EFFECTS OF INSECTICIDES ON INSECT CONTROL
AND SOME IMPORTANT PLANT TRAITS IN
GRAIN SORGHUM UNDER SELFING-BAGS

By

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CHAPTER I

INTRODUCTION

In the production of hybrids and most of the breeding work with grain sorghum Sorghum bicolor (L.) Moench, it is necessary to enclose the panicles with selfing-bags to ensure self-pollination. Plants that are to be selfed or to serve as female parents (male sterile) are bagged just before blooming begins. Moisture from the plant creates a humid condition when the panicle is enclosed with a selfing-bag. This humid condition is favorable for the development of the corn earworm, Heliothis zea (Boddie), and the corn leaf aphid, Rhopalosiphum maidis (Fitch). Sorghum plant breeders and other researchers have sought for some time to reduce seed losses caused by these insects on bagged panicles. Several insecticides and combinations of insecticides have been tried in selfing-bags before; however, optimum control of both insects at the same time has been difficult without affecting some important plant traits.

In this study seven insecticides were applied by different methods of application and at different times. The purpose of this study was to determine the effectiveness of the insecticides, the optimum time of application, and the effects on some important plant traits of three sorghum varieties.

CHAPTER II

LITERATURE REVIEW

Since the discovery of a male-sterile plant in 1943 (Dahms et al., 1955), breeding work in sorghum has been intensified and as a result seeds of single and three-way cross hybrids are being economically produced so as to be available to the farmers at low prices. Beginning as early as 1947, plant breeders and other researchers have treated bagged panicles with a variety of insecticides to control corn earworm (*Heliothis zea*) and corn leaf aphids (*Rhopolosiphum madis*) (Buckley and Burkhardt, 1962). Although corn earworm and corn leaf aphids were first reported occurring on sorghum in 1893 by Mally, the insects became a serious problem only when the use of selfing-bags began (Burkhardt and Breithaupt, 1955). Under field conditions the insects are seldom a problem to the farmers because of biological control or climatic conditions. In 1955, however, field infestations of up to 60 percent corn earmworm were reported in northeast Kansas. This level of investation caused from 25 to 30 percent yield reduction.

The high moisture content of the panicle before flowering and the increase in temperature caused by the selfing-bags over the panicle combine to create a special environment for the development of the corn earworm and the corn leaf aphids as well as disease organisms. Quinby and Gains (1942) reported that over 75 percent of the sorghum kernels on bagged panicles were destroyed by the corn earworm. Hayes (1922) found that poor germination was caused by the heavy feeding of the corn leaf aphids. Buckley and Burkhardt (1962) enclosed sorghum panicles in cylindrical cages to determine the damage to the sorghum panicle by a particular number of larvae. They found that one larva could consume up to 166 kernels and 13 larvae up to 1549 kernels per panicle. The damage increased by about 100 kernels per larva up to 13 larvae; after this number the damage continues to increase but at a decreasing rate. A regression line ($\hat{y} = 71 + 102X$) was developed to predict grain damage by the corn earworm in a range of 1 to 13 larvae. Starks and Burton (1979) also evaluated damage to sorghum panicles caused by the corn earworm, but their results did not closely agree with the prediction equation given by Buckley and Burkhardt (1962). They suggested that at high numbers of larvae per panicle, damage does not increase greatly, probably due to cannibalism which is known to occur in late instars of corn earworm. Starks and Burton (1979) indicated also that at last instar the larva will cut a hole through the selfing-bag as a means to escape before pupation. In this study selfing-bags were used to enclose the panicles until harvest so as to determine any relation between the number of holes per bag and the level of infestation inside the bags. Sorghum plants were infested at different stages of development with up to 16 first-instar larvae. Heavy leaf feeding by young larvae was observed at the whorl stage of development, but this did not cause reduction of yields. The number of holes per bag was not directly correlated to the level of infestation; however, those bags with more holes showed more damage. For experimental purposes the results suggested that counting the number of holes in selfing-bags can be an easy way to estimate larval survival after insecticide treatment of the selfing-bag. The greatest damage by one larva was caused when plants were infested at 50 percent bloom, but more significant damage was done when plants were infested 14 days after 50 percent bloom. From this study it was concluded that the corn earworm must oviposit on sorghum one week after flowering for the larvae to become established. However, when the panicles were enclosed in selfing-bags, infestations at early bloom did a good deal of damage. Possible pollen feeding of the first instar larvae could be counted for the better development at this stage. Furthermore, Kinzer and Henderson (1968) reported that a third-instar larva placed in the panicle at the flowering stage consumed 95 percent of the grain by the time it had completed its larval development. It was also determined that first and second instar larvae developed better when sorghum panicles were at the flowering stage, and the third to sixth instar did better when the plant was at the milk stage.

Laboratory studies were conducted (Harrel et al., 1979) in order to determine the effects of temperature, relative humidity, and air velocity on the development of the corn earworm. Relative humidity had the most effect on population density with high humidity being more favorable. Days to pupation were mostly controlled by temperature; the average number of days to pupation decreased as the temperature increased. Air velocity did not have a direct effect, but did have a great influence when coupled with relative humidity. Benschoter (1970) reported that pupation and the production of diapause in corn earworm larvae were also affected by light.

Experiments with methods of application as well as rates for the use of insecticides in selfing-bags for sorghum began as early as 1947. Tests were conducted at the Oklahoma Agricultural Experiment Station (Dahms et al., 1951) with 12 insecticides at different concentrations and over 50 combinations. The first problem encountered with most of the insecticides was the inability of the chemical to control both of the insects at the same time. Aldrin emulsion at 0.5 percent concentration used to impregnate the bags was reported to provide the best control for both insects. Other insecticides like Benzene hexochloride, chlordane, and parathion provided good control but caused high sterility. Aldrin applied by dusting the bags or the panicles (Dahms et al., 1955) did not give as good control as in 1948, when it was used as a liquid; however, impregning and drying the bags does involve extra work. Good control of the corn earworm was obtained by Burkhardt and Breithaupt (1955) when spraying Mevinphos on sorghum panicles.

In a laboratory study (Lentz and Carr, 1974) corn earworm was tested for susceptibility to several insecticides and combinations. Methyl paration had the lowest LD_{50} value to which the corn earworm showed great susceptibility. The duration of the susceptibility to methyl parathion was tested in a separate study (Carter and Phillips, 1970). Methyl parathion dosages were given to 11 successive generations of the corn earworm which were raised in the laboratory. Tolerance increased in each generation as the LD_{50} value increased and for the final generation the larvae had from 8 to 10 fold levels of resistance to methyl parathion (Whitten and Bull, 1970). Organophosphorus insecticides had been proven to be effective against the corn earworm in cotton fields, and this family of insecticides was considered an alternative to increasing the resistance to organochlorines and carbamate insecticides.

Although several insecticides were proven to be effective in controlling corn earworm under field conditions, further tests were needed to establish their use in selfing-bags because of possible sterility in the panicles and practicality of application.

Four biotypes of corn leaf aphids were reported by Painter and Pathak (1962) who named them KS-1, KS-2, KS-3, and KS-4. Other studies by Wide and Feese (1973) with sorghum (RS701) seedlings indicated the appearance of a new biotype based on differences of reproduction and feeding habits. They found that the optimum temperature for reproduction of the new biotype which fed on sorghum was 85°F and that the four biotypes described by Painter and Pathak (1962) have a low reproductive rate at the same temperature.

Starks and Burton (1979) with the development of sorghum cultivars resistant to greenbugs (Schizaphis graminum Rondoni) insecticide use in sorghum dropped sharply and this allowed other insects to be more of a threat to sorghum production. In nine studies, Wilde and Ohigu (1976) found the control of corn leaf aphids under field conditions was unprofitable in sorghum production. These studies included high populations of corn leaf aphids (3500/plant) in combination with greenbugs on the bottom leaves. Not significant differences in yield were obtained between treated and untreated plants. Several studies on the development of corn leaf aphids indicated that temperature and light intensity strongly influence population of corn leaf aphids (Singh and Painter, 1964; Berry, 1969).

Radioactive isotopes have been used (Guss and Branson, 1972) to study the ingestion and effects of test solutions on corn lead aphids. Data from these studies indicated that a feeding deterrent is the cause of corn leaf aphid's failure to survive on Tripsicum floridanum. Cate et al. (1973) used insecticide treatment to control corn leaf aphids, which indicated that sprays of dementon, disulfoton, parathion, carbophenothion, diazinon, and malathion are all effective in controlling corn lead aphids. Studies in combination with greenbugs indicated that reduction of the standard rates lowered the insecticide effectiveness to control the corn leaf aphids, but this did not reduce the effectiveness to control greenbugs. Dahms et al. (1955) reported that dusting the sorghum heads with DDT gave good corn earworm control but increased the population of corn leaf aphids. Dusting the heads with benzene hexochloride resulted in good control of the aphids, but high sterility was caused at three different rates. Other insecticides reported to cause high sterility were chlordane and parathion.

CHAPTER III

MATERIALS AND METHODS

Three varieties of sorghum (Redlan, OK632 and Frontier 412R) were planted on May 27, 1981, at the Oklahoma State University Agronony Research Station near Perkins, Oklahoma. The soil present at the site belongs to the series Teller loam which is a member of the fine-loamy, mixed, thermic, udic argiustoll. This experiment consisted of 12 treatments including the control, and each of the test varieties received the whole set of treatments. The experimental design was a randomized complete block with three replications in which each replication consisted of 36 rows. From each row, containing approximately 50 plants, 12 plants were randomly selected to be used for one of the treatments. The cultural practices used for this study were the same as those used at the Perkins Agronomy Research Station.

Just before anthesis, all plants that were selected for the study were infested with one-day-old corn earworm larvae from a laboratory culture. This was done by mixing the larvae with corn-grits and placing them in an applicator which released approximately seven larvae per application. Each sorghum head received one application and was immediately covered with a selfing-bag. This was done for all treatments except for treatment 1 (control) which did not require selfing-bags. Corn leaf aphid infestation occurs regularly every year at this location and there was no need for artificial infestations. All bags except for those in treatment 2 (untreated) were treated with chemicals (see Table I).

TABLE I

TREATMENTS AND DOSAGES OF INSECTICIDES

Treatments	Active Ingredient Per Bag	Method of Application
1. No bags (Check)		
2. Untreated bags		
3. Ambush + diazinon	47.8 mg + 50 mg	Injected
4. Dipel + pirimor	160 mg + 100 mg	Dusted
5. Sevin + pirimor	20 mg + 50 mg	Dusted
6. Diazinon	50 mg	Impregnated
7. Ambush + malathion	47.8 mg + 100 mg	Injected
8. Methomyl	48.2 mg	Injected Day Zero[1]
9. Methomyl	48.2 mg	Injected Day Five[2]
10. Methomyl	48.2 mg	Injected Day Ten[3]
11. Malathion	100 mg	Injected Day Zero
12. Malathion	100 mg	Injected Day Five

[1]Chemical applied one day before anthesis.

[2]Chemical applied four days after anthesis began.

[3]Chemical applied nine days after anthesis began.

Treatments 3 to 12 involved the use of seven different insecticides, three forms of application, and three different times of application. The insecticides used were: diazinon, methomyl, malathion, Ambush + diazinon, Dipel + Piromor, Sevin + Pirimor, and Ambush + malathion. In Table I the different rates of application for each of the insecticides are given. Rates of application were based on previous studies designed to determine optimum rates. Trade and common names as well as formulation of the insecticides are given in Table II.

One form of application was dusting, which was done by placing the appropriate amount of insecticide in the selfing-bag and striking it before it was placed on the sorghum panicle. Another method used was impregnation by simply soaking the bags in liquid insecticide until they were saturated and then drying the bags before using them. A third method of application consisted of spraying the individual heads by injecting the insecticide through the paper bags with a needle connected to a pressurized tank. This last form of application permitted the spraying at any time after the bags were on the panicles with no need to remove them. Methomyl was applied one day before anthesis began (day zero), 5 days (day five), and 10 days after day zero (day ten). Malathion was also applied at two different times (day zero and day five). The purpose of these different times of application was to determine if there was a critical time for the application of some insecticides. Also, the three times of application may determine if there is any difference in susceptibility of the larvae to the insecticides at different instars.

During the last week of September, all three replications were harvested by hand and without the removal of the selfing-bags. Although 12 plants per row were treated and harvested, only 10 plants per row were

TABLE II

INSECTICIDES USED IN THE EXPERIMENT

Common Name and Trade Name	Chemical Name	Concentration and Formulation	LD_{50} Values
Diazinon (Basudin)	0,0-diethylo-(2-Isopropyl-6-methyl-4-pyrimidinyl) Phosphorothioate	12% Emulsifiable concentrate	108 mg/kg[3]
Permethrin (Ambush)	(3-phenoxyphenil)methyl (±)cis, Tran-3-(2,2-dichloro-ethenyl)-2, 2-dimethylcyclo-propane-carboxilate	23% Emulsifiable concentrate	400 mg/kg[2]
Bacillus thuringiensis (Dipel)		16000 International units/mg wettable powder	Nontoxic
Primicarb (Pirimor)	2-(dimethylamino)-5, b-di-methyl-4-pirymidinyl dimethyl-carbamate	50% Wettable powder	500 mg/kg[2]
Carbaryl (Sevin)	1-Naphthyl N-methylcarbamate	50% Flowable	500 mg/kg[2]
Methomyl (Nudrin)	S-methyl N-methylcarbomoyl Oxy/Thioacetatimidate	24.1% Emulsifiable concentrate	17 mg/kg[3]
Malathion (Lorox)	0,0-dimethylphosphorodithioate of diethylmercaptosuccinate	50% Emulsifiable concentrate	1000 mg/kg[1]

[1]Low LD_{50} rating. [2]Medium LD_{50} rating. [3]High LD_{50} rating. All oral dosages with rats.

needed for the experimental design. After harvest, all panicles were taken to the greenhouse where the selfing-bags were removed and the panicles were rated on a scale of 1 to 6 for sterility, corn leaf aphid incidence, and corn earworm damage (see Table III). The rating for sterility was done by estimating the percentage of sterility in each panicle and this ranged from 1 (zero percent sterility) to 6 (over 80% sterility). For the corn earworm damage an estimation of the amount of frass left by the larvae and the percentage of kernel damage was used. The amount of frass helped in part to distinguish between corn earworm and sterility. If no frass was found, it indicated an absence of the larvae and no damage to the grain (rating 1). If large amounts of frass and over 80 percent kernel damage were found, then the rating was 6. The corn leaf aphid incidence was measured by the amounts of exuviate, honeydew, and the density of aphids or aphids per panicle. No exuviate or aphids were rated as 1 and a solid mass of aphids and large amounts of honeydew were rated as 6. Before the panicles were threshed, individual panicle weights were recorded for each of the rows. Average grain-weight per panicle for each row was then divided by the average panicle weight in order to obtain the threshing percentage for each treatment and each variety. The grain from each row was then taken to the sorghum laboratory where 100 kernels from each row were weighed (100 kernel weight). After weighing, the 100 kernels were placed on germination blotters in a chamber at 86°F (day) and 68°F (night) for seven days and seven nights. This germination test was necessary to determine possible phytotoxicity and/or corn leaf aphid damage effects on germination. The seeds were treated with fungicide (vitavax) before the test.

TABLE III

RATING SCALES USED FOR MEASURING STERILITY AND INSECT DAMAGE

Scale	Sterility	Corn Lead Aphids	Corn Earworm
1	None	None (no exuviae)	None (no frass)
2	5% or less on tip	1-10 aphids, some exuviae	1 larva or small amount of frass less than 5% kernel damage
3	6-20%	10-50 aphids, some exuviae	1 larva, moderate amount of frass, 6-20% kernel damage
4	21-40%	50-200 aphids, some exuviae, some honeydew	2 larvae, large amount of frass, 21-40% kernel damage
5	41-80%	Aphids or exuviae throughout panicle, much honeydew	More than 2 larvae, large amount of frass, 41-80% kernel damage
6	Above 80%	Panicle a solid mass of aphids, exuviae and honeydew	More than 2 larvae, large amount of frass, more than 80% kernel damage

The data of this study were statistically analyzed at the computer center of Oklahoma State University. The computer is programmed to produce the Duncan's multiple range test of the means and the analysis of variance for each variable analyzed. Treatments and varieties were the two factors involved in the study and the possible interaction of the two factors was also analyzed.

CHAPTER IV

RESULTS AND CONCLUSIONS

Corn Earworm Damage

The analysis of variance for corn earworm damage is presented in Table IV. This table shows a significant difference among treatments and also for replications at the .01 level. The interaction between varieties and treatments was significant at the .05 level.

The general means for treatments will not be discussed for this variable due to the significant interaction between varieties and treatments. The means of each variety for all 12 treatments will be discussed. Tables V, VI, and VII show the means of each variety for all 12 treatments. Treatment 2 (untreated bags) showed the highest mean for corn earworm damage score on all three varieties. Treatment 9 (methomyl, day five) gave the best control of the corn earworm damage on Redlan and OK632, but not on Frontier 412R. Pirimor in combination with Dipel or Sevin (treatments 4 and 5) provided an intermediate control of the corn earworm with one exception for the variety Redlan, which had a lower mean damage on treatment 4 (see Table V). Treatments 10 and 6 gave a control of corn earworm damage that was not significantly different from treatments 4 and 5 on Frontier 412R. Treatment 3 (Ambush + diazinon) gave a good control for Redlan and OK632 varieties; however, Frontier had a high mean damage from this treatment. Methomyl gave better control from treatment 9 (methomyl, day five) than from treatments 8 or 10 (methomyl, day zero and day ten)

TABLE IV

ANALYSIS OF VARIANCE FOR CORN EARWORM DAMAGE SCORES

Source	Damage Scores DF	MS	Damage F Value
Total	107		
Replication	2	5.650	36.09**
Variety	2	0.444	2.84
Treatment	11	1.399	8.94**
Variety X Treatment	22	0.307	1.96*
Error	70	0.156	

**Significant at the .01 level of significance.

*Significant at the .05 level of significance.

TABLE V

MEANS FOR CORN EARWORM DAMAGE SCORES
FOR VARIETY REDLAN

Treatment	Mean[1]	Duncan's Range
2	3.03	A[1]
11	2.80	AB
8	2.63	BC
6	2.53	BC
10	2.43	CD
5	2.43	CD
7	2.33	CDE
1	2.13	DEF
12	2.03	EF
11	1.96	F
4	1.93	F
9	1.83	FG
Overall Mean	2.34	

[1]Means with the same letter are not significantly different at the .05 significance level.

TABLE VI

MEANS FOR CORN EARWORM DAMAGE SCORES FOR VARIETY OK632

Treatments	Mean[1]	Duncan's Range
2	2.93	A[1]
10	2.53	B
6	2.46	BC
4	2.43	BCD
12	2.23	BCDE
7	2.13	CDE
5	2.10	DEF
1	1.96	EF
8	1.93	EFG
3	1.76	FG
1	1.60	GH
9	1.33	H
Overall Mean	2.12	

[1]Means with same letter are not significantly different at the .05 significance level.

TABLE VII

MEANS FOR CORN EARWORM DAMAGE SCORES FOR VARIETY FRONTIER 412R

Treatment	Mean	Duncan's Range
2	3.73	A[1]
3	2.43	B
10	2.40	B
4	2.36	B
7	2.36	B
6	2.33	B
5	2.23	B
8	2.10	BC
12	1.86	CD
9	1.76	CD
11	1.70	DE
1	1.40	E
Overall Mean	2.22	

[1]Means with the same letter are not significantly different at the .05 significance level.

for all varieties. With the exception of treatment 12 (malathion, day five) the variety OK632 had a lower mean damage from the application of sprayed insecticides than from the other two methods of application (impregnation and dusting). It is possible that the open-type of panicle of OK632 could have a better coverage of the sprayed insecticides than the other two varieties which have a more compact panicle. Although the analysis of variance did not show significant difference among varieties, Duncan's test of means indicated that the general mean of OK632 was significantly different from the mean of Redlan at the .05 level. Graphical representation of the means of each treatment may be found in Figure 1. A comparison of the means for each variety is graphically presented in Figure 2.

Corn Earworm Holes Per Bag

There are two objectives in counting the number of holes per bag: (1) to determine possible correlation between the average number of holes per bag and the average amount of damage of the corn earworm, and (2) to utilize the average number of holes as an indicator of larval survival. The maximum number of holes found in one single bag was three, but one hole was the most common number. Those bags with three holes showed larger amounts of frass and significantly greater damage on the panicles than bags with only one hole. These observations then permitted the use of average number of holes in one treatment to estimate or to confirm larval survival from the application of a particular insecticide. Although treatments with high average number of holes did not indicate the number of larvae that survived, they indicated that there was a greater larval survival than in treatments with low average number of holes.

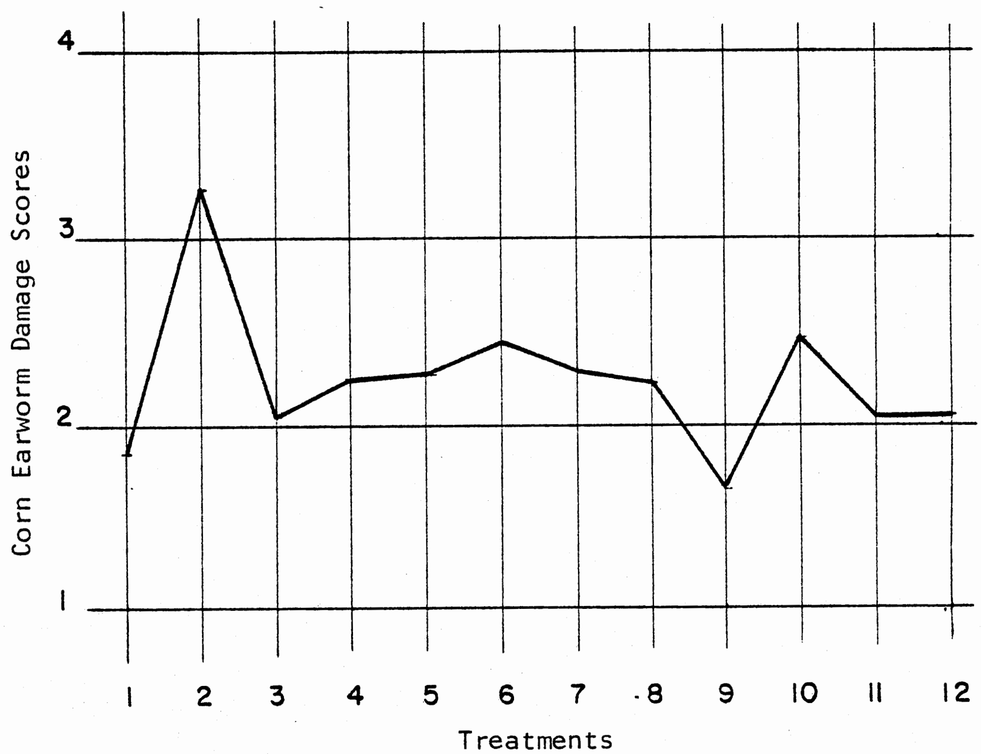

Figure 1. Distribution of Treatments for
Corn Earworm Damage Scores

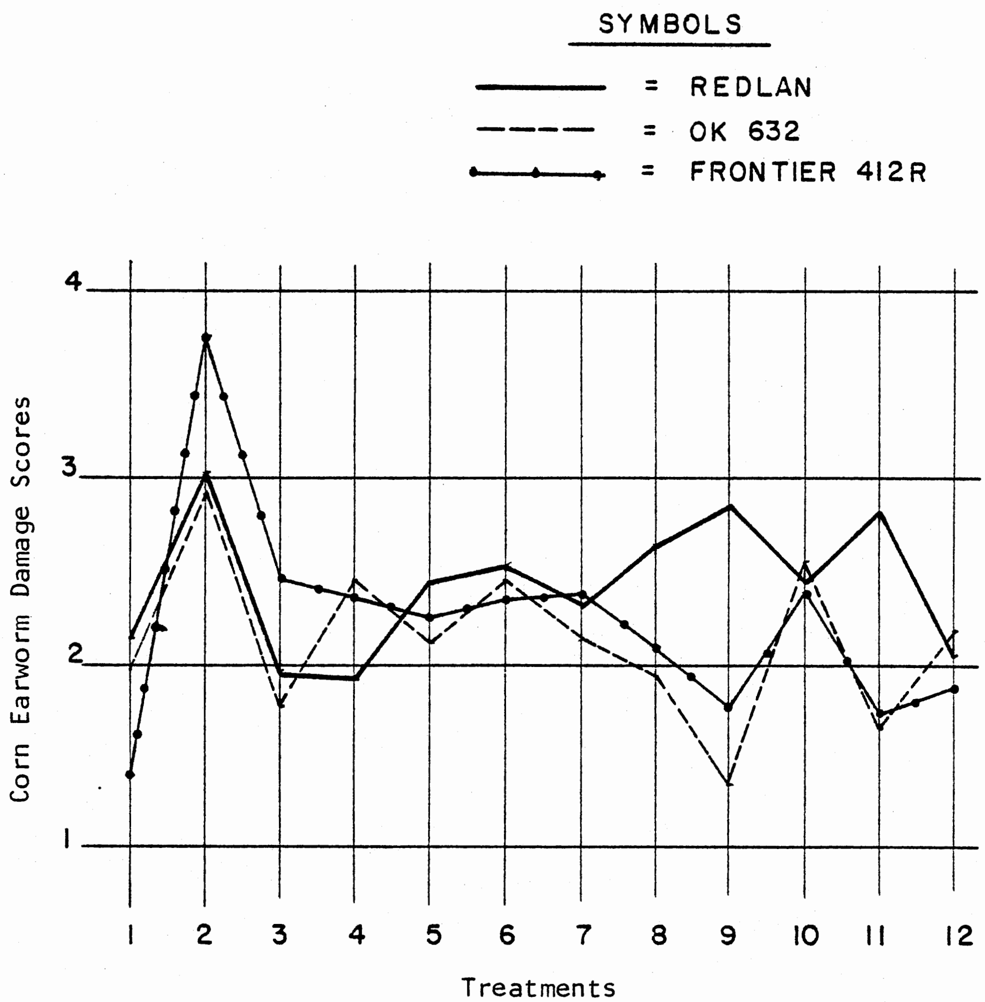

Figure 2. Distribution of Means for Varieties on Corn Earworm Damage Scores

There was some variation in the number of holes per bag within treatments with the exception of the untreated bags which were rather consistent in having one and two holes per bag.

Statistical differences were found only among treatments according to the analysis of variance presented in Table VIII. Variability among varieties was not significant as well as the interaction of varieties and treatments. The means for each treatment and variety are given in Table IX. The means in this table are actual counts of holes per bag while the means for damage, incidence and sterility are restricted to a range of scores from 1 to 6. Thus, column five of Table IX indicated that treatment 2 (untreated bags) had the highest number of holes and at the .05 level the mean for treatment 2 was significantly different from the others. Methomyl applied five days after anthesis began (treatment 9) was significantly different from methomyl applied before and 10 days after anthesis began (treatments 8, 10). The number of holes for each of these treatments (8, 9, 10) was proportionally consistent to the extent of insect damage. Among all the insecticide treatments, diazinon (treatment 6) had the highest mean of holes per bag but it was not significantly different from treatments 3, 8, 10, and 12. Low means were given by treatments 4, 5, 7, 9, and 11, and there were no significant differences among them. Graphical representation of the means for each variety is presented in Figure 3. Figure 4 presents the distribution of the means for the differences among treatments for holes per bag.

Sterility

The analysis of variance for sterility indicated a significant difference among treatments (Table X). The analysis does not indicate

TABLE VIII

ANALYSIS OF VARIANCE FOR HOLES PER BAG

Source	DF	M.S.	F-Value
Total	107		
Replication	2	0.17	1.16
Variety	2	0.18	1.13
Treatment	11	0.84	5.65**
Variety X Treatment	22	0.11	0.73
Error	70	0.15	

**Significant at the .01 level of significance.

TABLE IX

MEANS FOR CORN EARWORM HOLES PER BAG

Treatment	Variety: Redlan	OK632	Frontier 412R	Mean	Duncan's Range
2	1.07	1.10	1.07	1.08	A[1]
6	0.77	0.57	0.80	0.71	B
3	0.17	0.93	0.77	0.62	BC
10	0.50	0.73	0.60	0.61	BC
8	0.47	0.63	0.37	0.49	BCD
12	0.17	0.13	0.80	0.37	BCDE
5	0.43	0.20	0.23	0.29	DEF
7	0.13	0.10	0.53	0.25	DEF
4	0.07	0.30	0.33	0.23	DEF
9	0.27	0.13	0.20	0.20	DEF
11	0.07	0.13	0.03	0.08	EF
1	0.00	0.00	0.00	0.00	F
Mean	0.34	0.41	0.47		
Duncan's Range	A	A	A		

[1]Means with the same letter are not significant at the .05 level of significance.

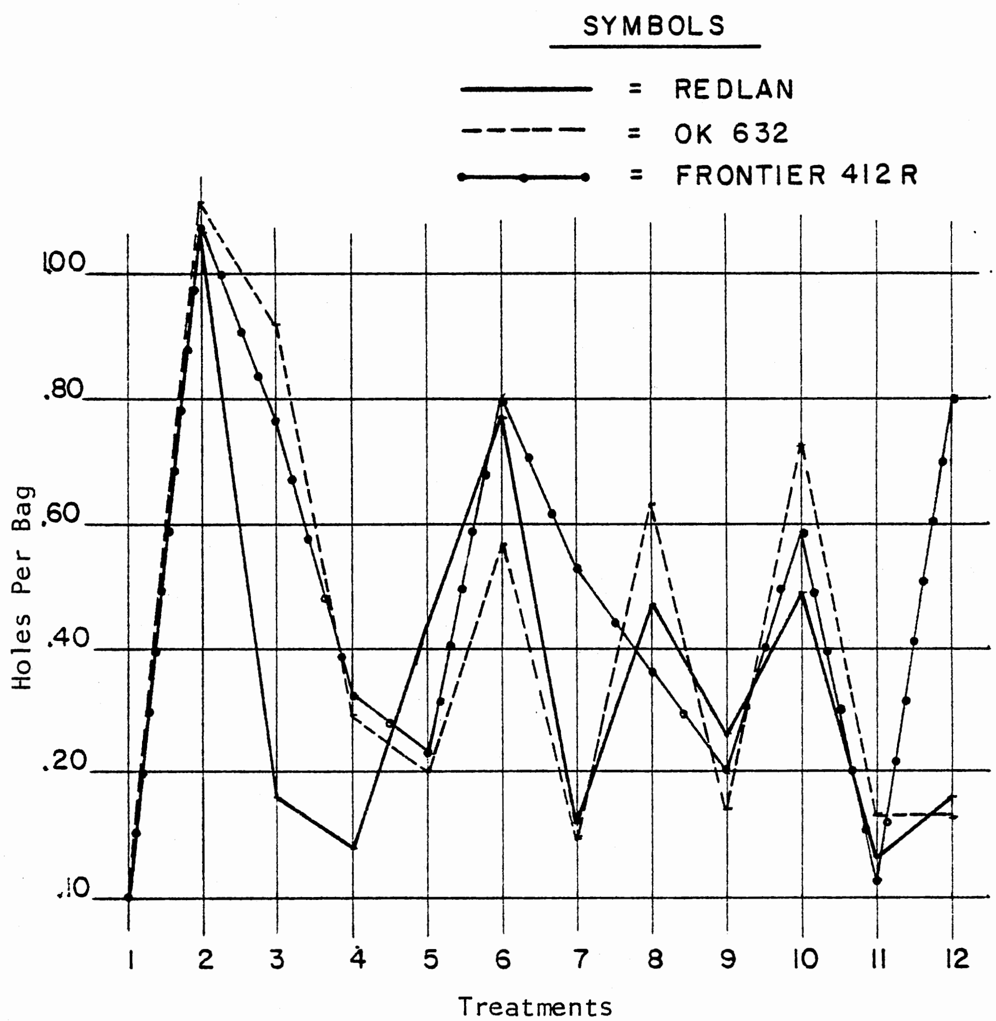

Figure 3. Distribution of Means for Varieties on Corn Earworm Holes Per Bag

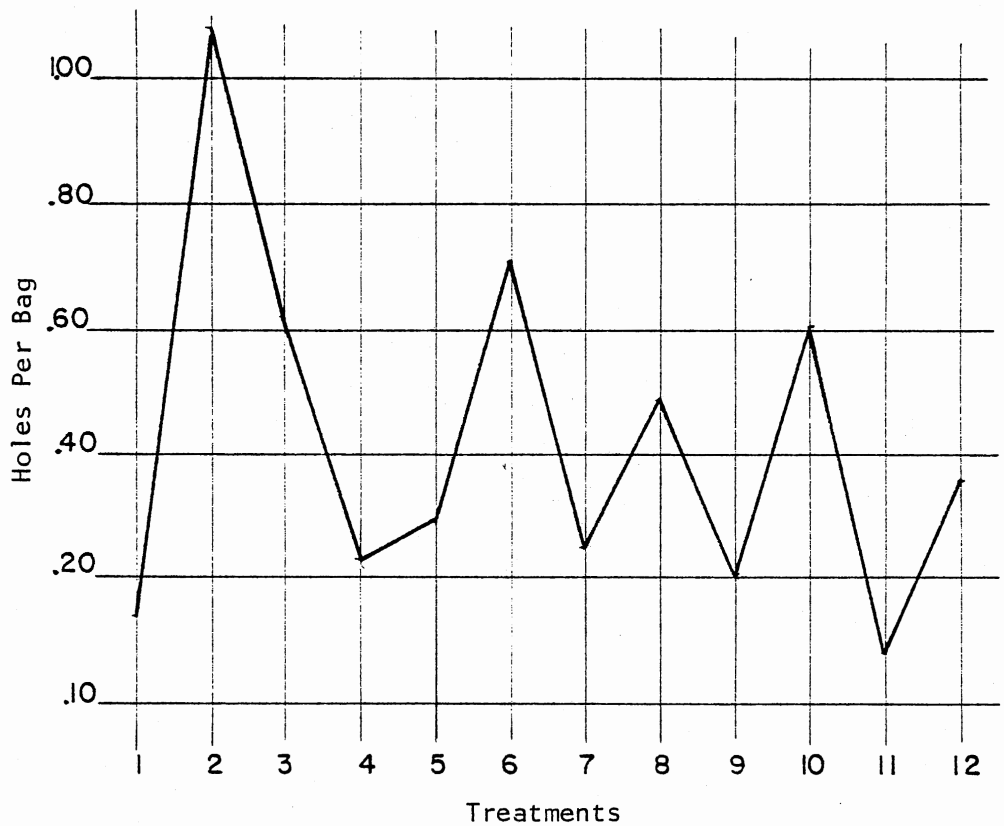

Figure 4. Distribution of Treatments for Corn Earworm Holes Per Bag

significance for the interaction between varieties and treatments. Since sterility can be caused in part by toxic effects from the insecticides, differences among treatments for sterility is of great importance in this study. There were significant differences in the level of sterility from the application of methomyl at different times. A difference in the level of sterility from the application of malathion at different times was not significant though.

The results for the level of sterility for each treatment are given in Table XI. Among all the treatments, the lowest mean was for treatment 1 (no bags) which did not have an insecticide application, but this was not significantly different from treatments 2, 4, 5, 9, 10, and 12. The light sterility (less than 1%) recorded in treatments 1 and 2 cannot obviously be attributed to phytotoxicity, because there was no insecticide used in these treatments. The sterility for these treatments was found only at the lower part of the panicle and it occurred mostly in the Redlan and Frontier 412R varieties which had a high incidence of aphids. The environmental conditions were exceptionally good at Stillwater in the summer of 1981; however, a new biotype (E) of the greenbug and heavy infestation of the corn leaf aphids could explain why some panicles in treatments 1 and 2 showed some sterility. Among all treatments, Ambush + diazinon (treatment 3) had the highest mean for sterility and it was significantly different from all the other treatments at the .05 level. Average sterility for treatment 3 was over 30 percent; however, single heads were found with levels of sterility of 50 to 75 percent. When comparing treatment 3 with other treatments in which Ambush was used and where diazinon was used by itself, one concludes that Ambush was largely reponsible for the high sterility of treatment 3. The levels of sterility for treatments

TABLE X

ANALYSIS OF VARIANCE FOR STERILITY SCORES

Source	DF	MS	F-Value
Total	107		
Replication	2	0.88	2.21
Variety	2	0.37	0.93
Treatment	11	3.75	9.37**
Variety X Treatment	22	0.20	0.50
Error	70	0.40	

**Significant at the .01 level of significance.

TABLE XI

MEANS FOR STERILITY SCORES

Treatment	Variety: Redlan	Variety: OK632	Variety: Frontier 412R	Mean	Duncan's Range
3	4.03	2.97	2.80	3.26	A[1]
7	2.80	2.17	2.00	2.32	B
11	2.16	1.53	1.97	1.89	BC
8	1.80	1.87	2.00	1.87	BC
6	1.30	1.57	1.70	1.52	C
12	1.40	1.40	1.23	1.34	CD
5	1.30	1.13	1.33	1.26	D
4	1.23	1.20	1.23	1.22	D
2	1.06	1.40	1.10	1.18	D
10	1.23	1.20	1.10	1.18	D
9	1.30	1.00	1.20	1.16	D
1	1.10	1.10	1.13	1.11	D
Mean	1.73	1.54	1.56		
Duncan's Range[1]	A	A	A		

[1]Means with the same letter are not significantly different at the .05 significance level.

9 and 10 (methomyl, day five and day ten) were almost the same; however, this level was significantly different from treatment 8 (methomyl, day zero). The higher sterility in treatment 8 could be due to poor flower development, since the insecticide was applied before flowering began in this treatment. Although the differences were not significant between malathion applied one day before blooming began (treatment 11) and five days later (treatment 12), the latter had a lower sterility mean. Pirimor in combination with either Sevin or Dipel (treatments 4 and 5) had low sterility and they were not sitnificantly different from treatments 2, 9, 10, 12, or the control. Although the analysis of variance did not show significant differences among varieties, it is interesting to note that variety Redlan had a higher sterility in some treatments, especially those in which the insecticide was sprayed. The relation between treatments and the level of sterility is graphically presented in Figure 5. The means for each variety in all 12 treatments were plotted and are presented in Figure 6.

Corn Leaf Aphid Incidence

The analysis of variance for corn leaf aphids is presented in Table XII. The analysis showed a significant difference among varieties and also among treatments. The interaction between varieties and treatments was not significant. Variation in the level of aphid infestation among varieties was expected, because the corn leaf aphids appear to prefer a compact type of panicle rather than an open type of panicle. Redlan and Frontier 412R have a compact panicle, while OK632 has an open type of panicle. Natural infestation for the 1981 summer was high, and even the OK632

Figure 5. Distribution of Treatments for Sterility Scores

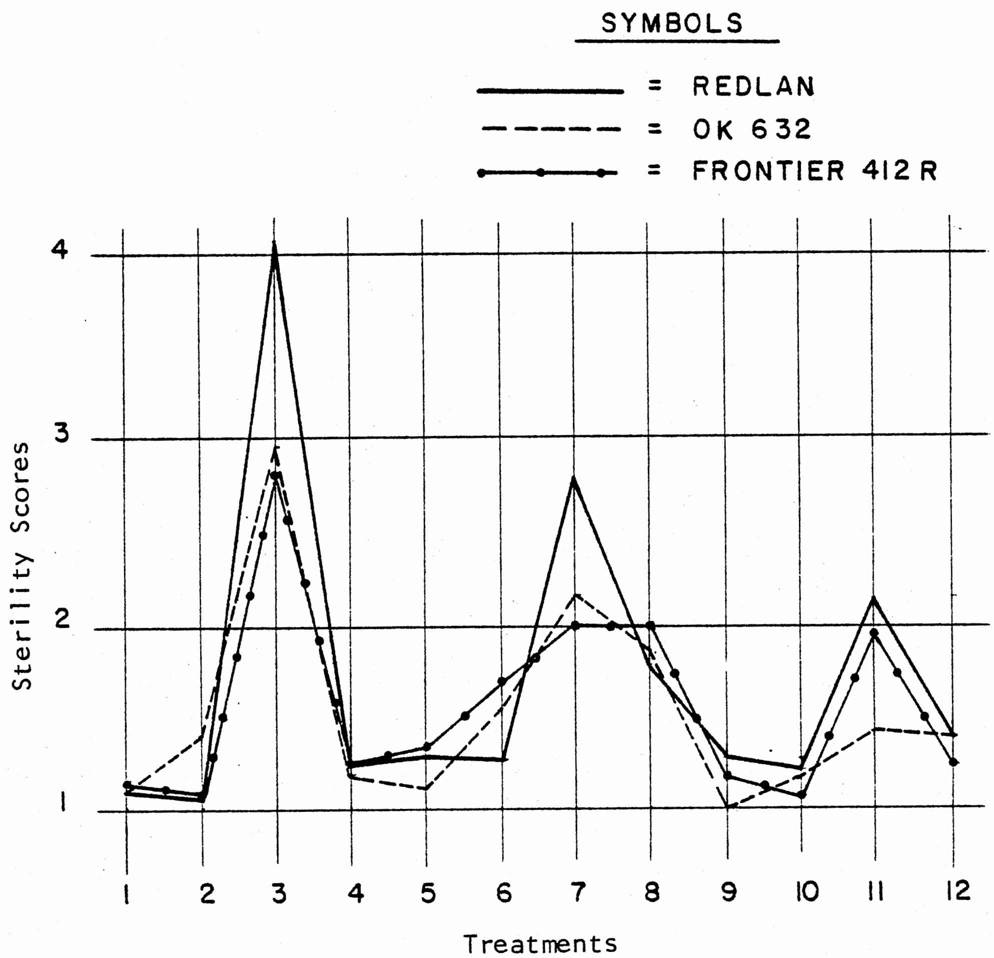

Figure 6. Distribution of Means for Varieties on Sterility Scores

TABLE XII

ANALYSIS OF VARIANCE FOR CORN LEAF APHID DAMAGE SCORES

Source	DF	MS	F-Value
Total	107		
Replication	2	0.36	0.70
Variety	2	6.18	12.10**
Treatment	11	6.37	12.47**
Treatment X Variety	22	0.69	1.36
Error	70	0.51	

**Significant at the .01 level of significance.

variety had a high corn leaf aphid incidence, but still it was significantly lower than the other two varieties (see Table XIII). Greenbug infestation was moderate during the season but there was no interaction with the corn leaf aphids and most of the damage from the greenbugs was confined to the lower two leaves.

In most treatments the variety OK632 ranked lower than Redlan or Frontier 412R for corn leaf aphid damage (Table XIII). Treatment 2 (untreated bags) showed the highest mean of all treatments. All three treatments of methomyl had high incidence, but treatments 9 and 10 (methomyl, day five and day ten) had even higher incidence of corn leaf aphid than treatment 8 (methomyl, day zero). This was due probably to the aphids becoming more numerous and more protected in those treatments with the later applications. The lowest mean of incidence was given by treatment 3 (Ambush + diazinon) which in some cases gave almost complete control. The effectiveness of treatment 3 should be attributed mostly to Ambush because diazinon used by itself in treatment 6 did not give good control of the aphids. Ambush used in combination with malathion gave a moderate control (treatment 7). There was a significant difference between malathion applied one day before flowering (treatment 11) and five days later (treatment 12) in which the latter gave a better control. Treatment 1 (no bags) had practically the same incidence as treatment 3 (best control). Pirimor in combination with Dipel or Sevin (treatments 4 and 5) gave a rather low control, but it was significantly better than the mean of the untreated bags. Treatments 6, 9, and 10 were not significantly different from the untreated bags (treatment 2). The distribution of the means for all the treatments is graphically presented in Figure 7

TABLE XIII

MEANS FOR CORN LEAF APHID DAMAGE SCORES

Treatment	Variety: Redlan	Variety: OK632	Variety: Frontier 412R	Mean	Duncan's Range
2	3.97	3.50	4.67	4.04	A[1]
9	4.50	3.73	3.87	4.03	A
10	4.46	2.27	4.43	3.72	AB
6	3.07	3.37	4.23	3.55	ABC
11	2.97	3.10	4.07	3.38	BC
8	3.87	2.67	3.77	3.37	BC
5	3.50	2.40	3.40	3.10	C
4	3.13	2.50	3.57	3.07	CD
7	2.47	2.00	3.10	2.52	DE
12	2.23	2.00	2.60	2.28	E
1	1.73	1.90	1.33	1.65	F
3	1.40	1.70	1.70	1.60	F
Mean	3.11	2.58	3.39		
Duncan's[1] Range	A	B	A		

[1]Means with the same letter are not significantly different at the .05 significance level.

and the variation of means for the three varieties is presented in Figure 8.

Panicle Weight

Individual panicle weights were recorded; however, the average panicle weight for each row was used for statistical analysis. In the analysis of variance presented in Table XIV, it is noted that the greatest variation for panicle weight was found among varieties. Significant differences at the .01 level were found among treatments, but no significant difference was found for the interaction of varieties and treatments. Variation among varieties was mostly influenced by the difference in the potential of each variety for panicle size. As mentioned earlier, environmental conditions were favorable during the summer of 1981, and panicle size was better than in years before. The variety Frontier 412R recorded individual panicle weights as high as 148 g. Redlan in general had the lowest panicle weight and OK632 fell in between.

The general means for treatments and the means for the varieties are given in Table XV. Panicle weight as well as grain weight can also be good estimators of damage or sterility of a treatment within a variety. As an example, treatment 9, which gave the best corn earworm control and a low sterility, had one of the highest panicle weights. Methomyl treatments (treatments 8, 9, and 10) had nonsignificant differences, but these treatments had means significantly higher than treatments 2, 3, 6, and 7. Treatment 3 (Ambush + diazinon) gave the lowest mean for panicle weight among all the treatments. This can be attributed mainly to the high sterility in treatment. In spite of the heavy corn earworm damage in the untreated bags (treatment 2), the mean panicle weight for this treatment

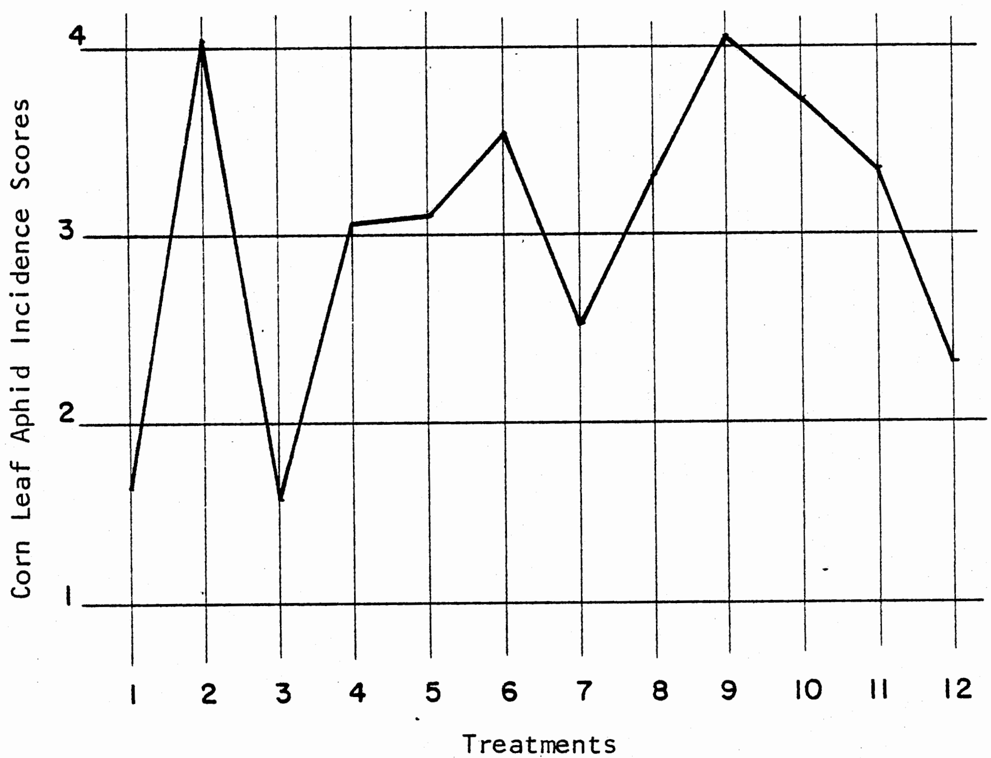

Figure 7. Distribution of Treatments for Corn Leaf Aphid Incidence Scores

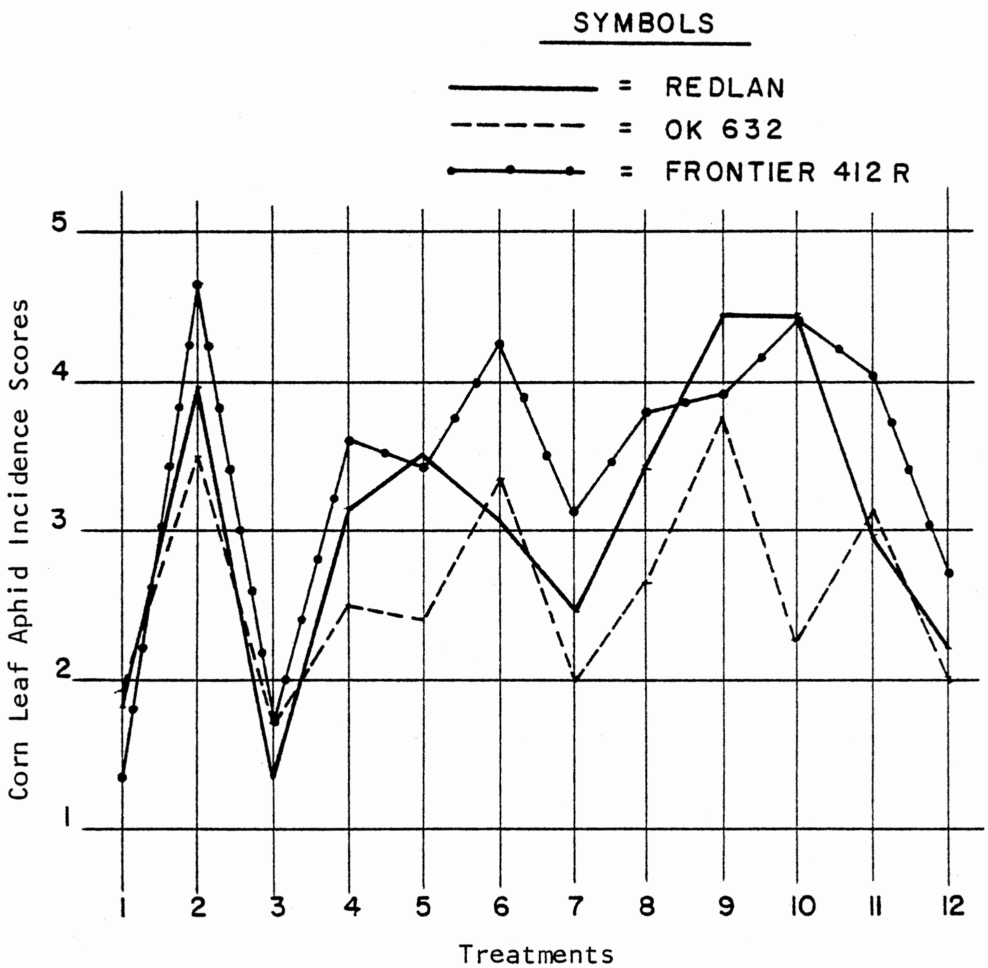

Figure 8. Distribution of Means for Varieties on Corn Leaf Aphid Incidence Scores

TABLE XIV

ANALYSIS OF VARIANCE FOR PANICLE WEIGHT

Source	DF	MS	F-Value
Total	107		
Replications	2	3.79	0.03
Variety	2	5099.87	40.38**
Treatment	11	1168.25	9.25**
Variety X Treatment	22	104.83	0.83
Error		126.30	

**Significant at the .01 level of significance.

TABLE XV

MEANS FOR PANICLE WEIGHT

Treatment	Variety: Redlan	Variety: OK632	Variety: Frontier 412R	Mean	Duncan's Range
	g				
1	78.70	86.57	104.30	89.85	A[1]
9	65.67	78.17	96.12	79.99	AB
10	69.32	77.22	88.62	78.40	B
4	67.37	71.92	88.87	76.05	BCD
5	67.42	72.22	86.87	75.50	BCD
12	64.77	64.10	90.04	72.97	BCDE
8	63.42	68.42	83.70	71.85	BCDE
11	49.97	76.13	83.82	69.98	CDE
6	66.02	58.50	79.27	67.92	DE
2	60.42	65.57	65.20	63.92	EF
7	39.52	52.62	74.80	55.65	FG
3	29.10	49.40	61.70	46.72	G
Mean	60.15	68.41	83.61		
Duncan's Range	C	B	A		

[1]Means with the same letter are not significant at the .05 significant level.

was significantly higher than treatment 3. Treatment 2 was no different from treatments 6, 7, and 11, all of which had low panicle weight means. Ambush + malathion (treatment 7) gave the second lowest panicle weight mean and it was significantly lower than treatments 1, 4, 5, 6, 8, 9, 10, 11, and 12. Pirimor in combination with Dipel or Sevin (treatments 4 and 5) could be classified as intermediate in panicle weight among all the treatments. Diazinon (treatment 6) had a mean panicle weight lower than many other treatments, probably due to sterility. General means for panicle weight in each treatment is graphically presented in Figure 9. A distribution of the means for varieties can be observed in Figure 10.

Grain Weight

The analysis of variance for grain weight is shown in Table XVI. The analysis of variance indicated that variation for grain weight was significant among varieties and treatments at the .01 level. Interaction between varieties and treatments was not significant.

The means of grain weight for the varieties and for the treatments are given in Table XVII. The total means for the varieties show that Frontier 412R had the highest grain weight mean. In treatment 1 (no bags) Frontier 412R gave a mean of 72.8 g, which was the highest mean. Variation among treatments was due mostly to the strong difference between the control (treatment 1) and treatment 3 (Ambush + diazinon). Treatment 3 showed a mean grain weight of 27.65 while treatment 1 showed a mean of 63.1. Variation among other treatments was not significant, with the exception of treatments 2, 6, and 7 which had means significantly lower than other treatments. It is interesting to note that the mean

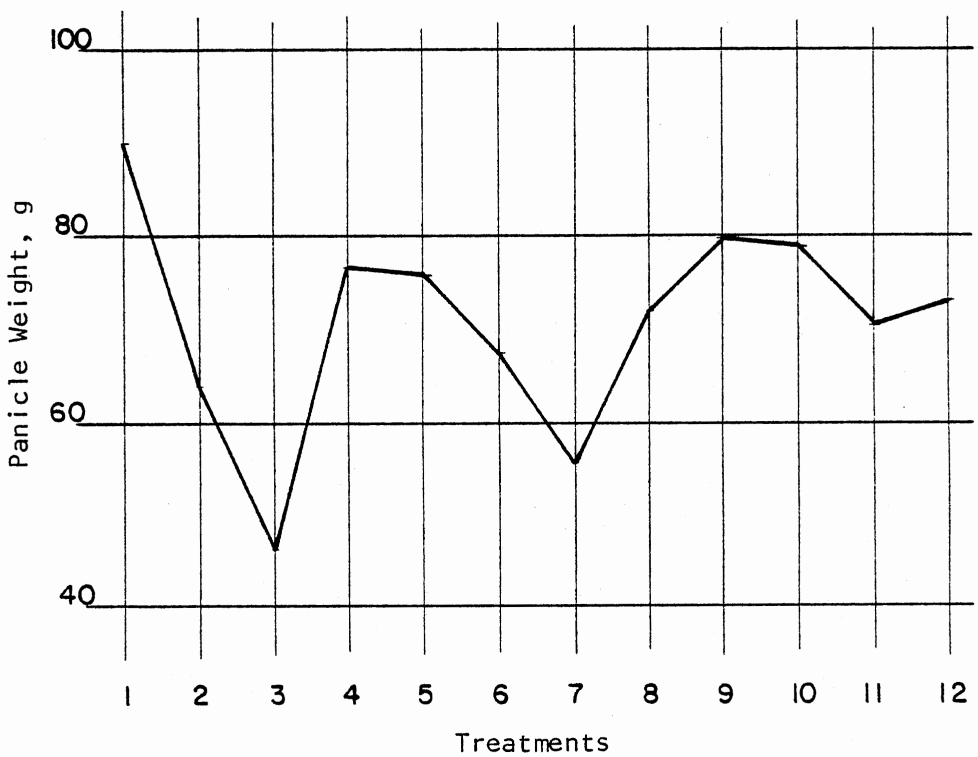

Figure 9. Distribution of Treatments for Panicle Weight

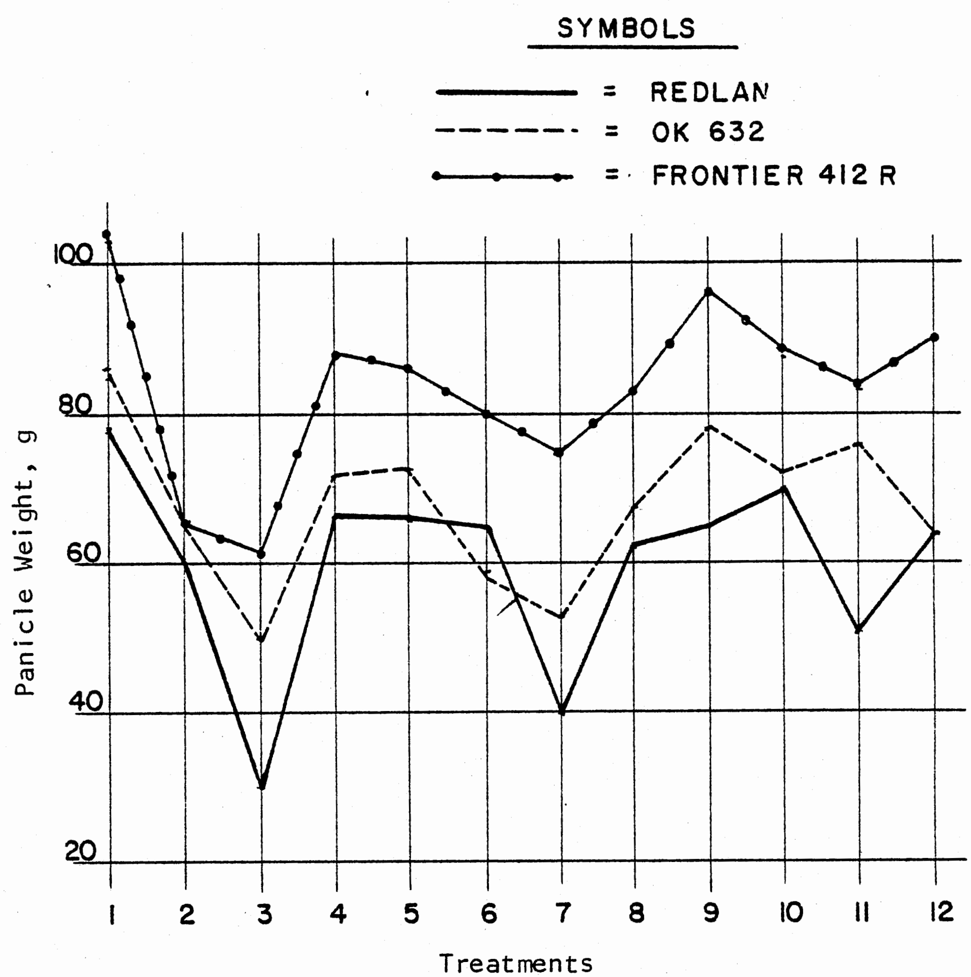

Figure 10. Distribution of Means for Varieties on Panicle Weight

TABLE XVI

ANALYSIS OF VARIANCE FOR GRAIN WEIGHT

Source	DF	MS	F-Value
Total	107		
Replication	2	81.84	1.12
Variety	2	1702.52	23.30**
Treatment	11	773.80	10.59**
Variety X Treatment	22	82.57	1.13
Error	70	73.06	

**Significant at the .01 level of significance.

TABLE XVII

MEANS FOR GRAIN WEIGHT

Treatment	Variety: Redlan	OK632	Frontier 412R	Mean	Duncan's Range
	-----------	g	-----------		
1	54.22	62.30	72.80	63.10	A[1]
9	42.10	52.00	61.12	51.73	B
4	44.60	48.37	58.62	50.52	B
10	45.77	51.20	54.32	50.42	B
5	45.57	48.92	56.77	50.41	B
8	44.22	50.62	52.47	49.10	BC
12	41.77	43.30	59.27	48.10	BC
11	31.22	54.97	52.70	46.30	BCD
6	41.80	37.27	46.47	41.83	CD
2	38.92	42.52	35.32	38.92	DE
7	22.62	33.40	46.22	34.09	EF
3	14.67	32.07	36.22	27.65	F
Mean	38.95	46.40	52.70		
Duncan's Range	C	B	A		

[1]Means with the same letter are not significant at the .05 significant level.

for treatment 9 (methomyl, day five) almost doubled the mean grain weight of treatment 3 (Ambush + diazinon). The strong difference on the level of sterility that these two treatments had can largely explain the strong difference on grain weight. Graphic representation of the variation among varieties can be observed in Figure 11, and the distribution of the means for all the treatments is given in Figure 12.

Weight of 100 Kernels

The weight of 100 kernels was expected to vary for two reasons: first, due to a phytotoxic effect causing poor development of the seeds, and second, due to difference in seed size depnding on the number of seeds per panicle. The analysis of variance presented in Table XVIII indicated significant differences among varieties and among treatments. The interaction between varieties and treatments was significant and as result, the means for each of the varieties will be presented in Tables XIX, XX, and XXI.

A great part of the significant interaction was caused by differences in variation among treatments between Redlan and the other two varieties. For treatments 2, 4, 11, and 12, Redlan showed means of 100 kernels that were substantially higher than the means of OK632 or Frontier 412R. Treatment 1 (no bags), however, indicated that Redlan had a low mean relative to the other two varieties. Frontier 412R gave the highest total mean and the variation of means among treatments for this variety was relatively low (see Table XXI). The lowest total mean for weight of 100 kernels was given by OK632. Treatment 3 (Ambush + diazinon) did not show any interaction, since all three varieties had their lowest means in this treatment. Graphic representation of the 100-kernel weight means

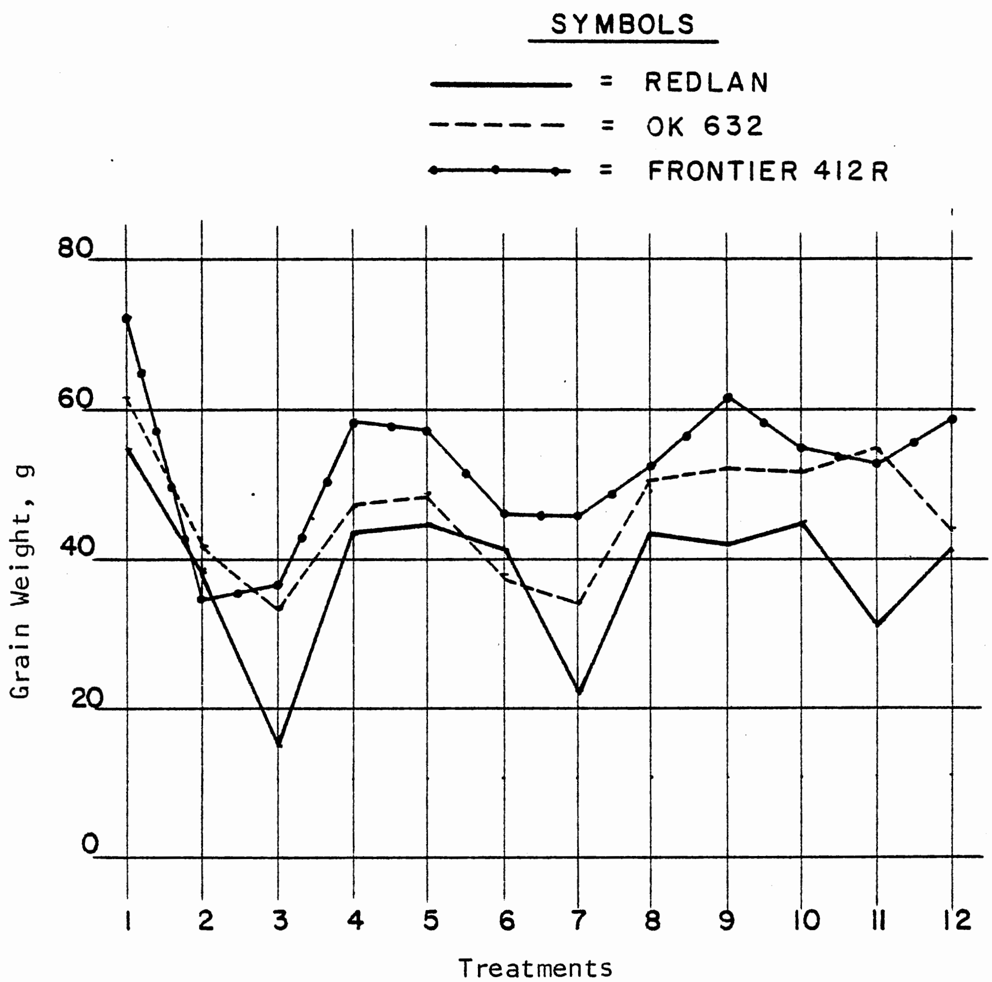

Figure 11. Distribution of Means for Varieties on Grain Weight

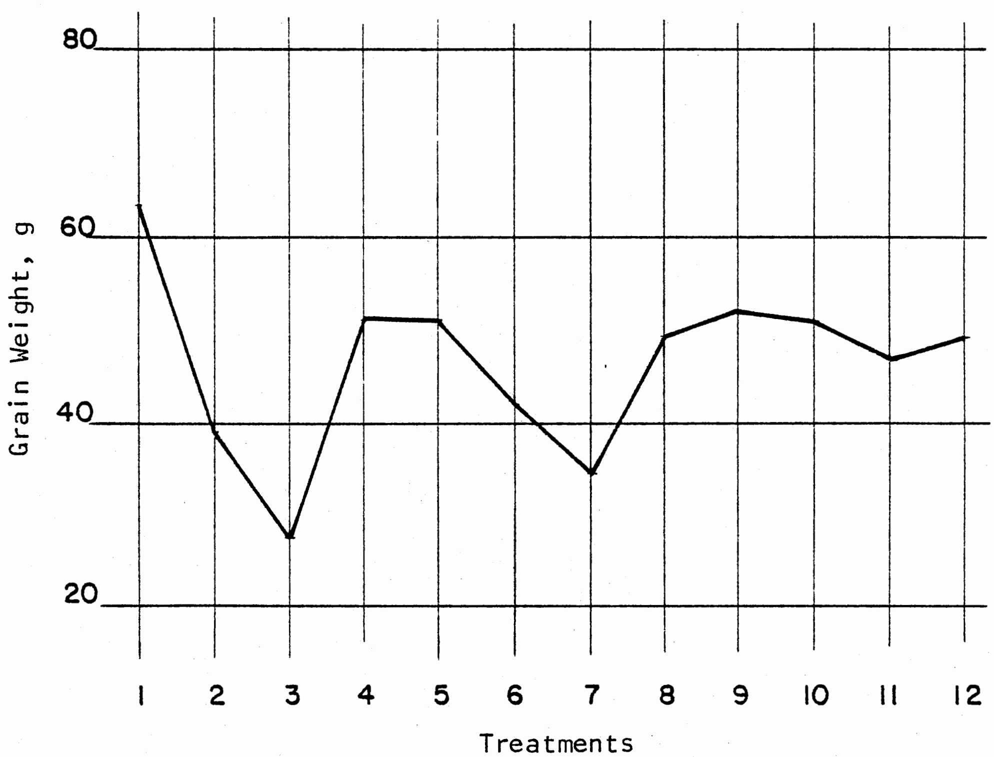

Figure 12. Distribution of Treatments for Grain Weight

TABLE XVIII

ANALYSIS OF VARIANCE FOR WEIGHT OF 100 KERNELS

Source	DF	MS	F-Value
Total	107		
Replication	2	0.13	1.45
Variety	2	1.42	15.76**
Treatment	11	0.38	4.19**
Variety X Treatment	22	0.23	2.49**
Error	70	0.09	

**Significant at the .01 level of significance.

TABLE XIX

MEANS FOR WEIGHT OF 100 KERNELS FOR VARIETY REDLAN

Treatment	Mean	Duncan's Range
	----g----	
2	3.22	A[1]
5	3.17	AB
4	3.07	ABC
12	3.00	ABCD
11	2.90	BCDE
8	2.87	CDE
6	2.77	DE
10	2.72	DE
9	2.70	E
7	2.30	F
1	2.23	F
3	1.93	G
Overall Mean	2.74	

[1]Means with the same letter are not significantly different at the .05 significance level.

TABLE XX

MEANS FOR WEIGHT OF 100 KERNELS FOR VARIETY OK632

Treatment	Mean	Duncan's Range
	----g----	
8	2.87	A[1]
1	2.83	A
9	2.82	A
11	2.77	A
5	2.47	B
6	2.47	B
10	2.40	BC
4	2.27	BCD
12	2.27	BCD
7	2.20	BCD
2	2.12	CD
3	2.07	D
Overall Mean	2.46	

[1]Means with the same letter are not significantly different at the .05 significance level.

TABLE XXI

MEANS FOR WEIGHT OF 100 KERNELS
FOR VARIETY FRONTIER 412R

Treatment	Means	Duncan's Range
	----g----	
5	3.12	A[1]
9	3.07	AB
8	3.00	ABC
7	2.97	ABCD
10	2.97	ABCD
4	2.87	ABCDE
11	2.82	BCDEF
2	2.77	CDEF
1	2.70	DEF
6	2.67	EF
12	2.67	EF
3	2.57	F
Overall Mean	2.85	

[1]Means with the same letter are not significantly different at the .05 significance level.

for all treatments is presented in Figure 13. Variation of the means for the three varieties is also graphically presented in Figure 14.

Germination

Germination percentage could be affected by heavy feeding of the corn leaf aphids, seed damage caused by the corn earworm and/or phytotoxic effects. In the literature reviewed it was concluded that low germination was found to be caused by the aphid damage. The results obtained in this test did not reject that possibility; however, since in this study there were two other factors possibly affecting germination, it was difficult to attribute the effects to any one single factor.

The analysis of variance presented in Table XXII indicated significatn differences for varieties and treatments. The interaction between varieties and treatments was found nonsignificant. Differences among the total means of germination for the three varieties indicated significant difference between Redlan and the other two varieties (see Table XXIII). Although variation among treatments was significant at the .01 level, the general means for treatments indicated that only treatment 3 was significantly different from the others.

Germination percentage for treatment 9 (methomyl day five) was not affected by the high incidence of corn leaf aphids that this treatment had. Treatment 9 differed only one percent from treatment 1 (no bags). The highest mean for germination percentage was given by treatment 1, due probably to the low insect damage and the absence of insecticides in this treatment. Treatments 10 (methomyl day ten), 2 (untreated bags), and 3 (Ambush + diazinon) had the lowest means in germination, but only

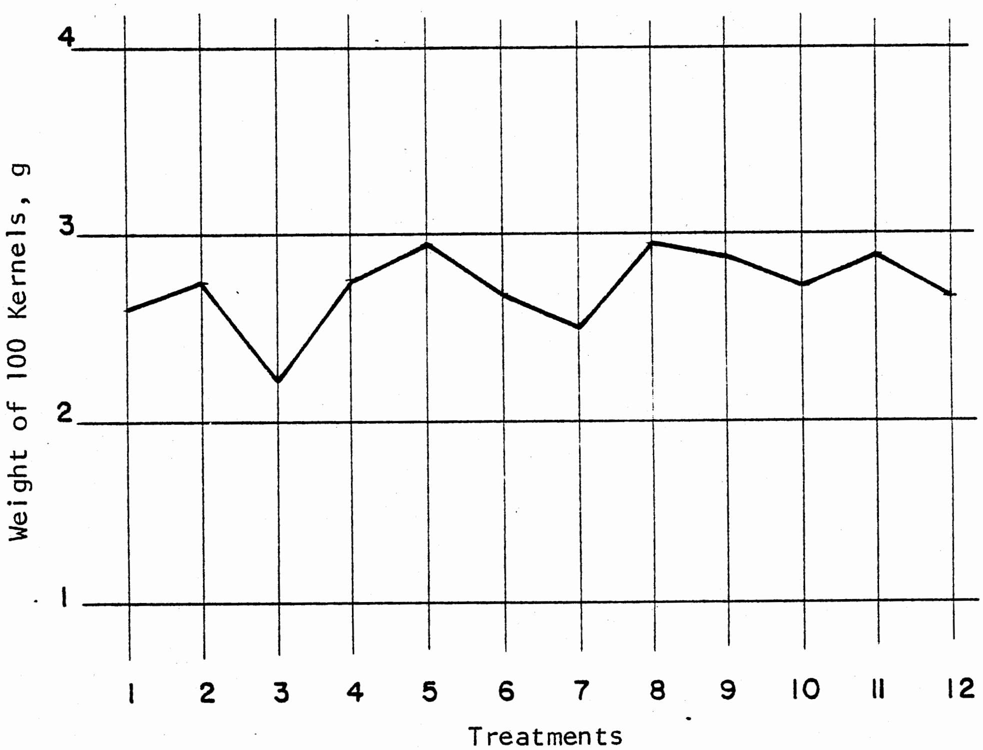

Figure 13. Distribution of Treatments for Weight of 100 Kernels

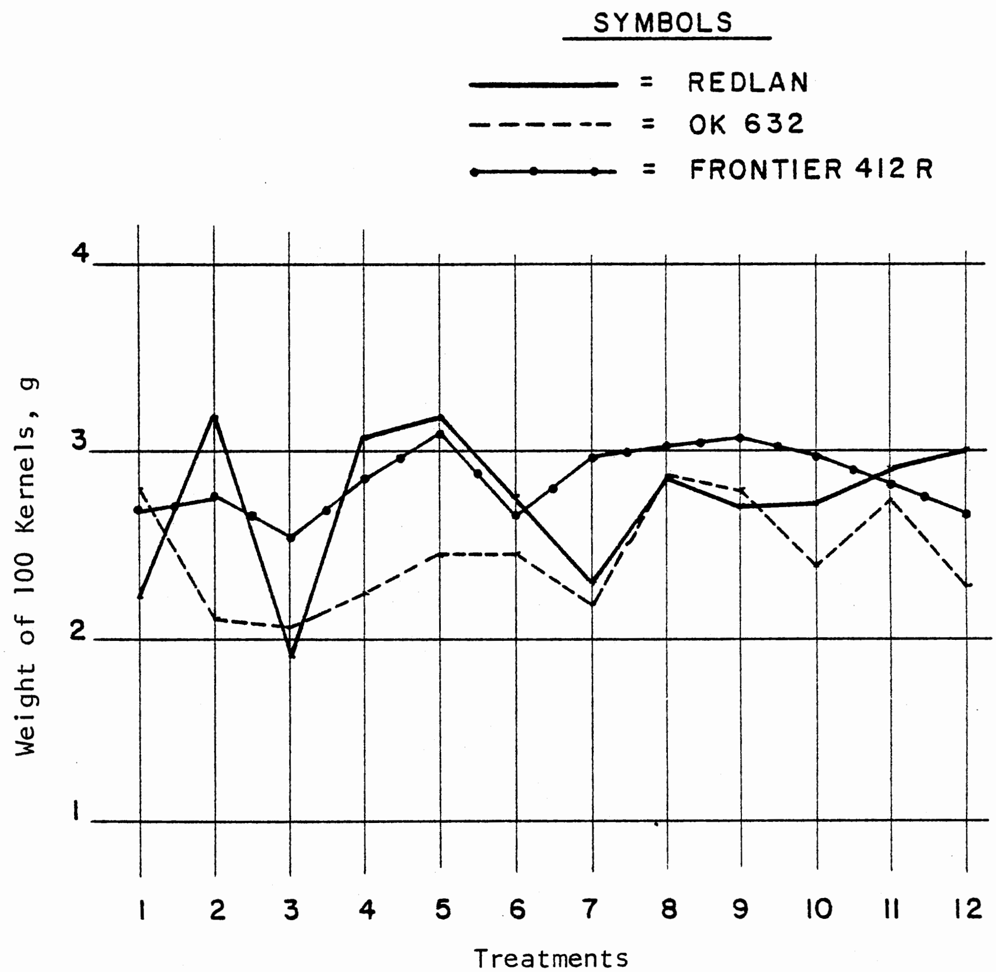

Figure 14. Distribution of Means for Varieties on Weight of 100 Kernels

TABLE XXII

ANALYSIS OF VARIANCE FOR PERCENT GERMINATION

Source	DF	MS	F-Value
Total	107		
Replication	2	0.97	0.02
Variety	2	294.76	6.09**
Treatment	11	124.87	2.58**
Variety X Treatment	12	32.91	0.68
Error	70	48.40	

**Significant at the .01 level of significance.

TABLE XXIII

MEANS FOR PERCENT GERMINATION

Treatment	Variety			Mean	Duncan's Range
	Redlan	OK632	Frontier 412R		
	----------------------	%	----------------------		
1	93.00	86.33	90.67	90.00	A[1]
9	90.33	85.67	91.67	89.22	A
4	90.67	86.67	86.67	88.00	A
5	88.33	85.67	85.00	86.33	A
6	91.00	87.00	79.33	85.78	A
8	90.00	84.33	80.00	84.78	A
7	88.33	84.33	81.33	84.67	A
11	88.67	81.67	83.33	84.55	A
12	92.33	82.00	79.00	84.44	A
10	84.33	81.00	83.00	83.00	AB
2	87.33	75.67	84.33	82.44	AB
3	73.66	73.33	80.00	75.67	B
Mean	88.17	82.80	83.75		
Duncan's Range	A	B	B		

[1]Means with the same letter are not significant at the .05 significant level.

treatment 3 differed significantly from the rest of the treatments. Low germination in treatment 3 could be caused in large part by phytotoxic effects and by the corn earworm damage; but little if any can be attributed to the aphids because this treatment (3) gave almost complete control of the aphids. Most seeds in treatment 3 were poorly developed, shriveled, and relatively small. The low germination obtained in treatment 2 (untreated bags) was due in large part to the kernel damage caused by both insects. Treatment 10 also had a high incidence of both insects and this could account for lower germination percentage. In Figure 15, the distribution of all treatment means for germination are presented. The distribution of the variety means for each treatment have been plotted in Figure 16.

Threshing Percentage

With some accuracy threshing percentage can be predicted in sorghum. In this study variation of threshing percentage caused by sterility of some panicles and/or corn earworm damage in others made it necessary to compute threshing percentage. For this calculation the average grain weight per panicle was divided by the average panicle weight for each row. The analysis of variance in Table XXIV indicated significant difference among the varieties as well as among the treatments. The interaction of varieties and treatments was not significant.

The general mean for each treatment and for each variety is given in Table XXV. Treatment 3 (Ambush + diazinon) gave the lowest mean for threshing percentage and it was significantly different from the rest of the treatments except for treatment 7 (Ambush + malathion) which also gave a low threshing percentage. Treatment 9 (methomyl day five) was

Figure 15. Distribution of Treatments for Percent Germination

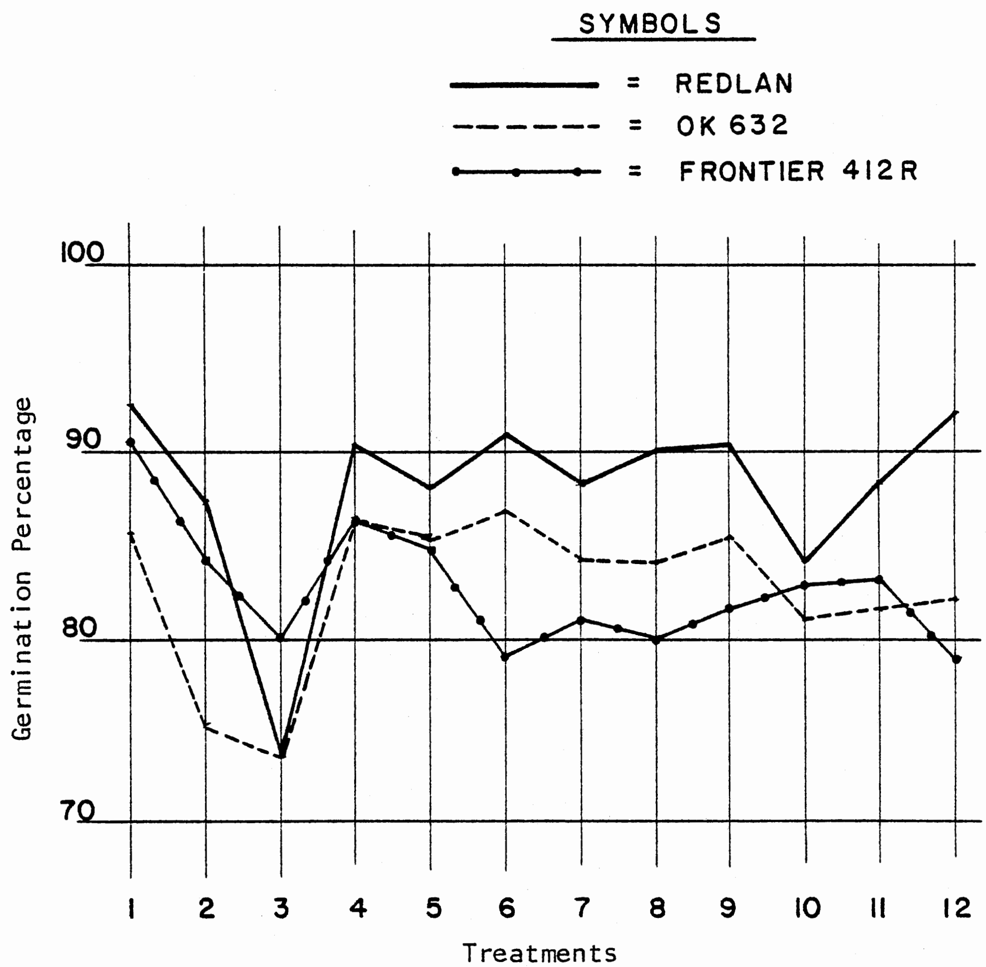

Figure 16. Distribution of Means for Varieties on Percent Germination

TABLE XXIV

ANALYSIS OF VARIANCE FOR THRESHING PERCENTAGE

Source	DF	MS	F-Value
Total	107		
Replication	2	71.18	2.72
Variety	2	234.74	8.97**
Treatment	11	143.41	5.48**
Variety X Treatment	22	35.33	1.35
Error		26.17	

**Significant at the .01 level of significance.

TABLE XXV

MEANS FOR THRESHING PERCENTAGE

Treatment	Variety: Redlan	Variety: OK632	Variety: Frontier 412R	Mean	Duncan's Range
	-------------------	%	-------------------		
1	68.83	72.03	69.89	70.25	A[1]
8	69.44	73.55	63.04	68.68	AB
5	67.55	67.43	65.26	66.75	AB
4	66.18	67.33	66.08	66.53	AB
11	62.23	72.15	62.96	65.78	ABC
12	64.77	67.11	65.34	65.74	ABC
10	65.89	66.76	61.30	64.65	BCD
9	64.07	65.91	63.67	64.55	BCD
6	62.88	63.82	58.53	61.74	CD
2	64.50	64.79	54.20	61.16	CD
7	55.95	62.93	61.65	60.18	D
3	46.24	63.06	63.06	55.82	E
Mean	63.21	67.24	62.51		
Duncan's Range	B	A	B		

[1]Means with the same letter are not significantly different at the .05 significance level.

expected to have a rather high threshing percentage because of the higher grain weight of this treatment, but it was intermediate among the treatments. The highest threshing percentage mean was given by treatment 1 (no bags), but this mean was no different from the means for treatments 4, 5, 8, 11, and 12. Graphic representation of the distribution of the means of treatments for threshing percentage is presented in Figure 17. Threshing percentage mean for each variety and each treatment is also presented in Figure 18.

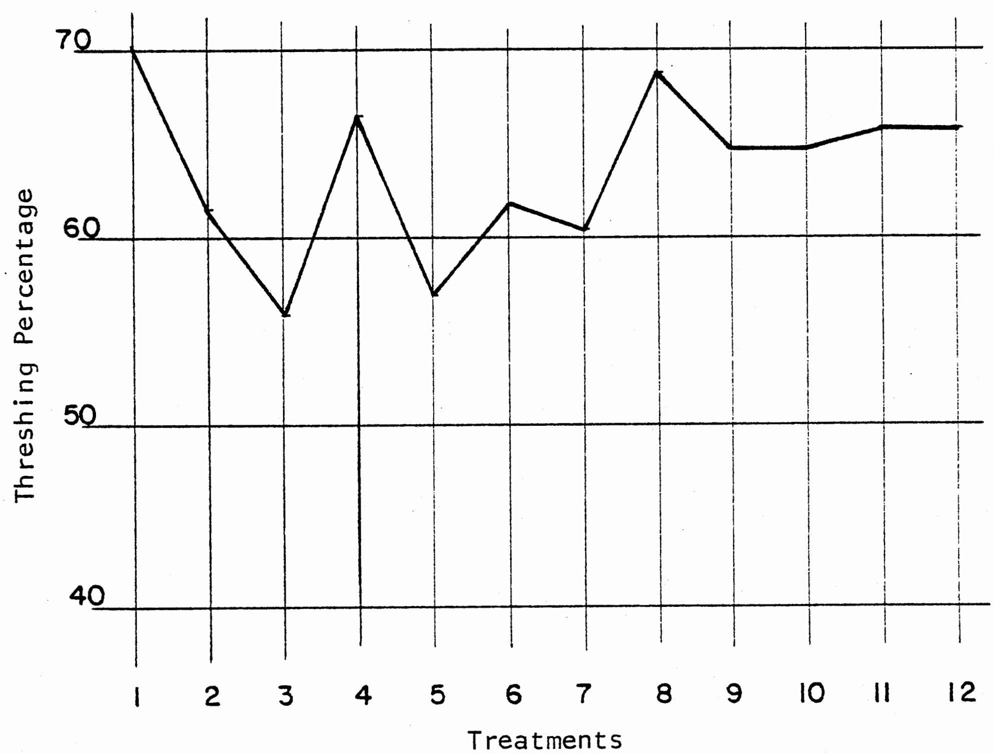

Figure 17. Distribution of Treatments for Threshing Percentage

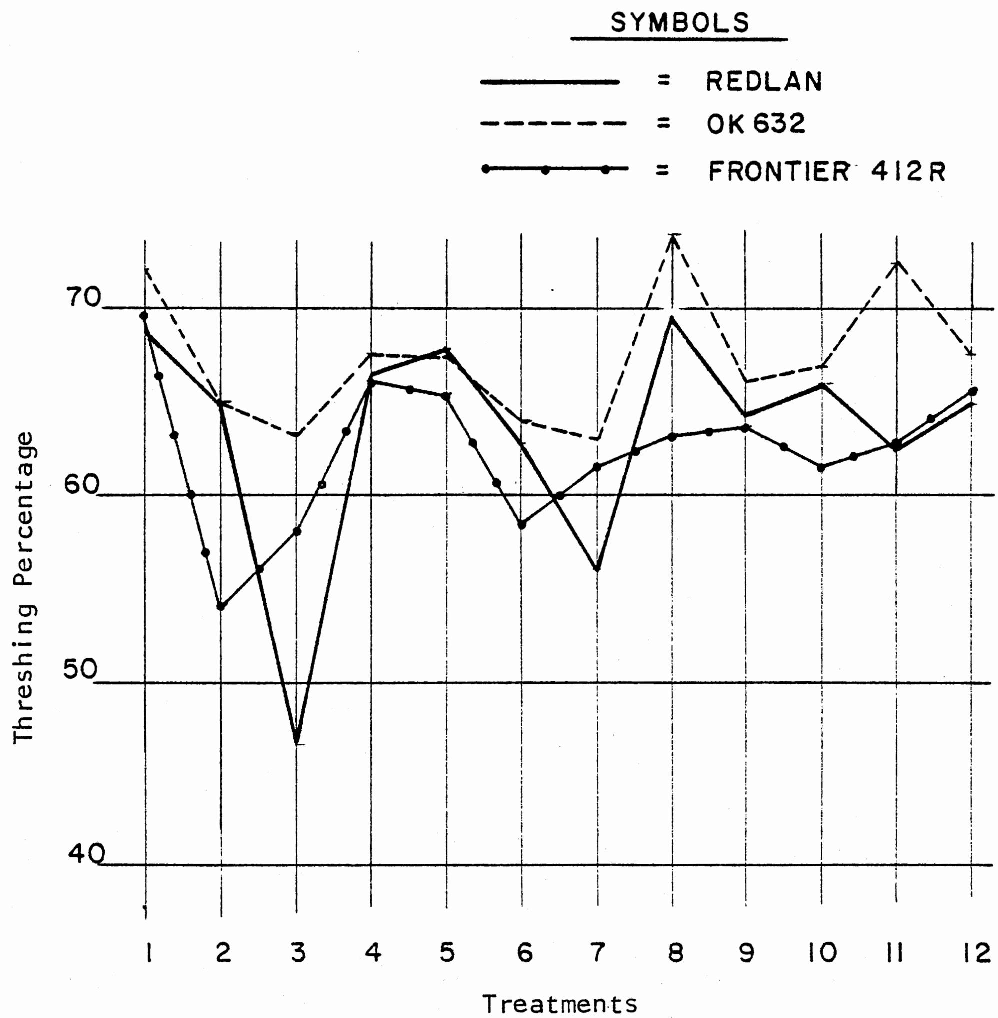

Figure 18. Distribution of Means for Varieties on Threshing Percentage

CHAPTER V

SUMMARY AND CONCLUSIONS

Seven insecticides were tested on three sorghum varieties (Redlan, OK632, and Frontier 412R) to determine their effectiveness to control corn earworm and corn leaf aphids. Possible phytotoxic effects on the bagged sorghum panicles was also investigated.

The study involved the use of 12 different treatments for each of the varieties being tested. The treatments included the application of seven insecticides, two of which were applied at different times of panicle development and two treatments which did not involve the use of any insecticides. The insecticides were applied by three different methods: dusting the insecticide in the selfing-bag, impregnating the bags with liquid insecticide, and spraying the insecticide by injecting the bags.

The experimental design for this study was a randomized complete block with three replications. Each row consisted of approximately 50 plants from which 10 panicles were randomly selected for each treatment. All the selected panicles were infested with one-day-old corn earworm larvae (7 per panicle) approximately one day before anthesis was to occur. With the exception of treatment 1 (no bags), all panicles were bagged immediately. Insecticide treatments were also done at this time with the exception of treatments 9 and 12, which were applied five days later and treatment 10, which was applied ten days later. The bags remained on the panicles until the panicles were harvested and were ready for evaluation.

Natural infestation of corn leaf aphids was high and there was also a moderate infestation of the new tiotype E of greenbug which killed one or two leaves per plant. Weather conditions were exceptionally good at the Perkins Agronomy Research Station with adequate moisture during the entire season.

After all panicles were rated for insect damage and sterility on a scale of 1 to 6, panicles were weighed and threshed. The grain was then taken to the laboratory for kernel weight and germination test. Statistical analysis of the data was then carried out using Duncan's multiple range test of means. The analysis included the following nine variables: corn earworm damage, number of holes per bag, sterility, corn leaf aphid incidence, panicle weight, grain weight, weight of 100 kernels, germination percentage, and threshing percentage.

In the analysis of variance, varieties were found to be significantly different at the .01 level for all the variables except for corn earworm damage, holes per bag, and sterility. Corn leaf aphid incidence was significantly higher for Redlan and Frontier 412R varieties than it was for OK632. This was perhaps due to the preference of the aphids for the compact type of panicle (Redlan and Frontier 412R) over the open type of panicle (OK632). Frontier 412R had the highest pancile weight and it was significantly higher than OK632. Redlan had the lowest panicle weight and it was significantly lower than OK632.

Treatments were significantly different at the .01 level of significance for all variables studied. There were only two variables (weight of 100 kernels and corn earworm damage) for which the analysis produced significant interaction of varieties X treatments.

Some insecticides produced phytotoxic effects causing sterility, poor kernel development, and low germination percentage. These effects were more evident in treatments 3 (Ambush + diazinon) and 7 (Ambush + malathion). Treatment 7 caused significantly lower sterility than treatment 3, but the sterility was still high. Germination percentage was substantially reduced in treatment 3 and it was significantly lower than treatment 7. Methomyl when applied before blooming (day zero) caused significantly higher sterility than when applied five and ten days later. Diazinon by itself (treatment 6) had low to moderate effects on sterility or germination percentage. Pirimor in combination with Dipel or Sevin (treatments 4 and 5) did not have significant toxic effects on the plants.

The best control for corn earworm damage was given by treatment 9 (methomyl, day five). Treatments 8 (methomyl, day zero) and 10 (methomyl, day ten) had higher corn earworm damage and higher number of holes per bag than treatment 9, which indicated greater larval survival in treatments 8 and 10. Methomyl gave poor control of the corn leaf aphids in all three applications; however, the aphid incidence was lower in treatment 8 (methomyl, day zero). Germination was not affected in treatment 9 regardless of the high incidence of corn leaf aphids in this treatment. Treatment 9 also had the highest grain weight after treatment 1 (no bags) which suggested that the high aphid incidence did not significantly reduce the grain yield.

Malathion provided fair control of the corn earworm and the level of control averaged practically the same for the two applications (treatment 11, day zero; treatment 12, day five). Malathion (treatment 11) gave moderate control of the corn leaf aphids, but the control was better when malathion was applied five days after the bags were put on (treatment 12).

Although nonsignificant, both malathion treatments gave grain weights that were lower than the grain weights for methomyl treatments. Pirimor in combination with Dipel or Sevin (treatments 4 and 5) gave moderate control of the corn earworm and a rather poor control of the corn leaf aphids. The control of aphids, however, was better than that of the methomyl treatments.

The best corn leaf aphid control was achieved by Ambush + diazinon (treatment 3) which had a mean for aphid incidence even lower than treatment 1 (no bags). The control became moderate when Ambush was combined with malathion rather than with diazinon. Corn earworm was moderately controlled by treatment 3, but low control was obtained when Ambush was combined with malathion (treatment 7). The grain weight means for treatments 3 and 7 were the lowest of all the treatments. Germination percentage was lower for treatment 7 and even significantly lower for treatment 3. Diazinon by itself (treatment 6) did not give good control of the corn earworm and neither did it give good control of the corn leaf aphids. The grain weight for treatment 6 was low due to insect damage plus the moderate sterility caused by the insecticide.

In all of the varieties treatment 2 (untreated bags) had a mean for insect damage (aphids and corn earworm) that was substantially higher than most others. As compared to other treatments, the higher larval survival and damage in treatment 2 correlated with the higher number of holes in the bags of this treatment. When comparing the means for grain weight, treatment 2 had a mean that was significantly higher than the means for treatments 3 and 7 which had an average of over 30 percent sterility. If we compare treatments 2, 3, and 7, there was a trade-off between insect control and sterility and the net effect was that the untreated bags had a better grain weight than those treatments with high sterility (3, 7).

There was little, if any, trade-off between insect control and sterility in treatment 9 (methomyl, day five) as far as corn earworm damage was concerned. Methomyl injected through the bags five days after the beginning of blooming gave the best control of the corn earworm, and it also had the lowest sterility among the treatments involving insecticides. From the results of the three different times of methomyl applications, it was shown that corn earworm was most susceptible to the second application (treatment 9, day five) when the larvar were six days old, and the least susceptibility was shown when the larvae were eleven days old (treatment 10, day ten). Methomyl did not control the corn leaf aphids significantly. Although the aphids did not reduce grain yield significantly, they deposited large amounts of honey-dew which interfered with threshing and proper storage. Further studies to control corn leaf aphids with methomyl at different dosages and/or in combination with other insecticides will be needed.

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