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I am submitting herewith a thesis written by Gayle Franklin Bailey entitled "Evaluation of In-furrow and Foliar Insecticidal Treatments for the Control of Thrips (Thysanoptera) on Seedling Cotton in Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Biology.

C. D. Pless, Major Professor

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Graduate Studies and Research

EVALUATION OF IN-FURROW AND FOLIAR INSECTICIDAL TREATMENTS FOR THE CONTROL OF THRIPS (THYSANOPTERA) ON SEEDLING COTTON IN TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Gayle Franklin Bailey

December 1976

ACKNOWLEDGMENTS

The author wishes to express appreciation to his committee chairman, Dr. C. D. Pless, for his invaluable assistance and counseling during this study. Sincere appreciation is extended to Dr. G. L. Lentz for his supervision and advice in the research and organization of this thesis. He is also indebted to Dr. R. R. Gerhardt for his valuable suggestions in the preparation of the manuscript.

Appreciation is extended to Dr. E. H. Moody for his guidance during his stay on the committee and to Dr. W. L. Sanders for his aid in performing statistical analysis.

Gratitude is expressed to Dr. J. E. Pendergrass and Dr. E. E. Burgess for their helpful suggestions. He also wishes to thank Mr. Bill Wyatt, Mr. Walton Mullins, and Mr. Steve Tracy for their aid and encouragement.

Special appreciation is extended to his wife, Debbie, for her encouragement and understanding during the preparation of this thesis.

ABSTRACT

In-furrow and foliar insecticides are the two most common treatments used to control injurious levels of thrips on seedling cotton. Six in-furrow insecticidal treatments and seven foliar insecticidal treatments were applied at four different locations in the spring of 1976 in the West Tennessee area. These treatments were evaluated in regard to thrips control on seedling cotton and also their effect upon plant populations, plant heights, and plant vigor.

In-furrow treatments were applied at planting while foliar sprays were applied after the cotton seedlings had emerged. Whole-plant samples were taken from all treated plots exactly one week after the foliar sprays had been applied. The plants were then taken to the laboratory, where the thrips were extracted from the plants and counted.

All in-furrow treatments gave excellent control of thrips populations with no treatment giving significantly better results than another. Among the foliar treatments, dicrotophos, monocrotophos, methamidophos, and SD 43775 were judged to give acceptable thrips control. Malathion, azinphosmethyl, and dimethoate were judged unacceptable for use as foliar treatments for the control of thrips infestations.

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CHAPTER I

INTRODUCTION

The importance of thrips (Thysanoptera) as pests of cotton has been a debatable question for many years. Although most researchers have found that thrips retard or delay the growth and vigor of cotton plants, relatively few of this number have found thrips to reduce yields. Most researchers now seem to agree that thrips infestations are greatly influenced by a number of environmental factors, the cumulative effect of which may allow thrips populations to develop to unusually high levels. Although economic thresholds have been established for thrips, their minute size makes counting very difficult, especially using in-field counting methods.

Temperature and rainfall seem to be the primary environmental factors involved in increasing or decreasing thrips populations (Lewis, 1973). Thrips often become a problem when weather conditions are most unfavorable for the cotton plants. Mumford and Hey (1930) and others have concluded that plants with a disturbed water content are generally more heavily infested with thrips. Plants that emerge during cool, wet springs generally have poor root systems and lack vigor, often resulting in a buildup of thrips on these stressed plants. Although climatic factors are considered to be the most important determinates of thrips populations, other factors such as soil type and time of planting are also involved (Lewis, 1973).

In many areas, thrips generally are not a problem in years of near-normal temperature and rainfall (Lewis, 1973). However, when large amounts of rainfall followed by cool temperatures occur shortly after the plants emerge, such as happened in the West Tennessee area in 1976, thrips populations can become large enough to merit control. The economic threshold in Tennessee has been established at one thrips per plant (Pendergrass, 1976). In other words, control measures should be instigated when there is an average of one thrips on every cotton seedling. Usually, counts are made in the field by shaking the plants vigorously over a container or piece of colored cardboard. Although movement by the larger, darker adults can usually be detected using this method, it is questionable whether the smaller, translucent, slower moving immatures can be observed without the aid of a microscope.

Another method that can be used in determining whether thrips control is necessary is by examining plant damage. Thrips damage can be recorded as light, medium, or heavy. Damage is considered to be light when the newest unfolding leaves show only a brownish tinge along the edges with no silvering of the undersides of the leaves. Damage is considered medium if the newest leaves show browning along the edges and some silvering on the undersides of most leaves. Insecticides should be applied at this level. Plant damage is considered heavy when the terminal buds show injury, the plant is deformed, and silvering of the leaves is readily noticeable (Velsicol Chemical Co., 1965).

Control of thrips on cotton seedlings has been achieved primarily through the use of chemicals. These chemicals are generally applied either as in-furrow granules and sprays at planting time or as foliar sprays applied after the cotton seedlings have emerged. Most of these chemicals are organic phosphate compounds, although a few, such as Temik[R] (aldicarb), belong to the carbamate group. Those chemicals applied at planting work systemicly to control thrips on plants, while those applied as foliar sprays may act as either contact or systemic poisons or both.

The purpose of this study is to compare the different chemicals used to control thrips on cotton and to evaluate them based on their control of thrips populations and their effects upon the cotton plants.

CHAPTER II

LITERATURE REVIEW

Although thrips have been recognized as economically important pests for over 175 years (Marsham, 1796), little attention had been given to their relationship with cotton until the early 1900's. Morrill (1917) stated that the only innury to cotton in the U.S. by insects of the order Thysanoptera was caused by a western species of the bean thrips (*Heliothrips fasciatus* Haliday; Heliothripinae) in the Imperial Valley of California.

A comprehensive study of thrips and their association with the cotton plant was published in the Annals of Applied Biology between the years 1927 and 1937. Wardle (1927) began the eight part series with a report on the relation between the degree of infestation and the amount of water supplied to the plant. He found that rainfall was a factor in reducing the number of some species of thrips; rainfall causes the soil to cake and thus prevents some larvae from going into the soil to pupate. MacGill (1927) continued the study with a report on the relation between temperature and the life cycle of Thysanoptera. Basing his conclusions on observations predominantly of the onion thrips (Thrips tabaci) on cotton, he found the average life cycle lasted 23-31 days from oviposition to imaginal emergence but decreased in length with an increase in temperature. His studies were conducted under conditions of temperature varying between a mean maximum of 26.7°C. and a mean minimum of 11.25°C. and of relative humidity varying between a mean maximum of 92.4% and a mean minimum of 74.7%. He separated the life cycle into the following components: (1) an egg stage that lasted roughly eight days, (2) two larval stages with a combined duration of ten to fourteen days, (3) a prepupal stage of one to two days, and (4) a pupal stage of four to seven days.

A description of the type of injury caused by thrips was published by Wardle and Simpson (1927). They found that thrips gash a single epidermal cell of plant tissue using pickaxe-like movements of the single mandible. Leaf injury results from necrosis of a patch of mesophyll cells lying immediately below the gash in the epidermal cell. In the later stages of leaf injury, they found that such necrosis involves the whole leaf, all the layers become disorganized, and premature shedding occurs.

MacGill completed the series on Thysanoptera in the Annals of Applied Biology with five papers. He reported that surface caking does have an important influence on thrips infestation in the field (1929) and that light soil is more favorable to multiplication of soil pupating species of thrips than an easily caking, clay soil (1930). In a second paper in 1930, MacGill stated that plants sown late in the season in light soil were most affected by thrips, the infestation being relatively high almost from germination, plants sown in light soil earlier in the year had a low initial infestation but became high at the end of the season, and plants sown in clay soil at different dates did not show a marked difference in infestation (MacGill, 1930a). He concluded that although temperature has a most marked effect on the length of the life cycle of _Thrips tabaci_, the degree of relative humidity appears neither to accelerate nor retard the development of this insect (MacGill, 1931). In his final paper, he reported that relative humidity does not have a marked effect on the length of the life cycle of Thysanoptera. He found that the length of the life cycle varies with absolute humidity of atmosphere, and at vapour pressures below 15 mm. the conditions have a retarding influence on development, while those between 15 and 25 mm. accelerate development (MacGill, 1937).

Mumford and Hey (1930) explored the relation between water balance of plants and its effect upon thrips population. They concluded that a disturbed water content from whatever cause, renders the cotton plant more susceptible to feeding of sap feeding insects such as thrips.

Bailey (1932) devised a method for rearing thrips in the laboratory. The apparatus consisted of a single cotton leaf placed in a petri dish of water. A method for collecting thrips was developed by Gaines (1934), who with the use of Berlese funnels, extracted thrips from plants for observation. Whole plants were placed in the funnels and heated, the thrips being induced to leave the plants and fall into a vial of alcohol below each funnel.

Watts (1934) identified and studied the life cycles of three important thrips species on cotton. His findings indicated that the three most important thrips species in South Carolina were the flower thrips, _Frankliniella tritici_ (Fitch), the tobacco thrips, _F. fusca_ (Hinds) and the onion thrips, _Thrips tabaci_ Lind. He found _F. fusca_ to have the longest life cycle (18.5 days), lay the largest number of eggs (55.5 eggs per female), and to live the longest in the adult stage (29.08 days). Watts also did an excellent study two years later on F. tritici in which he found thrips to exhibit a negative geotrophic response and a positive phototropic response (Watts, 1936). In 1937 he updated his earlier work, listing a total of thirteen species attacking cotton, representing ten genera belonging to three families and two suborders. However, he still maintained that F. tritici (Fitch), F. fusca (Hinds), and Thrips tabaci Lind. were the most important (Watts, 1937).

One of the first experiments to determine if thrips caused economic damage was conducted by Dunnam and Clark (1937). Of 40 cotton varieties tested, 34 were found to produce less seed cotton when damaged by thrips. The average boll crop for all varieties was reduced 7.72% and was set from ten days to two weeks later on the damaged plants than on normal plants. The average boll size was also reduced. Fletcher and Gaines (1939) had similar results in Texas tests. They found mature cotton plants to have smaller and fewer bolls per plant when attacked by thrips, and 358 lb./acre of seed cotton were lost.

Between 1945 and 1960, persistent chlorinated hydrocarbons, mainly BHC, DDT, aldrin, dieldrin and toxaphene, were generously applied to growing crops as sprays and dusts to kill thrips living in exposed positions on plants (Lewis, 1973). Gaines et al. (1952) found malathion to be an effective as dieldrin but not as effective as parathion for thrips control. Demeton was found to have very effective immediate control but failed to show a long residual toxicity.

The research of Davis et al. (1957) showed that the control of thrips with such chlorinated hydrocarbon insecticides as dieldrin and toxaphene was better than that obtained with the phosphorus compounds azinphosmethyl, methyl parathion, and thrichlorfon. According to Davis, the period of residual control afforded by chlorinated hydrocarbon insecticides was longer than that afforded by phosphorous insecticides, especially when low dosages were used.

Parencia et al. (1957) compared seed treatments with foliar sprays. Seeds were mechanically treated in a rotating drum using systemic compounds in activated-carbon carrier. Toxaphene spray was found to do a better job than the seed treatments tested. Phorate seed treatment showed some phytotoxic effects on the cotyledons of the cotton plants, but these were not severe. In a similar work, Reynolds et al. (1957) found that thrips were controlled by .5 to 1 lb. phorate per 25 lb. seed for a period of four to five weeks. Testing foliar sprays, Davis et al. (1958) observed that toxaphene, methyl parathion, azinphosmethyl, and carbaryl all gave good thrips control.

Phorate and Bayer 19639 seed treatments were tested by Dobson (1958) to determine their effects upon two different varieties of cotton, Pima S-1 and Acala 1517C. Both materials reduced seedling stands of Pima S-1 while phorate retarded blossoming and reduced growth of both varieties during the early part of the season. However, neither seed treatment reduced yields in either of the two cotton varieties. Hopkins et al. (1958) reached similar conclusions, adding that grade and staple length, as well as yields, were not affected by the treatments.

Mistric and Spyhalski (1959) evaluated phorate treated seed at four widely separated locations in North Carolina. They found phorate gave good thrips control but delayed cotton fruiting. Tuttle and Wene (1959), in Arizona, concluded that toxaphene, heptachlor, dieldrin, and malathion all gave good thrips control. However, they found no increase in yields from any treatment over that of the untreated plots. Race (1961), in studies in New Mexico, found that in-furrow planting of disulfoton and phorate controlled infestations of western flower thrips, *F. occidentalis* (Pergande), on cotton seedlings for up to 7 weeks. Spray applications of methyl parathion and m.p. plus toxaphene also controlled thrips, but toxaphene alone did not. His results showed that early-season thrips control on cotton in New Mexico increased yields, and that in-furrow applications of disulfoton were especially effective.

Hightower (1958) studied the effect of thrips infestation on the height and weight of seedling cotton plants. Stem growth in plants infested with *F. fusca* using 10 adults per plant was consistently reduced 28% and more below that of the check plants, while green weight was reduced by approximately 50%.

The relation of migration, temperature, and precipitation upon thrips infestations was investigated by Harding (1961) in South Texas. His research showed that precipitation and mean daily temperatures below 50°F. reduced thrips movement. Driving rains reduced thrips infestation on the plants and mean daily temperatures below 58°F. favored destructive infestations. Heavy infestations resulted from build-up in the field and not from thrips movement in the field.

The importance of predaceous insects, spiders, and mites upon thrips infestations was investigated by Whitcomb and Bell (1964) in Arkansas cotton fields. They reported that the insidious flower bug (*Orius insidiosus*), lady beetles, nymphs of several other species of Hemiptera, and predatory thrips (primarily, *Aeolothrips fasciatus*), were the primary predators of thrips. Ripper and George (1965) also found syrphid flies and lacewing larvae to be of importance as thrips predators in the Sudan.

Although much research had been conducted on the use of chemicals to control thrips, many researchers were finding that moderate infestations of thrips did not decrease yields. Watson (1965), using various chemicals to control thrips, found that chemical treatments resulted in more uniform and vigorous plants. However, thrips control had no influence on rate of maturity or on the total yield of seed cotton. Experiments by Pfrimmer (1966) indicated that control of thrips resulted in earlier fruiting of plants, but that yields were not increased. King (1966) reviewed literature published from 1940 through 1965 and found that yields were increased in only 19 of more than 150 tests when thrips were chemically controlled.

Although King's report indicated that chemical control was probably unnecessary at low and moderate levels of infestation, most researchers agreed that chemical control was beneficial at higher infestations. Beckham (1967, 1970), Lall and Singh (1968) and many others continued work on chemicals including aldicarb, carbofuran, parathion, aldrin, benzene hexachloride, malathion, DDT, endrin, and demeton. Increased significance was placed upon in-furrow granules when aldicarb (Temik)[R], applied at planting to control thrips, was also found to suppress boll weevil populations (Boyd et al., 1973) (Timmons et al., 1973).

Weeds and small grain were found by Beckham (1969) to be important host plants for development of thrips and subsequent migration to cotton. He found that grain thrips Limnothrips cerealium (Haliday) and the composite thrips Microcephalothrips abdominalis (Crawford) moved from maturing grain into cotton. The most common species on cotton, he reported, were the tobacco thrips Frankliniella fusca (Hinds), the onion thrips Thrips tabaci Lindeman, and the flower thrips Frankliniella tritici (Fitch), F. exigus (Hood), and Sericothrips variabilis Beach.

Hosny and Shoeib (1970) first reported hourly fluctuations in thrips populations. Taking cotton seedlings from the field every 2 hours, the thrips were extracted and the number of thrips recorded. Maximum numbers were found between 4 a.m. and 6 a.m. and minimum numbers at 2 p.m. More than 60% of the daily total number of thrips were present on the seedlings between midnight and 8 a.m., and less than 10% between 10 a.m. and 2 p.m. They concluded that chemical control measures should be applied as late in the afternoon as possible and that sampling should be carried out early in the morning.

An economic threshold for thrips was conceived by El-Saadany et al. (1975) for Thrips tabaci on cotton in Egypt. They discovered that a unit infestation (one insect/seedling) by T. tabaci caused a decrease of .30 cm. in the average length of infested seedlings, a 4% reduction in the total number of green bolls per plant and an

8% to 9% loss in total average yield per feddan (1.038 acres). They determined that a practical damage threshold for cotton sown during the period from early March to early April would be 9-10 insects per seedling. At this level chemical control measures should be applied. Otherwise such measures would not be necessary as long as the average number of thrips per seedling is below the injury level.

Leggett and Cross (1976) investigated the possibility of using traps to lure and capture thrips. The Leggett trap, the electric grid trap and the Whittam trap were used, both baited and unbaited. The Whittam trap was the only one to catch any thrips, working better unbaited than baited. Neither the Leggett nor the electric grid trap caught any thrips, baited or unbaited.

CHAPTER III

MATERIALS AND METHODS

Thirteen different chemical treatments were evaluated for control of thrips infestation in cotton at four different locations in the spring of 1976. Four of the treatments were in-furrow granules, two were in-furrow sprays, and the remaining seven were foliar sprays. Table 1 summarizes the treatments, their formulations, and rates of application.

Two-row plots of cotton, 20 feet long, replicated four times in a randomized complete block design, were planted at the Milan Field Station at Milan, the Ames Plantation near Grand Junction, and at two sites at the West Tennessee Experiment Station at Jackson, Tennessee, following recommended tillage procedures. Cotoran^R herbicide was applied broadcast at 1.5 lb. ai/A at all locations. Plots were planted with a one-row, tractor-mounted planter with in-furrow granular treatments and in-furrow spray treatments applied at planting.

When the plants were approximately four inches in height, the foliar spray treatments were applied. Prior to their application, pre-treatment samples were taken to determine if the thrips population was uniformly distributed among the plots. Foliar sprays were applied using a hand-held pressure sprayer unit attached to a CO_2 cartridge. The foliar treatments were applied at Milan on June 8, on the early planted field at Jackson on June 14, and on the late planted field at

Table 1. Insecticidal Treatments

Treatment	Formulation	Rate (lbs. ai/Acre)	Method of Application
1. disulfoton	15 G	0.75	In-furrow
2. phorate	15 G	0.50	In-furrow
3. aldicarb	15 G	0.40	In-furrow
4. phenamiphos	15 G	1.60	In-furrow
5. UC 21865	75 WP	1.50	In-furrow
6. UC 21865	75 WP	3.00	In-furrow
7. dicrotophos	8 EC	0.125	Foliar
8. monocrotophos	5 EC	0.625	Foliar
9. dimethoate	2.67 EC	0.165	Foliar
10. azinphosmethyl	2 EC	0.165	Foliar
11. methanidophos	4 EC	0.100	Foliar
12. malathion	5 EC	0.470	Foliar
13. SD 43775	2.4 EC	0.050	Foliar
14. check			

Jackson on June 29. No foliar spray treatments were applied at Ames due to insufficient stands.

Exactly one week after the foliar sprays were applied, samples were taken from all treatments. Each sample consisted of two plants from each row of the two-row plot making a total of four plants in each sample. The plants were gently lifted out of the soil and placed in labeled pint jars. The whole-plant samples were then refrigerated until the thrips could be extracted and counted. At Ames, samples were taken only from plots treated with in-furrow granules and in-furrow sprays.

The thrips were extracted from the whole plant samples using a modified version of a technique developed by Bullock (1963). Plants were beaten together vigorously over a large funnel, the thrips falling into a large vial attached to the funnel opening. The funnel was then washed with 90% ethanol, which was also collected in the vial. Between samples, the funnel was washed thoroughly to insure that all thrips were removed from the funnel. Thrips were counted with the aid of a microscope.

Plant height was evaluated at Milan and at both fields at Jackson. In taking plant height measurements, three plants from each row of the two row plot were measured making a total of six plants measured per plot. Plant vigor was evaluated at Milan and at the early planted field at Jackson. Both plant height and vigor ratings were evaluated approximately seven to ten days after the foliar treatments were applied. Stand counts were also made at Milan on July 8. Stand counts were not made on the early-planted field at

Jackson due to relatively poor stands nor at the late-planted field at Jackson where all treatments were judged to have equal plant densities (see Table 2).

To determine the residual control of the treatments, samples were taken from the early planted field in Jackson again on July 9, 25 days after the foliar treatments were applied and 18 days after the first samples were taken. The thrips were extracted from the plants and counted in the manner previously described.

Aphid populations were also evaluated at all locations, but were found to be insignificant. Thrips were sent to the Systematic Entomology Laboratory at Beltsville, Maryland, for identification.

A summary of the insecticides used, their chemical names, and manufacturers are given in Table 3.

Table 2. Summary of Procedures

Location	Planting Date	Foliar Sprays Applied	Thrips Sampled	Plant Heights Recorded	Plant Vigor Recorded	Stand Counts Recorded	Thrips Sampled
Milan	May 12	June 8	June 15	June 15	June 15	July 8	
Jackson (early)	May 12	June 14	June 21	June 29	June 29		July 9
Jackson (late)	June 8	June 29	July 7	July 6			
Ames	May 11		June 18				

Table 3. Summary of Insecticides

Common Name	Trade Name	Manufacturer	Chemical Name
disulfoton	Di-Syston	Chemagro[a]	0,0-Diethyl S-[2-(ethylthio) ethyl] phosphorodithioate
phorate	Thimet	American Cyanamid[b]	0,0-diethyl S-[(ethyl thio) methyl] phosphoradithioate
aldicarb	Temik	Union Carbide[c]	2-Methyl-2-(methylthio) propionaldehyde
phenamiphos	Nemacur	Chemagro	Ethyl 3-methyl-4-(methylthio) phenyl (1-methylethyl) phosphoramidate
UC 21865		Union Carbide	2-methyl-2-(methylsulfonyl) propionaldehyde 0-(methylcarbamoyl) oxime
dicrotophos	Bidrin	Shell[d]	Dimethyl phosphate of 3-hydroxy N,N-dimethyl-cis-crotonamide
monocrotophos	Azodrin	Shell	Dimethyl phosphate of 3-hydroxy-N-methyl-cis-crotonamide
dimethoate	Cygon	American Cyanamid	0,0-dimethyl S-(N-methylcarbamoylmethyl) phosphorodithioate
azinphosmethyl	Guthion	Chemagro	0,0-Dimethyl S-[(4-oxo-1,2,3-benzotriazin-3(4H)-yl)methyl] phosphorodithioate
methamidophos	Monitor	Chemagro	0,S-Dimethyl phosphoramidothioate
malathion	Cythion	American Cyanamid	0,0-dimethyl phosphorodithioate of diethyl mercaptosuccinate
SD 43775		Shell	chemical identity not been released

[a]Chemagro Corporation, P. O. Box 4913, Kansas City, Missouri 64120.

[b]American Cyanamid Company, P. O. Box 400, Princeton, New Jersey 08540.

[c]Union Carbide Chemical Company, P. O. Box 1906, Salinas, California 93901.

[d]Shell Chemical Company, 2401 Crow Canyon Road, San Ramon, California 94583.

CHAPTER IV

RESULTS AND DISCUSSION

A. THRIPS CONTROL USING IN-FURROW GRANULES AND SPRAYS

In-furrow granules and sprays gave consistently good thrips control at all locations. Disulfoton, phorate, aldicarb, phenamiphos, and UC 21865 all gave significant control of thrips when compared with the untreated check while no significant difference was found between any two in-furrow treatments at any location (see Table 4).

B. THRIPS CONTROL USING FOLIAR SPRAYS

Results of tests with foliar treatments were not as consistent as those of in-furrow treatments. At Milan, all foliar sprays gave significant thrips control when compared to the untreated check. Monocrotophos, dicrotophos, dimethoate, and methamidophos gave significantly better thrips control than did azinphosmethyl, malathion, and SD 43775. These results are summarized in Table 5.

When the earliest planted cotton at Jackson was sampled on June 21, all treatments gave significant thrips control except malathion when compared with the untreated check. All other treatments were significantly better in controlling thrips than malathion. These results are shown in Table 6.

At the late planted field at Jackson, all foliar treatments were significantly better than the untreated check in the number of thrips present. However, dicrotophos and methamidophos gave the best

Table 4. Number of Thrips Per Treatment[a]

Treatment	Rate (lb. ai/A)	Location[b]				
		Milan (June 15)	Ames (June 18)	Jackson early (June 21)	Jackson late (July 7)	Jackson early (July 9)
disulfoton	0.75	1	6	4	1	0
phorate	0.5	0	3	3	1	0
aldicarb	0.4	3	8	0	0	0
phenamiphos	1.6	0	12	3	0	0
UC 21865	1.5	0	5	2	3	0
UC 21865	3.0	1	3	3	1	0
check		284	114	27	44	33

[a]Numbers of thrips collected from 16 plants (4 plants/sample x 4 reps).

[b]Dates samples were taken in parentheses.

Table 5. Thrips Control Using Foliar Spray Treatments at Milan, June 15

Treatment	lb. ai/Acre	Avg. No. Thrips Per 16 Plants[a]
monocrotophos	0.625	2 a
dicrotophos	0.125	4 a
methamidophos	0.10	9 a
dimethoate	0.165	9 a
azinphosmethyl	0.165	82 b
SD 43775	0.050	96 b
malathion	0.470	130 b
check		284 c

[a]Means within a column followed by the same letter are not significantly different at the 5% level using Newman-Keuls multiple range test and transformed data ($\sqrt{N + 1}$).

Table 6. Thrips Control Using Foliar Spray Treatments at Jackson, June 21

Treatment	lb. ai/Acre	Avg. No. Thrips Per 16 Plants[a]
dicrotophos	0.125	2 a
SD 43775	0.050	3 a
methamidophos	0.10	4 a
monocrotophos	0.625	4 a
dimethoate	0.165	6 a
azinphosmethyl	0.165	11 a
malathion	0.470	24 b
check		27 b

[a]Means within a column followed by the same letter are not significantly different at the 5% level using Newman-Keuls multiple range test and transformed data ($\sqrt{N + 1}$).

control, being significantly better than azinphosmethyl, malathion, and SD 43775. These results are shown in Table 7.

When the early planted cotton at Jackson was sampled again on July 9, no significant differences were found between any treatments nor between any treatment and the untreated check.

C. EVALUATION OF THRIPS CONTROL BETWEEN IN-FURROW AND FOLIAR TREATMENTS

Although the smallest number of thrips were found on the in-furrow treatments at all locations, the in-furrow treatments were not significantly better than some of the foliar treatments.

At Milan, none of the in-furrow treatments differed significantly from the foliar treatments dimethoate, methamidophos, dicrotophos, or monocrotophos but all differed significantly from the foliar treatments malathion, SD 43775, and azinphosmethyl. The differences between the foliar and in-furrow treatments at Milan are shown in Table 8.

Malathion was the only foliar spray that differed significantly from any of the in-furrow treatments at the early planted field at Jackson sampled on June 21. The number of thrips found on the malathion treated cotton was significantly greater than the number found on each of the in-furrow treatments. These results are shown in Table 9.

The differences between the foliar sprays and in-furrow treatments at the late planted field at Jackson are shown in Table 10. None of the in-furrow treatments worked significantly better than methamidophos,

Table 7. Thrips Control Using Foliar Spray Treatments at Jackson, July 7

Treatment	lb. ai/Acre	Avg. No. Thrips Per 16 Plants[a]
dicrotophos	0.125	2 a
methamidophos	0.10	2 a
monocrotophos	0.625	5 ab
dimethoate	0.165	11 abc
SD 43775	0.050	12 bc
malathion	0.470	15 bc
azinphosmethyl	0.165	24 c
check	0.165	44 d

[a]Means within a column followed by the same letter are not significantly different at the 5% level using Newman-Keuls multiple range test and transformed data ($\sqrt{N + 1}$).

Table 8. Thrips Control at Milan, June 15: Comparisons Between In-furrow and Foliar Treatments

Treatment	Method of Application	lb. ai/Acre	Avg. No. Thrips Per 16 Plants[a]
UC 21865	In-furrow	1.50	0 a
phenamiphos	In-furrow	1.60	0 a
phorate	In-furrow	0.50	0 a
UC 21865	In-furrow	3.00	1 a
disulfoton	In-furrow	0.75	1 a
monocrotophos	Foliar	0.625	2 a
aldicarb	In-furrow	0.40	3 a
dicrotophos	Foliar	0.125	4 a
methamidophos	Foliar	0.10	9 a
dimethoate	Foliar	0.165	9 a
azinphosmethyl	Foliar	0.165	82 b
SD 43775	Foliar	0.050	96 b
malathion	Foliar	0.470	130 b
check			284 c

[a]Means within a column followed by the same letters are not significantly different at the 5% level using Newman-Keuls multiple range test and transformed data ($\sqrt{N+1}$).

Table 9. Thrips Control at Jackson, June 21: Comparisons Between In-furrow and Foliar Treatments

Treatment	Method of Application	lb. ai/Acre	Avg. No. Thrips Per 16 Plants[a]
aldicarb	In-furrow	0.40	0 a
dicrotophos	Foliar	0.125	2 a
UC 21865	In-furrow	1.50	2 a
UC 21865	In-furrow	3.00	3 a
phorate	In-furrow	0.50	3 a
phenamiphos	In-furrow	1.60	3 a
SD 43775	Foliar	0.50	3 a
disulfoton	In-furrow	0.75	4 a
monocrotophos	Foliar	0.625	4 a
methamidophos	Foliar	0.10	4 a
dimethoate	Foliar	0.165	6 a
azinphosmethyl	Foliar	0.165	11 a
malathion	Foliar	0.470	24 b
check			27 b

[a]Means within a column followed by the same letter are not significantly different at the 5% level using Newman-Keuls multiple range test and transformed data ($\sqrt{N + 1}$).

Table 10. Thrips Control at Jackson, July 7: Comparisons Between In-furrow and Foliar Treatments

Treatment	Method of Application	lb. ai/Acre	Avg. No. Thrips Per 16 Plants[a]
aldicarb	In-furrow	0.40	0 a
phenamiphos	In-furrow	1.60	0 a
disulfoton	In-furrow	0.75	1 ab
phorate	In-furrow	0.50	1 ab
UC 21865	In-furrow	1.50	1 ab
dicrotophos	Foliar	0.125	2 ab
methamidophos	Foliar	0.10	2 ab
UC 21865	In-furrow	3.00	3 ab
monocrotophos	Foliar	0.625	5 ab
dimethoate	Foliar	0.165	11 b
SD 43775	Foliar	0.050	12 c
malathion	Foliar	0.470	15 c
azinphosmethyl	Foliar	0.165	24 c
check			44 c

[a]Means within a column followed by the same letter are not significantly different at the 5% level using Newman-Keuls multiple range test and transformed data ($\sqrt{N+1}$).

dicrotophos, or monocrotophos. All in-furrow treatments provided significantly better thrips control than did the foliar sprays azinphosmethyl, malathion, and SD 43775.

When the early planted cotton at Jackson was sampled again on July 9, none of the in-furrow treatments gave significantly better thrips control than the foliar treatments dicrotophos, monocrotophos, SD 43775 and methamidophos. All in-furrow treatments gave better thrips control than the foliar sprays malathion, dimethoate, and azinphosmethyl. These results are shown in Table 11.

The results of the tests on the early planted cotton at Jackson indicates that in-furrow treatments may exhibit longer residual control than the foliar sprays. At the second sampling of the early planted field on July 9, fewer thrips were found on each of the in-furrow treatments than were found at the first sampling on June 21. However, a larger number of thrips were extracted from the foliar spray treated plants during the second sampling than during the first sampling.

D. COMPARISON OF PLANT HEIGHTS AMONG IN-FURROW AND FOLIAR TREATMENTS

The average heights of cotton plants at both fields at Jackson are shown in Table 12 and at Milan in Table 13. Each value was found by averaging the heights of six randomly selected plants from each of four replicate plots. Results are not consistent among locations. Disulfoton, for example, had the largest average plant height at Milan but the smallest average plant height at the late planted field

Table 11. Thrips Control at Jackson, July 9: Comparisons Between In-furrow and Foliar Treatments

Treatment	Method of Application	lb. ai/Acre	Avg. No. Thrips Per 16 Plants[a]
disulfoton	In-furrow	0.75	0 a
phorate	In-furrow	0.50	0 a
aldicarb	In-furrow	0.40	0 a
phenamiphos	In-furrow	1.60	0 a
UC 21865	In-furrow	1.50	0 a
UC 21865	In-furrow	3.00	0 a
monocrotophos	Foliar	0.625	13 a
dicrotophos	Foliar	0.125	14 a
methamidophos	Foliar	0.10	15 a
SD 43775	Foliar	0.050	19 a
azinphosmethyl	Foliar	0.165	27 b
dimethoate	Foliar	0.165	33 b
check			33 b
malathion	Foliar	0.470	47 b

[a]Means within a column followed by the same letter are not significantly different at the 5% level using Newman-Keuls multiple range test and transformed data ($\sqrt{N + 1}$).

Table 12. Heights of Cotton Plants at Two Fields at Jackson[a]

Treatment	lb. ai/Acre	Location: Jackson Early Planted (June 29)	Location: Jackson Late Planted (July 6)
disulfoton	0.75	4.031	6.188
phorate	0.50	4.115	6.219
aldicarb	0.40	3.958	6.208
phenamiphos	1.60	4.156	7.177
UC 21865	1.50	3.708	7.104
UC 21865	3.00	3.954	6.583
dicrotophos	0.125	3.802	6.730
monocrotophos	0.625	3.510	6.959
dimethoate	0.165	3.365	6.792
azinphosmethyl	0.165	3.667	6.906
methamidophos	0.10	3.760	7.063
malathion	0.470	4.011	6.771
SD 43775	0.050	3.896	6.917
check		3.875	6.865

[a]Average height in inches of 24 plants (6 plants/sample x 4 reps).

Table 13. Comparison of Plant Heights Among Treatments at Milan, June 15

Treatment	lb. ai/Acre	Mean Height of 24 Plants[a] (in inches)
disulfoton	0.75	3.396 a
phorate	0.50	3.084 ab
UC 21865	1.50	2.761 ab
SD 43775	0.050	2.657 ab
aldicarb	0.40	2.615 ab
phenamiphos	1.60	2.50. ab
UC 21865	3.00	2.501 ab
azinphosmoehyl	0.165	2.417 ab
dicrotophos	0.125	2.334 ab
malathion	0.470	2.334 ab
monocrotophos	0.625	2.292 b
dimethoate	0.165	2.230 b
methamidophos	0.10	2.136 b
check		2.021 b

[a]Means within a column followed by the same letter are not significantly different at the 5% level using Newman-Keuls multiple range test and untransformed data ($\sqrt{N + 1}$).

at Jackson. Significant differences between treatments were found only at the Milan location. At Milan, the average height of plants treated with disulfoton granules was significantly greater than plants treated with monocrotophos, dimethoate, and methamidophos. Only disulfoton treated plants were significantly greater in height than the untreated check.

E. COMPARISONS OF PLANT VIGOR AMONG IN-FURROW AND FOLIAR TREATMENTS

Plant vigor ratings were given to plants from each treatment at Milan and at the early planted field at Jackson. Ratings were based on a range from one to five, with a "one" rating given to extremely weak, nonvigorous plants and a "five" rating given to healthy, vigorous plants. Plants from each treatment were given ratings somewhere within this range based on their overall appearance and vigor. Significant differences are shown in Tables 14 and 15. Results are not totally consistent between the two locations. The untreated check and the malathion treated plants were given low vigor ratings at both locations.

F. COMPARISON OF PLANT POPULATIONS AMONG IN-FURROW AND FOLIAR TREATMENTS

Stand counts were taken at the Milan location only and are shown in Table 16. Plots planted with aldicarb granules had the smallest plant populations, it being the only treatment to have fewer plants than the untreated check. The number of plants per row in

Table 14. Comparison of Plant Vigor Ratings Among Treatments at Milan, June 15

Treatment	lb. ai/Acre	Average Rating[a]	
phorate	0.50	3.25	a
disulfoton	0.75	3.00	a
UC 21865	3.00	2.875	ab
aldicarb	0.40	2.625	abc
phenamiphos	1.60	2.625	abc
UC 21865	1.50	2.50	abc
methamidophos	0.10	2.125	bcd
SD 43775	0.050	2.125	bcd
dicrotophos	0.125	2.00	bcd
azinphosmethyl	0.165	2.00	bcd
dimethoate	0.165	1.875	cd
monocrotophos	0.625	1.75	cd
malathion	0.470	1.75	cd
check		1.375	d

[a]Means within a column followed by the same letter are not significantly different at the 5% level using Newman-Keuls multiple range test and untransformed data ($\sqrt{N + 1}$).

Table 15. Late Planted Field at Jackson, June 29: Comparison of Plant Vigor Ratings Among Treatments

Treatment	lb. ai/Acre	Average Rating[a]
monocrotophos	0.625	2.625 a
phenamiphos	1.60	2.375 ab
dicrotophos	0.125	2.25 ab
azinphosmethyl	0.165	2.25 ab
aldicarb	0.40	2.125 ab
UC 21865	3.00	2.125 ab
dimethoate	0.165	2.125 ab
phorate	0.50	2.00 ab
UC 21865	1.50	2.00 ab
disulfoton	0.75	1.875 ab
malathion	0.470	1.75 b
check		1.75 b
methamidophos	0.10	1.625 b
SD 43775	0.050	1.625 b

[a]Means within a column followed by the same letter are not significantly different at the 5% level using Newman-Keuls multiple range test and untransformed data ($\sqrt{N + 1}$).

Table 16. Number of Cotton Plants Per Row at Milan[a]

Treatment	lb. ai/Acre	Avg. Number of Plants[b]
phorate	0.50	61.875 a
disulfoton	0.75	59.50 ab
SD 43775	0.050	52.75 abc
UC 21865	1.50	49.00 abc
UC 21865	3.00	46.75 abc
methamidophos	0.10	45.875 abc
azinphosmethyl	0.165	45.625 abc
dimethoate	0.165	45.00 abc
malathion	0.470	43.25 abc
phenamiphos	1.60	40.75 abcd
monocrotophos	0.625	38.00 bcd
dicrotophos	0.125	37.50 bcd
check		34.75 cd
aldicarb	0.40	22.375 d

[a]Means based on average of 16 twenty-foot rows per treatment.

[b]Means within a column followed by the same letter are not significantly different at the 5% level using Newman-Keuls multiple range test and untransformed data ($\sqrt{N + 1}$).

the aldicarb treated plots were not found to be significantly lower, however, than the phenamiphos, monocrotophos, or dicrotophos treated plots, nor the untreated check.

CHAPTER V

SUMMARY AND CONCLUSIONS

In-furrow granular and spray treatments, when evaluated in regard to thrips control, plant populations, plant height, and plant vigor, proved to be superior to foliar spray treatments. In-furrow treatments afforded significantly better residual thrips control than the foliar sprays. Since in-furrow treatments are applied at planting, they generally have lower application costs and less equipment requirements than the foliar treatments. Although in-furrow treatments are superior to foliar sprays in these respects, this does not suggest indiscriminate use of in-furrow treatments rather than foliar treatments. A major advantage in using foliar treatments is the fact that they need be applied only when necessary, whereas in-furrow treatments are applied strictly as preventive treatments. When applying in-furrow treatments at planting, the applicator is assuming that thrips infestations will later be severe enough to cause economic damage. In areas where thrips do not constitute a consistent economic problem, the use of foliar sprays may be the wiser choice since chemicals may then be applied in only those years when thrips infestations cause economic damage. In areas where thrips or other early season insects have consistently been a major problem, the application of in-furrow granules or sprays would probably be the better choice. Since the advantage of using foliar sprays over in-furrow treatments lies mainly in the fact that they can be applied when they are needed, meaningful comparisons based only on thrips control and chemical damage to plants cannot be made between treatments of one group with treatments of the other group. Further comparisons will be limited to differences among treatments within each separate group.

Among the in-furrow treatments, there seem to be no major differences between any of the treatments in regard to thrips control, plant height, and plant vigor. Aldicarb does seem to have an adverse effect on plant populations but this effect may have been magnified somewhat by unusually poor growing conditions which produced weak, stressed plants that are more susceptible to chemical injury. The late planted cotton at Jackson, which was planted during a period of warm, dry weather, showed no apparent differences in stands between treatments. In-furrow treatments are ranked in Table 17 based on the four criteria.

There appears to be a much larger degree of variability among foliar spray treatments than among in-furrow treatments. Malathion and azinphosmethyl gave considerably less control of thrips than did the other treatments, in most cases not significantly better control than the untreated check. They did not adversely affect plant populations, plant height, and plant vigor, however. Dimethoate gave relatively poor thrips control and also rated low in its effect on plant height. In regard to thrips control alone, dicrotophos and monocrotophos were the better foliar treatments. They did appear to limit plant stands and plant heights. Plants treated with dicrotophos and monocrotophos were rated as having moderate vigor. Overall dicrotophos, monocrotophos, methamidophos, and SD 43775 were judged

Table 17. Ranking of In-furrow Treatments Based on Thrips Control, Plant Height, Plant Vigor, and Plant Populations

Treatment	lb. ai/A	Plant Populations	Plant Vigor	Plant Heights	Thrips Control
disulfoton	0.75	2	5	4	6
phorate	0.50	1	3	3	3
aldicarb	0.40	7	4	5	2
phenamiphos	1.60	5	1	1	1
UC 21865	1.50	3	6	2	4
UC 21865	3.00	4	2	7	5
check		6	7	6	7

acceptable while malathion, azinphosmethyl, and dimethoate were judged unacceptable for use as foliar spray treatments for the control of thrips infestations. Table 18 ranks the foliar sprays tested in regard to thrips control, effect upon plant populations, damage to plant height, and overall plant vigor.

Table 18. Ranking of Foliar Sprays Based on Thrips Control, Plant Height, Plant Vigor, and Plant Populations

Treatment	lb. ai/Acre	Thrips Control	Plant Populations	Plant Vigor	Plant Heights
dicrotophos	0.125	1	7	1	5
monocrotophos	0.625	2	6	3	6
dimethoate	0.165	5	4	4	8
azinphosmethyl	0.165	6	3	1	3
methamidophos	0.10	3	2	5	3
malathion	0.470	7	5	7	2
SD 43775	0.050	4	1	5	1
check		8	8	8	6

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VITA

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