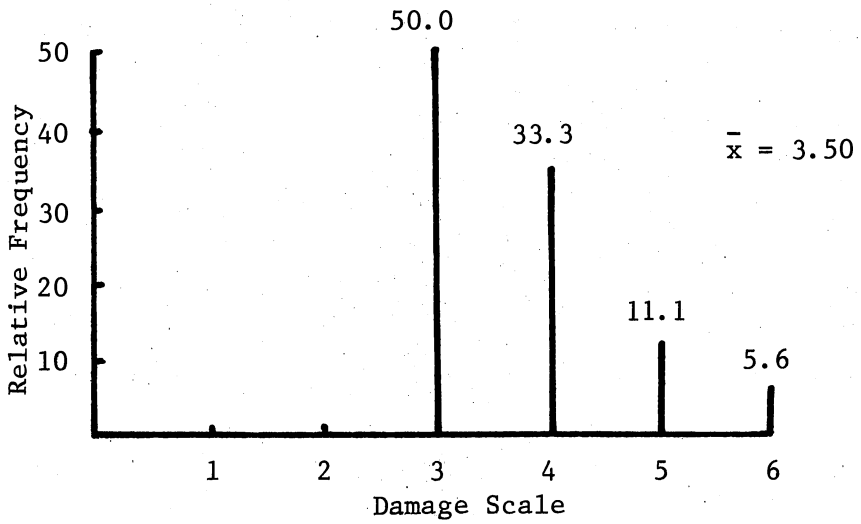

Figure 5. Relative Frequency Distribution of F_1 for Damage Readings in the First Set of Readings.

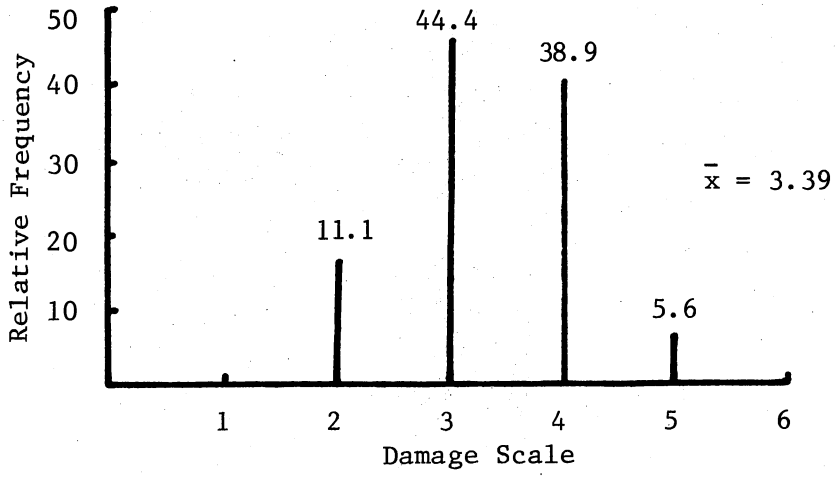

Figure 6. Relative Frequency Distribution of F_1 for Damage Readings in the Second Set of Readings.

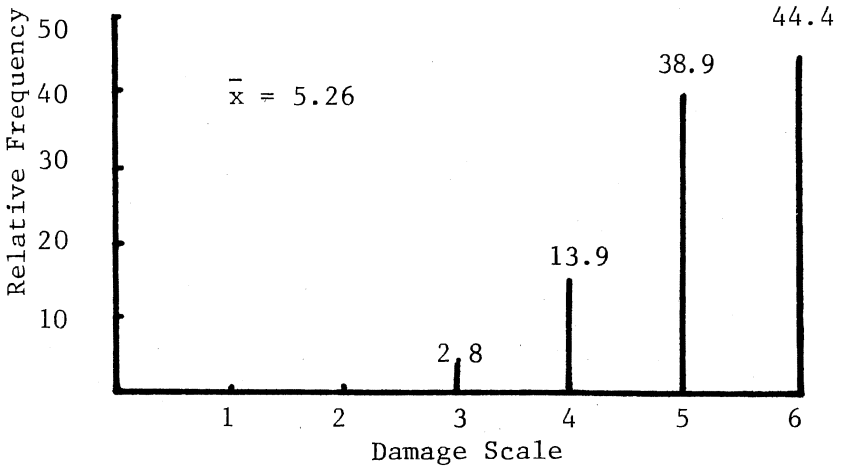

Figure 7. Relative Frequency Distribution of RS 610 for Damage Readings in the First Set of Readings.

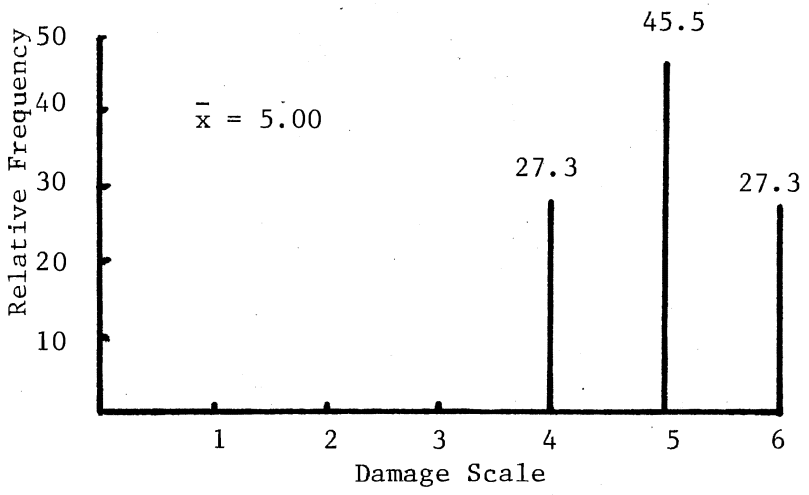

Figure 8. Relative Frequency Distribution of RS 610 for Damage Readings in the Second Set of Readings.

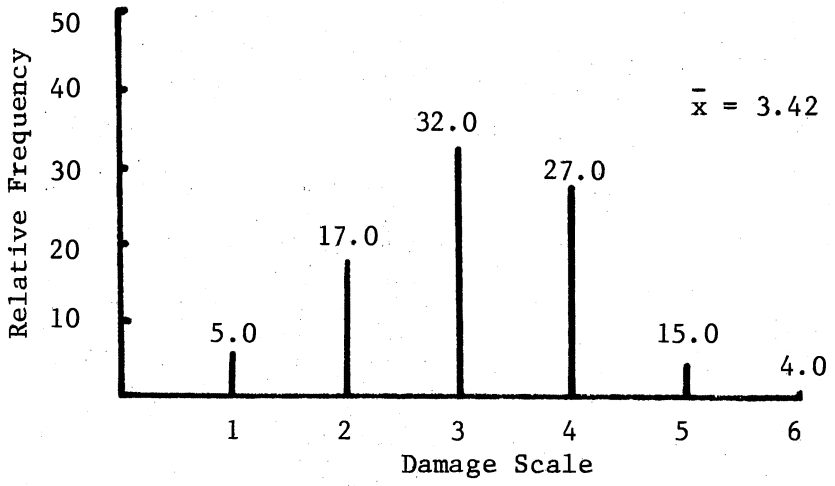

Figure 9. Relative Frequency Distribution of F_2 for Damage Readings in the First Set of Readings.

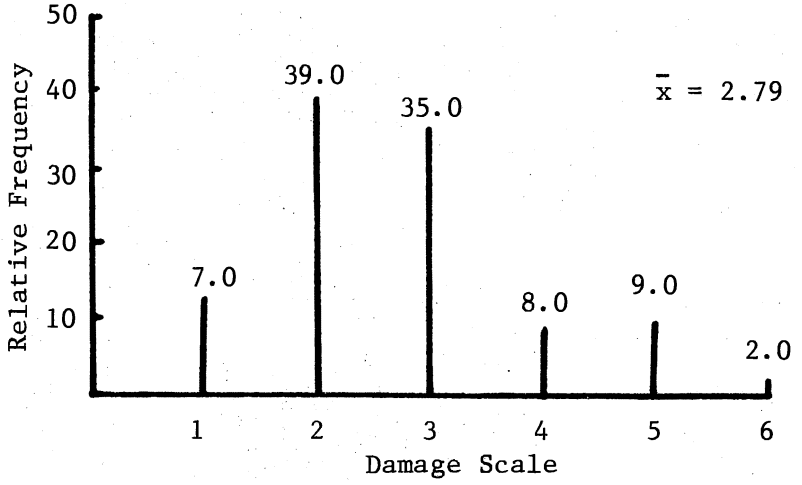

Figure 10. Relative Frequency Distribution of F_2 for Damage Readings in the Second Set of Readings.

The F_2 population was divided into four groups; distributions of the bloom sorghums in the first and second set of readings (Figures 11 and 12), and distributions of the bloomless sorghums in the first and second set of readings (Figures 13 and 14). In the bloom sorghums, the differences between the first and second set of readings were very similar to the previous figures and to the complete F_2 population. In the bloomless sorghums the first set of readings ranged higher on the scale than either the complete F_2 populations or the bloom portion of the F_2 population. The second set of readings was quite similar to those from the corresponding F_2 populations. The data indicates that the plants in the F_2 bloomless group had less resistance than the bloom sorghum.

Table II shows the analysis of variance for damage readings in all entries. The F value for replication was not significant, indicating a lack of significant differences among replications. The highly significant F value for entry showed that there were significant differences among entries. The highly significant F value for set reflected the effect of age of the plants on tolerance to damage. The entry x set interaction was not significant which means the difference among entries was not significantly different from the first set to the second set of readings.

Table III shows the analysis of variance for damage readings of bloom and bloomless in the F_2 population. The non-significant F value for the bloom type indicated that plants with the bloom and bloomless characteristic were not significantly different. This indicates that bloomless can be combined with the normal form of resistance to greenbugs, thereby improving the total resistance. The

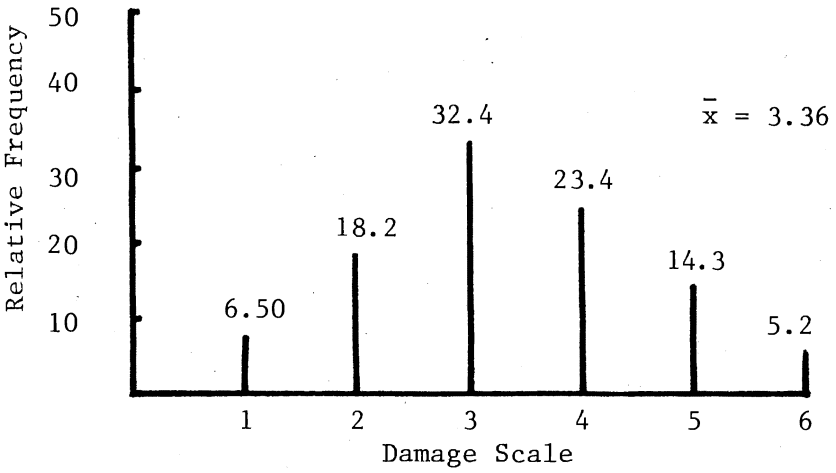

Figure 11. Relative Frequency Distribution of Bloom Sorghum Segregates from the F_2 for Damage Readings in the First Set of Readings.

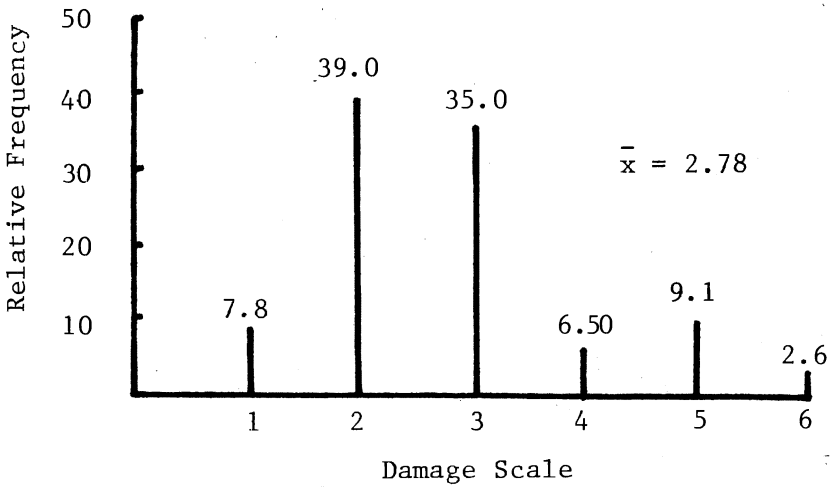

Figure 12. Relative Frequency Distribution of Bloom Sorghum Segregates from the F_2 for Damage Readings in the Second Set of Readings.

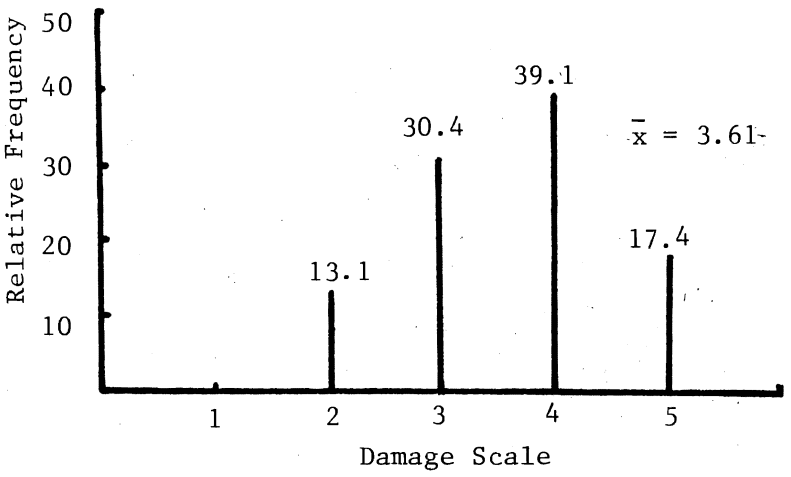

Figure 13. Relative Frequency Distribution of Bloomless Sorghum Segregates from the F_2 for Damage Readings in the First Set of Readings.

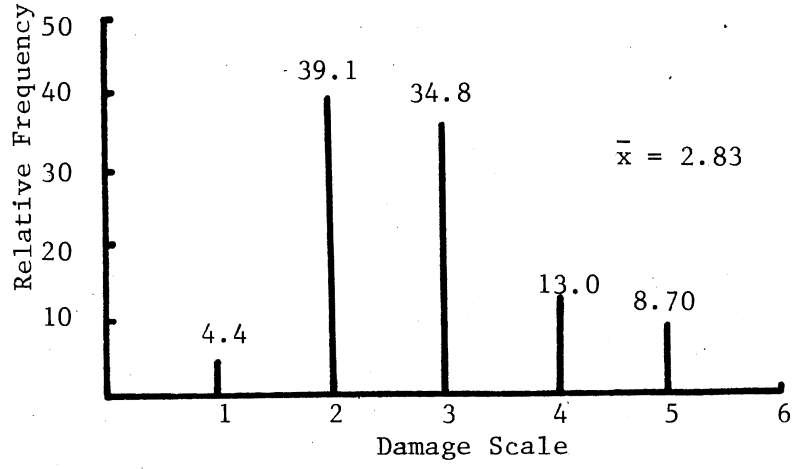

Figure 14. Relative Frequency Distribution of Bloomless Sorghum Segregates from the F_2 for Damage Readings in the Second Set of Readings.

F value for set was significant and the F value for bloom type x set was not significant. An explanation similar to that given for the analysis of all entries in Table II applies here.

Table IV consists of means and variances of damage readings for all entries in both sets. This table shows that RS 610 had the highest damage readings and IS 809 had the lowest. RWD3-Weskan was somewhat less susceptible to greenbug damage than RS 610. The F_1 plants gave damage readings intermediate between the parents, but they tended toward the susceptible parent. The mean of the total F_2 population showed more resistance than the F_1 plants, especially from the second set of readings. The variances of F_2 bloom and F_2 bloomless groups in both sets were higher than for other entries.

Inheritance of Tolerance to Damage

Tables V and VI show the observed and expected frequency distributions, means, and variances of the F_2 population for damage readings for the first and second sets of readings, respectively. The expected frequency distribution, mean, and variance for the F_2 population were calculated assuming one major effective gene pair by applying the partitioning method of genetic analysis. The Chi-Square for both sets of readings was not in the acceptance region. Therefore, the hypothesis of one major effective gene pair was rejected. This information showed that the tolerance to damage in IS 809 was not regulated by a single incompletely dominant gene. The results do not agree with those reported by Weibel *et al.* (24) and Weibel, Starks, and Buajarern (25) that the resistance to damage is regulated by a single incompletely dominant gene. However, these workers studied

TABLE II

ANALYSIS OF VARIANCE FOR DAMAGE
READINGS OF ALL ENTRIES

Source	d.f	SS	MS	F
Replication	3	3.69	1.23	1.39
Entry	5	599.27	119.85	135.06***
Error a	15	13.31	0.89	----
Set	1	12.58	12.58	10.97***
Entry x Set	5	4.52	0.90	0.79
Error b	18	20.65	1.15	----

***Significant at less than 0.005 level of Probability.

TABLE III

ANALYSIS OF VARIANCE FOR DAMAGE READINGS OF BLOOM AND BLOOMLESS SUBGROUPS OF THE F_2 POPULATION

Source	d.f.	SS	MS	F
Replication	3	6.55	2.18	1.57
Bloom type	1	0.42	0.42	0.30
Error a	3	4.18	1.39	----
Set	1	14.74	14.74	15.87**
Bloom type x Set	1	0.19	0.19	0.20
Error b	6	5.57	0.93	----

** Significant at 0.01 level of Probability.

TABLE IV

MEANS AND VARIANCES OF DAMAGE READINGS FOR ALL ENTRIES IN BOTH SETS OF READINGS

Entry	First Set		Second Set	
	Mean	Variance	Mean	Variance
IS 809	1.59	0.46	1.31	0.32
RWD3-Weskan	4.85	0.77	4.50	0.77
F_1	3.50	0.62	3.39	0.60
F_2 Bloom	3.36	1.60	2.78	1.33
F_2 Bloomless	3.61	0.89	2.83	1.06
RS 610	5.26	0.67	5.00	0.57

TABLE V

OBSERVED AND EXPECTED FREQUENCY DISTRIBUTIONS, MEANS, AND VARIANCES FOR THE F_2 POPULATION FOR DAMAGE READINGS IN THE FIRST SET OF READINGS

F_2 Population	Damage Scale 1	2	3	4	5	6	$\bar{x}$	s^2
Observed	5.00	17.00	32.00	27.00	15.00	4.00	3.42	1.44
Expected	12.81	9.61	28.85	24.35	15.18	9.20	3.47	2.10
	$x^2 = 13.99$	Probability between 0.05 and 0.01						

TABLE VI

OBSERVED AND EXPECTED FREQUENCY DISTRIBUTIONS MEANS, AND VARIANCES FOR THE F_2 POPULATION FOR DAMAGE READINGS IN THE SECOND SET SET OF READINGS

F_2 Population	Damage Scale 1	2	3	4	5	6	$\bar{x}$	s^2
Observed	7.00	39.00	35.00	8.00	9.00	2.00	2.79	1.26
Expected	18.60	10.68	25.98	30.70	10.30	3.75	3.15	1.90
$x^2 = 103.22$ Probability less than 0.005								

total resistance; whereas my results were based on the tolerance component of resistance. There was no significant difference in damage readings between bloomless and bloom sorghum in F_2, but the effect of bloomless or other genetic factors may have caused this difference.

Antibiotic Effect

Table VII presents the analysis of variance for antibiotic effect of entries on greenbugs in both sets of readings. The effect of entries (RWD3-Weskan, IS 809, F_1, and RS 610) on antibiosis was significantly different. The non-significant F value for sets indicated that production of offspring on plants of different ages was not different. In comparison with the results of tolerance to damage, the antibiotic effect of entries was not influenced by age or size of plant. The larger leaf blade of older plants did not affect antibiosis, and interaction of entries x set was not significant. Table VIII gives the means and variances for antibiotic effect of entries on greenbugs in both sets of readings. There were more nymphs per day for RWD 3-Weskan than for F_1 or IS 809, and less than for RS 610 for both sets of readings. The production of nymphs per day for the F_1 was intermediate between IS 809 and RWD3-Weskan with a tendency toward RWD3-Weskan.

Nonpreference

Table IX shows the analysis of variance for nonpreference test at three different ages of the plants. The F value for entries was significant at the seedling stage and at 70 days of age. The means of

TABLE VII

ANALYSIS OF VARIANCE FOR ANTIBIOTIC EFFECT
OF ENTRIES IN BOTH SETS OF READINGS

Source	d.f	SS	MS	F
Replication	3	0.75	0.25	0.82
Entry	3	12.47	4.16	13.72***
Error a	9	2.73	0.30	----
Set	1	0.11	0.11	0.32
Set x Entry	3	0.67	0.22	0.66
Error b	12	4.06	0.34	----

***Significant at less than 0.005 level of Probability.

TABLE VIII

MEANS AND VARIANCES OF ANTIBIOTIC EFFECT (NYMPHS PER DAY) FOR ENTRIES IN BOTH SETS OF READINGS

	First Set		Second Set	
Entry	Mean	Variance	Mean	Variance
IS 809	1.91	0.05	1.84	0.25
RWD3-Weskan	2.83	1.18	3.01	0.03
F_1	2.27	0.18	2.13	0.03
RS 610	3.12	0.16	3.49	0.19

TABLE IX

ANALYSIS OF VARIANCE FOR NONPREFERENCE TESTS
AT THREE DIFFERENT AGES OF PLANTS

	Seedling Stage		50 Days Old		70 Days Old	
Source	d.f	MS	d.f	MS	d.f	MS
Entries	3	836.73***	2	55.50	3	231.99***
Errors	28	13.22	15	118.96	21	26.49

***Significant at less than 0.005 level of Probability.

nonpreference effect (percentage of greenbugs per plant) at three different ages of the plants are listed in Table X. IS 809 showed higher nonpreference than the other entries in the seedling stage. RWD3—Weskan showed more nonpreference than RS 610 but less than the F_1 which was between the two parents. With plants 50 days old the differences between entries were not significant. This could result from bloomless sorghum becoming more resistant to greenbugs as the plants become older. With plants 70 days old, the test included RS 610 (check). The only significant difference was between RS 610 and the other entries. In this case, the nonpreference component of resistance could account for the bloomless sorghum showing resistance equal to IS 809 and the F_1 at the older stage.

TABLE X

MEANS OF NONPREFERENCE EFFECTS (PERCENTAGE OF GREENBUGS PER PLANT) AT THREE DIFFERENT AGES OF PLANTS

Sorghum Entry	Seedling Stage	50 Days Old	70 Days Old
IS 809	11.16	30.07	20.93
RWD3-Weskan	30.18	36.08	26.40
F_1	24.44	33.85	19.45
RS 610	34.32	---	33.18
$LSD_{.01}$	5.06	NonSignificant	8.41

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to study the nature of the resistance of bloomless sorghum (RWD3—Weskan) to greenbugs (Biotype C) and to determine the feasibility of combining the normal greenbug resistance (IS 809) with the bloomless form of resistance.

The experiment was conducted in the Agronomy and Entomology greenhouses in the winter of 1974-75. The three components of greenbug resistance-tolerance to damage, antibiosis, and nonpreference were studied. Tolerance to damage was measured by using the scale of 1 to 6 with 1 representing no damage and 6 a dead or dying leaf. For the antibiotic effect the progeny of one adult in each cage was counted and removed at two to three day intervals for the life of the adult. Nonpreference was studied in three different ages of plants utilizing the plastic cylinders for seedling stage and big plastic cages for the later stages. Adult apterous greenbugs were released in the center of each plastic cylinder or plastic cage and allowed to go to the plant leaf of their choice.

Conclusions

1. The bloomless characteristic was regulated by a single completely recessive gene.
2. In the F_2 population which was segregating for the bloom vs

bloomless character, the bloom plants exhibited the same degree of tolerance as the bloomless plants.

3. The bloomless type of resistance and normal type of resistance are regulated by independent genetic factors, and there is no apparent difficulty in combining them to improve resistance.
4. The hypothesis of a single incompletely dominant gene that regulates the normal form (IS 809) of resistance of greenbugs was not accepted. This difference from previous studies might be the effect of bloomless sorghum or other genetic factors.
5. The sorghum entries appeared to increase their tolerance to damage with increasing age.
6. The antibiotic effect appeared to be different in the entries with IS 809 showing the highest type of resistance.
7. The production of nymphs per day did not increase or decrease as the age of the plants increased.
8. The bloomless sorghums in nonpreference tests showed an increase in nonpreference with an increase in the age of the plants, and they were not significantly different from IS 809 at 50 and 70 days of age.

LITERATURE CITED

1. Ayyanager, B. N. R., and B. W. X. Ponnaiya. 1941. The occurrence and inheritance of a bloomless sorghum. Current Sci. 10:408-409.

2. Cummins, D. G. 1974. Comparative silage yields of bloom and bloomless sorghums in a humid environment. Sorghum Newsletter 17:79.

3. _____ and J. W. Dobson, Jr. 1972. Digestibility of bloom and bloomless sorghum leaves as determined by a modified In Vitro technique. Agron. J. 64:682-683.

4. Curtis, Byrd C., A. M. Schlehuber, and E. A. Wood, Jr. 1960. Genetics of greenbug (Toxaptera graminum Rond.) resistance in two strains of common wheat. Agron. J. 52:599-602.

5. Gardenhire, James H. 1965. Inheritance of greenbug resistance in oats. Crop Sci. 4:443.

6. _____ and H. L. Chada. 1961. Inheritance of greenbug resistance in barley. Crop Sci. 1:349-352.

7. Hackerott, H. L. and T. L. Harvey. 1971. Greenbug injury to resistant and susceptible sorghum in the field. Crop Sci. 11:641-643.

8. Hanna, W. W., W. G. Monson, and G. W. Burton. 1974. Leaf surface effects on In Vitro digestion and transpiration in isogenic lines of sorghum and pearl millet. Crop Sci. 14:837-838.

9. Harvey, T. L. and H. L. Hackerott. 1969. Plant resistance to a greenbug biotype injurious to sorghum. J. Eco. Entomol. 62:1271-1274.

10. _____ and _____. 1969. Recognition of a greenbug biotype injurious to sorghum. J. Eco. Entomol. 62:776-779.

11. _____ and _____. 1974. Effect of greenbugs on resistant and susceptible sorghum seedlings in the field. J. Eco. Entomol. 67:377-380.

12. Johnson, J. W., D. T. Rosenow, and G. L. Teetes. 1974. Response of greenbug resistant grain sorghum lines and hybrids to a natural infestation of greenbugs. Crop Sci. 14:442-443.

13. Juneja, P. S., R. K. Gholson, R. L. Burton, and K. J. Starks. 1972. The chemical basis for greenbug resistance in small grains. 1. Benzyl alcohol as a possible resistance factor. Ann. Entomol. Soc. Amer. 65:961-964.

14. Lambright, L. E. and A. B. Maunder. 1974. Study of drought tolerance relative to stomatal diffusive resistance. Sorghum Newsletter 17:96.

15. Martin, John H. 1930. The comparative drought resistance of sorghum and corn. Agron. J. 22:993-1003.

16. Maunder, A. B., L. E. Lambright, and T. H. McNeely. 1974. Resistance to the sorghum greenbug as related to growth stages of resistant and susceptible genotypes. Sorghum Newsletter 17:96.

17. Powers, L. 1963. Statistical genetics and plant breeding: the partitioning method of genetic analysis and some aspects of its application to plant breeding. Nat. Acad. Sci. Nat. Res. Counc. Pub. 982:280-318.

18. Saxena, P. N. and Harvey L. Chada. 1971. The greenbug, Schizaphis graminum. 1. Mouth part and feeding habits. Ann. Entomol. Soc. Amer. 64:897-904.

19. Schuster, D. J. and K. J. Starks. 1973. Greenbug: components of host-plant resistance in sorghum. J. Econ. Entomol. 66:1131-1134.

20. Smith, O. D., A. M. Schlehuber, and B. C. Curtis. 1962. Inheritance studies of greenbug (Toxoptera graminum Rond.) resistance in four varieties of winter barley. Crop Sci. 2:489-491.

21. Starks, K. J. and E. A. Wood, Jr. 1974. Greenbugs: damage to growth stages of susceptible and resistant sorghum. J. Econ. Entomol. 67:456-457.

22. Teetes, G. L., C. A. Schaefer, and J. W. Johnson. 1974. Resistance in sorghum to the greenbug: laboratory determination of mechanisms of resistance. J. Econ. Entoml. 67:393-396.

23. _____, _____, _____, and D. T. Rosenow. 1974. Resistance in sorghum to the greenbug: field evaluation. Crop Sci. 14:706-708.

24. Weibel, D. E., K. J. Starks, E. A. Wood, and R. D. Morrison. 1972. Sorghum cultivars and progenies rated for resistance to greenbugs. Crop Sci. 12:334-336.

25. Weibel, D. E., K. J. Starks, and W. Buajarern. 1974. Comparison of SA 7536-1, IS 809 and PI 264453 for resistance to greenbugs. Sorghum Newsletter 17:93.

26. Wood, E. A., Jr. 1971. Designation and reaction of three biotypes of the greenbug cultured on resistant and susceptible species of sorghum. J. Econ. Entomol. 64:183-185.

27. _____. 1961. Biological studies of a new greenbug biotype. J. Econ. Entomol. 54:1171-1173.

28. _____, H. L. Chada, and D. N. Saxena. 1969. Reaction of small grains and grain sorghum to three greenbug biotypes. Okla. Agr. Exp. Sta. Prog. Rep. 618.

VITA

Iraj Amini

Candidate for the Degree of

Master of Science

Thesis: A STUDY OF GREENBUG RESISTANCE IN A PROGENY FROM "BLOOMLESS" SORGHUM

Major Field: Agronomy

Biographical:

Personal Data: Born in Tehran, Iran, June 17, 1944.

Education: Graduated from Adib High School at Tehran in May, 1963. Received the Licentiate degree (June, 1968) and the Above Licentiate degree (June, 1972) from University of Tehran, Karakj, Iran, with a major in Agronomy.

Professional Experience: Corn breeder from 1970 to 1973 at Institute of Plant Breeding, Karadj, Iran.