STUDIES INTO THE CONTROL OF THE SQUASH BUG ANASA TRISTIS DEGEER

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SQUASH BUG ANASA TRISTIS DEGEER

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PREFACE

This dissertation is presented in four parts. Chapter I provides a general introduction to the squash bug and its importance in Oklahoma squash production. Chapter II, entitled "Field Test for Screening Insecticides Against the Squash Bug, Anasa tristis," was designed to evaluate five different insecticides for their control of various life stages of A. tristis. Chapter III, "Bioassay of Three Insecticides on Six Life Stages of the Squash Bug," was undertaken to further investigate the toxicity of three insecticides that showed promise for controlling the squash bugs in Chapter II. The final division is Chapter IV, "Evaluations of Carbofuran in the Greenhouse and the Field for Control of the Squash Bug," which was designed to evaluate a systemic insecticide for controlling the nymphal and adult life stages of the squash bug. These three studies are an attempt to answer some of the questions relating to squash bug control failures.

These investigations would not have been completed without the assistance and guidance from many people. I would like to express my sincere appreciation to Dr. W. Scott Fargo for his guidance, assistance, understanding, and patience through this study. Dr. Ronald McNew provided his

time and expertise on statistical analyses and my gratitude is expressed for his efforts. Special appreciation is directed toward Mr. Andronikos Mauromoustakos who greatly assisted me in the analyses of the data.

Drs. James Motes and William Drew reviewed the manuscript and made valuable comments and encouragements for its completion.

The field and laboratory work could not have been completed without the assistance of Mr. Edmond Bonjour and Mr. Chris Ball who took time from their other duties to help.

Mr. and Mrs. Glenn Selk's friendship and encouragement greatly helped and was truly appreciated.

Most of all I would like to express special thanks and appreciation to my wife, Angela, for her patience, endurance, encouragement, and support over the years.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The squash bug, Anasa tristis DeGeer, has been a problem in pumpkin and squash (both summer and winter varieties) production since 1892 (Hoerner 1938). Bonjour & Fargo (1987) reported a significant preference for Cucurbita pepo type cucurbits by the squash bug. Muskmelon, watermelon, and cucumber are less preferred, possibly because these cucurbits are not native to the Western Hemisphere and were introduced by explorers (Whitaker & Davis 1962). The distribution of the squash bug corresponds to the areas where its hosts are grown. There are some exceptions, however, as squash bugs are not a problem in the Rio Grande Valley of Texas (Cartwright, personnel communication). Reports of inadequate control are numerous and well documented [Eichmann (1945), Harries & Matsumori (1955), Wright & Decker (1955), Beevers & Santoro (1985)].

Cucurbit production in Oklahoma is expected to increase from the present 10,500 acres valued at $9,000,000 to 16,000 acres with a value of $17,200,00 in less than 20 years (Tweeten 1982). Control of the crop's major insect pest is essential for expansion of the commodity. Due to the

potential for crop expansion and the erratic efficacy of insecticides, a field study was undertaken to identify foliar applied insecticides for control of the squash bugs. Topical and contact bioassay's were preformed on the most promising insecticides from the field study in an effort to identify the most susceptible life stages of the squash bug. Investigation into the use of a systemic insecticide for control of squash bug life stages was also undertaken.

CHAPTER II

FIELD TEST FOR SCREENING INSECTICIDES AGAINST THE SQUASH BUG, *ANASA TRISTIS*

Introduction

Early control suggestions for *A. tristis* included hand picking, overseeding, planting early, row covers and providing protective netting over seedlings [(Conradi 1901, Wadley 1920, Knowlton 1933, Hoerner 1938)]. Hoerner (1938) reported that flushing with a 2 - 3% kerosene solution aided the hand picking process. Horner also suggested placing boards in the fields under which the bugs would seek shelter during the night. During the cool part of the next day the bugs could be collected from under the boards and destroyed.

Chemical control began with nicotine sulfate, calcium cyanide and pyrethrins. These products provided varying degrees of control but as a rule, control decreased with increasing maturity of the squash bug (Knowlton 1933, Elliot 1935, Moore 1936, Hoerner 1938, Eichmann 1945).

A number of insecticides were developed after 1945 due to advances in technology during World War II. Among them, the chlorinated hydrocarbons (DDT, aldrin, dieldrin, and lindane) appeared as possible controls; however, DDT was

only effective on first to third instar nymphs (Walton 1946 and Watkins 1946). Walton (1946), reported good control from a field test with caged plants using a 10% sabadilla dust for first instar through adult stages. In the same study, a 5% DDT dust provided good control (96% mortality) for first through third instar but not for older stages (<60% mortality). Walton conducted a similar test in the laboratory with a 10% sabadilla dust and a 10% DDT dust which, after eight days, provided 86% and 82% mortality respectively. Insecticide tests by Harries & Matsumori (1955) and Wright & Decker (1955) indicated dieldrin would provide long term control of adults, while dust of malathion and parathion would provide short term control. Wright & Decker (1955) reported parathion was the most toxic topically applied insecticide to squash bugs in laboratory tests. Some present day insecticides, much like older chemicals, work well against young nymphs, while others work well against adults. Recent studies indicated that control of nymphs and adults may be achieved with acephate, methomyl, cypermethrin, permethrin, or fenvalerate (Latheef & Ortiz 1982 and Beevers & Santoro 1985).

Elliot (1935) and Eichmann (1945) stated the key to chemical control was to concentrate on protecting seedlings and begin insecticide treatments when insect egg hatch commences. This scheduling permits the insecticide to be applied to the most susceptible squash bug life stages at a time when the population is at its lowest. Rensner et al.

(1987) indicated that two periods may exist which would permit this synchronization of treatment with large numbers of immature squash bugs. The first period is early in the season before the first generation adults begin oviposition. The second period occurs when the second generation nymphs become plentiful. Watkins (1946) demonstrated the theory of spraying at egg hatch and stated, "The materials which showed considerable toxicity to newly hatched nymphs were also tested against nymphs at least 21 days old, and it was at this point that nearly all the sprays proved ineffective at concentrations safe to foliage and sufficiently cheap to be used commercially." The 21 day old nymphs would have been third to fifth instars and depending on the rate of development, probably fourth or fifth instars. The insecticides referred to are pyrethrins, rotenone, rotenone + pyrethrins, light petroleum oil, mannitan monolaurate + pyrethrins, and DDT in an oil base. Many early researchers stated the same theory as Elliot (1935) and Eichmann (1945) and added that a long residual insecticide was needed to reduce the number of sprays necessary for complete control (Weed & Conradi 1902, Knowlton 1933, Hoerner 1938, and Watkins 1946).

Materials and Methods

Five insecticides (carbaryl 80S, cypermethrin 2.5E, endosulfan 3E, fenvalerate 2.4E, and methomyl 1.8E) were efficacy tested against the various squash bug life stages.

Rates for these treatments were: cypermethrin (45.3 and 67.9 g [AI]/ha), carbaryl (1131.3 g [AI]/ha), endosulfan (1131.3 g [AI]/ha), fenvalerate (226.3 g [AI]/ha) and methomyl (1018.9 g [AI]/ha). All insecticides were applied with a CO_2 sprayer delivering 475 liters of water per hectare. A non-treated control was included. `Hyrific' yellow straight neck squash (Cucurbita pepo L. var. melopepo) was planted on June 14, 1984, at the Horticultural Research Station, Perkins, Okla. The design was a randomized complete block replicated three times. Each block had seven rows with a total of 49 plants in the block. A row constituted a plot and a treatment was randomly assigned to a plot within a block. A row spacing of 1.5m between rows and 0.9m in the row constituted a plot. Early in the study each individual plant (21 plants per treatment) was inspected for the presence of squash bugs and egg masses. When the squash bug population became too large to permit inspection of all 147 plants, two plants per plot were randomly selected and inspected (6 plants per treatment). Insecticide applications were made when sufficient squash bug numbers appeared. Applications were made on July 11, 14, 21, 25, 30, August 6, 9, 13, and 15. Data was taken before and after each insecticide application (experimental period). Data recorded for each plant were the number in each of the five nymphal instars, males, females, and egg masses present. Fruit was harvested and weighed using the same criteria as Rensner et al. (1987).

A statistical analysis of the data was conducted to determine if differences exist among individual treatments with regard to total squash bug numbers, total adults, total nymphs, total squash bugs minus first instars, total nymphs minus first instars, and total egg masses. Analyses were also conducted to determine if differences in yield occurred between insecticide treatments.

The change between the pretreatment (before) and post treatment (after) counts for each experimental period was analyzed using analysis of variance (SAS Institute 1985).

Due to a large amount of variation, the data was transformed. Data transformation was performed by taking the natural logarithm of the count + one for each variable recorded. Due to spray by treatment interaction, treatment comparisons were made by experimental period. An ANOVA was conducted on the mean transformed before treatment value minus the transformed after treatment value for total nymphs, total squash bugs, total adults, total nymphs minus first instar nymphs, total squash bugs minus first instar nymphs, and total egg masses. Means were separated using least significant difference (LSD) at a probability of 0.10. The mean square error and approximate degrees of freedom for the LSD were calculated by pooling the main unit (treatment) and subunit (experimental period) errors in an ordinary split-plot design (Steel & Torrie, 1980). Since the first four experimental periods had seven samples per treatment (a total of 21 per plot) and the last five experimental periods

had two samples per treatment (a total of six per plot), a the LSD was calculated based on a pooled MSE with 21 degrees of freedom (df) for the first four experimental periods and six df for the last five experimental periods (Satterthwaite's approximation). The LSD's were calculated for: total nymphs, total squash bugs, total adults, total nymphs minus first instars, total squash bugs minus first instars, and total egg masses.

Mature fruits were harvested and weighed. The yield data was analyzed using general linear models (SAS Institute 1985).

Results and Discussion

Analyses results for the non-transformed, before treatment counts are presented in Tables I through VI. Table I presents the mean number of total nymphs present during each experimental period. Means for the cypermethrins and fenvalerate were significantly different from the means for carbaryl and the check for most experimental periods. Fenvalerate and methomyl means were generally lower than those of carbaryl and the check. However, means for fenvalerate and methomyl were not always significantly different from the means for carbaryl or the check. Carbaryl's mean often was larger than that of the check for a given experimental period. Means for endosulfan were less than the means for carbaryl or the check, but

TABLE I

BEFORE TREATMENT MEANS FOR TOTAL SQUASH BUG NYMPHS

Treatment	Rate g AI/ha	Experimental Period[1] 1	2	3	4	5	6	7	8	9
Check	----	0.5	0.7	1.1ab	4.1ab	13.5	44.0a	62.1a	73.0ab	90.3a
Carbaryl	1131.3	1.8	1.1	2.5ab	4.1ab	5.8	30.3ab	48.5ab	88.6a	83.3a
Endosulfan	1131.3	0.5	1.0	3.4a	7.0a	7.1	28.8ab	38.0abc	41.6bc	45.0b
Methomyl	1018.9	2.6	0.9	0.9ab	0.8b	11.3	17.3bc	16.0bc	30.5c	15.1bc
Fenvalerate	226.3	3.0	1.7	0.0b	1.7b	11.8	6.3c	18.0bc	12.3c	14.3bc
Cypermethrin	45.3	0.6	1.2	0.0b	0.0b	0.1	4.0c	11.5bc	20.3c	3.3c
Cypermethrin	67.9	2.3	0.2	0.0b	0.6b	3.1	4.1c	9.5c	22.5c	15.1bc

[1]Means within columns followed by the same letter are not significantly different (P=0.05;Duncan's [1955] multiple range test).

greater than those of methomyl or either pyrethroid for a given experimental period.

Total squash bug means are presented in Table II and the same trend holds as for nymphs. Cypermethrin and fenvalerate means had the lowest number of total squash bugs present while carbaryl and the check had the highest number present. Means for methomyl tended to be greater than those for the pyrethroids, but less than carbaryl, the check, or endosulfan means.

Methomyl, fenvalerate, and the cypermethrin applications tended to reduce the number of adults present (Table III). Carbaryl and endosulfan did not reduce the number of adults present per experimental period and often had more adults present that the check. Although, there was often an overlap of significant differences, the pyrethroid insecticides had fewer adults present per experimental period than the check or plots treated with carbaryl or endosulfan.

The results of removing first instars was quite evident for the pyrethroid's and methomyl (Table IV and V). With the first instar nymphs removed from the counts, the means for total nymphs per experimental period (Table IV) remained very low for methomyl, fenvalerate, and the cypermethrins'. The mean number of nymphs present for a particular experimental period remained low for the pyrethroids and relative low for methomyl compared to the mean number of nymphs present for the check, carbaryl, and endosulfan. The

TABLE II

BEFORE TREATMENT MEANS FOR TOTAL SQUASH BUGS

Treatment	Rate g AI/ha	Experimental Period[1] 1	2	3	4	5	6	7	8	9
Check	----	0.5	1.0	2.2ab	6.4ab	20.5	57.3a	76.0a	90.5ab	104.5a
Carbaryl	1131.3	1.9	1.3	2.9ab	5.4abc	11.5	46.5a	59.6ab	109.8a	96.8a
Endosulfan	1131.3	0.7	1.3	4.3a	9.1a	13.0	43.0ab	51.6abc	53.1bc	51.6b
Methomyl	1018.9	2.6	1.2	1.3ab	1.8bcd	18.8	25.8bc	24.3bc	40.3c	19.5bc
Fenvalerate	226.3	3.0	1.7	0.1b	2.3bcd	13.1	11.8c	25.8bc	23.7c	20.3bc
Cypermethrin	45.3	0.6	1.4	0.1b	0.4d	0.6	8.5c	17.5bc	26.0c	4.8c
Cypermethrin	67.9	2.3	0.2	0.1b	1.0cd	5.6	10.6c	11.6c	27.6c	17.5bc

[1]Means within columns followed by the same letter are not significantly different (P=0.05;Duncan's [1955] multiple range test).

TABLE III

BEFORE TREATMENT MEANS FOR ADULT SQUASH BUGS

Treatment	Rate g AI/ha	Experimental Period[1] 1	2	3	4	5	6	7	8	9
Check	----	0.00	0.23	1.0a	2.3	7.0	13.3	13.8a	17.5ab	14.1a
Carbaryl	1131.3	0.09	0.23	0.3bc	1.2	5.6	16.1	11.1ab	21.1a	13.0a
Endosulfan	1131.3	0.14	0.38	0.8ab	2.1	5.8	14.1	13.6a	11.5abc	6.6ab
Methomyl	1018.9	0.04	0.28	0.4abc	1.0	7.5	8.5	8.3ab	9.8bc	4.3ab
Fenvalerate	226.3	0.00	0.00	0.1c	0.6	1.3	5.5	7.8ab	10.8bc	6.0ab
Cypermethrin	45.3	0.00	0.14	0.09c	0.4	0.5	4.5	6.0ab	5.6c	1.5b
Cypermethrin	67.9	0.00	0.04	0.04c	0.4	2.5	6.5	2.1b	5.1c	2.3ab

[1]Means within columns followed by the same letter are not significantly different (P=0.05;Duncan's [1955] multiple range test).

TABLE IV

BEFORE TREATMENT MEANS FOR TOTAL SQUASH BUG NYMPHS MINUS FIRST INSTARS

Treatment	Rate g AI/ha	Experimental Period[1] 1	2	3	4	5	6	7	8	9
Check	----	0.5	0.6	1.1	2.0ab	5.3a	23.5a	33.1a	50.5a	60.5a
Carbaryl	1131.3	0.3	1.1	1.6	1.9ab	1.0b	11.6bc	16.8b	30.1b	31.6b
Endosulfan	1131.3	0.4	0.6	1.5	3.6a	0.1b	14.0b	13.5b	20.5bc	24.3b
Methomyl	1018.9	1.1	0.9	0.3	0.09b	0.0b	3.5cd	2.8b	5.8cd	4.1c
Fenvalerate	226.3	0.7	0.8	0.04	0.04b	0.0b	0.3d	2.0b	0.5d	2.6c
Cypermethrin	45.3	0.5	0.1	0.04	0.0b	0.1b	0.0d	0.0b	2.3cd	0.0c
Cypermethrin	67.9	0.6	0.0	0.09	0.04b	0.3b	0.0d	3.0b	0.0d	0.0c

[1]Means within columns followed by the same letter are not significantly different (P=0.05;Duncan's [1955] multiple range test).

check consistently had more squash bug nymphs present per experimental period and was significantly different from the other treatments on experimental periods five through nine.

The mean number of total squash bugs minus first instar nymphs per experimental period are presented in Table V. Means for the check were larger and were significantly different from the mean number of squash bugs present for the cypermethrin's on experimental periods three, four, six, seven, eight, and nine. Means for fenvalerate tended to be lower than the means for carbaryl, endosulfan, or methomyl. However, means for these treatments often did not differ significantly.

The means for total egg masses per experimental period are presented in Table VI. Carbaryl and endosulfan means for experimental periods seven through nine were larger than the check's, however, the differences were not significant. Means for methomyl and cypermethrin (67.5 g [AI]/ha) were significantly different from the mean for carbaryl, but not for the check for most of the experimental periods. Fenvalerate means tended to be higher than those for methomyl or the cypermethrin's, and often did not differ from the means for either the check, endosulfan, or the cypermethrin's.

The squash bug population for all measurements increased throughout the duration of the test. Populations were low and significant differences were not declared for variable means during the early portion of the test. The

TABLE V

BEFORE TREATMENT MEANS FOR TOTAL SQUASH BUGS MINUS FIRST INSTARS

Treatment	Rate g AI/ha	Experimental Period[1] 1	2	3	4	5	6	7	8	9
Check	----	0.5	0.9	2.2a	4.3ab	12.3a	36.8a	47.0a	68.0a	74.6a
Carbaryl	1131.3	0.4	1.3	1.9b	3.1abc	6.6ab	27.8a	28.0b	51.3ab	44.6b
Endosulfan	1131.3	0.5	1.0	2.4a	5.7a	6.0ab	28.1a	27.1b	32.0bc	31.0bc
Methomyl	1018.9	1.1	1.2	0.7ab	1.0abc	7.5ab	12.0b	11.1bc	15.6c	8.5cd
Fenvalerate	226.3	0.7	0.8	0.1b	0.6bc	1.3ab	5.8b	9.8bc	11.3c	8.6cd
Cypermethrin	45.3	0.5	0.3	0.1b	0.4c	0.6b	4.5b	6.0c	8.0c	1.5d
Cypermethrin	67.9	0.6	0.04	0.1b	0.5c	2.8ab	6.5b	5.1c	5.1c	2.3d

[1]Means within columns followed by the same letter are not significantly different (P=0.05;Duncan's [1955] multiple range test).

TABLE VI

BEFORE TREATMENT MEANS FOR TOTAL EGG MASSES

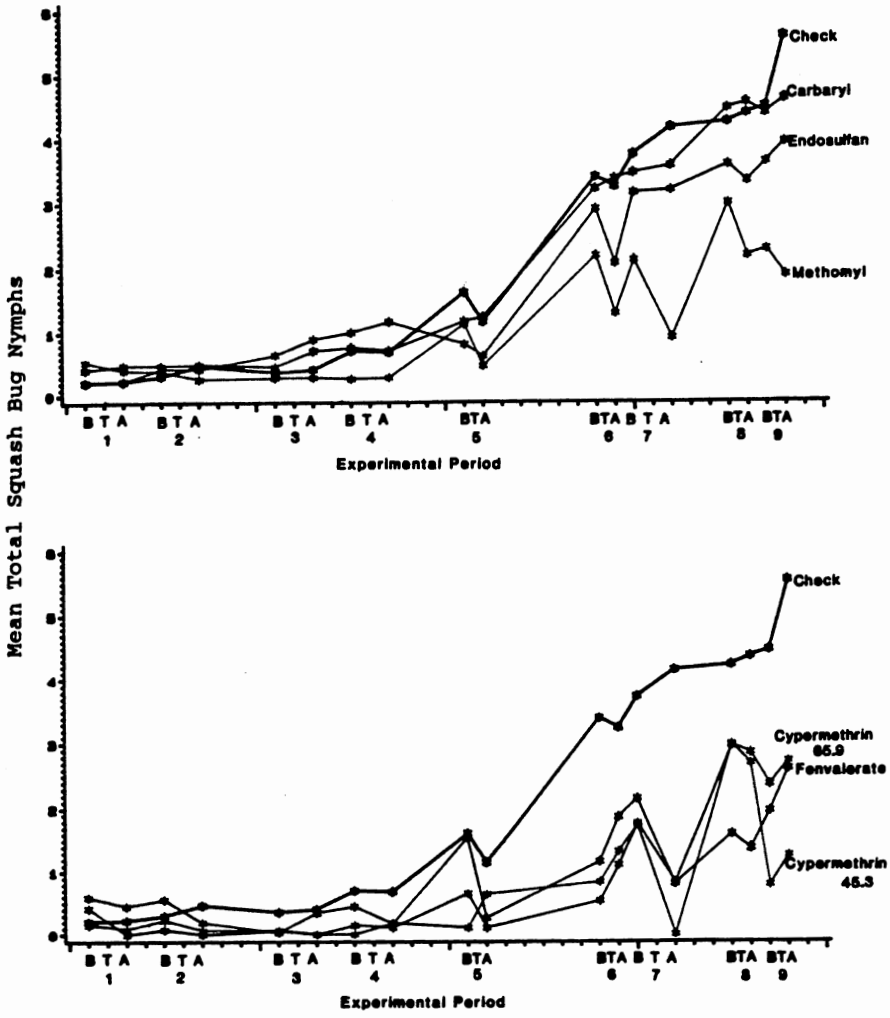
Treatment	Rate g AI/ha	Experimental Period[1] 1	2	3	4	5	6	7	8	9
Check	----	0.4	0.04	0.9bc	2.3ab	5.3	27.3a	29.3ab	38.3ab	37.5ab
Carbaryl	1131.3	0.1	0.3	1.3ab	2.4ab	6.8	28.1a	39.0a	43.0a	45.5a
Endosulfan	1131.3	0.1	0.4	2.1a	3.4a	5.8	23.3b	35.0a	36.6ab	48.6a
Methomyl	1018.9	0.3	0.5	0.7bc	1.6bc	5.0	11.1b	15.8b	19.8b	21.0b
Fenvalerate	226.3	0.4	0.5	0.7bc	1.5bc	3.6	12.1b	16.6b	25.1ab	27.1ab
Cypermethrin	45.3	0.04	0.04	0.2c	0.6c	3.0	14.5ab	19.5ab	18.1b	19.0b
Cypermethrin	67.9	0.2	0.2	0.1c	1.0bc	1.6	11.5b	17.3b	18.8b	18.0b

[1]Means within columns followed by the same letter are not significantly different (P=0.05;Duncan's [1955] multiple range test).

trend was for no significant differences to be declare on the first two or three experimental periods, then significance being declared with two to three clusters existing during the later portion of the test. The check and carbaryl treatments tended to have the largest number of squash bug life stage(s) present on any given experimental period. Means for the cypermethrin plots tended to be significantly different from the means for the check and carbaryl for every variable. Fenvalerate means were intermediate, being significantly different from the check and carbaryl means, but not from the means for methomyl, cypermethrin's and occasionally endosulfan over the experimental periods for each variable. The means for methomyl, generally, were not significantly different from those for endosulfan, fenvalerate, or the cypermethrins.

Figure 1 represents the experimental results for total nymphal counts. The comparisons are the response of the transformed after treatment count to the before treatment count. If the after count increases, it means that there were more insects after a treatment than before. If the count decreases, there were fewer insects present than before treatment. We are assuming migration and natural mortality were equal between plants and plots. As seen in Fig. 1, there is a steady increase in numbers of nymphs in the check and all treatment plots over time, however, the increase is less for insects treated with methomyl, fenvalerate, and both rates of cypermethrin. In the first

Figure 1. Log Means For Total Squash Bug Nymphs Per Experimental Period. Perkins, Okla. 1984. B=before treatment; T=treatment; A=after treatment


Mean Total Squash Bug Nymphs
Check
Carbaryl
Endosulfan
Methomyl
B T A 1
B T A 2
B T A 3
B T A 4
BTA 5
BTA 6
B T A 7
BTA 8
BTA 9
Experimental Period
Check
Cypermethrin 95.9
Fenvalerate
Cypermethrin 45.3
B T A 1
B T A 2
B T A 3
B T A 4
BTA 5
BTA 6
B T A 7
BTA 8
BTA 9
Experimental Period

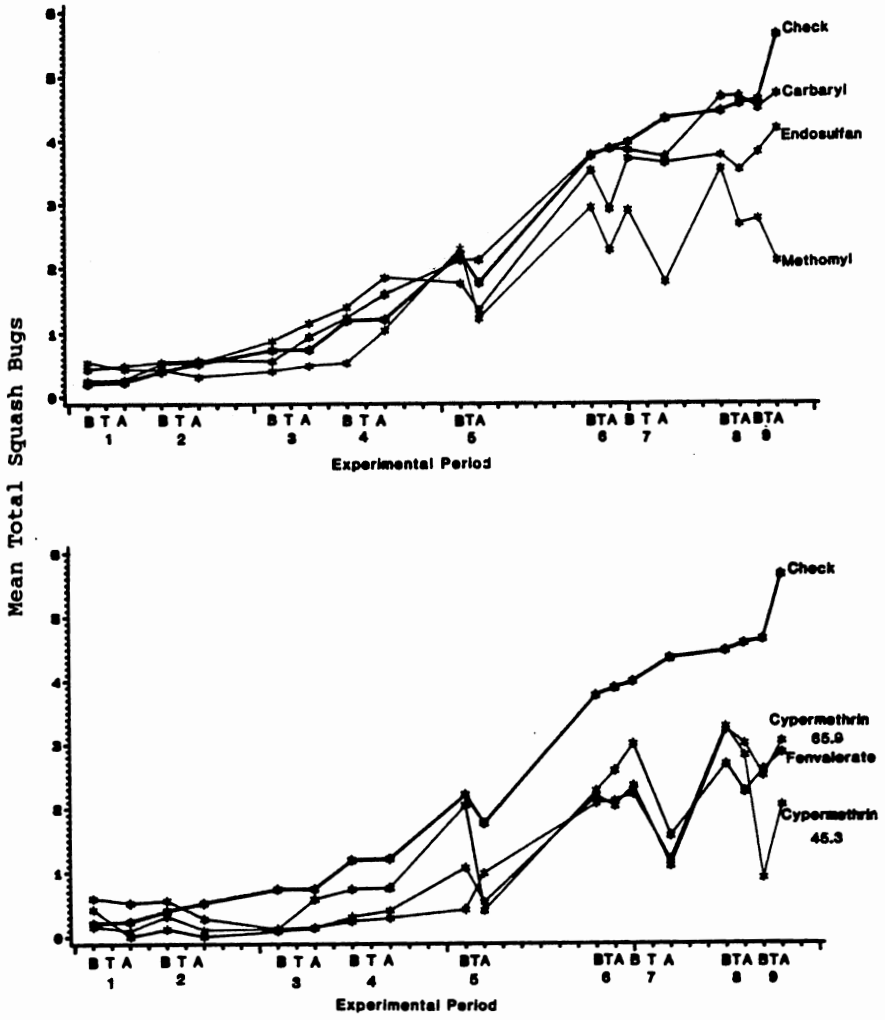
experimental period, carbaryl, the check, endosulfan, and cypermethrin (45.3 g [AI]/ha) responses were significantly different from that of cypermethrin (67.9 g [AI]/ha). Responses to methomyl and fenvalerate were not significantly different from either group. For the second experimental period, fenvalerate's response was significantly different from those of the check, carbaryl, and endosulfan. Cypermethrin (45.3 g [AI]/ha) and methomyl effects were not significant from either group, while cypermethrin (67.9 g [AI]/ha) was significant from the check. Responses for the two cypermethrin treatments were significantly different from fenvalerate on the third experimental period; however, carbaryl, the check, and endosulfan responses did not differ significantly from either fenvalerate or the cypermethrins. This means that the counts changed in the check plot about the same as in the other plots. During the fourth experimental period fenvalerate's change was significantly different from cypermethrin's (45.3 g [AI]/ha) and endosulfan's. The responses for the check, carbaryl, cypermethrin (67.9 g [AI]/ha), and carbaryl were not significantly different from the rest of the treatments. The response for carbaryl and cypermethrin (45.3 g [AI]/ha) were significantly different than responses for fenvalerate for the fifth experimental period. Cypermethrin (67.9 g [AI]/ha), methomyl, endosulfan, and the check were not significantly different from cypermethrin (45.3 g [AI]/ha), carbaryl, or fenvalerate. Carbaryl did not differ

significantly from endosulfan or the check, while cypermethrin (67.9 g [AI]/ha) did differ. By the fifth experimental period the trend lines began to separate. Methomyl, cypermethrin (67.9 g [AI]/ha), and fenvalerate each had large decreases from the before to the after treatment count. For the sixth experimental period, endosulfan and methomyl differed significantly from fenvalerate and both cypermethrins in their responses. Responses for carbaryl and the check were not significantly different from the other treatments. Methomyl began to separate from the check, carbaryl, and endosulfan populations on the seventh experimental interval. The LSD for the rate of change between before and after treatment counts for this date placed the check, carbaryl, and endosulfan together. Carbaryl and endosulfan responses were not significantly different from cypermethrin's (67.9 g [AI]/ha) response, but the check differed from the responses of all other treatments. Carbaryl, endosulfan, and the check were the only treatments which did not show an insect decrease during this experimental period. The responses of cypermethrin (45.3 g [AI]/ha), cypermethrin (67.9 g [AI]/ha), fenvalerate, and methomyl were not significantly different. Experimental period eight showed no significant differences between treatment responses. On the final experimental period methomyl's response was significantly different from the check's, while the check's response and the other treatment responses did not differ significantly.

Methomyl was the only treatment to show a decrease from the before treatment counts for this experimental period.

Figure 2 shows the changes from before and after treatment counts for all squash bug life stages, excluding eggs. Again, the trend is for the insect populations on the pyrethroid (fenvalerate and cypermethrin) and methomyl treated plots to increase at a slower rate than the check plot population or those treated with carbaryl or endosulfan. For experimental period one, cypermethrin (67.9 g [AI]/ha) was the only treatment to show a decrease and was significant from all other treatments. Responses of the other treatments were not significantly different from each other. Response to fenvalerate differed significantly from methomyl, endosulfan, carbaryl, and the check on the second experimental period. Both cypermethrin's response also differed significantly from the check but not from carbaryl or endosulfan and methomyl. The cypermethrin's began separating from the other treatments on experimental period three; however, their responses were not significantly different in comparison with the other treatment responses. Fenvalerate's response was significantly different from the checks but not from the response of the other treatments due to fenvalerate's large increase in after treatment counts. The check's response did not differ significantly from the other treatment responses. Cypermethrin (45.3 g [AI]/ha), fenvalerate, and the check's responses were significantly different on experimental period four from that of methomyl

Figure 2. Log means For Total Squash Bug Numbers Per Experimental Period. Perkins, Okla. 1984. B=before treatment; T=treatment; A=after treatment

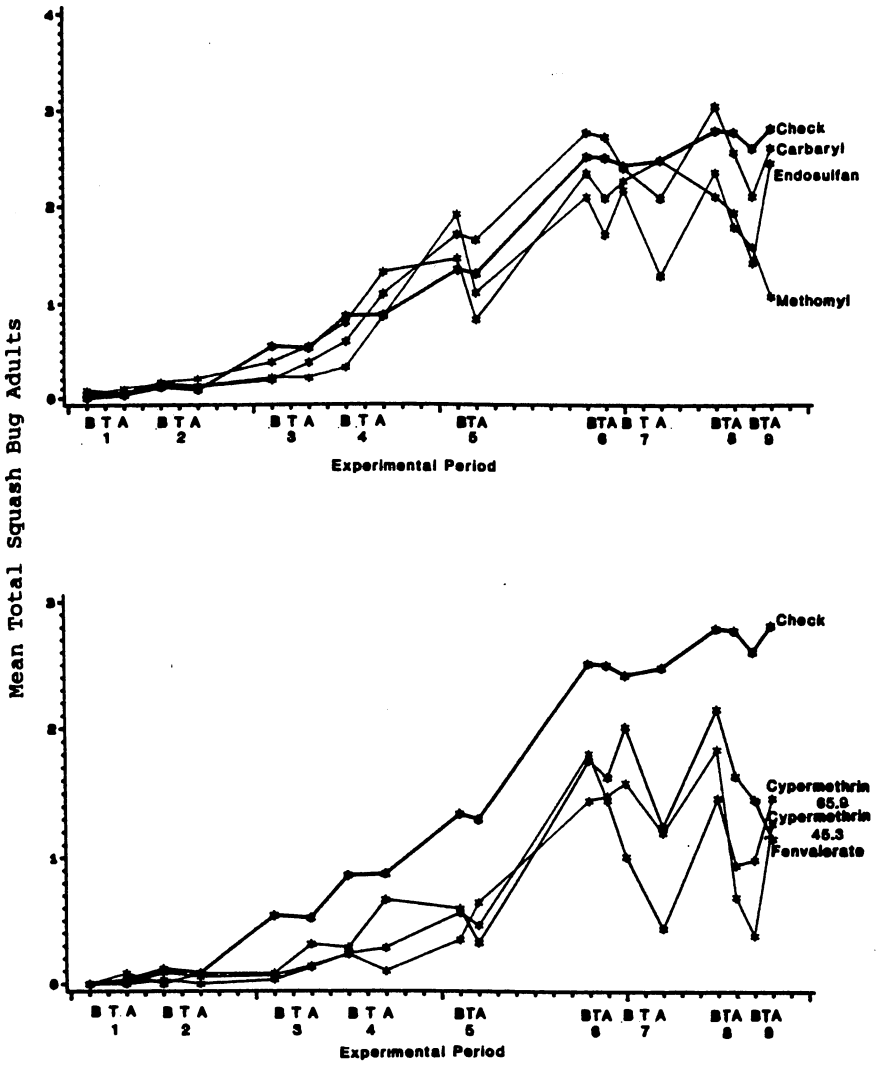

Mean Total Squash Bugs
Check
Carbaryl
Endosulfan
Methomyl
B T A
1
2
3
4
5
6
7
8
9
Experimental Period
Check
Cypermethrin
65.9
Fenvalerate
Cypermethrin
45.3
Experimental Period

but not from the responses of the other treatments. Methomyl's response did not differ significantly from the other treatment responses. Methomyl, cypermethrin (67.9 g [AI]/ha), fenvalerate, carbaryl, the check, and endosulfan had increases in after treatment counts for experimental period four. On experimental period five, fenvalerate's response was significantly different from all other responses except methomyl's. Large decreases occurred in the after treatment counts of methomyl and fenvalerate. Cypermethrin's (45.3 g [AI]/ha) effect differed from all other responses except those of carbaryl and endosulfan. Carbaryl's rate of change did not differ significantly from cypermethrin (67.9 g [AI]/ha) or the check's rate of change. The response for endosulfan did not differ from the responses for methomyl, cypermethrin (67.9 g [AI]/ha), or the check. During experimental period six, all counts increased from the previous date for before and after treatment counts; however, methomyl and fenvalerate's responses were the only ones that were significantly different. Experimental period seven had a large decrease in the after treatment insects counts for the cypermethrins, methomyl, and fenvalerate which were not significantly different from each other; all but cypermethrin (45.3 g [AI]/ha) differed significantly from the check, endosulfan, and carbaryl. The rate of change for the latter three were not significantly different from each other. For experimental period eight, methomyl's response was

significantly different from the check's. The effects of methomyl and the check were not significantly different from the other treatment responses. On the last experimental period, methomyl was the only treatment which the after treatment count decreased, and the response was significant from responses for the cypermethrins and the check. Endosulfan, the check, fenvalerate, and carbaryl responses could not be separated by the test we employed. Again, the overall trend appears to be for the pyrethroids and methomyl to decrease the squash bug population over the treatment period more than endosulfan or carbaryl. From these graphs carbaryl appears to be providing very little, if any, control of the squash bug. There seems to be a trend for methomyl and the pyrethroids to have smaller rates of change from before to after treatment counts than the other treatments, but this varies between experimental periods. A smaller rate of change in before and after treatment counts does not necessarily mean better control is achieved; however, when coupled with the population of the insect for a specific insecticide on the graph one can make a better assessment. For example, on experimental period five, six, and eight, endosulfan's response was greater or equal to most of the pyrethroid's responses; however, the insect population at experimental period nine is much greater than that for the pyrethroids.

Figure 3 represents the before and after treatment counts for adults only. Once again a trend for fewer squash

Figure 3. Log Means For Total Squash Bug Adults Per Experimental Period. Perkins, Okla. 1984. B=before treatment; T=treatment; A=after treatment


Mean Total Squash Bug Adults
Check
Carbaryl
Endosulfan
Methomyl
B T A 1
B T A 2
B T A 3
B T A 4
BTA 5
BTA 6
B T A 7
BTA 8
BTA 9
Experimental Period
Check
Cypermethrin 65.9
Cypermethrin 45.3
Fenvalerate
B T A 1
B T A 2
B T A 3
B T A 4
BTA 5
BTA 6
B T A 7
BTA 8
BTA 9
Experimental Period

bugs appears for the pyrethroids and methomyl. There were no significant response differences for experimental periods one, two, and three between any of the insecticides. The reason is that there were few adults present during the first three experimental periods. Carbaryl, endosulfan, and methomyl's after treatment counts increased significantly as compared to either cypermethrins' or the check's responses during experimental period four. Fenvalerate's response was significantly different from the check's and cypermethrin's (45.3 g [AI]/ha) but not the response of carbaryl, endosulfan, or methomyl. The response for cypermethrin (67.9 g [AI]/ha) did not differ from those of fenvalerate, cypermethrin (45.3 g [AI]/ha), or the check. Experimental period five had a decrease in the after treatment counts for most treatments. Responses for methomyl and endosulfan were not significantly different, but their responses did differ significantly from that of cypermethrin (45.3 g [AI]/ha) which did not differ significantly from the responses for the other treatments. On experimental period six, there was a general decrease in after treatment counts and the responses could not be separated even though the before treatment counts increased considerably. Endosulfan's response differed significantly from those of methomyl and fenvalerate on experimental period seven. Also, the check's response was not significantly different from that of carbaryl, fenvalerate, or either cypermethrin treatment. The cypermethrin's, methomyl, and fenvalerate responses were

not significantly different. For experimental period eight, all after treatment counts decreased. Cypermethrin (45.3 g [AI]/ha) response differed from carbaryl, endosulfan, and the check's. All other responses were not significantly different from either of these treatments. Only methomyl and fenvalerate's after treatment counts increased on experimental period nine. Methomyl's response differed significantly from that of endosulfan, carbaryl, cypermethrin (45.3 g [AI]/ha), and cypermethrin (67.9 g [AI]/ha). The response for fenvalerate differed from endosulfan and cypermethrin (45.3 g [AI]/ha) responses. Carbaryl and cypermethrin (67.9 g [AI]/ha) were not significantly different in their rates of increase nor did they differ from endosulfan, fenvalerate, the check, or cypermethrin (45.3 g [AI]/ha). The check did not differ significantly in its response from any other treatment responses.

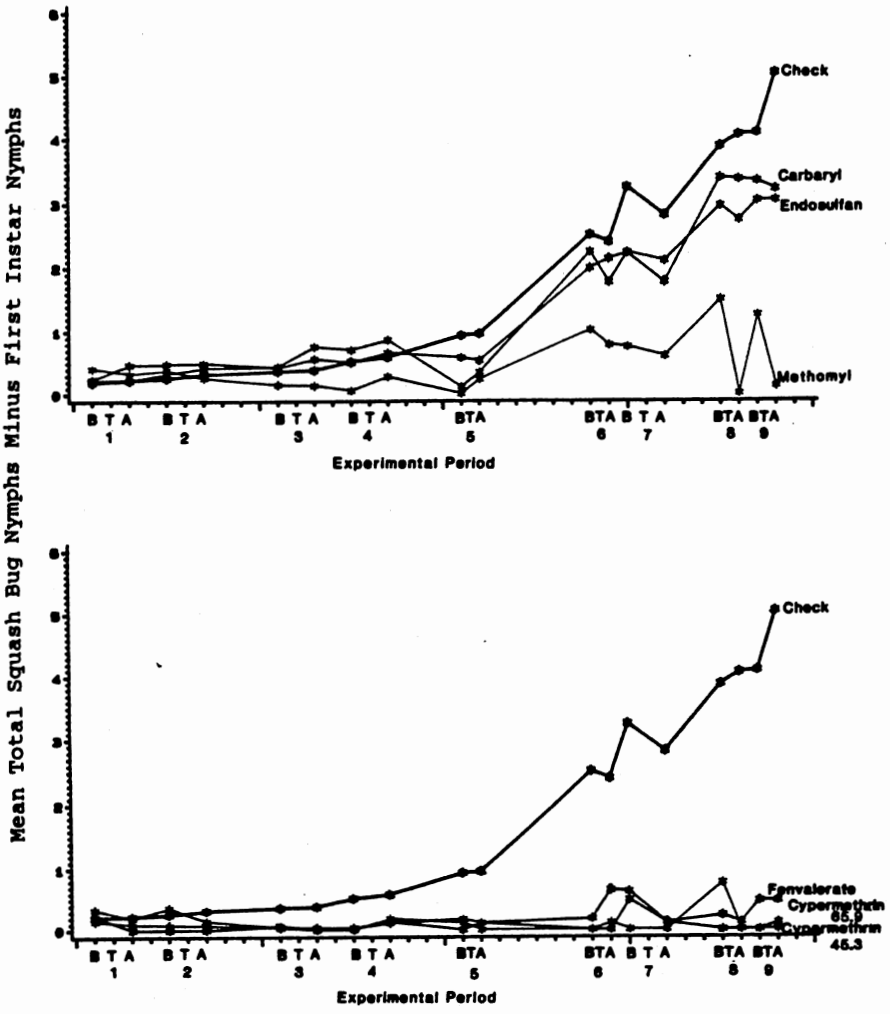
As can be seen from Fig. 1, 2, and 3, carbaryl and endosulfan do not appear to be controlling the squash bug. Endosulfan appears to be controlling nymphs better than adults. Neither carbaryl nor endosulfan seem to be approaching the control of methomyl or the pyrethroids. Methomyl also does not seem to control adults as well as the cypermethrins.

When collecting the after treatment samples, it was observed that a large number of first instar squash bugs were present. Since the first instars only remain in this

stage for 24 h, it was postulated that these nymphs were hatching and, due to their habit of clustering around the egg mass for the first few hours, were not being exposed to the insecticides long enough for the insecticides to act upon them before the counts were taken. Therefore, first instar squash bugs were removed from the data and analysis was made on the before and after difference without the presence of first instar squash bugs.

Figure 4 presents the graph for total nymphs minus first instar squash bugs. When compared to Fig. 1, it is apparent that the first instar squash bugs are present and counted before insecticides have acted upon them. On experimental period one, carbaryl differed significantly from all other treatments because of its increase in after treatment counts. The check and endosulfan responses differed from cypermethrin (67.9 g [AI]/ha) but not from the remaining treatments. Endosulfan differed significantly from fenvalerate and methomyl on experimental period two, but not from the other four treatments. The responses for methomyl, cypermethrin (45.3 g [AI]/ha), cypermethrin (67.9 g [AI]/ha), carbaryl, and the check did not differ significantly. For experimental period three, the pyrethroids and methomyl squash bug populations seem to diverge from the other treatments; however, the response for endosulfan was significantly different from all treatment responses except carbaryl's. Carbaryl's response did not differ from responses for the other treatments. There were

Figure 4. Log Means For Total Squash Bug Nymphs Minus First Instar Nymphs Per Experimental Period. Perkins, Okla. 1984. B=before treatment; T=treatment; A=after treatment

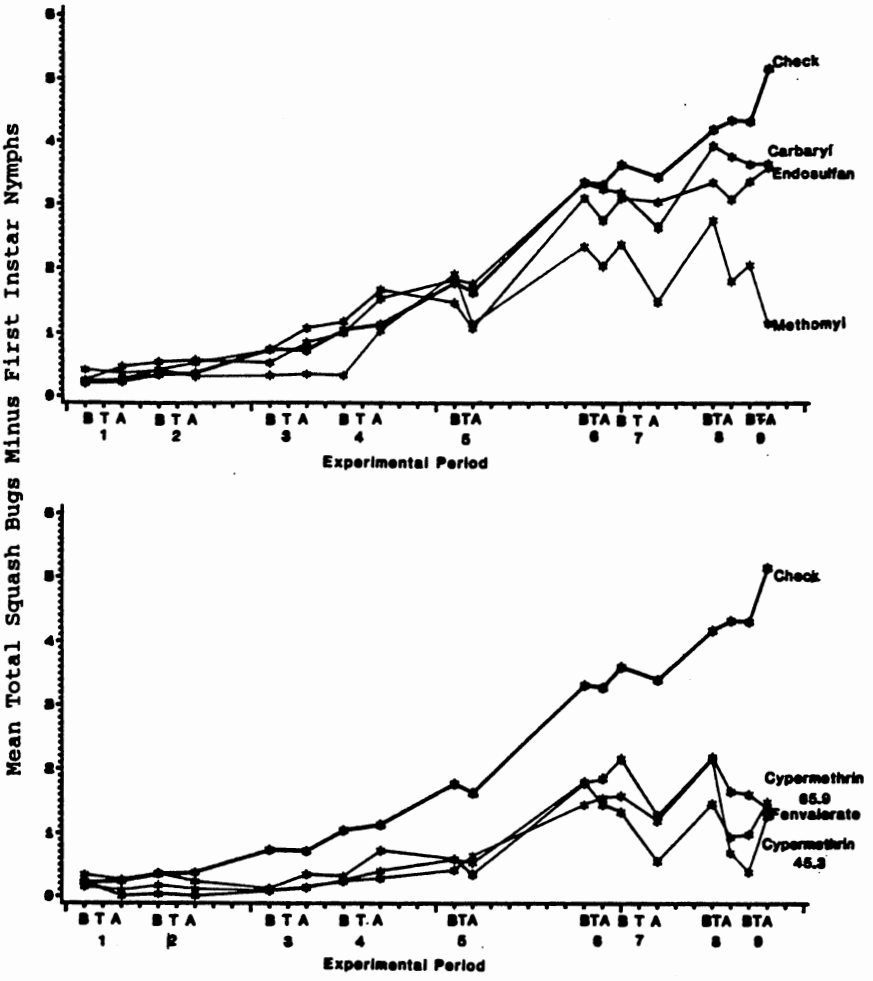

Mean Total Squash Bug Nymphs Minus First Instar Nymphs
Check
Carbaryl
Endosulfan
Methomyl
B T A 1
B T A 2
B T A 3
B T A 4
BTA 5
BTA 6
B T A 7
BTA 8
BTA 9
Experimental Period
Check
Fenvalerate
Cypermethrin 65.9
Cyhalothrin 45.3
B T A 1
B T A 2
B T A 3
B T A 4
BTA 5
BTA 6
B T A 7
BTA 8
BTA 9
Experimental Period

no significant differences for experimental periods four and five. Both periods had increases from before to after treatment counts even with first instar nymphs removed. For experimental period six, fenvalerate's response (an increase) was significantly different from that of endosulfan. All other treatments were not significantly different in their responses to each other or to fenvalerate and endosulfan. By experimental period seven, the pyrethroid squash bug populations were much lower than the check, carbaryl, and endosulfan populations; however, the rate of change from before to after treatment counts did not show this. All treatments decreased their populations for this period but at non-significant rates. There was a general increase in after treatment counts for experimental period eight. However, methomyl and cypermethrin (45.3 g [AI]/ha) had decreases in after treatment counts. These two insecticides did not differ significantly between their responses, but they were significantly different from the check's response. Methomyl was significantly different in its change from the change in the other treatments, except for cypermethrin (45.3 g [AI]/ha). Responses for the check, endosulfan, fenvalerate, carbaryl, and cypermethrin (67.9 g [AI]/ha) were not significantly different. The after treatment counts for methomyl decreased on experimental period nine and were significantly different from the other treatment responses. The check's after count had a large increase and differed significantly from all responses

except cypermethrin (67.9 g [AI]/ha). Cypermethrin's (67.9 g [AI]/ha) response did not differ from responses for carbaryl, endosulfan, fenvalerate, or cypermethrin (45.3 g [AI]/ha).

Figure 5 presents the total number of insects minus first instar nymphs. As with total nymphs, when the first instars are removed from the counts, methomyl, fenvalerate, and the cypermethrins show better performance when compared to the check. On experimental period one, the response for cypermethrin (67.9 g [AI]/ha) was significantly different from responses for the check, endosulfan, and carbaryl. Carbaryl's response differed significantly from that of methomyl, cypermethrin (45.3 g [AI]/ha), and fenvalerate, but the check and endosulfan did not differ significantly. Also, methomyl, cypermethrin (45.3 g [AI]/ha), fenvalerate, and cypermethrin (67.9 g [AI]/ha) did not differ significantly from each other in their responses. For experimental period two, endosulfan and fenvalerate differed significantly in their change of before and after treatment counts; however, the other treatments did not differ from either endosulfan or fenvalerate. During experimental period three, the check, methomyl, and cypermethrin (67.9 g [AI]/ha and 45.3 g [AI]/ha) had either a slight increase in after treatment counts or no increase. Responses could not be declared significantly different for this experimental period. During experimental period four, methomyl, carbaryl, and endosulfan had significant increases in their

Figure 5. Log Means For Total Squash Bugs Minus First Instar Nymphs Per Experimental Period. Perkins, Okla. 1984. B=before treatment; T=treatment; A=after treatment

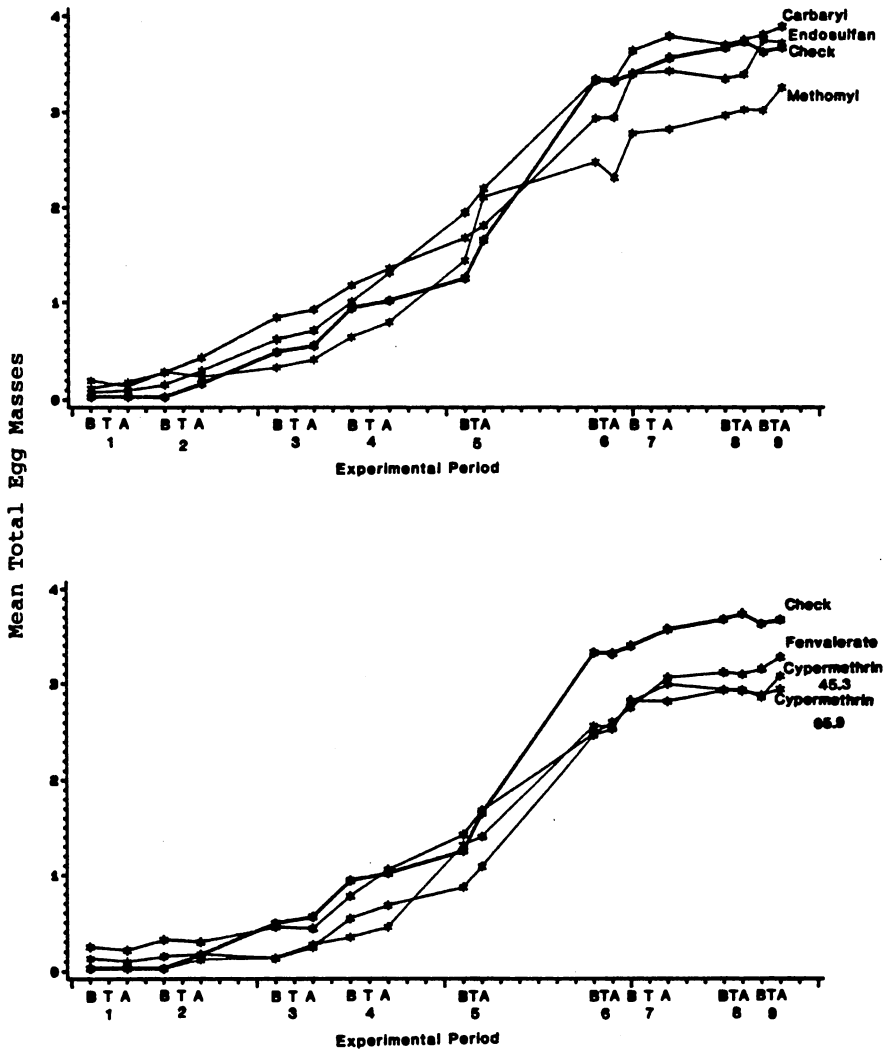

Mean Total Squash Bugs Minus First Instar Nymphs
Check
Carbaryl
Endosulfan
Methomyl
B T A 1
B T A 2
B T A 3
B T A 4
BTA 5
BTA 6
B T A 7
BTA 8
BTA 9
Experimental Period
Check
Cypermethrin 86.9
Fenvalerate
Cypermethrin 45.3
B T A 1
B T A 2
B T A 3
B T A 4
BTA 5
BTA 6
B T A 7
BTA 8
BTA 9
Experimental Period

after treatment counts compared to the cypermethrins, and the check. Responses for methomyl, endosulfan, and carbaryl did not differ from the fenvalerate response. The check and cypermethrin (45.3 g [AI]/ha) responses differed significantly from all other treatments except fenvalerate's and cypermethrin's (67.9 g [AI]/ha). Cypermethrin (67.9 g [AI]/ha) did not differ in its response from that of endosulfan or fenvalerate. On experimental period five, methomyl's response differed significantly from the response of cypermethrin (45.3 g [AI]/ha). All other responses were not significantly different from each other or from methomyl and cypermethrin (45.3 g [AI]/ha). By experimental period five, squash bug populations for the pyrethroids were beginning to separate from the other treatment's insect populations. During experimental period six, the methomyl insect population began to separate from the squash bug populations for the check, carbaryl, and endosulfan; however, rate of change on this experimental period did not differ significantly among treatments. By experimental period seven, there had been an increase in the number of squash bugs for the before treatment counts, and all treatments showed a decrease in their after treatment counts. Methomyl and fenvalerate had large reductions in after treatment numbers and were significantly different from endosulfan's response but not from the responses for the other treatments. The response for endosulfan did not differ significantly from the responses of the other

treatments. A decrease occurred, again, on experimental period eight for after treatment counts for all treatments except the check. Cypermethrin's (45.3 g [AI]/ha) response was significantly different from the responses for the check, carbaryl, endosulfan, fenvalerate, and cypermethrin (67.9 g [AI]/ha) but not from methomyl's response. Methomyl's response differed from that of the check's but not from carbaryl's, endosulfan's, fenvalerate's, or cypermethrin (67.9 g [AI]/ha). The check, carbaryl, endosulfan, fenvalerate, and cypermethrin (67.9 g [AI]/ha) did not differ in their rate of change from before to after treatment counts. Cypermethrin (67.9 g [AI]/ha and 45.3 g [AI]/ha), endosulfan, carbaryl, and the check increased from before to after treatment counts on experimental period nine. Responses of cypermethrin (45.3 g [AI]/ha) and the check were significantly different from those of carbaryl, methomyl, and fenvalerate but not from other treatment responses. Cypermethrin (67.9 g [AI]/ha) differed in its response only to methomyl. Carbaryl differed in its response only to methomyl, cypermethrin (67.9 g [AI]/ha), and the check. Methomyl's rate of change (a decrease) was significantly different from all treatments except fenvalerate's.

Egg mass counts taken before and after treatment are depicted in Fig. 6. Again, methomyl and the pyrethroids decreased the mean number of egg masses more than carbaryl or endosulfan. However, the reduction was not as great as

Figure 6. Log Means For Total Squash Bug Egg Mass Numbers Per Experimental Period. Perkins, Okla. 1984. B=before treatment; T=treatment; A=after treatment


Carbaryl
Endosulfan
Check
Methomyl
Mean Total Egg Masses
B T A
1
2
3
4
5
6
7
8
9
Experimental Period
Check
Fenvalerate
Cypermethrin
45.3
Cypermethrin
Experimental Period

for nymphs or total squash bugs (Fig. 1 and 2). Again, we are measuring the change in the before and after treatment counts. For experimental period one, methomyl and endosulfan differed significantly in their rate of change. The other treatments did not differ significantly from each other or from methomyl or endosulfan in their responses. Methomyl was again significantly different from endosulfan, carbaryl, the check, and cypermethrin (45.3 g [AI]/ha) which did not differ from each other in rate of change on experimental period two. Methomyl's rate of change did not differ from cypermethrin (67.9 g [AI]/ha) or fenvalerate's. Cypermethrin's and fenvalerate's responses were not significantly different, but did differ significantly from endosulfan, carbaryl, and the check. Experimental period three had an increase in after treatment counts for all treatments except fenvalerate and the check. However, there were no significant differences in the rates of change between insecticides. By experimental period four, egg mass numbers were increasing. Carbaryl's response differed significantly from the response for cypermethrin (45.3 g [AI]/ha) and the check. Carbaryl's response was not significantly different from the responses for endosulfan, methomyl, fenvalerate, or cypermethrin (67.9 g [AI]/ha). The check's rate of change did not differ from those of endosulfan, methomyl, or either cypermethrin. The response for methomyl was significantly different from all treatments on experimental period five due to a large after treatment

count. Responses for endosulfan and cypermethrin (45.3 g [AI]/ha) were significantly different from the check. However, fenvalerate, carbaryl, and cypermethrin (67.9 g [AI]/ha) did not differ significantly in their responses from the check or from endosulfan and cypermethrin (45.3 g [AI]/ha). From the after treatments counts on experimental period five to the before treatment counts on experimental period six, there was a large increase in number of squash bug egg masses. This indicated that the insecticides were not killing female squash bugs before they oviposited. There were general increases in after treatment counts for endosulfan, fenvalerate, and cypermethrin (67.9 g [AI]/ha). Fenvalerate's and methomyl's responses differed significantly from each other. Responses for the other treatments did not differ from each other or from fenvalerate's and methomyl's. On experimental period seven, fenvalerate's rate of change differed significantly from the rate of change for endosulfan and cypermethrin (67.9 g [AI]/ha) but not from the other treatments. The latter two did not differ from responses for the other treatments. There were no significant differences in the rates of change for experimental period eight. Most treatments had slight increases in their after treatment counts or remained relatively steady during this experimental period. For experimental period nine, methomyl and cypermethrin (45.3 g [AI]/ha) responses were significantly different from the response for endosulfan, which decreased, but not from

responses for the other treatments. Endosulfan's response did not differ significantly from the other treatments either.

From these six figures, it appears that control can be achieved with fenvalerate, cypermethrin, or methomyl. It also seems that cypermethrin, fenvalerate, and methomyl do control first instar squash bug nymphs as shown by the comparison of Figs. 1 and 4. There are indications that cypermethrin and fenvalerate are also controlling some of the adult population. Carbaryl and endosulfan do not appear to affect the squash bug population to any extent. Egg production is not affected greatly by insecticide treatments. A reduction in the number of egg masses would have a direct effect on the squash bug population. Bonjour & Fargo (1987) reported that the average number of eggs per egg mass was 19.5 on yellow straight neck `Hyrific' (C. pepo L. var. melopepo). They also reported that by Aug 21, 58% of all leaves on the squash plants had eggs present. Therefore, even a slight reduction in the number of egg masses may have an enormous impact on the squash bug population. The check populations for total adults, total squash bugs, total nymphs, and total egg masses correspond to populations reported by Rensner et al. (1987).

One observation from Figs. 1 through 6 was that the change in the check's population from before to after treatment counts generally was zero, slightly positive, or noticeably negative. Only when after treatment counts were

taken did the check's population increase in a noticeable fashion. This may indicate that the treatments were having some effect on the check, or enough time had not elapsed between counts to detect a population increase in the control. Another possible explanation could be migration from adjacent plots. In either case, future investigations into insecticide control of the squash bug should take this information into account. There may be a need to have a greater distance between plots than the 1.5 m used in our test. This distance may also have to be expanded to limit squash bug movement between plots or some method devised to measure movement and take it into account during analysis.

The data was also analyzed to determine if differences occurred between treatments within the same experimental period for percent control. The exponential function of the log means, for each variable, was taken to convert them to the original numbers. The data was then converted to percent control using the formula

$$100 * [1 - (B_c * A_t / B_t * A_c)]$$

developed by Henderson & Tilton (1955) where B is the before counts and A is the after counts for c the control and t the treatment, and then analyzed using ANOVA (SAS Institute 1985) with the means separated by Duncan's Multiple Range Test. Since the formula incorporates both the before and after treatment counts, we believe it provides a better estimate of percent control than Abbott's formula (Abbott 1925) which considers only the after

treatment counts. Because of few insects in the early spray periods, the first four experimental periods were omitted and the remaining five experimental periods were analyzed to determine if significant differences occurred within an experimental period between treatments.

Percent control for total nymphs is presented in Table VII. Significance could not be declared for any experimental period. There were extreme differences between treatments within spray dates, but, due to large variations, significance could not be declared. Negative numbers in Table VII indicate that the squash bug population increased rather than decreased. There was a trend for methomyl, fenvalerate, and cypermethrin (45.3 g [AI]/ha and 67.9 g [AI]/ha) to exceed endosulfan and carbaryl in percent control over the experimental periods. Most of the percent control figures were generally in the "not acceptable level", ie <80%. Only once, on experimental period seven did a treatment exceed 80% control (fenvalerate 81.6%).

Total squash bug percent control is presented in Table VIII. Significance was declared on experimental period seven and eight. The percent control of methomyl and the pyrethroid's was significantly different from the percent control for carbaryl on experimental period seven. Fenvalerate had a significantly greater control as compared to endosulfan but not methomyl or either cypermethrin. Endosulfan and carbaryl did not differ significantly from each other in their percent control. On experimental period

TABLE VII

PERCENT CONTROL OF TOTAL SQUASH BUGS NYMPHS
PERKINS, OKLA. 1984

Treatment	Rate g AI/ha	Experimental Period[1] 5	6	7	8	9
Carbaryl	1131.3	-377.4	- 9.0	-17.48	3.88	53.08
Endosulfan	1131.3	-54.9	41.5	31.39	16.36	55.60
Methomyl	1018.9	-111.2	53.1	38.39	48.76	55.83
Fenvalerate	226.3	-91.7	-444.0	81.62	30.65	28.53
Cypermethrin	45.3	-980.5	-192.6	68.27	34.27	33.29
Cypermethrin	67.9	-45.4	-272.3	61.36	17.85	39.16

[1]Significance not declared at (p=0.05) by DMRT.

TABLE VIII

PERCENT CONTROL OF TOTAL SQUASH BUGS BY SPRAY DATE
PERKINS, OKLA. 1984

Treatment	Rate g AI/ha	Experimental Period[1] 5	6	7	8	9
Carbaryl	1131.3	-92.5	-19.7	10.86c	9.79c	50.04
Endosulfan	1131.3	-24.0	36.0	25.19bc	12.24bc	46.24
Methomyl	1018.9	-18.9	45.9	70.01ab	51.77a	62.16
Fenvalerate	226.3	57.4	-129.3	75.81a	47.79a	49.68
Cypermethrin	45.3	-750.2	-71.7	63.16ab	49.92ab	21.36
Cypermethrin	67.9	-10.4	5.5	62.81ab	31.33abc	34.32

[1] Means within the same column followed by the same letter are not significant at (P=0.05; Duncan's [1955] multiple range test).

eight, percent control for methomyl and the pyrethroids was significantly different from that of carbaryl. Methomyl and fenvalerate were also significantly different from endosulfan's percent control. Cypermethrin (45.3 g [AI]/ha) did not differ significantly from endosulfan's percent control, however, percent control for cypermethrin (67.9 g [AI]/ha) did not differ significantly from either endosulfan or carbaryl. Endosulfan and carbaryl were not significantly different in their percent control of squash bugs. Although percent control increased when nymphal and adult stages (Table VIII) of the squash bug were combined compared to percent control for adults (Table IX), generally, treatment means for total squash bugs could not be separated statistically. The decrease in total squash bug numbers for methomyl, fenvalerate, and the cypermethrins is evident for experimental period seven, Fig. 3 and Table VIII.

Table IX shows the percent control results for total adults. Only on experimental period seven were percent controls declared significantly different. Carbaryl and endosulfan's percent control were significantly different from methomyl's. Percent control for these three treatments did not differ significantly from the percent control for the other treatments. The results in Table IX are different from the results in Fig. 3. Measurements of percent control are presented in Table IX, whereas measurements in the change from before to after treatment counts are depicted in Fig. 3. Even though there are noticeable decreases in after

TABLE IX

PERCENT CONTROL OF ADULT SQUASH BUGS BY SPRAY DATE
PERKINS, OKLA. 1984

Treatment	Rate g AI/ha	Experimental Period[1] 5	6	7	8	9
Carbaryl	1131.3	-8.23	-95.57	9.69b	30.38	-6.4
Endosulfan	1131.3	37.00	7.54	-27.75b	10.34	-361.2
Methomyl	1018.9	16.81	29.09	48.89a	27.29	45.7
Fenvalerate	226.3	1.45	-46.91	42.39ab	36.61	-0.2
Cypermethrin	45.3	-63.85	-73.91	19.03ab	60.87	-108.5
Cypermethrin	67.9	-10.44	-27.24	31.65ab	46.15	-37.0

[1] Means within the same column followed by the same letter are not significant at (P=0.05; Duncan's [1955] multiple range test).

treatment counts, for example in experimental period eight, Fig. 3, the percent control, Table IX, does not necessarily correspond with the decrease in Fig. 3. The percent control is calculated with the before and after treatment counts of both the control and the treatment. If the control decreases in the after treatment count, the percent control will not be as great as when the after treatment count increases for the control. Also, often the after treatment count for the treatment(s) increased which can provide a lower percent control figure. Overall, methomyl and the pyrethroids reduced the adult populations but not at significantly different rates.

Total nymphs minus first instar nymphs are presented in Table X. Again, significance was not declared within an experimental period; however, for all experimental periods except periods five and seven, there was a trend toward an increase in percent control when compared to total nymphs in Table VII. This could indicate that first instar nymphs were counted before the insecticides acted upon them (Henderson & Tilton, 1955). A possible reason for experimental periods five and seven not exhibiting an increase in percent control over Table VII could be that in those experimental periods there were few first instar squash bugs present as compared to the other experimental periods. If first instar nymphs are not being affected by the insecticides before the after treatment counts are made as supported in Table X, then first instar nymphs should not

TABLE X

PERCENT CONTROL OF TOTAL SQUASH BUGS NYMPHS
MINUS FIRST INSTAR NYMPHS
PERKINS, OKLA. 1984

Treatment	Rate g AI/ha	Experimental Period[1] 5	6	7	8	9
Carbaryl	1131.3	-72.0	-21.89	11.71	17.72	52.34
Endosulfan	1131.3	-409.0	-16.30	-10.83	24.45	58.26
Methomyl	1018.9	-105.3	-36.96	-2.23	59.73	81.20
Fenvalerate	226.3	-101.6	-138.93	19.51	25.44	59.93
Cypermethrin	45.3	-86.2	-30.09	-59.94	53.57	59.93
Cypermethrin	67.9	-89.2	-12.99	-53.27	14.80	50.14

[1]No significant differences were declared at (p=0.05) by DMRT.

be considered in future efficacy testing programs unless enough time has elapsed to allow action by the insecticides on the insects. Otherwise, the sample may be biased against the insecticide.

Table XI presents percent control of total squash bugs minus first instars. Experimental period eight and nine had significant differences between treatments. Cypermethrin (45.3 g [AI]/ha) differed from carbaryl and endosulfan in percent control on experimental period eight, but not from the other treatments. Percent control for methomyl differed significantly from that of endosulfan but not carbaryl, while fenvalerate and cypermethrin's (67.9 g [AI]/ha) percent control did not differ significantly from percent control for any treatments. For experimental period nine, methomyl and cypermethrin (45.3 g [AI]/ha) differed significantly in their percent control, but the other treatment's percent control did not differ from each other or from methomyl and cypermethrin (45.3 g [AI]/ha). If, as stated before, first instar nymphs were being counted before the insecticides had time to act upon the newly hatched insects, one would expect percent control in the Table XI to be greater than in Table VIII when newly hatched insects were removed (Henderson & Tilton, 1955). This, in fact, did occur on experimental period eight. On experimental period five, four treatments increased in percent control and two decreased in percent control. Experimental periods six and seven had decreases in percent control when Table XI is

TABLE XI

PERCENT CONTROL OF TOTAL SQUASH BUGS MINUS FIRST INSTARS BY SPRAY DATE PERKINS, OKLA. 1984

Treatment	Rate g AI/ha	Experimental Period[1] 5	6	7	8	9
Carbaryl	1131.3	-25.74	-38.71	9.76	26.65bc	46.88ab
Endosulfan	1131.3	-19.00	-9.23	-12.04	22.00c	40.31ab
Methomyl	1018.9	-6.81	5.93	35.98	62.71ab	81.43a
Fenvalerate	226.3	10.97	-31.16	38.09	51.08abc	58.48ab
Cypermethrin	45.3	-63.12	-38.50	3.50	73.18a	-20.76b
Cypermethrin	67.9	-33.12	- 8.03	31.53	54.43abc	17.38ab

[1] Means within the same column followed by the same letter are not significant at (P=0.05; Duncan's [1955] multiple range test).

compared with Table VIII. On experimental period nine, there were four treatments that decreased in percent control and two that increased in percent controls. Either first instar nymphs did not affect total counts, or there are other factors such as migration entering into the picture. Together, Fig. 5 and Table XI pinpoint where methomyl and the pyrethroids decreased the squash bug population. Methomyl on experimental period five had a large decrease from before to after treatment as depicted in Fig. 5. This is also indicated in Table XI by the small percent control, (5.9%). Methomyl and the pyrethroids exhibited large decreases in after treatment counts on experimental period eight, Fig. 5. Table XI bears this out with 62.7, 51.0, 78.1, and 54.4 percent control respectively.

This data points out the problem of insect distribution within a plot or test area. A major reason for not being able to separate differences was a result of the large variation that occurred from sampling individual plants. Taylor (1987) stated that most of the efficacy testing conducted by entomologists is incorrect, or has <40% chance of being correct, due to the assumption made in analysis (that insects are randomly distributed) and the lack of knowledge of the insect(s) distribution before and after treatment. Taylor's statement is, that the entomologist should know the distribution of the insect being studied before treatment and the distribution after treatment. By knowing the distribution, one knows how many samples to make

and where to take them. This study seems to support Taylor's statements.

Yield data from the test was analyzed by general linear models (SAS Institute 1985). Over all dates, the cypermethrin (45.3 g [AI]/ha) plots produced significantly more fruit, as measured by weight, than methomyl, the check, and endosulfan (Table XII). Methomyl, carbaryl, fenvalerate, cypermethrin (67.9 g [AI]/ha), and the check did not differ significantly in their yield of squash fruit. The check produced less squash by weight than any other treatment. Cypermethrin (45.3 g [AI]/ha) plots produced more yield than all other treatments. The order of production (yield) was cypermethrin (45.3 g [AI]/ha), fenvalerate, cypermethrin (67.9 g [AI]/ha), carbaryl, endosulfan, methomyl, and the check. Rensner et al. (1987) reported that as squash bug numbers increased the number of small and mature fruit per plant decreased. This seems to be reaffirmed from these yield results. However, it should be noted that the primary purpose of this study was not to measure yield, but to measure squash bug control.

TABLE XII

YIELD OF SQUASH PLANTS FOR PERKINS, OKLA. 1984

Treatment	Rate g AI/ha	wt kg/ha[1]
Check	----	1,434a
Endosulfan	1131.3	2,664a
Methomyl	1018.9	2,246a
Carbaryl	1131.3	3,046ab
Cypermethrin	67.9	3,052ab
Fenvalerate	226.3	3,136ab
Cypermethrin	45.3	5,839b

[1] Means within a column followed by the same letter are not significantly different by LSD (p=0.05).

CHAPTER III

BIOASSAY OF THREE INSECTICIDES ON SIX LIFE STAGES OF THE SQUASH BUG

Introduction

The field test results indicated that methomyl, fenvalerate, and cypermethrin have possibilities for providing control of the squash bug. To determine the toxicity of these three insecticides' to the squash bug, topical and contact bioassay tests were conducted on the nymphal and adult stages of the insect.

There are few reports of bioassay tests with squash bugs in the literature. Wright & Decker (1955) and Harries & Matsumori (1955) tested chlorinated hydrocarbon insecticides and parathion. To further expand the knowledge of insecticidal activity on squash bugs three insecticides from the 1984 field test were selected to test their topical and contact activity against various life stages of the squash bug. Since methomyl, fenvalerate, and cypermethrin appeared to perform the best in the 1984 field treatment, they were selected for the bioassay. Technical fenvalerate and methomyl (Shell Chemical) and cypermethrin (FMC) were used in the test.

Two methods for testing insecticide toxicity to squash

bugs were used in this study. The topical application method is probably the most common method used for insecticides. The contact method is another means of exposing insects to an insecticide (Matsumura 1976). Oppenoorth (1959) found that for many insecticides these two methods have a linear relationship to each other.

Materials and Methods

Topical Application Test

Effects of technical grade methomyl(98%), fenvalerate (91.7%) (Shell Chemical Co.), and cypermethrin (95%) (FMC) were investigated. All compounds were dissolved in UV spectrophotometry grade acetone. Test concentrations were formulated as serial dilutions of the stock solution. Initial screening was conducted to determine ranges for testing, i.e. 100% and <5% mortality. Tests were conducted using procedures developed by DeBarr & Nord (1978) for Leptoglossus corculus (Say) (Hemiptera:Coreidae)

Application of technical insecticide dilution to second instar through adult life stages was made with a DRUMMOND digital microdispenser (Model 150) delivering 1µl of the dilution per insect. Control insects were treated with the acetone solvent. Applications were made to the dorsum of the thorax, holding the insect legs with forceps during treatment. This procedure did not harm the insects in pretest.

Dilutions for the first instars consisted of stock

solution diluted with deionized water. First instar squash bugs were dipped into the dilutions. This procedure, similar to the method Busvine (1951) used for aphids, was used because pretesting indicated that acetone was toxic to first instar nymphs.

All insects were held for 24 h in 30 cc cups with filter paper lining the bottom and a nylon mesh lid. Mortality was recorded at 12 and 24 h intervals. Four replications per concentration per life stage were run. Ten insects from each life stage were used per replication resulting in 40 insects per life stage being tested per concentration. Ten first and second instar nymphs were placed in each cup, while five third through fifth instar nymphs and adults were placed in a cup with two cups making a replication. Mortality was indicated when the insect did not move when prodded or was unable to obtain its balance when locomotive (Busvine 1951).

Insects were obtained from field populations. First instars were both collected in the field and hatched from eggs collected in the field. Second instar nymphs were collected in the field and reared from first instars in the laboratory. All other life stages were field collected. Squash bug life stages were held in individual gallon containers with filter paper lining the bottom and a squash fruit placed on the filter paper for nourishment.

Probit analysis was made using a computer analysis package (SAS Institute 1985) with the control (C) specified.

This procedure specifies a constant threshold rate for the control for the data set analyzed. C was specified by dividing the number of responses (dead insects) for the control by the number of total insects in the control. Therefore, if one insect died then C would be 0.025 (1/40).

Contact Test

The same collection and holding procedures were used for this test as for the topical test.

Filter paper was treated with a given concentration of insecticide dissolved in acetone to give $\mu g/cm^2$. Checks were filter papers treated with the acetone solvent. All filter papers were air dried for 24 h and then placed inside aluminum foil wrappers until used. Insects were placed in a petri dish with treated filter paper in the bottom. The top of the petri dish had holes punched into it for ventilation. Insects were monitored at 12 h and 24 h for mortality.

Three replications were run on each concentration of insecticide and life stage.

Probit analysis was made using a computer analysis package (SAS Institute 1985) with the control (C) specified. This procedure specifies a constant threshold rate for the control for the data set analyzed, and the same procedure was used as for topical applications to specify C.

Results and Discussion

Topical application of the three insecticides was more toxic than contact application. The order of toxicity was cypermethrin, fenvalerate, and methomyl for both methods of application. Tables XIII to XV present the LD_{50} value, slope, and intercept for the different treatments. The LD_{50} values for topical applications to specific stages within an insecticide treatment were smaller than for the contact LD_{50} values. Slopes for topical applications were also smaller than the slopes of contact applications. These results indicate that a topical application of each insecticide is more toxic to each life stage of the squash bug than exposure via contact. The fourth, male, and female stages for 24 h contact cypermethrin were exceptions. In these cases, the topical application had a greater slope than the contact. The intercepts for cypermethrin topical were also greater than for cypermethrin contact at both recording periods (Table XIII). This could indicate cypermethrin may have the same rate of effect for each treatment, but the contact requires a higher dose. First and second instars were the most susceptible to topical applications with a trend for succeeding instars to be less susceptible. There were noticeable differences - such as fifth instar at the 12 h period for cypermethrin (Table XIII) being less affected than males. Fourth instars at 12 h for methomyl (Table XIV) also had a higher LD_{50} than fifth instars. This trend held true for the 24 h recording. Fenvalerate topically applied

TABLE XIII

LD_{50}, SLOPES, AND INTERCEPTS FOR CYPERMETHRIN

TOPICAL
12hr

Stage	LD_{50} µg/µl	95% Fiducial Limits	Slope	SE	Int	SE
1st instar	1.85E-14	2.17E-17 - 3.42E-14	.18	.08	9.72	.69
2nd instar	1.00E-8	2.17E-11 - 7.00E-8	.22	.04	11.03	1.15
3rd instar	2.57E-6	2.80E-7 - 5.40E-5	.14	.08	6.92	.42
4th instar	4.06E-3	1.90E-3 - 8.70E-3	.60	.11	8.31	.67
5th instar	0.024	0.010 - 0.061	.72	.11	7.70	.22
male	0.018	0.014 - 0.022	1.07	.12	9.31	.23
female	0.030	0.024 - 0.036	1.13	.11	8.98	.42

TOPICAL
24hr

Stage	LD_{50} µg/µl	95% Fiducial Limits	Slope	SE	Int	SE
1st instar	3.98E-15	2.42E-18 - 3.42E-14	.18	.08	9.72	.69
2nd instar	8.43E-9	1.40E-14 - 1.00E-8	.16	.03	8.42	.66
3rd instar	2.20E-7	9.00E-8 - 5.40E-7	.18	.01	7.87	.29
4th instar	2.88E-3	2.49E-3 - 3.42E-3	1.36	.17	12.95	1.01
5th instar	0.011	9.00E-3 - 0.015	1.10	.15	9.94	.79
male	0.015	0.012 - 0.018	1.51	.18	11.31	.80
female	0.030	0.024 - 0.036	1.42	.19	9.95	.65

TABLE XIII (Continued)

CONTACT
12hr

Stage	LC_{50} µg/cm^2	95% Fiducial Limits	Slope	SE	Int	SE
1st instar	4.54	3.45 - 5.72	.19	3.74	3.17	.36
2nd instar	0.66	0.54 - 0.81	1.38	.18	5.56	.15
3rd instar	4.17	2.08 - 7.74	.83	.16	3.80	.32
4th instar	4.37	3.35 - 5.70	.73	.06	3.91	.13
5th instar	5.86	4.85 - 7.04	1.53	.19	2.28	.37
male	6.95	4.56 - 10.87	1.30	.25	2.47	.51
female	10.63	8.62 - 13.15	1.16	.13	2.23	.32

CONTACT
24hr

Stage	LD_{50} µg/cm^2	95% Fiducial Limits	Slope	SE	Int	SE
1st instar	1.62	0.69 - 3.04	0.79	0.16	4.61	.23
2nd instar	0.25	0.19 - 0.30	1.99	0.42	7.75	.54
3rd instar	1.63	0.63 - 3.04	0.84	0.19	4.58	.26
4th instar	1.07	0.54 - 1.94	0.86	0.18	4.94	.21
5th instar	4.66	2.70 - 7.78	1.79	0.36	2.23	.61
male	2.70	2.16 - 3.35	1.12	0.13	3.88	.18
female	4.95	3.88 - 6.30	0.89	0.09	3.55	.19

TABLE XIV

LD_{50}, SLOPES, AND INTERCEPTS FOR METHOMYL

TOPICAL
12HR

Stage	LD_{50} µg/µl	95% Fiducial Limits	Slope	SE	Int	SE
1st instar	0.17	2.71E-5 - 0.36	1.04	0.39	6.80	.61
2nd instar	0.12	0.07 - 0.18	0.93	0.15	6.96	.33
3rd instar	0.12	0.06 - 0.22	1.03	0.23	7.13	.48
4th instar	0.41	0.18 - 0.64	1.33	0.35	6.18	.32
5th instar	0.29	0.18 - 0.48	1.33	0.26	6.62	.39
male	0.54	0.42 - 0.70	0.78	0.10	5.48	.12
female	1.22	0.57 - 4.94	0.94	0.23	4.80	.23

TOPICAL
24HR

Stage	LD_{50} µg/µl	95% Fiducial Limits	Slope	SE	Int	SE
1st instar	0.06	0.01 - 0.12	0.63	0.14	6.78	.39
2nd instar	0.04	0.02 - 0.08	0.71	0.12	7.14	.34
3rd instar	0.11	0.06 - 0.17	0.98	0.18	7.13	.39
4th instar	0.27	0.01 - 0.41	1.62	0.57	7.09	.62
5th instar	0.22	0.10 - 0.52	0.95	0.22	6.41	.41
male	0.31	0.26 - 0.36	1.33	0.14	6.55	.19
female	1.04	0.59 - 7.36	1.23	0.36	4.94	.25

TABLE XIV (Continued)

CONTACT
12HR

Stage	LD_{50} µg/cm^2	95% Fiducial Limits	Slope	SE	Int	SE
1st instar	92.60	57.55 - 164.90	1.18	0.22	-0.38	1.00
2nd instar	136.77	112.22 - 164.21	1.69	0.25	-3.36	1.30
3rd instar	222.72	138.75 - 365.91	1.71	0.39	-4.29	2.13
4th instar	218.44	180.34 - 268.30	1.41	0.18	-2.60	1.00
5th instar	262.16	222.91 - 311.03	1.97	0.29	-6.01	1.62
male	178.66	152.59 - 209.89	2.11	0.31	-5.98	1.63
female	207.71	111.23 - 464.54	2.89	0.89	-10.46	4.77

CONTACT
24HR

Stage	LC_{50} µg/cm^2	95% Fiducial Limits	Slope	SE	Int	SE
1st instar	83.88	5.58 - 241.35	1.15	0.38	-0.13	1.77
2nd instar	110.27	86.48 - 131.48	2.53	0.59	-6.90	2.86
3rd instar	154.21	118.89 - 192.20	1.45	0.24	-2.31	1.28
4th instar	143.39	91.16 - 234.13	1.48	0.28	-2.35	1.41
5th instar	181.15	151.75 - 217.59	1.65	0.21	-3.60	1.14
male	168.62	147.83 - 194.39	3.08	0.56	-10.80	2.88
female	179.41	83.28 -1180.41	3.17	0.95	-11.46	4.92

was more toxic than when squash bugs were exposed to treated filter paper (Table XV). The differences between LD_{50} values for topical and contact applications methods was not as great for fenvalerate as to those of cypermethrin for first, second, and third instar nymphs.

The sequence of toxicity for topical application, as derived from Tables XIII through XV, of the three insecticides tested is presented in Table XVI. For cypermethrin at 12 h, first instars were more susceptible than second, second instars more susceptible than third, then fourth instars, males, fifth instars, and females. For 24 h exposure the order was first instar, second instar, third instar, fourth instar, fifth instar, male, and female. The order for methomyl topical was second instar, third instar, first instar, fifth instar, fourth instar, male, and female for 12 h and second instar, first instar, third instar, fifth instar, fourth instar, male, and female for 24 h (Table XVI). It is interesting to note that methomyl at 24 h for the females has a lower LD_{50} value than fenvalerate at 24 h. Fenvalerate, topically applied, at 12 h had an order of second instar, first instar, third instar, fourth instar, fifth instar, male, and female. After 24 h, the order remained the same.

The low LD_{50} levels of cypermethrin and fenvalerate correspond to data by Orchard (1980) who reported that permethrin doubled the frequency of the electrical activity of the neurosecretory axons of Rhodnius prolixus Stal at

TABLE XV

LD_{50}, SLOPES, AND INTERCEPTS FOR FENVALERATE

		TOPICAL 12HR				
Stage	LD_{50} µg/µl	95% Fiducial Limits	Slope	SE	Int	SE
1st instar	4.47E-4	1.25E-4 - 9.86E-4	0.67	.16	10.22	1.25
2nd instar	2.70E-4	1.93E-4 - 3.68E-4	0.59	.06	9.89	0.49
3rd instar	1.04E-3	5.19E-4 - 2.27E-3	0.45	.07	8.11	0.51
4th instar	0.12	0.022 - 0.68	0.24	.04	5.49	0.17
5th instar	1.37	0.38 - 5.07	0.37	.07	4.87	0.16
male	4.20	1.23 - 19.63	0.75	.21	3.90	0.36
female	4.96	1.86 - 19.47	0.77	.20	3.75	0.36

		TOPICAL 24HR				
Stage	LD_{50} µg/µl	95% Fiducial Limits	Slope	SE	Int	SE
1st instar	4.24E-4	9.15E-5 - 9.30E-4	0.81	.22	11.31	1.70
2nd instar	3.18E-4	1.16E-4 - 6.93E-4	0.64	.12	10.18	1.01
3rd instar	6.56E-4	2.80E-4 - 1.51E-3	0.44	.07	8.23	0.56
4th instar	1.16E-2	3.56E-3 - 0.036	0.40	.06	6.80	0.34
5th instar	0.41	0.16 - 0.92	0.41	.05	5.36	0.13
male	1.99	0.52 - 5.10	0.84	.20	4.41	0.31
female	2.82	0.90 - 6.07	0.89	.20	4.07	0.34

TABLE XV (Continued)

CONTACT
12HR

Stage	LC_{50} µg/cm^2	95% Fiducial Limits	Slope	SE	Int	SE
1st instar	2.52	0.78 - 9.67	0.84	.25	4.21	0.39
2nd instar	5.49	2.59 - 16.95	0.96	.29	3.35	0.51
3rd instar	27.21	10.53 - 37.85	1.66	.54	-0.48	1.93
4th instar	29.87	20.08 - 47.57	0.92	.15	1.84	0.50
5th instar	70.33	58.73 - 88.34	1.74	.30	-2.40	1.27
male	60.16	45.85 - 87.37	0.93	.14	1.16	0.53
female	55.96	44.74 - 73.79	1.17	.18	0.28	0.71

CONTACT
24HR

Stage	LC_{50} µg/cm^2	95% Fiducial Limits	Slope	SE	Int	SE
1st instar	2.21	8.0E-4 - 3.33	1.58	.62	3.73	0.73
2nd instar	1.34	0.67 - 1.86	0.92	.23	4.72	0.24
3rd instar	12.65	9.60 - 16.10	1.22	.18	1.89	0.51
4th instar	10.43	5.86 - 19.66	0.73	.13	3.26	0.34
5th instar	41.62	35.10 - 49.53	1.84	.26	-1.87	0.98
male	23.91	19.40 - 29.46	1.22	.15	1.11	0.49
female	22.31	9.67 - 44.30	1.16	.24	1.37	0.82

TABLE XVI

ORDER OF TOPICAL SUSCEPTIBILITY

	12 h						
	Most						Least
CYPERMETHRIN	1[a]	2	3	4	M	5	F
FENVALERATE	2	1	3	4	5	M	F
METHOMYL	2	3	1	5	4	M	F
	24 h						
	Most						Least
CYPERMETHRIN	1[a]	2	3	4	5	M	F
FENVALERATE	2	1	3	4	5	M	F
METHOMYL	2	1	3	5	4	M	F

[a]Nymphs: 1=first instar, 2=second instar,3=third instar, 4=fourth instar, 5=fifth instar; Adults: M=male, F=female.

1×10^{-9}. Orchard & Osborne (1979) also found that concentrations of permethrin at 5×10^{-11} effect massive frequency reactions to the peripheral neurosecretory cells in the stick bug, Carausius morosus Brunner. Corbett et al. (1984) stated that the quick knockdown often seen with pyrethroids indicates the site of action may be the peripheral nerves; therefore, topical applications should have a greater chance of penetrating the insects cuticle and reaching the site of action than contact applications.

Results for the contact test were similar. Order of toxicity was cypermethrin, fenvalerate, and methomyl.

First instars at 12 h for cypermethrin (Table XIII) had a higher LC_{50} than second, third, and fourth instars. The order of cypermethrin toxicity (Table XVII) at 12 h was second, third, fourth, first, fifth, male, and female. At 24 h, first instar LC_{50}'s were still greater than LC_{50}'s for second and fourth but not third instars. The order of LC_{50}'s for the cypermethrin contact test was second, fourth, first, third, male, fifth, and female after 24 h. Order of toxicity for methomyl contact (Table XVII) at 12 h was first, second, third, fourth, female, male, and fifth. At 24 h, the order was first, second, fourth, third, male, female, and fifth. Order of toxicity for fenvalerate contact (Table XVII) at 12 h was first, second, third, fourth, female, male, and fifth. For 24 h, the order was second, first, fourth, third, female, male, and fifth.

TABLE XVII

ORDER OF CONTACT SUSCEPTIBILITY

	12 h						
	Most						Least
CYPERMETHRIN	2[a]	3	4	1	5	M	F
FENVALERATE	1	2	3	4	F	M	5
METHOMYL	1	2	M	F	4	3	5

	24 h						
	Most						Least
CYPERMETHRIN	2[a]	4	1	3	M	5	F
FENVALERATE	2	1	4	3	F	M	5
METHOMYL	1	2	4	3	M	F	5

[a]Nymphs: 1=first instar, 2=second instar,3=third instar, 4=fourth instar, 5=fifth instar; Adults: M=male, F=female.

From these results, it appears that cypermethrin is the most toxic insecticide to squash bugs by both contact and topical treatments. Fenvalerate is the next most toxic with methomyl being least toxic of the three tested. However methomyl was more toxic to fifth instars, males and females at 24 h than fenvalerate. It also appears that topical applications of these insecticides have a better chance of effecting control than from residual or contact methods based on the LD_{50} and LC_{50}'s, slopes, and intercepts of the two testing methods. Due to variation in responses for first and second instars for topical application, one is cautious about making definite statements regarding order of control for instars of the squash bug.

For all but the fenvalerate and methomyl contact tests, females required the highest dose for LC_{50}. Generally, males and fifth instars were the next least susceptible stages, with the exception of methomyl contact, where third and fourth instars were less susceptible than either adult males or females at 12 h. The fifth instars, male and female life stages had the highest LC_{50} values overall, and therefore, were less susceptible to the insecticides tested than other life stages. First and second instars were generally more susceptible to the insecticides for both types of test. One notable exception was the 24 h contact test in which the third instar nymphs were less susceptible than the fourth instars for all insecticides tested.

Hughes et al. (1987) found that when testing different insecticides against the western spruce budworm (Choristoneura occidentalis Freeman) (Lepidoptera:Tortricidae) that within an instar, increasing concentrations of an insecticide produced higher mortality. However, the same result was not achieved between instars, that is, from one instar to another increasing concentrations will cause greater mortality but may not result in the same intercepts and or slopes.

Since the topical applications provided the lowest LD_{50}'s compared to the LC_{50}'s for contact applications, this may explain why the 1984 field test was not succinct in the differences between treatments. The insecticides appear to have a greater toxicity to the squash bugs when they are actually in direct contact, via spray droplets, with the insects body rather than when the insect must come in contact with the insecticide by walking on treated surfaces. If this is the case, control of the squash bug is made more difficult by the insect's tendency to be found on the underside of the leaves and at the base of the plant; thus making direct contact with spray droplets more difficult.

CHAPTER IV

EVALUATIONS OF CARBOFURAN IN THE GREENHOUSE AND THE FIELD FOR CONTROL OF THE SQUASH BUG

Introduction

Elliot (1935) and Eichmann (1945) were among the first researchers to recognize the benefits of early control for regulating squash bug populations. Later, Rensner et al. (1987) supported this theory, stating that the overwintering generation was the key to squash bug population growth. If the overwintering generation did not have major constraints placed on them, the squash bug populations increased rapidly. Novero et al. (1962), reporting on results of squash bug preference tests, indicated that the insects remained the longest on the first squash plant they encountered, whether or not it was a preferred host. This information, combined with the information from the previous two chapters, that indicate aerially delivered control measures are dependent on the insecticide coming in direct contact with the insect, suggest that the use of a systemic insecticide that is toxic to the adults and emerging nymphs could provide early season control.

During 1984 insecticide trials for spotted cucumber

beetles (Dibrotica undecimpunctata howardi Barber) (Coleoptera:Chrysomelidae), it was observed that squash bug adults were killed in carbofuran treated plots. We then decided to design an experiment to specifically test carbofuran for possible control of squash bug nymphs and adults on young plants.

Carbofuran movement and location in plants is well documented. Ashworth & Sheets (1970) reported carbofuran, tagged with C^{14}, accumulated in the leaves of tobacco more than other plant parts. Greater concentrations occurred in the larger leaves than in the terminal bud. Ashworth & Sheets postulated this was possibly due to the higher rate of transpiration in the leaf. Uptake peaked at day 8 and dropped on day 21 suggesting a half life of 4 days once the source was exhausted. Their findings on tobacco corresponds to Bhirud & Pitre (1972a) who reported carbofuran treated corn plants, when checked at 21, 28, and 35 days after treatment, exhibited the same pattern of concentration in the leaves and plant. In a similar test, Bhirud & Pitre (1972b) reported that carbofuran controlled leafhoppers on corn for 21 days. In their study, third instar leafhoppers were more susceptible than fifth instar, and fifth were more susceptible than adults. The percent mortality for third and fifth instars decreased after 21 days for exposure periods of 0.25, 0.5, and 1 hour. Leafhopper mortality was highest on the lower leaves and lowest on terminal leaves. Metcalf et al. (1968) stated that carbofuran increased from

0.83 ppm in the upper leaves of cotton after five days to 1.3 ppm after 14 days and reached 10 ppm at 30 days when injected into the base of the stem. Based on this information and observations made in the 1984 field test, greenhouse and field investigations were made to determine the life stages of the squash bug that were most susceptible to carbofuran and the length of time that carbofuran may be active in the plant.

Materials and Methods

Greenhouse Test

`Hyrific' yellow straight neck squash seed was planted in individual four inch pots in the greenhouse in the following manner. Sphagnum peat moss was placed in the bottom 3/4 of each pot. The seed was placed on the peat moss, then a layer of sand placed on the seed and the carbofuran applied and incorporated into the sand. The carbofuran was applied at the rate of 1.12 and 2.24 kg [AI]/ha to each pot; this was 6 and 12 g per pot respectively. After emergence, another layer of sand was placed on the surface. This was done to avoid aerial contamination by the volatilization of carbofuran (Talekar et al. 1977). Five squash bugs from each life stage were placed on squash plants when the plants had one, three, and five true leaves. A non-treated control was maintained for each treatment. The test was replicated four times in a completely randomized design. Mortality was recorded at 24

h and 48 h after insect placement on the plants. Squash bugs were confined on one leaf at a time with cages (Beard 1937).

Field Test

In a second test, carbofuran was used in a band application at planting in the field. Carbofuran was applied at the rates of 1.12 kg [AI]/ha and 2.24 kg [AI]/ha as an incorporated band at planting. A non-treated plot was used as the control. `Hyrific' yellow straight neck squash was planted on September 13 at the Horticulture Research Station in Stillwater, Okla. The plot was a randomized complete block design replicated five times. The number of plants, live and dead squash bugs per plot were recorded.

Statistical analysis was conducted using General Linear Models (SAS Institute 1985) for the live and dead squash bugs in the field test, and an ANOVA test was used to test for significance for plant population (SAS Institute 1985).

Results and Discussion

Greenhouse Test

Carbofuran at the 1.12 kg AI/ha rate killed all first through third squash bug nymphs after 24 h (Table XVIII). Of the remaining life stages, fifth instar nymphs were the least affected. The mean number of dead insects for fifth instars on third and fifth leaf stage plants was not significantly different from the means for the checks after

TABLE XVIII

MEAN NUMBER OF DEAD SQUASH BUGS PER LEAF STAGE
FOR CARBOFURAN 1.12 kg AI/ha

Leaf Stage	Time	Nymphs					Adults	
		1st	2nd	3rd	4th	5th	Male	Female
1st leaf	24	5.00a[1]	5.00a	5.00a	5.00a	3.50ab	4.00a	4.25a
3rd leaf	24	5.00a	5.00a	5.00a	4.00a	1.75bc	2.75a	2.50a
5th leaf	24	5.00a	5.00a	5.00a	4.50a	2.00bc	3.25a	2.75a
1st leaf	48	5.00a	5.00a	5.00a	5.00a	4.50a	4.25a	4.25a
3rd leaf	48	5.00a	5.00a	5.00a	4.75a	3.25ab	3.50a	3.50a
5th leaf	48	5.00a	5.00a	5.00a	4.50a	3.25ab	4.00a	3.00a
Check	24	0.50b	0.50b	0.50b	0.00b	0.25c	0.00b	0.00b
Check	48	0.75b	1.00b	0.75b	0.25b	0.25c	0.00b	0.00b

[1]Means within the same column followed by the same letter are not significantly different (P = 0.01; Duncan's [1955] multiple range test).

24 h. By the 48 h recording period, the mean number of dead fifth instars for all leaf stages tested was significantly different from the means for the checks.

The mean number of dead squash bugs for carbofuran at the 2.24 kg AI/ha rate are presented in Table XIX. All life stages of the squash bug had significantly more dead than the life stages on the checks for each leaf stage tested. First through third instars, on the treated plants, were all killed by the 48 h recording. The fifth instar nymphs were the least affected after 24 and 48 h. However, they did not differ significantly from the other treatment means but they were significantly different from the means for the checks.

From these results, it appears that carbofuran at either the 1.12 kg AI/ha or the 2.24 kg AI/ha rate will provide protection against the nymphal and adult life stages of the squash bug through the fifth leaf stage of the squash plant.

Field Test

There were an abundant number of squash bugs in the area at the time of this test. Fifteen meters to the east of the squash test plot was a watermelon variety planting that was rapidly declining due to an extremely large infestation of squash bugs. Squash bug adults and fifth instar nymphs were found migrating away from the watermelon planting.

Differences in the means were significant between

TABLE XIX

MEAN NUMBER OF DEAD SQUASH BUGS PER LEAF STAGE
FOR CARBOFURAN 2.24 kg AI/ha

Leaf Stage	Time	Nymphs					Adults	
		1st	2nd	3rd	4th	5th	Male	Female
1st leaf	24	5.00a[1]	5.00a	5.00a	4.00a	3.50a	4.75a	4.75a
3rd leaf	24	5.00a	5.00a	4.75a	4.25a	3.50a	2.50a	4.00a
5th leaf	24	5.00a	5.00a	5.00a	4.75a	2.75a	4.50a	4.00a
1st leaf	48	5.00a	5.00a	5.00a	5.00a	4.00a	4.75a	5.00a
3rd leaf	48	5.00a	5.00a	5.00a	4.25a	3.75a	4.00a	4.25a
5th leaf	48	5.00a	5.00a	5.00a	4.75a	4.00a	4.75a	4.50a
Check	24	0.50b	0.50b	0.50b	0.00b	0.25b	0.00b	0.00b
Check	48	0.75b	1.00b	0.75b	0.25b	0.25b	0.00b	0.00b

[1]Means within the same column followed by the same letter are not significantly different (P = 0.01; Duncan's [1955] multiple range test).

treatments for plant stand, dead, and live squash bugs. Carbofuran (2.24 kg [AI]/ha) had significantly more plants on each sample date than carbofuran 1.12 kg [AI]/ha (Table XX). The check was not significantly different from carbofuran 2.24 kg [AI]/ha on the first sample date or different from carbofuran 1.12 kg [AI]/ha on any sample date. Carbofuran's 1.12 kg [AI]/ha plant population remained relatively steady over the three sample dates, while carbofuran 2.24 kg [AI]/ha decreased slightly, and the check's plant population decreased the most. Carbofuran 2.24 kg [AI]/ha had significantly more plants over the sample dates (Table XXI) than the other treatments. Carbofuran 1.12 kg [AI]/ha and the check did not have significantly different plant populations over the sample dates (Table XXI). The seeds were planted in dry soil and the irrigation pattern did not totally cover the entire plot; thus the seeds did not emerge at the same rate. This is thought to be one possible cause for differences between the carbofuran treatments.

Neither sampling dates differed significantly in the number of live or dead squash bugs found (Table XXII). Carbofuran 2.24 kg [AI]/ha had significantly more dead bugs over the two sampling dates than the check, but not significantly more than carbofuran 1.12 kg [AI]/ha. The check had significantly more live squash bugs (3.9) than either carbofuran treatments (Table XXIII).

As a result of excessive rains in early October, the

TABLE XX

MEAN NUMBER OF PLANTS PER TREATMENT BY SAMPLE DATE STILLWATER, OKLA. 1986

Treatment	Rate kg AI/ha	Date[1] 9/20	9/24	10/7
Carbofuran 15G	2.24	17.6a	17.8a	16.4a
Carbofuran 15G	1.12	13.0b	13.8b	13.4b
Check	----	15.6ab	15.0ab	11.4
$LSD_{(0.05)}$		3.55	2.94	2.62

[1]Means within a column followed by the same letter are not significantly different (P=0.05).

TABLE XXI

MEAN NUMBER OF PLANTS FOR ALL SAMPLE DATES
STILLWATER, OKLA. 1986

Treatment	Rate kg AI/ha	Mean No.[1] Plants
Carbofuran 15G	2.24	17.26a
Carbofuran 15G	1.12	13.40b
Check	----	14.00b
$LSD_{(0.05)}$		2.55

[1]Means within a column followed by the same letter are not significantly different (P=0.05).

TABLE XXII

MEAN NUMBER OF SQUASH BUGS PER TREATMENT
BY SAMPLE DATE STILLWATER, OKLA. 1986

Treatment	Rate kg AI/ha	DEAD[1] 9/20	DEAD[1] 9/24	LIVE 9/20	LIVE 9/24
Carbofuran 15G	2.24	1.4	1.4	0.4	1.6
Carbofuran 15G	1.12	0.8	0.6	1.6	0.4
Check	----	0.4	0.4	4.2	3.6
$LSD_{(0.05)}$		2.38	1.01	4.38	3.73

[1]Significance not declared at (p=0.05) by LSD.

TABLE XXIII

MEAN NUMBER OF SQUASH BUGS BY TREATMENT OVER ALL DATES STILLWATER, OKLA. 1986

Treatment	Rate kg AI/ha	Mean No.[1] Dead	Mean No. Live
Carbofuran 15G	2.24	1.4a	1.0b
Carbofuran 15G	1.12	0.7ab	1.0b
Check	---	0.4b	3.9a
$LSD_{(0.05)}$		0.93	1.58

[1]Means within a column followed by the same letter are not significantly different (P=0.05).

test was shortened considerably, therefore it is difficult to know how the treatments would have affected plant population and squash bug numbers later in time. Initial information from the test is important to the overall control scheme for squash bugs. This information, combined with the information in Appendix I, shows a trend for increased plant populations with the use of carbofuran at 1.12 or 2.24 kg [AI]/ha when compared to the check (no insecticide). If this is true, it could mean reduced seeding rates are possible, and protection of the crop from overwintering squash bug adults, during the very susceptible seedling stage. Combined with the information from the greenhouse test, it appears that carbofuran can be used on seeded squash to control both adult and nymphal squash bugs. Carbofuran can be used on early or mid-season plantings to control adults and young nymphs, thus preventing the population from increasing at a time when the squash plant is most susceptible and also before harvest commences.

Summary and Conclusions

During the summer of 1984, an insecticide efficacy test was conducted at the O.S.U. Horticulture/Agronomy Research Station near Perkins, Okla. Individual plants were sampled before and after each experimental period for total number of adults (males and females), immature squash bugs, and egg masses. Squash bug numbers increased in the control plots as reported by Rensner et al. (1987). There was an overall

trend for methomyl, fenvalerate, and cypermethrin to provide control of nymphs, total squash bug numbers, and to depress adults and egg mass numbers over time. Population growth on plots treated with carbaryl and endosulfan did not seem to differ from the check, and carbaryl treated plots often exceeded the check plots in squash bugs present. Yield was greatest on cypermethrin (45.3 g [AI]/ha) treated plots and least on the control plots.

Topical application of methomyl, fenvalerate, and cypermethrin were more toxic than contact applications to the life stages of the squash bug. Cypermethrin was more toxic than fenvalerate, and fenvalerate was more toxic than methomyl for both types of application. First and second instar nymphs were affected by the smallest amount of insecticide with either application method. Generally, female and male squash bugs were the least affected, except for the fifth instar nymphs for methomyl and fenvalerate for the contact applications. Methomyl was more toxic than fenvalerate to fifth instar nymphs, males, and females.

In the greenhouse test with the systemic insecticide carbofuran, control of all stages of the squash bug was provided using 1.12 kg [AI]/ha and 2.24 kg [AI]/ha on squash plants up to the fifth leaf stage. First through third instar nymphs were killed within 24 h after placement on the plants with both rates of carbofuran. Control decreased slightly at both rates for fourth and fifth instars and adults at 24 h, but improved by the 48 h recording period.

Control for all life stages after 48 h were significantly different from the checks for both rates of carbofuran at each leaf stage tested.

Carbofuran applied as an incorporated band in the field had a larger plant population with the 2.24 kg [AI]/ha rate over the 1.12 kg [AI]/ha rate and the check. The 1.12 kg [AI]/ha initially had fewer plants due to irrigation pattern, but by the end of the test had more plants than the check plot where plant numbers decreased over the sampling period. There were significantly fewer live squash bugs recorded in the treated plots than the check. Carbofuran at 2.24 kg [AI]/ha had significantly more dead squash bugs over the test period than the check. The 1.12 kg [AI]/ha rate of carbofuran did not differ significantly from either the 2.24 kg [AI]/ha carbofuran rate or the check for dead squash bugs recorded.

Results from this study, when combined with existing knowledge of the squash bug's biology, can lead to improved control schemes and timing of insecticide applications. Carbofuran may be used at planting for the control of overwintering squash bugs early in the season in an attempt to "break" their life cycle at this point in time as postulated by Rensner et al. (1987). A foliar insecticide application of methomyl, fenvalerate, or cypermethrin can be used to control the nymphs before they become fourth instar nymphs or adults, as Elliot (1935) and Eichmann (1945) stated.

Thorough coverage appears to be necessary for foliar applications due to the difference in toxicity levels between topical and contact bioassay. The targeted stage should be the first to third instars for best results. Late planted squash may need a combination of carbofuran at planting and a foliar insecticide application later in the season to protect the planting from the second generation of squash bugs that may be present in large numbers in surrounding areas.

This study also points out the need for an improved method of sampling squash bugs and more information on their distribution and movement in a field before and after an insecticide treatment. It also reveals that first instar nymphs do not need to be sampled in an efficacy test, if recording is done within one day after application.

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APPENDIXES

APPENDIX A

EFFICACY TESTS FOR PLANT STAND AND SPOTTED CUCUMBER BEETLE

SQUASH: Cucurbita pepo
'Lemondrop'

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SQUASH STAND COUNTS, 1985: Lemondrop squash was seeded 31 May in a completely randomized block design and replicated 4 times. Plots were 3m rows with 20 hills/row and 3 seeds/hill. Rows were 2m apart. Sevin treatments were made 11, 17, 25 June. Furadan treatments were made at planting.

No phytotoxicity or significant differences were observed.

Squash Test, Bixby - 1985

Insecticide	Method of Application	Rate AI/A	Plants Per Row* 6/12	6/17	6/28
Furadan 15G	furrow	1.0	39.00A	38.25A	38.25A
Furadan 15G	band	1.0	34.50A	33.50A	33.50A
Furadan 15G	furrow	2.0	46.25A	45.50A	45.50A
Furadan 15G	band	2.0	50.75A	50.25A	48.50A
Sevin 50W	spray	2.0	39.50A	39.25A	39.25A
Check	-	-	53.75A	53.00A	52.75A

* Means followed by the same letter are not significantly different (P = .05).

WATERMELON: Citrullus lanatus 'Crimson Sweet'

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WATERMELON STAND COUNTS, 1985: Crimson Sweet watermelon was planted 31 May in a completely randomized block design and replicated 4 times. Plots were 3 m rows with 20 hills/row and 3 seeds/hill. Treatments were made, 11, 17, 25 June. Stand counts were made on a per row basis.

Due to excessive rainfall one block was deleted from the trial. No significant differences were found. Band treatments appeared to be better than furrow.

Treatment and Rate	(lb) AI/A	Method of Application	x Plants/Row 6/12	6/17	6/28
Vydate L	2.00	Band	53.67	52.67	50.67
Furadan 4F	2.00	Band	49.67	48.00	47.00
Vydate L	1.00	Band	49.00	46.33	44.33
Thiodan 50W	1.00	Spray	38.67	35.33	35.00
Nudrin 1.8	0.45	Spray	38.67	38.67	35.33
Furadan 15G	2.00	Band	33.67	31.67	33.33
Check	-	-	33.67	31.67	30.33
Sevin 50W	1.00	Spray	30.33	27.67	27.33
Diazinon AG500	3.00	PPI	29.33	27.67	25.67
Furadan 4F	2.00	Furrow	32.33	23.33	21.67
Furadan 15G	2.00	Furrow	20.33	28.67	15.67
			NS	NS	NS

WATERMELON: Citrullus lanatus 'Crimson Sweet'

Spotted Cucumber Beetle: Diabrotica undecimpunctata howardi Barber

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SPOTTED CUCUMBER BEETLE CONTROL ON WATERMELON, Fall, 1984: Crimson Sweet watermelon was planted 22 August at Vegetable Research Station, Bixby, Oklahoma in a complete randomized block design. Three seeds were planted/hill with 20 hills per row. Plots were 1 row, each 3 m long and replicated 4 times. No herbicide was applied.

Treatments were made 29 August and 4 September.

Plants and dead cucumber beetles were counted on 3 sample dates. No differences were observed for dead beetles on 13 September. Significant differences were observed on 13 September for plant stand.

Phytotoxicity was observed with Furadan 4F.

Treatment and Rate	(lb) AI/A	Method of Application	x dead beetles per row 9/13
Sevin 50W	1.00	Spray	3.25
Nudrin 1.8	0.45	Spray	2.75
Furadan 15G	1.00	Furrow	2.50
Thiodan 50W	1.00	Spray	2.25
Furadan 15G	2.00	Band	2.00
Furadan 15G	2.00	Furrow	2.00
Furadan 15G	1.00	Band	1.25
Furadan 4F	2.00	Band	1.25
Furadan 4F	2.00	Furrow	0.50
Vydate L	2.00	Band	0.25
Vydate L	1.00	Furrow	0.00
Check	-	-	0.00
			NS

Treatment and Rate	(lb) AI/A	Method of Application	Mean Number of Plants 8/31	9/5	9/13
Furadan 15G	1.00	Furrow	49.00	48.75	48.25A
Furadan 15G	1.00	Band	51.75	49.50	46.75A
Check	----	----	48.50	46.75	46.75A
Thiodan 50W	1.00	Spray	48.25	47.00	46.25A
Nudrin 1.8	0.45	Spray	48.25	47.25	45.50A
Furadan 15G	2.00	Band	49.75	47.50	45.25A
Vydate L	1.00	Band	45.75	43.00	42.25AB
Sevin 50W	1.00	Spray	45.25	43.75	41.50AB
Furadan 15G	2.00	Furrow	49.75	44.00	41.00AB
Vydate L	2.00	Band	40.25	37.75	36.00AB
Furadan 4F	2.00	Furrow	42.75	34.00	31.75B
Furadan 4F	2.00	Band	40.25	33.75	31.00B

Means in the same column followed by the same letter are not significantly different, (P=0.05), DMRT.

APPENDIX B

LD_{50}, 95% FIDUCIAL LIMITS, SLOPE AND INTERCEPT FOR CONTROL SPECIFIED AND OPTIMIZING CONTROL

CYPERMETHRIN TOPICAL

Stage	Time	LD_{50} µg/µl	Lower	Upper	C*
1st instar	12	1.85E-14	2.17E-17	3.42E-14	0.075
2nd instar	12	1.00E-8	2.17E-11	7.00E-8	0.025
3rd instar	12	2.57E-6	2.80E-7	5.403-5	0.0
4th instar	12	4.06E-3	1.903-3	8.70E-3	0.0
5th instar	12	0.024	0.010	0.061	0.0
males	12	0.018	0.014	0.022	0.0
females	12	0.030	0.024	0.036	0.0
1st instar	24	3.93E-15	2.42E-18	3.42E-14	0.125
2nd instar	24	8.43E-9	1.40E-14	1.00E-8	0.125
3rd instar	24	2.20E-7	9.00E-8	5.40E-7	0.025
4th instar	24	2.88E-3	2.49E-3	3.42E-3	0.075
5th instar	24	0.011	0.009	0.015	0.0
males	24	0.015	0.012	0.018	0.025
females	24	0.030	0.024	0.036	0.05

CYPERMETHRIN TOPICAL

Stage	Time	LD_{50} µg/µl	Lower	Upper	OPTC**
1st instar	12	3.00E-25	5.30E-27	4.44E-23	0.048
2nd instar	12	1.17E-19	2.80E-22	3.91E-16	0.013
3rd instar	12	1.27 E-6	2.61E-19	6.12E-5	0.0
4th instar	12	2.61E-3	4.35E-4	9.23E-3	0.0
5th instar	12	0.015	0.002	0.089	0.0
males	12	0.015	0.010	0.020	0.0
females	12	no convergence			
1st instar	24	7.31E-26	3.12E-29	8.39E-24	0.085
2nd instar	24	1.27E-21	1.16E-25	4.68E-18	0.101
3rd instar	24	2.7E-7	6.0E-8	8.0E-7	0.039
4th instar	24	2.77E-3	2.30E-3	3.31E-3	0.046
5th instar	24	9.46E-3	6.84E-3	0.013	0.000
males	24	0.015	0.012	0.018	0.022
females	24	0.029	0.022	0.035	0.030

* C = Control
** OPTC = Optimizing the control

FENVALERATE TOPICAL

Stage	Time	LD_{50} µg/µl	Lower	Upper	C*
1st instar	12	4.47E-4	1.25E-4	9.86E-4	0.075
2nd instar	12	2.70E-4	1.93E-4	3.68E-4	0.025
3rd instar	12	1.04E-3	5.19E-4	2.27E-3	0.0
4th instar	12	0.12	0.02	0.68	0.0
5th instar	12	1.37	0.38	5.07	0.0
males	12	4.20	1.23	19.6	0.0
females	12	4.96	1.86	19.4	0.0
1st instar	24	4.24E-4	9.15E-5	9.30E-4	0.2
2nd instar	24	3.18E-4	1.16E-4	6.93E-4	0.2
3rd instar	24	6.56E-4	2.80E-4	1.51E-3	0.025
4th instar	24	1.16E-2	3.56E-3	0.03	0.0
5th instar	24	0.41	0.16	0.92	0.0
males	24	1.99	0.52	5.10	0.025
females	24	2.82	0.90	6.07	0.05

FENVALERATE TOPICAL

Stage	LD_{50} Time	µg/µl	Lower	Upper	OPTC**
1st instar	12	0.0004	0.0001	0.0010	0.089
2nd instar	12	0.0002	0.00018	0.0003	0.012
3rd instar	12	0.0004	0.00008	0.0020	0.0
4th instar	12	0.0538	0.0009	0.7259	0.0
5th instar	12	no convergence			
males	12	2.49	0.01	3.83E+1	0.0
females	12	2.95	0.05	43.00	0.0
1st instar	24	0.0005	NC***	0.0012	0.278
2nd instar	24	0.0002	0.00009	0.0005	0.119
3rd instar	24	0.0002	0.00004	0.0011	0.0
4th instar	24	0.0061	0.0006	0.0336	0.0
5th instar	24	0.19	0.02	0.78	0.0
males	24	1.94	0.51	4.97	0.012
females	24	2.75	0.79	5.98	0.037

* C = Control
** OPTC = Optimizing the control
*** NC = not calculated

METHOMYL TOPICAL

Stage	Time	LD_{50} µg/µl	Lower	Upper	C*
1st instar	12	0.17	2.71E-5	0.36	0.075
2nd instar	12	0.12	0.07	0.18	0.075
3rd instar	12	0.12	0.06	0.22	0.10
4th instar	12	0.41	0.18	0.64	0.075
5th instar	12	0.29	0.18	0.48	0.0
males	12	0.54	0.42	0.70	0.0
females	12	1.22	0.57	4.94	0.0
1st instar	24	0.06	0.01	0.12	0.10
2nd instar	24	0.04	0.02	0.08	0.075
3rd instar	24	0.11	0.06	0.17	0.10
4th instar	24	0.27	0.01	0.41	0.075
5th instar	24	0.22	0.10	0.52	0.0
males	24	0.31	0.26	0.36	0.0
females	24	1.04	0.59	7.36	0.0

METHOMYL TOPICAL

Stage	LD_{50} Time	µg/µl	Lower	Upper	OPTC**
1st instar	12	0.25	0.17	0.30	0.178
2nd instar	12	0.11	0.06	0.18	0.055
3rd instar	12	0.11	0.04	0.21	0.067
4th instar	12	0.39	0.12	0.62	0.085
5th instar	12	no convergence			
males	12	0.45	0.28	0.66	0.0
females	12	0.83	NC***	NC***	0.0

METHOMYL TOPICAL

1st instar	24	0.06	0.01	0.14	0.101
2nd instar	24	0.04	0.02	0.08	0.068
3rd instar	24	0.10	0.04	0.17	0.082
4th instar	24	0.30	NC***	0.41	0.137
5th instar	24	0.40	0.38	0.42	0.119
males	24	no convergence			
females	24	0.77	NC***	NC***	0.0

* C = Control
** OPTC = Optimizing the control
*** NC = not calculated

CYPERMETHRIN CONTACT

Stage	Time	LC_{50} µg/cm^2	Lower	Upper	C*
1st instar	12	4.54	3.45	5.72	0.066
2nd instar	12	0.66	0.54	0.81	0.03
3rd instar	12	4.17	2.08	7.74	0.03
4th instar	12	4.37	3.37	5.70	0.0
5th instar	12	5.86	4.85	7.04	0.0
males	12	6.95	4.56	10.87	0.0
females	12	10.63	8.62	13.15	0.0
1st instar	24	1.62	0.69	3.04	0.13
2nd instar	24	0.25	0.19	0.30	0.16
3rd instar	24	1.63	0.63	3.04	0.13
4th instar	24	1.07	0.51	1.94	0.0
5th instar	24	4.66	2.70	7.78	0.0
males	24	2.70	2.16	3.35	0.0
females	24	4.95	3.88	6.30	0.0

CYPERMETHRIN CONTACT

Stage	LC_{50} Time	µg/cm^2	Lower	Upper	OPTC**
1st instar	12	4.48	3.12	5.76	0.055
2nd instar	12	0.52	0.28	0.94	0.0
3rd instar	12	4.14	1.61	7.98	0.027
4th instar	12	3.35	1.53	6.18	0.0
5th instar	12	no convergence			
males	12	4.99	2.16	9.86	0.0
females	12	10.98	7.61	13.78	0.006
1st instar	24	1.53	0.40	3.18	0.108
2nd instar	24	0.24	0.20	0.29	0.086
3rd instar	24	1.58	0.45	3.16	0.113
4th instar	24	0.61	0.04	1.82	0.0
5th instar	24	no convergence			
males	24	1.93	0.83	3.51	0.0
females	24	no convergence			

* C = Control
** OPTC = Optimizing the control

FENVALERATE CONTACT

Stage	Time	LC_{50} µg/cm^2	Lower	Upper	C*
1st instar	12	2.52	0.98	9.67	0.0
2nd instar	12	5.49	2.59	16.95	0.03
3rd instar	12	27.21	10.53	37.85	0.03
4th instar	12	29.87	20.08	47.47	0.0
5th instar	12	70.33	58.73	88.34	0.0
males	12	60.16	45.85	87.37	0.0
females	12	55.96	44.74	73.79	0.0
1st instar	24	2.21	8.0E-4	3.33	0.13
2nd instar	24	1.34	0.67	1.86	0.16
3rd instar	24	12.65	9.60	16.10	0.13
4th instar	24	10.43	5.86	19.66	0.0
5th instar	24	41.62	35.10	49.53	0.0
males	24	23.91	19.40	29.46	0.0
females	24	22.31	9.67	44.30	0.0

FENVALERATE CONTACT

Stage	Time	LC_{50} µg/cm^2	Lower	Upper	OPTC**
1st instar	12	5.48	4.81	6.24	0.104
2nd instar	12	5.84	NC***	NC***	0.050
3rd instar	12	29.96	15.92	36.06	0.057
4th instar	12	30.64	23.94	39.17	0.004
5th instar	12	50.04	31.34	88.42	0.005
males	12	no convergence			
females	12	42.00	8.46	449.86	0.000
1st instar	24	2.12	NC***	3.29	0.118
2nd instar	24	1.44	0.69	2.08	0.184
3rd instar	24	12.35	9.25	15.92	0.117
4th instar	24	no convergence			
5th instar	24	30.43	19.42	46.31	0.009
males	24	17.87	7.61	36.22	0.000
females	24	16.87	7.00E-3	19.67	0.000

* C = Control
** OPTC = Optimizing the control
*** NC = not calculated

METHOMYL CONTACT

Stage	Time	LC_{50} µg/cm^2	lower	upper	C*
1st instar	12	92.60	57.55	164.90	0.0
2nd instar	12	136.91	112.62	164.30	0.03
3rd instar	12	222.72	138.75	365.91	0.0
4th instar	12	218.44	180.34	268.30	0.0
5th instar	12	262.16	222.91	311.03	0.0
males	12	178.66	152.59	209.89	0.0
females	12	207.71	111.23	464.54	0.0
1st instar	24	83.88	5.58	241.35	0.13
2nd instar	24	110.27	86.48	131.48	0.16
3rd instar	24	154.21	118.89	192.20	0.13
4th instar	24	143.39	91.16	234.13	0.0
5th instar	24	181.15	151.75	217.59	0.0
males	24	168.62	147.83	194.39	0.0
females	24	179.41	83.28	1180.14	0.0

METHOMYL CONTACT

Stage	Time	LC_{50} µg/cm^2	lower	upper	OPTC**
1st instar	12	98.37	NC***	117.16	0.017
2nd instar	12	134.26	109.82	161.56	0.016
3rd instar	12	167.13	24.75	617.73	0.0
4th instar	12	226.48	177.05	275.09	0.009
5th instar	12	210.71	100.14	400.74	0.0
males	12	148.56	67.88	265.69	0.0
females	12	NC***	NC***	NC***	0.17
1st instar	24	77.21	0.87	208.41	0.093
2nd instar	24	105.34	77.35	126.66	0.117
3rd instar	24	149.63	110.33	189.27	0.109
4th instar	24	no convergence			
5th instar	24	190.10	154.91	225.65	0.01
males	24	no convergence			
females	24	150.90	55.50	312.78	0.0

* C = Control
** OPTC = Optimizing the control
*** NC = not calculated

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