THE EFFECTS OF CERTAIN SORGHUM CULTURAL PRACTICES ON GREENBUG POPULATIONS IN THE FIELD

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THE EFFECTS OF CERTAIN SORGHUM CULTURAL

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IN THE FIELD

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PREFACE

It has often been said that a Master of Science degree is a learning degree. To this I wholeheartedly agree. As a result of my masters program I have gained a great appreciation of field work and all the complexities involved. I have also gained appreciation for good experimental design, for without it field work becomes useless. Last but not least I have gained much experience in doing cooperative ventures. I would like to acknowledge those who made this learning experience possible.

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INTRODUCTION

Overpopulation threatens the ability of the world to feed itself. In 1977 the world population will reach 4 billion, and by 2000 the population is expected to reach 7 billion (Pimentel, 1976). Losses of field and vegetable crops due to insect attack are estimated at over 1 billion dollars yearly (Metcalf et al. 1962, Stoner, 1970), and this figure does not include the cost of applying insecticides. In an effort to feed a growing population, much must be done to reduce this high crop loss due to pests.

One such pest, the greenbug, Schizaphis graminum (Rondani), is considered the most destructive pest of small grains in the central and southwestern United States (Wood and Henderson, 1965), and it is also considered the most destructive pest of sorghum, Sorghum bicolor (L.) Moench, (Daniels and Chedester, 1972). Sorghum losses by insects in Oklahoma for 1972 were listed at slightly over 1 million dollars. Of this amount 37% was attributed to the greenbug (Anonymous, 1973). In 1973 Oklahoma sorghum growers lost slightly over 5 million dollars to insects. Of this amount 36% was attributed to the greenbug (Anonymous, 1974).

Starting about 1951 successful control of the greenbug was achieved with emulsions of ethyl parathion (Dahms, 1951). The number of chemicals for greenbug control has steadily grown until at present 7 differ-

ent organophosphates are recommended for greenbug control in Oklahoma (Massey et al. 1976). Although chemicals are still the most important means of greenbug control, their use is causing some problems which are of concern.

The first problem is our increasing concern over dwindling fossil fuel supplies. Population pressure on world croplands and fossil fuel has already resulted in straining our supplies of these resources. Pimentel (1976) predicted that if we fed the world population (at present levels) on a U.S. type diet, produced by our modern agricultural system, we would use up the known petroleum reserves in about 13 years. The production, formulation, packaging and application of pesticides require significant quantities of energy. A conservative estimate is that a total of 33,000 Kcal are utilized/application of 1 lb. of pesticide/acre (Pimentel, 1976).

A second problem, which just recently became apparent, is insecticidal resistance by the greenbug. Although not attributed to resistance by the greenbug, first hints of poor chemical control were reported in 1973 (Teetes et al. 1975). It was not until 1974 (Peters et al. 1975) that repeated applications or the use of alternate insecticides to obtain satisfactory control of greenbugs on grain sorghum was necessary in some states.

A third problem results from the unsound insect control presently practiced on the High Plains. Lopez and Teetes (1976) found that eliminating the aphids in grain sorghum upon which predators depend for multiplication would influence predator abundance in cotton. They feel that, for the most part, aphid control is of a preventive nature and disregards pest densities. They postulate that such scientifically-

unsound insect control will surely lead to increasing problems with secondary pest outbreaks in grain sorghum as well as in cotton. In view of these problems, more knowledge of the influence of host plant resistance and cultural practices on greenbug population dynamics becomes essential. For this reason experiments were conducted during the summers of 1976 and 1977 measuring the influence of sorghum planting date, canopy, and plant resistance on greenbug populations in the field.

CHAPTER II

REVIEW OF LITERATURE

The greenbug was first described by Rondani in Italy in 1852. The first specimens to be found in the United States were probably collected from oats in Virginia ca. 1882 (Webster and Phillips, 1912).

Until recently, the greenbug was primarily recognized as a pest of small grains, although a localized outbreak was reported on sorghum in Kansas in 1912 (Anonymous, 1968). In fact, there were very few reports of it occurring on sorghum.

Prior to the development of the sorghum biotype only two biotypes were recognized. These two biotypes were designated as biotype A and B. Biotype A could be separated from B on the basis of reaction of resistant wheat lines as described by Wood (1961) and Starks and Burton (1977). In 1968 the sorghum greenbug was recognized as biotype C and could be separated from biotypes A and B on the basis of reaction to host plants as described by Harvey and Hackerott (1969). Finally, with the development of the organophosphate resistant greenbug, a fourth biotype D, is recognized (Teetes et al., 1975). Biotype D has the same host plant reaction as biotype C (Teetes et al. 1975). At present, it is believed that only the C and D biotypes may be found in the field in Oklahoma.

Although the greenbug is capable of transmitting maize dwarf mosaic virus (MDMV) and may predispose sorghum to charcoal rot (Daniels and Toler, 1971; Frederiksen and Daniels, 1970; and Teetes et al. 1973),

most attention is attracted by the greenbug's feeding habits. As the greenbug feeds on a leaf it injects a toxic salivary fluid which is capable of killing the leaf (Wadley, 1931) and eventually the entire plant.

Since the greenbug destroys the older leaves first (Smith et al. 1969), much work has been done on the effect of greenbug defoliation on grain production. Li and Liu (1935) working with kaoliang showed that mechanical defoliation at the time when the plant is in the dough stage results in insignificant reductions both in yield and in kernel weight. They also showed that defoliation done prior to this stage results in reduction both in yield and in kernel weight, the reduction being directly proportional to the earliness of defoliation. Stickler and Pauli (1961) mechanically removed leaves of grain sorghum during the late boot and anthesis stage and found that the relationship between grain yield and leaf area was curvilinear since the quadratic component was significant (5%).

Smith et al. (1969) made the first attempt at mechanically simulating greenbug damage. They removed all leaves except the upper three throughout the vegetative stage. In doing this the authors were able to achieve a 30% yield loss.

Harvey and Hackerott (1970) related stage of plant growth, greenbug densities, and plant damage to yield loss of grain sorghum. They showed that at the milk stage of growth, 6,000 greenbugs/plant significantly reduced yields when left untreated. They reported that when this population was treated, a leaf kill of 4.6/plant occurred, compared with 8.6 where no controls were applied. These authors reported also a yield loss which resulted from a population of 1,700 greenbugs/plant at pre-

boot when left untreated. At the soft-dough stage, 3,000 greenbugs/plant did not kill significantly more leaves, or reduce seed weights or yield when treated or untreated.

Teetes and Johnson (1973) determined the economic threshold for greenbug populations. These authors reported that apparently a mean of ca. 1300-1500 greenbugs/plant at about the bloom stage of growth and mean leaf death in excess of 3/plant were required to cause economic loss.

Although pesticides are most often considered to be the most important control measure, bioenvironmental controls are as important as pecticides when a comparison is based on managed acres (Pimentel, 1976). Bioenvironmental control is described as any method utilized to reduce pest populations "by manipulation of the pest's environment and ecology or by altering the pest's physiology, genetics, and behavior or by a combination of these" (PSAC 1965).

Insect pests are often controlled by altering planting dates. Such has been the case with preventing damage by the southwestern corn borer, Zeadiatrea grandiosella (Dyar), (Henderson and Douglas, 1967), and the European corn borer, Ostrinia nubilalis (Hubn.), (Chiang and Hodson, 1963). Wiseman and McMillian (1969) found a relationship between planting date and damage to grain sorghum by the sorghum midge, Contarinia sorghicola (Coquillett).

The above mentioned papers were on experiments demonstrating plants avoiding damage by escaping peak insect populations. Abernathy and Thurston (1969) showed that certain varieties of tobacco plants, Nicotiana tabacum L. and N. bethamiana (Domin.), avoided aphid damage not by escaping them, but by increasing toxicity to the aphid with in-

creasing plant age. Starks and Wood (1974) while working with sorghum showed that greenbug resistance can be present in various stages of plant growth.

Insect resistant cultivars are very useful in reducing insect damage. Schalk and Ratcliffe (1976) claimed if all the acreage planted to resistant cultivars was eliminated and replaced with susceptible cultivars, a 37% (over 63 million lb.) increase in the use of insecticide would be required to maintain present level of control. They also reported that a .5 ton yield increase in sorghum/acre is possible with the use of greenbug resistant cultivars as compared to using susceptible cultivars (Schalk and Ratcliffe, 1976).

Another bioenvironmental factor that can be altered is canopy cover. Goldsworthy (1970) expressed sorghum canopy in terms of a leaf-area index. Changes in this reflect changes in the number and size of the individual leaves in the crop. Planting rate is also a factor which can affect sorghum canopy.

Pimentel (1961) working with Brassica oleracea (L.) found an inverse relationship between plant density and the total number of animal taxa present at various plantings. An important exception to this trend was the aphid, Myzus persicae (Sulz.), which was found more abundant in dense plantings.

Davis (1966) working with Radar-2 oats, Avena sativa (L.), also did work relating plant densities to the size and kind of arthropod community supported. In this experiment oats were seeded in 3-, 6-, and 12-in. row widths at 1, 2, and 4 bu./acre. The largest number of phytophagous arthropods/plant was recovered from the plantings having 3-in. row spacing, planted with 4 bu. of seed/acre. Among the total arthropods

counted were the following grain aphids: corn leaf aphid, Rhopalosiphum maidis (Fetch); oat-bird cherry aphid, R. padi (L.); greenbug and English grain aphid, Macrosiphum granarium (Kirby).

These results seem to hold true for the greenbug. Daniels (1957) while working with wheat found that grazing or clipping the foliage limits the food supply and habitat of the greenbug, thus keeping the population down and preventing a buildup while the wheat is short. Any practice that would increase or improve greenbug habitat should increase greenbug numbers. Smith and Rankin (1947) and Daniels (1957) found that the addition of nitrogen created luscious plant growth in wheat and therefore, individual plants harbored more greenbugs.

Barbulescu (1973) while working with sorghum monitored the role of cultural measures in the control of the greenbug. This author reported that infestation was heavier and damage greater on sorghum sown early. In experiments on row spacing and plant density, plots in which each row was 1 m from the next and the density was only 130,000 plants/ha had a fairly light infestation. In comparing yield losses none of these factors were significant in protecting sorghum from the greenbug.

Although no research has been done on the effects on sorghum leaf area or leaf number on greenbug population dynamics, it is important to know of factors that determine leaf area and leaf number as well as how to measure them. In sorghum, leaves continue to be initiated in the meristem until a floral bud is initiated (Quinby and Liang, 1969). Sieglinger (1936) observed that the presence of an additional leaf delayed heading by about 3 days.

Peck and Weibel (1971) working with early, medium, and late maturing sorghum hybrids achieved the following results. The late ma-

turing hybrid produced a greater number of leaves than the early maturing hybrid. Likewise a greater number of leaves developed on each genotype when seeded early than when seeded late. The late maturing hybrid produced a greater leaf area than the earlier maturing hybrids. Also, greater leaf area was produced by each genotype when seeded early than when seeded late.

Liang et al. (1973) conducted experiments to evaluate the amount of heterosis for leaf-blade area in grain sorghum. The authors state that total leaf-blade area of hybrids correlated positively and significantly with leaf blade areas 5 through 12. They further state that leaf number 7 (flag leaf as number 1) of hybrids could be used as an indicator of total leaf-blade area.

CHAPTER III

MATERIALS AND METHODS

This study was conducted at the Agronomy Research Farm, Perkins, Oklahoma. Dimensions of the test were 36.5 by 18m. There were 4 replications with a total of 216 rows. One and one-half meter alleys were cut between the 4 replications leaving 6.1 m of row for collecting data. Therefore, each plot was 6.1 m long by 6 rows wide. With 3 planting dates, 2 row spacings, 4 replications, and 6 sorghum hybrids, the test area consisted of 144 plots. Each subplot was further subdivided to give two 3-row subplots. The experimental design was a split plot design with main plots arranged as randomized complete blocks. The main plots were hybrids and the subplots were insecticide treated versus untreated.

To determine the effects of planting date on greenbug populations three different planting dates were chosen. During the growing season of 1976 these planting dates were April 27, May 19, and June 4. During the 1977 growing season these planting dates were April 27, May 15, and June 9.

To determine the effects of canopy, the plant population rate was varied. Two different row spacings were used; 91.4 cm and 76.2 cm. Those plants in the 91.4 cm rows were thinned to 12.7 cm centers, while those in the 76.2 cm rows were thinned to 7.6 cm centers. This was done to create a large difference in total plant population between the two

spacings. Total plant population for the 91.4 cm rows was ca. 86,000 plants/ha. Total plant population for the 76.2 cm rows was ca. 172,000 plants/ha. To vary the number of leaves/plant, three different maturing hybrids were chosen. The maturing categories were early, medium, and late.

To determine the effects of resistant plants on greenbug populations, near isogenic lines for each of the maturity categories were obtained from the DeKalb AgResearch, Inc. The susceptible lines were early C-42a, medium E-59, and late F-67. The resistant lines were early C-42a^{+}, medium E-59^{+}, and late F-67^{+}.

An insecticide was used to obtain greenbug free check plots. A block of three of the six rows in a plot were treated with insecticide, the three row subplot being randomly assigned. For this block 15% granular disulfoton was applied at the rate of ca. 1.13 k ai/ha. Application was delayed until a substantial greenbug population had developed to avoid undue selective pressure. Multiple treatments were avoided by this method. The insecticide applicator consisted simply of a small glass jar with a perforated lid with which granules were shaken into the whorls of the sorghum plants.

Measurements were made by sampling 10 consecutive plants from the center of each subplot. Plants to be sampled were chosen by use of a random numbers table. The following measurements were taken: greenbugs/plant, mummies/plant, predators/plant, and leaf area. During the summer of 1977 only two persons recorded counts on the untreated plants. The response by each counter was noted so that the variance between these individuals' counts could be determined. During the summer of 1976 no attempt was made to measure this source of variation.

Weekly population counts were made beginning one week after insecticide application. During the summer of 1976 only adult coccinellids were sampled. This was increased in 1977 to include other major greenbug predators. Additional predators were coccinellids (adult and immature), green and brown lacewings, and syrphid fly larvae.

Leaf number 7 (flag leaf as number 1) was used as the best indicator of leaf blade area and its area was obtained by the use of an electronic leaf area meter[1]. This measurement was taken one week after full bloom by sampling ten plants from the center row of each subplot. These plants were chosen in the same manner as plants used in population counts. During the summer of 1976 only treated plants were sampled, but due to extremely low pest populations in 1977 the blade area measurements were abandoned. Grain yield was also determined for the 1976 and 1977 studies. Grain was obtained by harvesting 3 m of the middle row from each subplot. The unthreshed grain was weighed to give plot head weight. Then the grain was threshed to give plot test weight.

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[1]LAMDA Instruments, P.O. Box 4425, Lincoln, Nebraska.

CHAPTER IV

RESULTS AND DISCUSSION

As stated in the Materials and Methods section the field design was a split plot, with subplots being insecticide treated versus untreated. Since treated plants were virtually void of greenbugs it was decided to neglect these plants in the analysis. Therefore, data collected for insect counts and leaf area measurements were statistically analyzed as a randomized complete block design. Because planting dates and row spacing were treated as individual experiments these two factors could not be included in the statistical analysis. During the application of the insecticide on the first planting, with 91.4 cm row spacing, three hybrids were double treated. As a result of the missing data this planting date and row spacing combination was left out of population discussions. It should further be noted that each counting date and response variable were analyzed independent of each other. All treatment means were compared using the LSD test (5% level). The week of July 19-23 was chosen for detailed examination because it was the peak week for greenbug numbers.

Table I gives the results obtained from insect counts made on July 19, 1976 for planting date 1 and 76.2 cm row spacing. The overall mean number of greenbugs/plant was 19.4 while the overall mean number of mummies and lady beetles was less than 1/plant. Analysis of variance showed that there was a significant difference in the mean number of

TABLE I

MEAN NUMBER OF INSECTS PER SORGHUM PLANT.
PLANTING DATE 1[1], ROW SPACING 76.2 cm,
PERKINS, OK, JULY 19, 1976

Maturity	Resistance[2]	n	Greenbugs/ plant[3]	Lady beetles/ plant[3]	Mummies/ plant[3]
Early	R	4	7.9 a	0.58 ab	0.00 a
Early	S	4	79.3 b	1.30 c	0.25 a
Medium	R	4	4.8 a	0.45 ab	0.00 a
Medium	S	4	14.8 a	0.55 ab	0.05 a
Late	R	4	1.5 a	0.20 a	0.00 a
Late	S	4	8.1 a	0.73 b	0.03 a
	R	12	4.8 a	0.41 a	0.00 a
	S	12	34.1 b	0.86 b	0.03 a
Early		6	43.6 a	0.94 a	0.01 a
Medium		6	9.8 b	0.46 b	0.03 a
Late		6	4.8 b	0.53 b	0.01 a
Overall Means		24	19.4	0.63	0.02

[1]Planting was made April 27, 1976.

[2]R = resistant plant; S = susceptible plant.

[3]Means not followed by the same letter are significantly different at the 5% level of significance (LSD).

greenbugs/plant between the two resistance levels. More greenbugs were found on the susceptible plants. There was also a significant difference between mean greenbugs/plant at the three levels of maturity. Significantly more greenbugs were found on the early maturing hybrids, but there was no difference between the medium and late categories. Analysis of the greenbug data also resulted in a significent interaction between plant maturity and resistance. More greenbugs were found on the early hybrids with greenbug numbers decreasing with an increase in maturing time of the hybrid, but the magnitude depended on resistance. On the average there were more greenbugs on the susceptible plants as compared to the resistant plants. The mean number of greenbugs/plant on the early susceptible plants was significantly different from the other treatment comparisons. There were no other differences observed.

The response of coccinellids to the different treatments is given in Table I. There were significantly more lady beetles on the susceptible plants as compared to the resistant ones. This can probably be attributed to the larger number of greenbugs on the susceptible plants. There were also significantly more lady beetles on the early maturing hybrids than the medium hybrids, but there was no difference in counts between the medium and late hybrids. This too is probably attributed to differences in greenbug numbers. Comparison of means for the different treatment combinations are also given in Table I. Significantly more lady beetles were found on the early susceptible plants as compared to the other combinations. A significant interaction did not occur.

Parasite responses to the different treatments are also given in Table I. Here no significant differences were found. This is probably of no consequence as mummy counts were extremely low reflecting very

little parasite activity.

Results obtained from counts made on July 21, 1976, planting date 2, and 76.2 cm row spacing are given in Table II. The overall mean number of greenbugs/plant was 203.0. The overall mean number of lady beetles was 0.83, while the overall mean number of mummies was 0.13/plant. Analysis of variance showed no significant difference in the mean number of greenbugs/plant between the two resistance levels. However, significant differences were found between the three maturity levels. Significantly more greenbugs were found on the early maturing hybrids than on the medium and late maturing plants. Yet no differences were observed between the medium and late maturing plants. The analysis of the greenbug data also showed a significant interaction. Proceeding from one level of resistance to the other disregarding maturity, significant differences in greenbug numbers were encountered. The late resistant plants had significantly fewer greenbugs than the late susceptible plants as well as both early hybrids. Observing means from the three levels of maturity, disregarding resistance, significant differences occurred. The early hybrids had significantly more greenbugs than the medium and late hybrids.

Coccinellids and parasite responses are also given in Table II. Again, no significant differences were found.

Table III gives the results obtained from counts made on July 21, 1976 for planting date 2 and 91.4 cm row spacing. The overall mean number of greenbugs/plant was 211.5. The overall mean number of lady beetles and mummies was 1.13, and 0.12, respectively. A significant difference in the mean number of greenbugs/plant between the two resistance levels was detected by the analysis. Significantly more greenbugs

TABLE II

MEAN NUMBER OF INSECTS PER SORGHUM PLANT.
PLANTING DATE 2[1], ROW SPACING 76.2 cm,
PERKINS, OK, JULY 21, 1976

Maturity	Resistance[2]	n	Greenbugs/ plant[3]	Lady beetles/ plant[3]	Mummies/ plant[3]
Early	R	4	405.3 c	1.13 a	0.30 a
Early	S	4	336.2 c	0.83 a	0.18 a
Medium	R	4	125.3 ab	0.78 a	0.10 a
Medium	S	4	129.5 ab	0.68 a	0.15 a
Late	R	4	41.0 a	0.58 a	0.05 a
Late	S	4	180.9 b	1.00 a	0.03 a
	R	12	190.6 a	0.83 a	0.15 a
	S	12	215.5 a	0.83 a	0.12 a
Early		8	370.7 a	0.98 a	0.24 a
Medium		8	127.4 b	0.73 a	0.13 a
Late		8	111.0 b	0.79 a	0.04 a
Overall Means		24	203.0	0.83	0.13

[1]Planting was made May 19, 1976.

[2]R = resistant plant; S = susceptible plant.

[3]Means not followed by the same letter are significantly different at the 5% level of significance (LSD).

TABLE III

MEAN NUMBER OF INSECTS PER SORGHUM PLANT.
PLANTING DATE 2[1], ROW SPACING 91.4 cm,
PERKINS, OK, JULY 21, 1976

Maturity	Resistance[2]	n	Greenbugs/ plant[3]	Lady beetles/ plant[3]	Mummies/ plant[3]
Early	R	4	315.1 bc	1.35 c	0.13 a
Early	S	4	474.0 c	0.83 ab	0.20 a
Medium	R	4	83.8 a	1.25 bc	0.15 a
Medium	S	4	192.9 ab	1.53 c	0.05 a
Late	R	4	59.8 a	0.55 a	0.08 a
Late	S	4	143.8 a	1.28 bc	0.10 a
	R	12	152.9 a	1.05 a	0.12 a
	S	12	270.2 b	1.21 a	0.12 a
Early		8	394.5 a	1.09 a	0.16 a
Medium		8	138.3 b	1.39 a	0.10 a
Late		8	101.8 b	0.91 b	0.90 a
Overall Means		24	211.5	1.13	0.12

[1]Planting was made May 19, 1976.

[2]R = resistant plant; S = susceptible plant.

[3]Means not followed by the same letter are significantly different at the 5% level of probability (LSD).

were found on the susceptible plants. Significant differences were also found in the mean number of greenbugs among the three maturity levels. There were significantly more greenbugs on the early maturing plants than on the medium and late maturing hybrids. Yet again no differences were noted between the medium and late maturing plants. The results of the different treatment combinations are also given in Table III. The early resistant and early susceptible plants had significantly more greenbugs than the other hybrids except the medium susceptible hybrid. In the case of the two early hybrids only the early susceptible had significantly more greenbugs than the medium susceptible hybrid.

Results obtained from the coccinellid counts are given in Table III. No significant differences were found between the two resistance levels. A significant difference did occur between the maturity levels; there being significantly fewer coccinellids on the late maturing hybrids when compared to the early and medium hybrids. No significant difference occurred between the latter two hybrids. A significant interaction between the different treatments was also found. The early resistant hybrid had significantly more lady bettles on the average than the early susceptible hybrid. The late resistant hybrid had significantly fewer lady beetles than the late susceptible hybrid. Yet no significant differences occurred between the late resistant and the early susceptible hybrids, and between the late susceptible and early resistant hybrids. Again, no significant differences were encountered among the parasite responses.

Results obtained from counts made on July 23, 1976, planting date 3, and 76.2 cm row spacing are given in Table IV. The overall mean number of greenbugs/plant was 107.7. Overall mean number of lady beetles

TABLE IV

MEAN NUMBER OF INSECTS PER SORGHUM PLANT.
PLANTING DATE 3[1], ROW SPACING 76.2 cm,
PERKINS, OK, JULY 23, 1976

Maturity	Resistance[2]	n	Greenbugs/ plant[3]	Lady beetles/ plant[3]	Mummies/ plant[3]
Early	R	4	129.8 ab	0.35 ab	0.67 a
Early	S	4	275.4 a	0.70 a	8.70 a
Medium	R	4	77.8 b	0.15 b	0.25 a
Medium	S	4	68.1 b	0.13 b	0.95 a
Late	R	4	33.2 b	0.23 b	0.25 a
Late	S	4	62.2 b	0.18 b	0.65 a
	R	12	80.3 a	0.24 a	0.39 a
	S	12	135.2 a	0.33 a	3.43 a
Early		8	202.6 a	0.53 a	4.69 a
Medium		8	73.0 b	0.14 b	0.60 a
Late		8	47.7 b	0.20 b	0.45 a
Overall Means		24	107.7	0.29	1.9

[1]Planting was made June 4, 1976.

[2]R = resistant plant; S = susceptible plant.

[3]Means not followed by the same letter are significantly different at the 5% level of probability (LSD).

and mummies was 0.29 and 1.9 respectively. Analysis of variance produced no significant difference in greenbug numbers between the two levels of resistance, but a significant difference was noted between the three levels of maturity. Again, the early maturing hybrids proved to have significantly more greenbugs/plant than the medium and late maturing hybrids. No difference was shown to occur between the latter two hybrids. Also no significant interaction was detected in the analysis. The results of the different treatment combinations are given in Table IV. The early resistant and early susceptible plants were not significantly different from each other, although only the mean number of greenbugs on the early susceptible plants were significantly different from the medium and late treatment maturity combinations.

Table IV shows the results obtained from the coccinellid counts. No significant difference in the mean lady beetle count/plant occurred between resistant and susceptible plants. There were however significantly more lady beetles on the early maturing hybrids than the medium and late hybrids, although no significant difference came about between medium and late hybrids. Comparisons of means for the different treatment combintaions are also given in Table IV. Mean lady beetle counts for the early resistant and early susceptible plants were not significantly different, yet the mean number of lady beetles on the early susceptible plants were significantly different from the medium and late treatment combinations.

Parasite responses to the different treatments are also given in Table IV. Again, no significant differences were found.

Results obtained from counts made on July 23, 1976, planting date

3, and 91.4 cm row spacing are given in Table V. The overall mean number of greenbugs/plant was 318.9, while the overall mean number of lady beetles and mummies was 0.71 and 5.8 respectively. Analysis of variance produced a significant difference in the mean number of greenbugs/plant between the two resistance levels. The highest counts were found on the susceptible plants. There was also a significant difference in the number of greenbugs at the three levels of maturity. Significantly more greenbugs were found on the early maturing hybrids as compared to the medium and late hybrids. Again, there were no significant differences between the medium and late hybrids. Analysis of the greenbug counts resulted in significant interaction between plant maturity and plant resistance. Again, more greenbugs were found on the early hybrids with greenbug numbers decreasing with an increase in maturing time of hybrid. The mean number of greenbugs/plant on the early susceptible plant was significantly different from the other treatment comparisons. The early resistant plant was significantly different from all treatment comparisons except the medium susceptible hybrid.

Coccinellid and parasite responses are also given in Table V. No significant differences were found. It should be pointed out that the highest parasite counts were found on this planting date and row spacing combination. As a result of the low parasite and lady beetle counts further discussions of these insects does not seem warranted.

Due to the inherent weakness in the design, statistical comparisons could not be made between the row spacings and planting dates, but it is possible to make general comparisons. Figure 1 shows a comparison of greenbug counts for the week of July 19-23. There is a large difference in the greenbug counts for the first planting as compared to the second

TABLE V

MEAN NUMBER OF INSECTS PER SORGHUM PLANT.
PLANTING DATE 3[1], ROW SPACING 91.4 cm,
PERKINS, OK, JULY 23, 1976

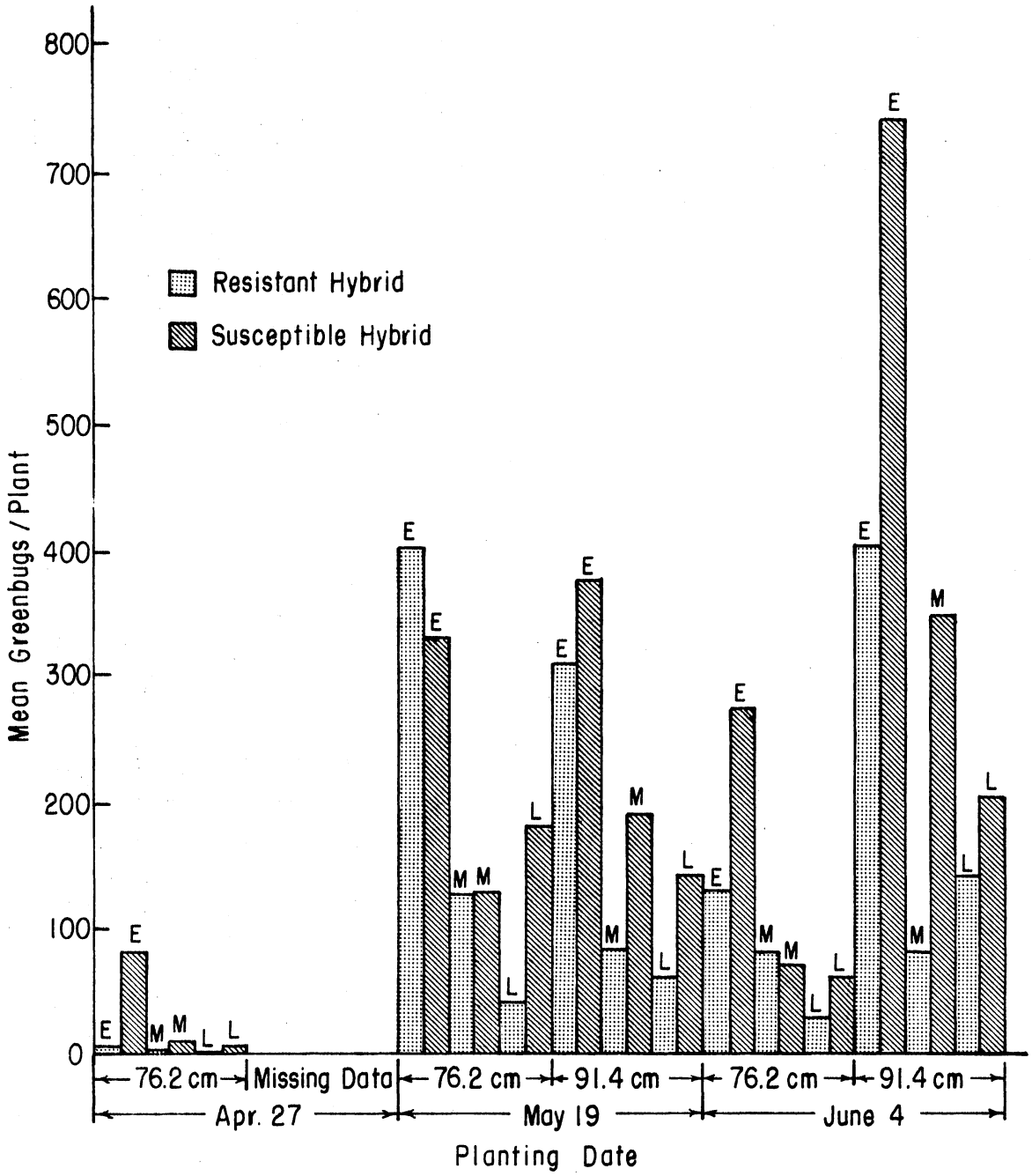
Maturity	Resistance[2]	n	Greenbugs/ plant[3]	Lady beetles/ plant[3]	Mummies/ plant[3]
Early	R	4	407.2 c	0.93 a	3.0 a
Early	S	4	742.0 d	1.05 a	3.1 a
Medium	R	4	80.1 a	0.43 a	2.1 a
Medium	S	4	346.0 bc	0.93 a	7.4 a
Late	R	4	137.5 a	0.55 a	2.3 a
Late	S	4	200.5 ab	0.40 a	16.9 a
	R	12	208.3 a	0.63 a	2.5 a
	S	12	429.5 b	0.79 a	9.1 a
Early		8	547.6 a	0.99 a	3.1 a
Medium		8	213.0 b	0.68 a	9.6 a
Late		8	169.0 b	0.48 a	4.8 a
Overall Means		24	318.9	0.71	5.8

[1]Planting was made June 4, 1976.

[2]R = resistant plant; S = susceptible plant.

[3]Means not followed by the same letter are significantly different at the 5% level of significance (LSD).

Figure 1. Comparison of Greenbug Counts for the Week of July 19-23, 1976, Perkins, OK


800
700
600
500
400
300
200
100
0
Mean Greenbugs / Plant
Resistant Hybrid
Susceptible Hybrid
E
M
L
76.2 cm
Missing Data
76.2 cm
91.4 cm
76.2 cm
91.4 cm
Apr. 27
May 19
June 4
Planting Date

and third plantings, but it is more difficult to distinguish between the second and third plantings. This fact also becomes apparent after examining the overall means from Tables I-V. Comparisons of overall means also show that there were more greenbugs on the 91.4 cm spacing as compared to the 76.2 cm spacing. The early hybrids always had significantly more greenbugs than the medium and late hybrids, but no significant differences were found between the medium and late hybrids. Although plant resistance played an important role in the maturity by resistance interaction, it was not always important when averaged over maturity. From Tables II and IV no significant differences were found between resistant and susceptible plants.

Up until now all the analysis has been centered on the week of July 19-23. It soon became apparent that certain patterns developed, but do these patterns persist over a counting period of 11 weeks?

The comparison of row spacing and plant resistance on greenbug numbers over the entire counting period is given in Table VI. Although again no statistical conclusions can be drawn, general observations can be made. The pattern that develops is as follows: differences in resistance get larger with lateness in planting and the 76.2 cm row spacing always has fewer greenbugs than the 91.4 cm rows.

Table VII presents a comparison of row spacing and plant maturity on greenbug numbers over the entire counting period. As with other comparisons between row spacing and date of planting no statistical conclusions can be drawn, but general comparisons will be made. Again, the medium and late hybrids are comparable in numbers, while the early hybrids still maintain the highest counts. Similar to the data presented on Table VI and Figure 1, the largest differences between treatments

TABLE VI

COMPARISON OF ROW SPACING AND PLANT RESISTANCE ON GREENBUG NUMBERS. PERKINS, OK, 1976.

Planting date	Row spacing	Greenbug resistance[1]	Mean number of greenbugs/plant Counting week: 1	2	3	4	5	6	7	8	9	10	11	Overall mean
April 27	76.2 cm	R	3.8	12.4	5.4	4.3	4.2	4.8	0.2	0.0	0.8			4.0
		S	3.0	11.7	5.6	7.6	15.4	34.0	3.1	0.2	0.3			9.0
May 19	76.2 cm	R		3.8	21.0	36.7	38.6	190.6	20.6	2.0	2.0	0.0	0.1	31.6
		S		5.4	23.5	46.7	61.1	215.5	78.1	1.7	2.1	1.0	0.0	43.6
May 19	91.4 cm	R		4.3	23.2	34.5	59.0	152.9	72.0	5.1	5.2	0.1	0.2	35.6
		S		4.5	28.48	42.0	65.4	270.2	106.5	3.4	2.3	0.2	1.9	52.5
June 4	76.2 cm	R				3.6	20.0	80.3	48.5	22.1	15.7	0.9	0.4	24.0
		S				6.0	41.0	135.2	128.3	41.6	35.0	1.0	0.0	48.5
June 4	91.4 cm	R				15.4	60.0	208.3	88.1	57.2	56.0	12.1	1.4	62.3
		S				33.0	83.1	429.5	221.4	84.0	58.0	3.0	0.2	114.0

[1]R = resistant plant; S = susceptible plant.

TABLE VII

COMPARISON OF ROW SPACING AND PLANT MATURITY ON GREENBUG NUMBERS. PERKINS, OK, 1976.

Planting date	Row spacing	Plant maturity	Mean number of greenbugs/plant — Counting week: 1	2	3	4	5	6	7	8	9	10	11	Overall mean
April 27	76.2 cm	Early	3.8	18.4	7.1	9.1	15.1	43.6	4.3	0.1	0.4			11.3
		Medium	2.2	9.1	6.1	3.9	8.3	9.8	0.1	0.2	0.2			4.4
		Late	4.1	8.3	3.2	4.7	6.0	4.8	0.4	0.0	0.0			3.5
May 19	76.2 cm	Early		5.9	36.0	74.7	89.7	370.7	117.5	2.5	2.8	1.50	0.13	70.1
		Medium		4.7	17.1	31.0	31.3	127.4	9.4	2.9	1.5	0.04	0.01	22.5
		Late		3.3	13.7	19.3	28.5	111.0	21.2	0.1	1.9	0.06	0.11	19.9
May 19	91.4 cm	Early		4.9	36.4	56.7	96.1	394.5	193.4	10.2	5.9	0.00	0.93	79.9
		Medium		4.9	22.1	29.2	35.5	138.3	31.8	1.5	3.5	0.28	0.23	26.7
		Late		3.3	19.1	28.9	52.8	101.8	41.8	1.1	1.8	0.04	2.00	25.3
June 4	76.2 cm	Early				11.1	39.7	202.6	217.8	74.7	70.2	0.55	0.34	77.0
		Medium				1.6	39.4	73.0	32.5	12.4	2.8	2.15	0.15	20.5
		Late				1.7	12.3	47.8	14.9	8.4	1.3	0.01	0.11	10.8
June 4	91.4 cm	Early				34.3	90.1	574.8	284.5	131.0	145.8	10.28	0.55	158.9
		Medium				19.5	83.6	213.0	120.3	41.0	9.6	11.49	0.11	62.3
		Late				18.8	38.0	169.0	60.0	40.0	15.5	0.85	1.68	43.0

occur in the third planting with 91.4 cm row spacing.

Since leaf area measurements were taken only from the treated plots there is no way to estimate the effect of greenbug damage on leaf area, but it is possible to get some idea as to which plants potentially had the greatest leaf area and relate this to greenbugs numbers. Analysis of variance was performed for each row spacing and planting date combination and the results are as follows (Table VIII): 76.2 cm row spacings overall means range from 335.5 cm^2 - 383.2 cm^2. The surface area decreased with lateness of planting. Comparing means of the different planting dates with 91.4 cm row spacing, the overall means range from 349.5 cm^2 - 413.0 cm^2, but no trends existed here. Although one might expect the leaf area of the 76.2 cm row spacing to be smaller than the plants in the 91.4 cm row spacing due to plant competition, this was not necessarily true. In two of the three planting dates the 91.4 cm row spacing did have a larger overall mean leaf area, but those plants from the second planting had just the opposite results. A possible factor that contributed more to canopy, other than individual leaf area would be planting rate. The reason for this being that those plants in the 76.2 cm row spacing were thinned to 7.62 cm centers while those in the 91.4 cm rows were thinned to 12.7 cm centers.

No significant differences in leaf area were found to exist between the two resistance levels (Table VIII). This was expected as the two levels of resistance represent near isogenic lines. From every analysis performed the early hybrids had significantly smaller leaf area than the medium and late hybrids, but no significant difference occurred between the medium and late hybrids. This is in agreement with the findings of Peck and Weibel (1971). The medium maturing hybrid was really a late

TABLE VIII

LEAF AREA COMPARISON OF SORGHUM HYBRIDS AT DIFFERENT PLANTING DATES AND ROW SPACINGS. PERKINS, OK, 1976.

Planting date[1]	Row spacing	Maturity	Resistance[2]	n	Mean leaf area (cm^2)[3]	Overall mean
1	76.2 cm		R	120	384.8 a	
			S	120	381.6 a	
		Early		80	327.4 a	
		Medium		80	396.5 b	
		Late		80	425.7 b	
		Early	R	40	333.2 a	
		Early	S	40	321.6 a	
		Medium	R	40	383.5 b	
		Medium	S	40	409.6 bc	
		Late	R	40	437.9 c	
		Late	S	40	413.6 bc	
	Overall Means			240		383.2
1	91.4 cm		R	120	421.8 a	
			S	120	404.1 a	
		Early		80	358.0 a	
		Medium		80	442.4 b	
		Late		80	438.7 b	
		Early	R	40	358.3 a	
		Early	S	40	357.6 a	
		Medium	R	40	452.2 b	
		Medium	S	40	432.6 b	
		Late	R	40	454.9 b	
		Late	S	40	422.2 b	
	Overall Means			240		413.0
2	76.2 cm		R	120	352.0 a	
			S	120	354.2 a	
		Early		80	266.3 a	
		Medium		80	404.0 b	
		Late		80	389.1 b	

TABLE VIII (Continued)

Planting date[1]	Row spacing	Maturity	Resistance[2]	n	Mean leaf area (cm^2)[3]	Overall mean
		Early	R	40	267.1 a	
		Early	S	40	265.5 a	
		Medium	R	40	393.3 b	
		Medium	S	40	411.1 b	
		Late	R	40	392.6 b	
		Late	S	40	385.6 b	
	Overall Means			240		353.1
2	91.4 cm		R	120	342.3 a	
			S	120	356.7 a	
		Early		80	250.9 a	
		Medium		80	395.7 b	
		Late		80	402.0 b	
		Early	R	40	245.6 a	
		Early	S	40	256.2 a	
		Medium	R	40	280.8 b	
		Medium	S	40	410.6 b	
		Late	R	40	400.6 b	
		Late	S	40	403.4 b	
	Overall Means			240		349.5
3	76.2 cm		R	120	335.5 a	
			S	120	329.1 a	
		Early		80	288.6 a	
		Medium		80	354.3 b	
		Late		80	363.4 b	
		Early	R	40	295.2 ab	
		Early	S	40	282.1 a	
		Medium	R	40	351.5 c	
		Medium	S	40	357.1 c	
		Late	R	40	378.7 c	
		Late	S	40	348.1 bc	
	Overall Means			240		355.5
3	91.4 cm		R	120	372.8 a	
			S	120	362.6 a	
		Early		80	279.9 a	
		Medium		80	386.5 b	
		Late		80	436.7 b	

TABLE VIII (Continued)

Planting date[1]	Row spacing	Maturity	Resistance[2]	n	Mean leaf area (cm^2)[3]	Overall mean
		Early	R	40	279.7 a	
		Early	S	40	280.1 a	
		Medium	R	40	387.5 b	
		Medium	S	40	385.4 b	
		Late	R	40	451.2 c	
		Late	S	40	422.2 bc	
	Overall Means			240		367.7

[1]1 = April 27, 1976; 2 = May 19, 1976; 3 = June 4, 1976.

[2]R = resistant plant; S = susceptible plant.

[3]Means not followed by the same letter are significantly different at the 5% level of probability (LSD).

medium and probably explains why no significant difference was detected between the medium and late hybrid. It should be noted that this is similar to what happened with the greenbug data (Tables I-V). The early hybrids have significantly more greenbugs than the medium and late, therefore in terms of canopy more greenbugs are found in the less dense cover.

Yield data for the summer of 1976 are found in Table IX. Again, due to the inherent weekness in the design no statistical comparisons can be made between the planting date and row spacing combination, in fact it was decided that no statistical analysis should be performed. In addition to the experimental design, weather conditions were also a limiting factor in making conclusions. During the approximately five months that the plants were in the field very little percipitation was recorded. In fact from April 27 through August 31 a total of 18.38 cm of percipitation was recorded for the research area by the Oklahoma Agricultural Experiment Station. An additional 5 cm of moisture was applied by irrigation; however, not until the plants had become extremely stressed. The results of the moisture stress were poor head development and poor seed set. Therefore, it would be very difficult to distinguish between greenbug damage and damage due to the lack of moisture. Looking at the data from Table IX it appears that no differences occurred between resistant and susceptible hybrids. The early hybrids from the first and second plantings have a slightly higher yield than the medium and late hybrids, but this is probably because late maturing hybrids have their moisture requirements stretched over a longer period of time. Therefore, it would seem that due to a low greenbug infestation no economic damage occurred.

TABLE IX

YIELD OF SORGHUM HYBRIDS AT DIFFERENT PLANTING DATES AND ROW SPACINGS. PERKINS, OK, 1976

Planting date[1]	Row spacing	Entry	Treatment[2]	Plot head wt. (g)[3]	Test wt. (g)[3]
1	76.2 cm	C-42a+	T	680.4	453.6
			U	635.0	453.6
		C-42a	T	680.4	453.6
			U	635.0	362.9
		E-59+	T	589.7	453.6
			U	499.0	317.5
		E-59	T	499.0	362.9
			U	589.7	408.2
		F-67+	T	90.7	45.4
			U	317.5	181.4
		F-67	T	408.2	272.2
			U	317.5	181.4
		Mean		499.0	331.1
1	91.4 cm	C-42a+	T	997.9	725.8
			U	861.8	453.6
		C-42a	T	1134.0	680.4
			U	997.9	680.4
		E-59+	T	952.5	635.0
			U	907.2	635.0
		E-59	T	680.4	408.2
			U	725.7	453.6
		F-67+	T	385.6	226.8
			U	499.0	362.9
		F-67	T	635.0	453.6
			U	421.8	272.2
		Mean		771.1	499.0
2	76.2 cm	C-42a+	T	861.8	544.3
			U	861.8	499.0
		C-42a	T	861.8	589.7
			U	861.8	544.0
		E-59+	T	589.7	362.9
			U	544.3	408.2
		E-59	T	544.3	317.5
			U	362.9	272.2

TABLE IX (Continued)

Planting date[1]	Row spacing	Entry	Treatment[2]	Plot head wt. (g)[3]	Testwt. (g)[3]
		F-67+	T	362.9	226.8
			U	544.3	362.9
		F-67	T	408.2	226.8
			U	499.0	362.9
		Mean		589.7	408.2
2	91.4 cm	C-42a+	T	997.9	544.3
			U	816.5	499.0
		C-42a	T	1134.0	226.8
			U	952.5	635.0
		E-59+	T	544.3	408.2
			U	589.7	408.2
		E-59	T	589.7	362.9
			U	544.7	362.9
		F-67+	T	771.1	544.3
			U	544.3	408.2
		F-67	T	544.3	408.2
			U	544.3	408.2
		Mean		725.7	453.6
3	76.2 cm	C-42a+	T	997.9	499.0
			U	952.5	544.3
		C-42a	T	997.9	589.7
			U	1043.3	589.7
		E-59+	T	1134.0	680.4
			U	861.8	635.0
		E-59	T	1270.1	771.1
			U	1088.6	635.0
		F-67+	T	1179.3	725.8
			U	997.9	589.7
		F-67	T	1088.6	226.8
			U	1088.6	226.8
		Mean		1043.3	635.0
3	91.4 cm	C-42a+	T	1134.0	725.8
			U	1224.7	680.4
		C-42a	T	952.5	589.7
			U	952.5	544.3
		E-59+	T	1315.4	816.5
			U	1043.3	226.8
		E-59	T	1134.0	635.0
			U	1088.6	680.4
		F-67+	T	1043.3	635.0
			U	1179.3	771.1

TABLE IX (Continued)

Planting date[1]	Row spacing	Entry	Treatment[2]	Plot head wt. (g)	Test wt. (g)[3]
		F-67	T	1134.0	725.8
			U	1179.3	680.4
		Mean		1134.0	680.4

[1]1 = April 27, 1976; 2 = May 19, 1976; 3 = June 4, 1976.

[2]T = insecticide; U = no insecticide

[3]Average over reps.

During the summer of 1977 a substantial greenbug population failed to develop. As a result of the extremely low infestation, counts were not carried out for as long a period of time as in 1976. During the summer of 1977 only once did the overall mean number of predators/plant exceed 1. On July 27, planting date 1, and 91.4 cm row spacing the overall mean number of predators was 1.11/plant. There was no time that the overall mean number of mummies exceeded 1/plant. Because of these low mummy and predator counts, further discussions of these insects does not seem warranted.

Greenbug numbers on sorghum hybrids for planting date 1 and 76.2 cm row spacing are given in Table X. The overall mean number of greenbugs/plant for the three weeks of counting are 9.05, 10.97, and 0.93. There were no significant differences found for those counts made on June 27. On July 4 a significant difference between the two levels of resistance was found. There were more greenbugs on the susceptible plants. No difference occurred between the three maturity levels. Comparing the different treatment combinations on July 4, the late susceptible hybrid was the only susceptible hybrid that was not significantly different from the resistant counterparts. There were no significant differences found on July 11, and no significant interactions were encountered.

The greenbug numbers for planting date 1 and row spacing 91.4 cm are given in Table XI. The overall mean number of greenbugs/plant for June 27, July 4, and July 11 are 89.26, 97.24, and 20.16 respectively. The counts made on June 27 and July 4 produced no significant differences. Significant differences did occur between treatments for counts made on July 11. A significant difference was detected between the two

TABLE X

GREENBUG NUMBERS ON SORGHUM HYBRIDS.
PLANTING DATE 1[1], ROW SPACING
76.2 cm, PERKINS, OK, 1977.

Maturity	Resistance[2]	n	Counting date Greenbugs/plant[3] 6/27	7/04	7/11
Early	R	40	7.55 a	1.80 a	0.15 a
Early	S	40	24.60 a	23.00 bc	3.25 a
Medium	R	40	2.85 a	2.23 a	0.08 a
Medium	S	40	12.03 a	28.80 c	1.38 a
Late	R	40	1.30 a	2.15 a	0.25 a
Late	S	40	5.98 a	7.55 ab	0.45 a
	R	120	3.90 a	2.16 a	0.16 a
	S	120	14.20 a	19.78 b	1.69 a
Early		80	16.08 a	12.40 a	1.70 a
Medium		80	7.44 a	15.66 a	0.73 a
Late		80	3.64 a	4.85 a	0.35 a
Overall means		240	9.05	10.97	0.93

[1]Planting was made April 27, 1977.

[2]R = resistant plant; S = susceptible plant.

[3]Means not followed by the same letter are significantly different at the 5% level of significance (LSD).

TABLE XI

GREENBUG NUMBERS ON SORGHUM HYBRIDS.
PLANTING DATE 1[1], ROW SPACING
91.4 cm, PERKINS, OK, 1977

Maturity	Resistance[2]	n	Counting date Greenbugs/plant[3] 6/27	7/04	7/11
Early	R	40	97.2 a	45.3 a	17.65 a
Early	S	40	379.15 a	459.25 a	53.75 b
Medium	R	40	8.92 a	17.82 a	12.15 a
Medium	S	40	15.28 a	11.60 a	26.50 ab
Late	R	40	18.25 a	17.82 a	1.25 a
Late	S	40	16.75 a	11.60 a	9.65 a
	R	120	41.46 a	25.30 a	10.35 a
	S	120	137.06 a	169.18 a	29.96 b
Early		80	238.18 a	252.26 a	35.70 a
Medium		80	12.10 a	24.73 a	19.33 ab
Late		80	17.50 a	14.71 a	5.45 b
Overall Means		240	89.26	97.24	20.16

[1]Planting was made April 27, 1977.

[2]R = resistant plant; S = susceptible plant.

[3]Means not followed by the same letter are significantly different at the 5% level of significance (LSD).

levels of resistance. Again, more greenbugs were found on the susceptible plants. A significant difference also occurred among the three levels of maturity. The late maturing hybrids had significantly fewer greenbugs than the early hybrids, but not the medium hybrids. When comparing the means for different treatment combinations similar results occurred. The early susceptible plants had significantly more greenbugs than all other hybrids except the medium susceptible plants. Again, no significant interactions were found. It should be noted that the highest counts were found on this particular planting date and row spacing combination.

Planting date 2 and row spacing 76.2 cm average greenbug counts are found on Table XII. Overall mean number of greenbugs for the four weeks of counting are 6.80, 7.48, 6.71, and 0.30. There were no significant resistance or maturity differences for counts made on July 11. There were, however, differences in the various treatment combinations. The medium and late resistant hybrids were the only plants which had significantly fewer greenbugs than the early susceptible hybrid. Significant differences were not found in the counting weeks of July 18 and August 1. However, significant differences did occur during the week of July 25. A significant difference was found between the two levels of resistance, the resistant plants having fewer greenbugs than the susceptible plants. There was also differences in the various treatment combinations. The early susceptible hybrids had significantly more greenbugs than the medium and late resistant hybrids.

Table XIII gives the results obtained from greenbug counts for planting date 2 and 91.4 cm row spacing. The overall means for the four weeks of counting are 14.50, 15.66, 32.27, and 15.03. Counts made on

TABLE XII

GREENBUG NUMBERS ON SORGHUM HYBRIDS. PLANTING DATE 2[1], ROW SPACING 76.2 cm, PERKINS, OK, 1977.

Maturity	Resistance[2]	n	Counting date — Greenbugs/plant[3] 7/11	7/18	7/25	8/01
Early	R	40	5.40 ab	7.25 a	5.73 ab	0.00 a
Early	S	40	20.33 b	17.90 a	15.95 b	0.83 a
Medium	R	40	1.93 a	6.85 a	1.75 a	0.75 a
Medium	S	40	6.28 ab	7.25 a	12.73 ab	0.75 a
Late	R	40	1.93 a	1.28 a	0.98 a	0.04 a
Late	S	40	4.98 ab	4.38 a	3.13 ab	0.40 a
	R	120	3.08 a	5.13 a	2.82 a	0.16 a
	S	120	10.53 a	9.84 a	10.60 b	0.43 a
Early		80	12.86 a	12.58 a	10.84 a	0.41 a
Medium		80	4.10 a	7.05 a	7.24 a	0.08 a
Late		80	3.45 a	2.83 a	2.05 a	0.40 a
Overall Means		240	6.80	7.48	6.71	0.30

[1]Planting was made May 15, 1977.

[2]R = resistant plant; S = susceptible plant.

[3]Means not followed by the same letter are significantly different at the 5% level of significance (LSD).

TABLE XIII

GREENBUG NUMBER ON SORGHUM HYBRIDS.
PLANTING DATE 2[1], ROW SPACING
91.4 cm, PERKINS, OK, 1977.

Maturity	Resistance[2]	n	Counting date Greenbugs/plant[3] 7/11	7/18	7/25	8/01
Early	R	40	24.65 a	26.13 ab	29.95 a	7.40 a
Early	S	40	23.35 a	28.43 b	108.53 b	64.45 b
Medium	R	40	6.80 a	8.25 ab	5.88 a	1.50 a
Medium	S	40	19.75 a	16.88 ab	19.30 a	10.23 a
Late	R	40	2.53 a	4.75 a	10.38 a	1.35 a
Late	S	40	9.95 a	9.55 ab	19.60 a	5.28 a
	R	120	11.33 a	13.04 a	15.40 a	3.47 a
	S	120	17.68 a	18.28 a	49.14 b	26.65 b
Early		80	24.00 b	27.28 b	69.24 b	35.93 b
Medium		80	13.28 ab	12.56 ab	12.59 a	5.86 a
Late		80	6.24 a	7.15 a	14.99 a	3.31 a
Overall Means		240	14.50	15.66	32.27	15.03

[1]Planting was made May 15, 1977.

[2]R = resistant plant; S = susceptible plant.

[3]Means not followed by the same letter are significantly different at the 5% level of significance (LSD).

July 11 show a significant difference among the three maturity levels. The late hybrids had significantly fewer greenbugs than the early hybrids, but not the medium hybrids. The same maturity responses were encountered for the week of July 18. There were also differences between the various treatment combinations. The late resistant hybrid had significantly fewer greenbugs than the early susceptible hybrid. During the week of July 25 significance was detected between the two levels of resistance. Significantly more greenbugs were found on the susceptible hybrids. Differences also occurred among the maturity levels. Significantly more greenbugs were found on the early maturing hybrids, but there was no difference between the medium and late categories. Looking at the treatment combinations significant differences were found. The early susceptible hybrid had on the average significantly more greenbugs than the other hybrids. The results of July 25 were perpetuated to the week of August 1. The difference being slightly lower counts on the latter counting week. No significant interactions occurred.

Greenbug numbers on sorghum hybrids for planting date 3 and 76.2 cm row spacing are given in Table XIV. The overall mean number of greenbugs for each of the four weeks of counting were 11.95, 6.85, 5.61, and 1.98. The counts made on August 1 show a significant difference at the two resistant levels. More greenbugs were found on the susceptible hybrids. There was also a significant difference between greenbug resistant and susceptible plants for counts made on August 8. Also during the week of August 8 the results of the treatment combinations also showed significant differences. The late resistant hybrid was shown to have significantly fewer greenbugs than the early susceptible hybrid. Comparing responses at the next counting week, August 15, the significant

TABLE XIV

GREENBUG NUMBERS ON SORGHUM HYBRIDS. PLANTING DATE 3[1], ROW SPACING 76.2 cm, PERKINS, OK, 1977.

Maturity	Resistance[2]	n	Counting date — Greenbugs/plant[3] 8/01	8/08	8/15	8/22
Early	R	40	6.48 a	5.53 ab	1.83 a	0.90 a
Early	S	40	29.95 a	18.30 b	23.50 b	8.20 b
Medium	R	40	2.48 a	3.90 ab	1.95 a	1.13 a
Medium	S	40	17.33 a	6.40 ab	4.33 a	0.68 a
Late	R	40	0.83 a	0.13 a	0.38 a	0.28 a
Late	S	40	22.65 a	6.83 ab	1.68 a	0.73 a
	R	120	3.26 a	8.18 a	1.38 a	0.78 a
	S	120	20.64 b	10.51 b	9.83 b	3.20 a
Early		80	14.21 a	11.91 a	12.66 a	4.55 a
Medium		80	9.90 a	5.15 a	3.14 b	0.50 b
Late		80	11.74 a	3.48 a	1.03 b	0.90 b
Overall Means		240	11.95	6.85	5.61	1.98

[1]Planting was made June 9, 1977.

[2]R = resistant plant; S = susceptible plant.

[3]Means not followed by the same letter are significantly different at the 5% level of significance (LSD).

differences between resistance levels was still present. Again, the susceptible plants were found to have more greenbugs on the average than the resistant plants. There was also a difference among the maturity levels. Significantly more greenbugs were found on the early maturing hybrids, but there was no difference between the medium and late maturing hybrids. A significant interaction between resistance and maturity was also found during the week of August 15. Fewer greenbugs were found on the resistant hybrids as compared to the susceptible hybrid, but only the early susceptible plants were significantly higher in counts. As a matter of fact it had significantly more greenbugs than all the other treatments combinations. Although not significant the lowest counts were found on the late hybrids. The counts made during the week of August 22 was similar to the previous week. There was no difference between the resistance levels, but a significant difference was found among the levels of maturity. A significant interaction was found, and therefore about the only conclusion that could be made is the fact that the early susceptible hybrid had significantly more greenbugs than the other hybrids.

The results of greenbug counts made for planting date 3 and 91.4 cm row spacing are given in Table XV. The overall mean number of greenbugs for the four weeks of counting are 42.00, 34.91, 53.46, and 23.46. Counts made during the week of August 1 did not produce a significant difference between the two levels of resistance. A significant difference was found among the maturity levels. Again, significantly more greenbugs were found on the early hybrids but no difference existed between the medium and late hybrids. Looking at the various treatment combinations, no significant difference was found between the two early

TABLE XV

GREENBUG NUMBERS ON SORGHUM HYBRIDS. PLANTING DATE 3[1], ROW SPACING 91.4 cm, PERKINS, OK, 1977.

Maturity	Resistance[2]	n	Counting date — Greenbugs/plant[3] 8/01	8/08	8/15	8/22
Early	R	40	57.85 bc	28.63 a	30.98 a	4.93 a
Early	S	40	102.38 c	98.90 b	152.63 b	32.03 ab
Medium	R	40	29.43 ab	29.68 a	30.50 a	41.68 b
Medium	S	40	37.08 ab	26.38 a	60.15 a	37.28 ab
Late	R	40	8.37 a	6.75 a	3.60 a	6.15 a
Late	S	40	16.93 ab	19.13 a	42.93 a	17.50 ab
	R	120	31.87 a	21.68 a	21.69 a	17.58 a
	S	120	52.13 a	48.13 b	85.23 b	28.93 a
Early		80	80.11 a	63.76 a	91.80 a	18.48 ab
Medium		80	33.25 b	28.03 b	45.33 ab	39.48 a
Late		80	12.63 b	12.94 b	23.26 b	11.83 b
Overall Means		240	42.00	34.91	53.46	23.26

[1]Planting was made June 9, 1977.

[2]R = resistant plant; S = susceptible plant.

[3]Means not followed by the same letter are significantly different at the 5% level of significance (LSD).

hybrids, but the early susceptible hybrid did have significantly more greenbugs than the late resistant hybrid. Virtually the same responses were found in the week of August 8, except a significant interaction was found. Although not significantly fewer the lowest counts were found on the late hybrids, while the early susceptible had significantly more greenbugs than the other treatment combinations. The resistance and maturity responses for the week of August 15 were the same as the previous week. There was also a significant interaction between the resistant and maturity factors. More greenbugs were found on the early hybrids with greenbug numbers decreasing with an increase in maturing time of the hybrid, but the magnitude depended on resistance. There were always more greenbugs on the susceptible plants as compared to the resistant plants. Again, the mean number of greenbugs/plant on the early susceptible hybrid was significantly greater than on the other treatment comparisons. The counting week of August 22 was somewhat atypical. There was no significant differences between the two levels of resistance, however there were differences among the maturity levels. The unusual fact being the medium maturing hybrids had significantly more greenbugs than the late maturing plants, but was not significantly different from the early hybrids. This was the only time during the two summers of counting that this reverse phenomenon occurred. Making comparisons at the various treatment combinations, the early and late resistant hybrids had significantly fewer greenbugs than the medium resistant hybrids. A significant resistant by maturity interaction was not detected.

Yield data for the summer of 1977 are given in Table XVI. As with the 1976 data no statistical comparisons can be made between the plant-

TABLE XVI

YIELD OF SORGHUM HYBRIDS AT DIFFERENT PLANTING DATES AND ROW SPACINGS. PERKINS, OK, 1977

Planting date[1]	Row spacing	Entry	Treatment[2]	Plot head wt (g)[3]	Test wt. (g)[3]
1	76.2 cm	C-42a+	T	1179.4	544.3
			U	1134.0	635.0
		C-42a	T	1179.4	635.0
			U	997.9	544.3
		E-59+	T	1179.4	635.0
			U	1224.7	680.4
		E-59	T	1043.3	544.3
			U	952.6	499.0
		F-67+	T	952.6	635.0
			U	952.6	589.7
		F-67	T	1134.0	589.7
			U	1088.6	725.8
		Mean		1088.6	589.7
1	91.4 cm	C-42a+	T	1542.2	997.9
			U	1542.2	907.2
		C-42a	T	1633.0	1088.6
			U	1587.6	997.9
		E-59+	T	1633.0	1088.6
			U	1270.1	952.6
		E-59	T	1360.8	907.2
			U	1315.4	861.8
		F-67+	T	1270.1	816.5
			U	1542.2	997.9
		F-67	T	1451.5	861.8
			U	1542.2	907.2
		Mean		1496.9	952.6
2	76.2 cm	C-42a+	T	907.2	499.0
			U	861.8	544.3
		C-42a	T	907.2	499.0
			U	952.7	544.3
		E-59+	T	771.1	408.2
			U	952.7	499.0
		E-59	T	861.8	453.6
			U	952.7	544.3

TABLE XVI (Continued)

Planting date[1]	Row spacing	Entry	Treatment[2]	Plot head wt (g)[3]	Test wt. (g)[3]
		F-67+	T	861.8	499.0
			U	907.2	499.0
		F-67	T	952.7	544.3
			U	907.2	544.3
		Mean		907.2	544.3
2	91.4 cm	C-42a+	T	997.9	589.7
			U	1179.4	725.8
		C-42a	T	997.9	635.0
			U	1088.6	680.4
		E-59+	T	997.9	589.7
			U	997.9	635.0
		E-59	T	997.9	589.7
			U	907.2	589.7
		F-67+	T	907.2	544.3
			U	907.2	544.3
		F-67	T	1043.3	635.0
			U	997.9	589.7
		Mean		997.9	635.0
3	76.2 cm	C-42a+	T	952.6	589.7
			U	1043.3	725.8
		C-42a	T	1134.0	725.8
			U	1088.6	771.1
		E-59+	T	907.2	635.0
			U	816.5	499.0
		E-59	T	861.8	544.3
			U	1043.3	680.4
		F-67+	T	1043.3	680.4
			U	861.8	589.7
		F-67	T	997.9	771.1
			U	1179.4	771.1
		Mean		997.9	680.4
3	91.4 cm	C-42a+	T	1406.2	907.2
			U	1315.4	952.6
		C-42a	T	1542.2	1134.0
			U	1496.9	1088.6
		E-59+	T	1587.6	1179.4
			U	1542.2	1134.0
		E-59	T	1542.2	1134.0
			U	1587.6	1179.4

TABLE XVI (Continued)

Planting date[1]	Row spacing	Entry	Treatment[2]	Plot head wt (g)[3]	Test wt. (g)[3]
		F-67+	T	1451.5	1088.6
			U	1406.2	997.9
		F-67	T	1542.2	1134.0
			U	1633.0	1134.0
		Mean		1496.9	1088.6

[1]1 = April 27, 1977; 2 = May 15, 1977; 3 = June 9, 1977.

[2]T = insecticide; U = no insecticide.

[3]Average over reps.

ing date and row spacing combinations, again it was decided not to perform a statistical analysis. During the summer of 1977 available moisture was not a problem. From April 27 through August 31 a total of 33.63 cm of percipitation was recorded, and additional water was added by irrigation when needed. From the yield data, there again appears to be no differences between the treated and untreated plants. Differences between the near isogenic lines at each maturity levels were minimal. However, there were differences in yield between the two row spacings. The yield from the 76.2 cm row spacing was somewhat lower than the grain production from the 91.4 cm row spacing. This is probably related to plant competition for available moisture, competition being greater in the more dense plant population. Again, it would seem that very low greenbug populations prevented economic damage from occurring.

In retrospect, the 1977 data had certain patterns which developed. From comparing the overall means it became apparent that the 76.2 cm row spacing always had fewer greenbugs than the wider 91.4 cm row spacing. This too is in agreement with 1976 data. Except for the counting week of August 22, planting date 3, and 91.4 cm row spacing the maturity contrast was the same in 1977 as in 1976. Again, although not always significantly different, the medium and late hybrids were comparable in numbers, while the early hybrids maintained the highest counts. Also, in agreement with the 1976 data is the fact that the early susceptible hybrid had significantly higher counts than the other treatment combinations.

CHAPTER V

SUMMARY AND CONCLUSIONS

During the growing seasons of 1976 and 1977 experiments were conducted to measure the influence of sorghum planting date, canopy, and plant resistance on greenbug populations in the field. Three important factors created problems during the course of the experiment.

The first of these was the experimental design. Since row spacing and planting dates were treated as individual experiments these two factors could not be compared statistically. Even though it would prevent the use of large equipment it would behoove future researchers to randomize all treatments.

The second of these factors was the weather. During the growing season of 1976 the sorghum plants were heavily stressed from the lack of moisture. This moisture stress prevented good yields, thus effecting the data, and probably prevented a heavy infestation of greenbugs from developing.

The third problem was the very low greenbug infestation. The lack of an infestation did not seem to be related to moisture. The peak counts during the summer of 1977 were much lower than those made during the summer of 1976. In light of these problems certain questions were still answered, although some answers were really only indications.

Extremely low predator and parasite numbers seemed to be indicative of the two summers of research. The peak overall mean for the

mummy counts was 5.8 which occurred July 23, 1976, planting date 3, 91.4 cm row spacing. The peak overall mean for predator counts was 1.12 which occurred July 21, 1976, planting date 2, 91.4 cm row spacing. These peaks for predators and parasites occurred during the peak week for greenbug numbers. Since predators and parasites never really became established it would be difficult to make conclusions concerning these two response variables.

From the two summers of counting it appeared that planting date did not influence rate of infestation as no one planting date consistently had the highest counts. In 1976 the third planting (June 6) had the highest counts, but in 1977 the first planting (April 27) produced the highest counts.

Planting date and row spacing did not influence individual plant leaf area, as the overall means did not vary to any extent. Differences in plant maturity and planting rate seemed to contribute more to total plant canopy. The early hybrids had significantly smaller leaf area measurements than the medium and late hybrids.

The two factors that appeared to have the greatest influence on greenbug numbers were canopy and plant resistance. In terms of significant differences, greenbug responses to plant maturity were very similar to leaf area measurements. Although not always significant there were fewer greenbugs on the early maturing hybrids as compared to the medium and late maturing hybrids. In looking at the effects of row spacing on greenbug numbers there were always more greenbugs on the 91.4 cm row spacing as compared to the 76.2 cm row spacing. Quite possibly this could be related to moisture stress as 76.4 cm rows had slightly lower yield than 91.4 cm rows. In calculating the theoretical number of green-

bugs per hectare, during the peak week of July 19-23, 1976, the following results were found: planting date 1, 76.2 cm rows, 3,336,800 greenbugs/ha; planting date 2, 76.2 cm rows, 34,916,000 greenbugs/ha; planting 2, 91.4 cm rows, 18,189,000 greenbugs/ha; planting date 3, 76.2 cm rows, 18,524,400 greenbugs/ha; planting date 3, 91.4 cm rows, 27,425,000 greenbugs/ha. However, it can be argued that number of greenbugs/plant is the important factor, not the total number/unit area. It would therefore seem that the more sparse the canopy and planting rate the greater the number of greenbugs/plant.

Looking at the greenbug data for the two summers it was found that during some recording periods there were more greenbugs on the resistant plants when compared to the susceptible plant, especially when greenbug numbers were low. Therefore, it would seem that although plant resistance played an important role in the maturity by resistance interaction, it was not always important when averaged over maturity.

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APPENDICES

MEAN SQUARE OF 1976 AND 1977 RESPONSE VARIABLES USED IN RESULT AND DISCUSSION SECTION

TABLE XVII

MEAN SQUARES OF GREENBUG, LADY BEETLES, AND MUMMY COUNTS MADE DURING THE WEEK OF JULY 19-23, 1976

Planting date	Row spacing	Source	Response variable		
			Greenbugs	Lady beetles	Mummies
April 27	76.2 cm	Rep	1067.0	0.270	0.003
		Maturity	3560.0	0.558	0.001
		Resist	5150.0	1.215	0.007
		Mat*Resist	2654.0	0.204	0.001
		Error	427.0	0.077	0.002
May 19	76.2 cm	Rep	9888.0	0.254	0.170
		Maturity	169288.0	0.135	0.080
		Resist	3732.0	0.000	0.007
		Mat*Resist	22490.0	0.280	0.015
		Error	6987.0	0.263	0.044
May 19	91.4 cm	Rep	189.0	0.004	0.144
		Maturity	203609.0	0.462	0.013
		Resist	82567.0	0.150	0.000
		Mat*Resist	2900.0	0.802	0.016
		Error	12419.0	0.203	0.025
June 4	76.2 cm	Rep	3713.0	0.002	62.845
		Maturity	55234.0	0.346	46.249
		Resist	18133.0	0.050	55.510
		Mat*Resist	13069.0	0.100	37.295
		Error	10390.0	0.077	42.941

TABLE XVII (Continued)

Planting date	Row spacing	Source	Response variable		
			Greenbugs	Lady beetles	Mummies
June 4	91.4 cm	Rep	62307.0	0.080	354.0
		Maturity	396226.0	0.537	92.0
		Resist	293532.0	0.150	264.0
		Mat*Resist	39910.0	0.213	108.0
		Error	14997.0	0.227	129.0

TABLE XVIII

MEAN SQUARES OF LEAF AREA MEASUREMENTS OF SORGHUM HYBRIDS, 1976

Source	April 27		May 19		June 6	
	76.2 cm	91.4 cm	76.2 cm	91.4 cm	76.2 cm	91.4 cm
Rep	12020.0	6785.0	4565.0	50574.0	5263.0	18888.0
Maturity	204081.0	181906.0	456725.0	584413.0	133220.0	513088.0
Resist	633.0	18744.0	297.0	12470.0	9626.0	6303.0
Mat*Resist	13727.0	5174.0	2714.0	3850.0	6572.0	5347.0
Error	6525.0	6394.0	5251.0	5792.0	11274.0	11305.0

TABLE XVIX

MEAN SQUARES OF GREENBUG COUNTS MADE FROM PLANTING DATE 1, 1977

Planting date	Row spacing	Source	Counting date 6/27	7/04	7/11
April 27	76.2 cm	Rep	8183.0	2731.0	81.0
		Maturity	3249.0	2460.0	38.0
		Resist	6365.0	18638.0	141.0
		Mat*Resist	785.0	2370.0	42.0
		Error	2537.0	1589.0	76.0
April 27	91.4 cm	Rep	1398114.0	1627648.0	16494.0
		Maturity	1331154.0	1444202.0	18342.0
		Resist	548361.0	1242000.0	23088.0
		Mat*Resist	521202.0	1098645.0	4252.0
		Error	763813.0	1117843.0	5341.0

TABLE XX

MEAN SQUARES OF GREENBUG COUNTS MADE FROM PLANTING DATE 2, 1977

Planting date	Row spacing	Source	Counting date 7/11	7/18	7/25	8/01
May 25	76.2 cm	Rep	2463.0	2283.0	3731.0	3.0
		Maturity	2210.0	1912.0	1561.0	2.0
		Resist	3322.0	1334.0	3634.0	4.0
		Mat*Resist	848.0	564.0	478.0	4.0
		Error	1117.0	1744.0	808.0	3.0
May 25	91.4 cm	Rep	10157.0	5945.0	7649.0	15430.0
		Maturity	6400.0	8676.0	82107.0	26317.0
		Resist	2425.0	1648.0	68310.0	32387.0
		Mat*Resist	1032.0	202.0	30238.0	17268.0
		Error	2240.0	2149.0	18267.0	7621.0

TABLE XXI

MEAN SQUARES OF GREENBUG COUNTS MADE FROM PLANTING DATE 3, 1977

Planting date	Row spacing	Source	Counting date 8/01	8/08	8/15	8/22
June 9	76.2 cm	Rep	3859.0	1076.0	369.0	171.0
		Maturity	374.0	1596.0	3074.0	398.0
		Resist	18130.0	3219.0	4284.0	355.0
		Mat*Resist	297.0	533.0	2629.0	359.0
		Error	2440.0	973.0	735.0	132.0
June 9	91.4 cm	Rep	17599.0	12746.0	36165.0	288.0
		Maturity	95680.0	54506.0	97920.0	16663.0
		Resist	24624.0	41976.0	242252.0	7729.0
		Mat*Resist	8837.0	30037.0	51116.0	4961.0
		Error	9180.0	7041.0	19752.0	4830.0

VITA

William Harold White

Candidate for the Degree of

MASTER OF SCIENCE

Thesis: THE EFFECTS OF CERTAIN SORGHUM CULTURAL PRACTICES ON GREENBUG POPULATIONS IN THE FIELD

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