FIELD EVALUATION OF INSECTICIDES USING TWO METHODS OF SPRAYING FOR CONTROL OF THE *HELIOTHIS* COMPLEX, BOLL WEEVIL AND THEIR EFFECT ON PARASITISM

By

SANIT RATANABHUMMA

Bachelor of Science

Kasetsart University

Bangkok, Thailand

1968

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1972

FIELD EVALUATION OF INSECTICIDES USING TWO
METHODS OF SPRAYING FOR CONTROL OF THE
HELIOTHIS COMPLEX, BOLL WEEVIL AND
THEIR EFFECT ON PARASITISM

Thesis Approved:

Richard G. Price
Thesis Adviser

Jerry H. Young

William A. Drew

D. Durham
Dean of the Graduate College

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation and gratitude to my major advisor, Dr. R. G. Price, for his guidance, warm encouragement and generous support in the development and completion of this study.

Special thanks is extended to my committee members, Dr. J. H. Young, and Dr. W. A. Drew for their valuable advice and support in the preparation of this manuscript.

Indebtedness for the financial support is expressed to Thai Government for the scholorship which enabled the author to complete his Master's Degree.

Deepest appreciation is expressed to my fiancée, Boonsri, for her encouragement and moral support throughout the graduate program.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Cotton is susceptible to severe insect damage at all stages of growth. Cotton insect damage is one of the chief limiting factors in efficient cotton production. As the farmers strive for higher yields, cotton insects become a more and more important factor. Among the cotton insects, the bollworm, *Heliothis zea* (Boddie); the tobacco budworm; *Heliothis virescens* (F.); and the boll weevil, *Anthonomus grandis* (Boheman) are the most serious pests of cotton. Cotton growers lose several million dollars annually in crop reductions from these insects and the costs of their control. These insects not only attack cotton but also cause serious damage to other crops such as tobacco, corn, grain sorghum and other plant species.

According to Murray (1972), the *Heliothis* spp. problem becomes more serious due to the following factors: various hosts plants of the *Heliothis* spp. are planted in large areas contributing more available foods for the insect pests and enabling these insects to develop large populations; heavy applications of chemicals applied to cultivated areas reduces large numbers of beneficial arthropods; thus, enabling *Heliothis* spp. population to increase intensively and the development of resistance of these cotton pests to several previously recommended chemicals.

New control methods must be developed in order to cope with the problems previously mentioned. More information on quantitative biology, behavior of the *Heliothis* spp. and the ecology of beneficial arthropods, is necessary to obtain this goal.

The objectives of this study have been to obtain the following:

1. Evaluated insecticides for control of the bollworm, tobacco budworm, and boll weevil by using conventional sprays.

2. Develop more effective methods of control by comparing conventional sprays with accutrol air-emulsion sprays for Heliothis spp. and boll weevil control.

3. Study the effects of insecticides on parasites of Heliothis spp.

Hopefully, these studies will aid in contributing significant information that may be useful in future cotton insect control programs.

LITERATURE REVIEW

The bollworm, Heliothis zea (Boddie), was first recognized as a cotton pest in the United States in 1820. In 1841, the bollworm had become the most destructive pest of cotton and corn in the Southern United States. The bollworm is a general feeder and is known to attack more than 70 species of plants (Quaintance and Brues, 1905).

Chamberlin and Tenhet (1926) reported that the tobacco budworm, Heliothis virescens (F.), was one of the most important pests of tobacco in the southeastern part of the United States. It is not known when the tobacco budworm was first identified on cotton. The earliest record seems to be that of Folsom (1936) who reported in 1934 that the tobacco budworm occurred on cotton in numbers that were almost as great as that of the bollworm at Tallulah, Louisiana. It is possible that the tobacco budworm has been present on cotton for many years but was not recognized because of its similarity to bollworms. The tobacco budworm attracted wide attention as a cotton pest in 1949 and is still considered a major pest in many of cotton producing areas.

Bryan (1961) found that the bollworm and the tobacco budworm may form a species complex in cotton fields in Oklahoma. He reported that pure populations of each species are common, although the bollworm is usually predominant in mixed populations.

Hodges et al. (1966) reported that the term "bollworm complex" is referred collectively to both the bollworm and the tobacco budworm.

The boll weevil, Anthonomus grandis (Boheman), was found to be one of the most important pests of cotton in Texas in 1894 after entering the State from Northern Mexico (Hunter and Hinds, 1905). Since this time it has spread eastward to the Atlantic Ocean, northward to Oklahoma, and more recently westward to New Mexico, Arizona and California (Young, 1969).

Chemical Control of the *Heliothis* Complex and Boll Weevil

Since the 1940's synthetic organic insecticides have played an important part in cotton insect control. Many of the chlorinated hydrocarbons, organophosphate and carbamate insecticides have been very effective in the control of cotton pests. In recent years the bollworm complex has been difficult to control because of resistance and more recently failure to develop new insecticides.

Inadequate control of this pest with organochlorine insecticides was reported in 1956 in Louisiana. The occurrence of control failure became more frequent in 1956, and a three-year study of bollworm to various insecticides (1959-1961) indicated development of a low level of DDT-resistance by bollworms in Louisiana (Graves et al., 1964). In subsequent years, 10- to 40-fold levels of DDT-resistance were found in other major cotton producing areas of Louisiana (Graves et al., 1963, 1964). The first evidence of resistance to the chlorinated hydrocarbon insecticides by the tobacco budworm was reported in Texas in 1961 (Brazzel, 1963). The tobacco budworm at that time was found to be highly resistant to DDT. The boll weevil became resistant to the chlorinated hydrocarbon insecticides in Louisiana in the mid-1950's (Roussel and Clower, 1957).

However, other chlorinated hydrocarbon insecticides which were being used either alone or in a combination with DDT continued to provide adequate control of the bollworm complex and the boll weevil (Adkisson, 1967; Graves et al., 1967; Mistric et al., 1970).

In 1965 (Adkisson and Nemec, 1966) found that the bollworm had developed resistance to endrin, carbaryl, strobane-DDT and toxaphene-DDT in addition to DDT. The tobacco budworm developed resistance to organochlorine insecticides in a pattern similar to that for the bollworm (Graves et al., 1964, 1967a; Adkisson and Nemec, 1967; Lowry et al., 1965; Lowry, 1966; Pate and Brazzel, 1964; Brazzel, 1965). Graves et al. (1967b) reported that the LD_{50} to Azodrin for the boll weevil was approximately 12-fold greater. The cross-resistance levels to carbaryl and Mobil MCA-600 (benzo-[b] thien-4yl methylcarbamate) were 40-fold or greater.

The development of resistance by these cotton insects to organochlorine and carbamate insecticides forced cotton producers to rely entirely on organophosphorus (OP) compounds for effective economical control. Methyl parathion has been the insecticide of choice because of its high toxicity to cotton insect larvae and its relatively low cost (Whitten and Bull, 1970; Plapp, 1971). However, recent reports indicate clearly that in certain areas of the United States the tobacco budworm in now developing resistance to OP-insecticides (Nemec and Adkisson, 1969). Tolerance levels in the budworm, collected from central Texas and from the Rio Grande Valley, were higher in 1969 than in 1968 (Nemec, 1971). Carter and Phillips (1968) found an 8- to 10-fold increase in resistance to methyl parathion in a laboratory culture of bollworms after 10 selection cycles in 11 generations. Wolfenbarger and McGarr (1970) reported that since 1966 Rio Grande Valley growers have been increasing rates of methyl parathion and monocrotophos for tobacco budworm and bollworm control in cotton. By 1968 the rates required for control and incidence of control failure suggested resistance to methyl parathion and monocrotophos. The situation with the budworm is more serious in Mexico and Central America where decreases in susceptibility to methyl parathion of 100-fold or more have been reported (Lukefahr, 1970). Wolfenbarger et al. (1971) reported a Nicaragua bollworm population 45 times more resistant to methyl parathion than the Brownville, Texas population.

In recent years several new chemicals and their combinations have been developed for the control of bollworm complex and boll weevil. Hopkins and Taft (1964) reported that Guthion plus DDT at 0.375 and 1.0 lb per acre, respectively, and toxaphene plus DDT at 2.0 and 1.0 lb per acre, respectively, gave the best control of bollworm complex and boll weevil during 1960-1962 at Florence, South Carolina. In 1962, McGarr et al. (1965) reported that carbaryl and Bayer 37344 (4-(methylthio)-3, 5-xylyl methylcarbamate) at 1.5 and 1.86 lb per acre, respectively, were very effective against the boll weevil; while Zectran® (4-dimethylamino-3,5-xylyl methylcarbamate) and Bayer 44646 (4-dimethylamino-m-tolyl methylcarbamate) at 1.0 and 2.0 lb per acre, respectively, were significantly better than other chemicals tested against the bollworm complex. Zectan® and Matacil® (or Bayer 44646) gave 80% or better larval mortality of the bollworm complex in laboratory testing, and 90% or better mortality in field cages (Wolfenbarger et al., 1966). Graves et al. (1965) evaluated several organotin compounds against Heliothis spp. and found that trimethyltin acetate and trimethyltin hydroxide were the most toxic to resistant and non-resistant strains of the bollworm complex.

McGarr and Ignoffo (1966) reported that two new insecticides, Matacil® and Shell-SD-9129 (dimethylphosphate ester with 3-hydroxy-N-methyl-cis-crotonamide dimethylphosphate), applied at 0.8 and 2.0 lb per acre, respectively, were the most effective against the *Heliothis* spp. and boll weevil. Wolfenbarger et al. (1968a) studied the effects of organometallic compounds on larvae of the bollworm complex and found that acetoxytrimethyltin, hydroxytrimethyltin, and acetoxytriethyllead caused 92% or more mortality when applied topically and 52% or more when applied as foliar sprays. In field-cage studies, a 58% reduction occurred in populations of bollworm larvae treated with American cyanamid CL-24055 (4'-(3,3-dimethyl-1-triazeno)acetanilide). In a field test using CL-24055, a 22% reduction occurred in squares and boll damaged by *Heliothis* spp. (Wolfenbarger et al., 1968b). Wolfenbarger and Redfern (1968) reported that the carbamate duPont 1179 (methyl N-[(methylcarbamoyl)oxy] thioacetimidate) caused the greatest mortality to tobacco budworm larvae in laboratory and field cage studies. DuPont 1642 (methyl N-(carbamoyloxy)thioacetimidate) was the most effective against the boll weevil. In 1968, McGarr and Wolfenbarger (1970) found that EPN (O-ethyl O-P-nitrophenyl phenylphosphonothioate) gave the best control of the bollworm complex at 1.3 lb per acre. Wolfenbarger et al. (1970) evaluated 49 organophosphorus compounds and reported that conventional sprays of Stauffer N-2599 (O-P-chlorophenyl O-ethyl ethylphosphonothioate), N-2790 (O-ethyl S-phenyl ethylphosphonodithionate) (Dyfonate®), and N-3727 (O-methyl S-phenyl methylphosphonodithioate) killed 80% of tobacco budworm when used at 1 lb per acre.

Types of Applications Equipment Used for Cotton Insect Control

In recent years, spray equipment has been redesigned and modified in an effort to provide more effective control measures for the bollworm complex and boll weevil. Conventional machines have been the most widely used method of applying chemicals.

Fye and Hopkins (1959) reported that conventional sprayer placed the heaviest concentration of spray on parts on the plants where boll weevils were most numerous. In addition, this sprayer gave better coverage on the interior part of the plant and on the undersides of the plant surface.

In 1960, Wilkes et al. (1961) evaluated a new sprayer called the air-carrier sprayer and reported that this sprayer was less effective than the conventional boom-type sprayer when used against the bollworm complex. Confronted with the limitations of the hand sprayers and conventional tractor sprayers, modification of a commercial high-clearance sprayer for use in small plot testing was developed by several research workers (Wilkes and Walker, 1961; Harrendorf, 1965).

Equipment design is one of the major keys to successful low-volume (LV) spraying with ground equipment. Many groups are working on the design of LV equipment. In 1964, Thomas and Goddard (1966) developed a new ground machine for applying low-volume concentrated sprays for boll weevil control. Commerically available nozzles (Spraying Systems 730023 or equivalent) were fitted to a high-clearance sprayer. With this system it was possible to apply 25 ounces of technical malathion (2 pounds) per acre. This insecticide gave excellent boll weevil control. Adler et al. (1965) developed an aerosol sprayer which consisted of a compressed-air spray gun and a compressor driven by a 1-cylinder engine mounted on the rear of a small tractor. Taft and Hopkins (1965) developed a mist sprayer with mini-spin nozzles mounted in front of an air blast from a centrifugal fan. Harrell et al. (1966) developed a LV sprayer which used either a flat-fan or pneumatic nozzle. Taft and Hopkins (1967) found that experimental technical materials, solutions, and suspensions of malathion applied with a ground low-volume mist sprayer showed effectiveness in controlling the boll weevil and the bollworm.

One of the most recent developments for applying chemicals for control of insect pests is the ultra low volume (ULV) application of technical insecticides (Messenger, 1963). Burt et al. (1966) developed a rotary disc device for ground application of ULV undiluted pesticides. The applicator consisted of 2 rotating discs powered by a small electric motor and a metering nozzle. Certain pesticides were more effective when applied by this method. The rotary disc provided more uniform coverage across the width of the swath. Cleveland et al. (1966) reported that applications of ULV technical malathion at 8, 12, and 16 fl. oz./acre was as effective against the boll weevil as the standard application of methyl parathion at 0.4 lb/acre in 2 gal. water. Nemec and Adkisson (1966) compared the effectiveness of low volume concentrate and water emulsion sprays of certain insecticides for cotton insect control and found that, in the laboratory, ULV methyl parathion had longer residual activity and was as effective initially as a conventional water-emulsion spray. The cost of applying the insecticide as an ULV concentrate would be about 25% less than the cost of applying a high-volume emulsion. Adair et al. (1967) compared the effectiveness of several ULV formulations with several emulsifiable concentrate (EC) water-diluted insecticides and reported that the ULV formulation performed equally as well or better than the EC for control of the bollworm and the boll weevil. Awad et al. (1967) showed that the ULV formulation persisted longer on cotton than EC. They also reported that the EC formulation penetrated the leaf surface faster, and at a moderate temperature, evaporated faster than the ULV.

A new 8-row ground sprayer with auxiliary air for ULV application of pesticides to cotton was developed to minimize drift and to insure maximum deposit of insecticides on the target area by Taft et al. (1969). Ultra low volume application of Azodrin, technical grade Bay 41831 (O,O-dimethyl O-4-nitro-m-tolyl phosphorothioate), and toxaphene plus DDT were compared with conventional spray applications of toxaphene plus DDT and Azodrin against various cotton pests. Results against the boll weevil and the bollworm, using the materials applied with the new ULV sprayer, were at least as good as those obtained when the insecticides were applied with the conventional sprayer. Nemec et al. (1968) indicated that method of application had no significant effect on the initial toxicity of any of the insecticide tested to either bollworm or tobacco budworm. However, the residual toxicity of methyl parathion to the bollworm was greatly prolonged when applied by the ULV technique. In addition, the ULV technique may be more effective than the conventional low volume (CLV) (involve applying concentrated insecticides in spray solution, usually water, at rates ranging from 0.5 to 1.5 gal/acre), for applying insecticides. McGarr and Wolfenbarger (1969) reported that methyl parathion applied either as ULV or CLV was the most effective insecticide against several cotton insects at Brownsville, Texas, in 1967 and 1968. Toxaphene plus DDT plus methyl parathion was the best combination of materials when applied as a ULV spray, while toxaphene plus methyl parathion was the best combination when applied as a CLV spray. Ultra low volume sprays were more effective than CLV sprays. Lloyd et al. (1967) showed that azinphosmethyl when applied as an ULV spray at 0.2 and 0.25 lb per acre was as effective as a water-emulsion spray of methyl parathion (0.5 lb per acre) for control of the boll weevil. Awad and Vinson (1968) found that dead larvae on ULV-treated leaves contained a greater amount of malathion than larvae from EC treated leaves. The ULV droplet remained in a liquid form on the leaf while the EC dried and was less readily obtained by larvae crawling on the treated surface of the leaves. Cowan and Davis (1968) reported that ULV applications of azinphosmethyl at rates of 0.14 and 0.27 lb per acre and LV application of azinphosmethyl at a rate of 0.25 lb per acre gave good control of the boll weevil. Overall, the LV applications of Azodrin at 0.75 lb per acre gave the best control of boll weevils and bollworms and produced a significant increase in yield over all other chemicals. Wolfenbarger and Lowry (1969) reported that deutero-DDT (1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethane-2d$_2$), applied as a CLV spray, was the most effective of several diphenyl aliphatics tested against larvae of the bollworm complex. Wolfenbarger (1970) reported that ULV and conventional sprays of General Chemical GC-6506 (dimethyl p-(methylthio) phenyl phosphate) were initially about equally toxic to bollworms and tobacco budworms, but the residual toxicity of the ULV spray was greater. Harrell et al. (1970) evaluated another ULV ground machine which was modified for spraying cotton and found that the results in bollworm and boll weevil tests were equal to that obtained with conventional equipment under heavy insect pressure. Pfimmer et al. (1971) found that CIBA C-9491 (O-(2,5-dichloro-4-iodophenyl) O,O-dimethyl phosphorothioate) and Velsicol VCS-506 (O-(4-bromo-2,5-dichlorophenyl)O-methyl phenylphosphonothioate) applied as conventional sprays gave good control of Heliothis spp. ULV sprays of EPN (O-ethyl O-p-nitrophenyl phenylphosphonothioate), EPN plus methyl parathion, malathion plus methyl parathion, methyl parathion, and toxaphene plus DDT plus methyl parathion gave good control of the bollworm complex. Brasher et al. (1971) found that the ULV spraying method when used in combination with charging electrostatic spray particles and auxiliary air, approximately 90% control of boll weevil was achieved with 1.25 lb of malathion per acre. In addition, removal of the auxiliary air system reduced effectiveness of the spray.

Effect of Chemicals on Beneficial Insects

Predators and parasites play an important role in regulating cotton insect populations. In order to preserve these natural enemies, selective insecticide should be carefully employed (Ridgeway and Lingren, 1972). Insecticide treatments that adversely affect beneficial arthropod populations can result in rapid outbreaks of the bollworm and other cotton pests (Gaines, 1942; Ewing and Ivy, 1943). Aphid damage to cotton following applications of calcium arsenate apparently results from destruction of the insect enemies which normally control this pest (Isely, 1946). The population of the bollworm and damage by the insect may be greater in plots of cotton dusted with arsenicals for boll weevil control, or improperly dusted for bollworm control, than in similar undusted plots (Bishopp, 1929; Fletcher, 1929; Sherman, 1930; Ewing and Ivy, 1943). Newsom and Smith (1949) studied the effect of some commonly used cotton insecticides upon the populations of predators of the cotton bollworm and found that BHC and toxaphene were more detrimental to two predators, Geocoris punctipes (Say.) and Orius insidiosus (Say.), than was calcium arsenate-nicotine. Lincoln and Leigh (1957) reported that beneficial insects are usually effective in controlling bollworms, spider mites, and aphids on cotton. If unnecessary applications of insecticides are made, the beneficial insects may be killed, and further applications may then be required to control the pest species. Bartlett (1963) found that several adult parasitic hymenopterans of cotton pests were very susceptible to many commonly used pesticides. Ridway et al. (1967) reported that certain beneficial hymenopterans parasites of Heliothis spp. may be reduced by applications of systemic insecticides. Falcon et al. (1968) indicated that predator abundance was severely reduced in cotton fields treated with toxaphene plus malathion and dicrotophos. Laster and Brazzel (1968) reported that several predators of cotton pests were more affected by the mixture of toxaphene and DDT than by toxaphene alone. In addition, they found that Azodrin and Bidrin were more toxic to predaceous species than trichlorfon and phosphamidon. Lingren et al. (1968) showed that trichlorfon was less injurious to beneficial insects. He reported that plots treated with trichlorfon, infestations of the Heliothis spp. was lower, resulting in less damage to squares and bolls resulting in an increase in seed cotton. Cherry and Pless (1971) studied the effects of disulfoton and carbofuran on parasitism of the tobacco budworm by Campoletis perdistinctus (Viereck) and reported that parasitism was significantly greater in disulfoton treatments (49%) than in carbofuran (0%) and the untreated plot (2%). However, as the season progressed parasitism became more comparable in all treatments: disulfoton 88%, carbofuran 79% and the untreated plot 82%.

Bottrell et al. (1968) reported fifteen parasites representing the families Tachinidae, Braconidae and Ichneumonidae were obtained from rearing *Heliothis* spp. collected in 1965 and 1966 from cultivated crops in Oklahoma. The braconid, *Microplitis croceipes* (Cresson), was the parasite most commonly found in both the bollworm and tobacco budworm. This parasite was most abundant in the bollworm.

METHODS AND MATERIALS

During the summer of 1971, field tests were initiated to evaluate insecticides using conventional and accutrol air-emulsion sprays for control of <u>Heliothis</u> spp. and the boll weevil. In addition, studies were conducted to determine what effect these insecticides had on parasite populations.

Conventional Sprays (Test 1)

Eight compounds and compound combinations were evaluated in this test. Chemical names of products mentioned in the text and tables are as follows:

Azodrin® - 3-hydroxy-N-methyl-cis-crotanomide dimethyl phosphate (5.0 lbs per gal.).

Dow General® - 2-Sec-butyl-4,b-dinitrophenol (5 lbs per gal.).

Galecron® - N'-(4-Chloro-O-tolyl)-<u>N</u>-<u>N</u>-dimethylformamidine (4.0 lbs per gal.).

Methyl parathion - O,O-dimethyl-O-p-nitrophenyl thiophosphate (4.0 lbs per gal.).

Pencap M - encapsulated methyl parathion (2.0 lbs per gal.).

Phosvel™ - O-(2,5-Dichloro-4-bromophenyl)O-methyl phenylthiophosphonate (3.0 lbs per gal.).

Premerge® - 2-Sec-butyl-4,6-dinitrophenol as the alkanalamine salts (of the ethanol isopropanol series) (3.0 lbs per gal.).

Toxaphene - a chlorinated comphene and which contains 67-90% chlorine.

This test consisted of 9 treatments and 1 untreated check replicated 3 times in a randomized-block design. The plots were 8 (40 inches each) rows wide x 190 ft. long with a 15 ft. turnrow separating each block. These plots were not irrigated during the season. The plots were first planted on May 13 and replanted again on June 17 with Lankart 571 at 20 lbs per acre. Treatments were made with a John Deere Hi-cycle 600 sprayer equipped with a 8-row boom. The boom was fitted with 1 nozzle per row. The sprayer system was operated at 40 psi, and the ground speed of the sprayer was 4.5 mph. All plots were sprayed with methyl parathion at 0.5 lb per acre on August 4 in order to initiate a bollworm infestation. The first application consisted of using 3.28 gallons of total spray mixture per acre, with one No. 6 spray systems nozzle per row. Plots were first sprayed on August 12 and repeated again on August 13, 19, 24, 30 and September 3.

Bollworm, budworm, and boll weevil damage was determined by collecting 100 fruits at random prior to spraying from the upper one-third of the plant in each plot. The final square count was made on September 8.

Populations of the bollworm complex collected throughout the test were checked to determine species.

Conventional vs. Accutrol Air-Emulsion Sprays (Test 2)

This test consisted of comparing the two methods of application at

3 different tractor speeds using Phosvel as the standard insecticide. This material was applied at 1.5 lbs of actual toxicant per acre. Each treatment was replicated 3 times in a randomized block design. The plot size and design, time of planting, variety of cotton and lbs of seed per acre were the same as in Test 1. None of the plots were irrigated during the season. Treatments were made with a John Deere Hi-cycle 600 sprayer equipped with a 8-row boom. The boom was fitted with 1 nozzle per row. The ground speed of the sprayer was either 3.0, 6.0, or 9.0 miles per hour depending upon the treatment. The sprayer system was operated at 40 psi.

All plots were sprayed with methyl parathion at 0.5 lbs per acre on August 4 in order to initiate an infestation.

For the conventional sprays, one No. 6 spray systems nozzle per row was used. The total gallons of spray mixture applied per acre were as follows: 3 MPH = 8.13, 6 MPH = 3.9, and 9 MPH = 2.8.

The accutrol air-emulsion system differed from the conventional system in two ways: (1) nozzle unit, (2) addition of an adjuvant. The nozzle unit consisted of a brass adaptor, strainer, orifice, foam generator body, nozzle and nozzle nut. The foam generator body was the most important part of the unit. This generator allowed air to enter into the nozzle; thus, thoroughly mixing the solution into a foam prior to discharge. One Accutrol V-027 medium angle nozzle was used over each row. The total gallons of spray mixture applied per acre were as follows: 3 MPH = 19.7, 6 MPH = 8.12, and 9 MPH = 6.25. Foamwet® spray adjuvant was added to the spray mixture at the rate of 1 quart per 25 gallons of total spray mixture. Spray applications were made on August 19 and 24.

Bollworm, budworm and boll weevil damage was determined by the same method as used in Test 1. Damaged square counts were made on August 13, 18, 23 and 30.

Populations of bollworms and budworms collected throughout the test were combined with larvae in Test 1 and checked for parasitism and species identification.

Effect of Chemicals on Parasites in Treatment Area

Heliothis larvae were collected throughout the season from the plots sprayed with chemicals listed in Test 1 and 2. The total number of larvae collected varied according to their availability. These larvae were placed individually in 1-oz transparent plastic cups containing approximately ½-oz of artificial diet developed by Adkisson et al. (1960) and modified by Berger (1963). The larvae were returned to the laboratory to await parasite emergence. Heliothis larvae were identified to species using characteristics described by Peterson (1962).

RESULTS AND DISCUSSION

Conventional Sprays (Test 1)

The dry weather during the winter months which extended into May, June, and July greatly delayed the planting of cotton. After a stand was established, growth was slow due to an inadequate supply of irrigation water. Heliothis populations first appeared the first week in August and rose to economic levels on August 12. Immediately after spraying on August 13 a heavy rainstorm developed, producing approximately 2 inches of rain. Due to the condition of the field, the next applications was made on August 19. By this time a heavy population of Heliothis eggs and larvae were present in the field. The population remained extremely heavy until the test was terminated on September 9 as indicated by the check in Table I. During the treatment period, larvae were found eating leaves and stalks in the absence of squares and bolls in plots where control was ineffective.

The results of the insecticide applications and infestation counts of the bollworm complex and the boll weevil are given in Table I and II, respectively. In Table I, several compounds and compound combinations reduced the infestations of the bollworm complex significantly below that of the check. These compounds were under extremely heavy Heliothis pressure throughout the fruiting season as indicated by the damage in the check. Azodrin at 1.0 lb per acre gave the best control after four applications. The next most effective compounds were Galecron plus methyl parathion at 0.5 and 0.25 lb per acre, respectively, Phosvel at 1.5 lbs per acre and Galecron at 0.5 lb per acre. Damaged squares for the season averaged 5.1% for Azodrin, as compared with 6.4% for Galecron plus methyl parathion, 7.1% for Phosvel, 8.5% for Galecron, and 46.7% for the check. Galecron plus methyl parathion and toxaphene plus methyl parathion were more effective than methyl parathion alone. Pencap M, an encapsulated form of methyl parathion was slightly more effective than regular methyl parathion. The two dinitrol herbicides, Dow General® and Premerge®, which had shown some insecticidal activity against the Heliothis complex under laboratory conditions (correspondence with W. O. Miller, Dow Chemical Company) were ineffective. Plots sprayed with those two compounds were checked throughout the test to determine if any phytotoxicity existed. Cotton treated with Premerge® showed light to moderately phytotoxic symptoms after the second application while Dow General® was only slightly phytotoxic. In addition, plots sprayed with azodrin showed phytotoxic symptoms after two applications.

In similar experiments, Cowan and Davis (1968) conducted field tests in 1967 in Texas and found that Azodrin and methyl parathion applied as conventional low-volume sprays at the rates of 0.75 and 1.25 lb per acre, respectively, gave the best control of the bollworm complex and the boll weevil. Price and Young (1969) conducted field tests in 1968 in Oklahoma and found that Toxaphene plus DDT at 2.0 and 1.0 lb per acre, respectively, Velsicol Chemical VSC-506 (Phosvel) at 1.0 lb per acre, and Allied Chemical AC-6506 at 1.0 lb per acre gave the best control during the test period.

In the same test, boll weevil damage was recorded and is summarized in Table II. There was no significant difference between the first 7 compounds or compound combinations. It was felt that the populations were so low that an adequate evaluation of chemicals could not be made.

Since there was tremendous variation in size of cotton plants throughout the field tested, yield data was not taken.

Conventional vs. Accutrol Air-Emulsion Sprays (Test 2)

The results comparing conventional sprays with accutrol air-emulsion sprays at 3 different tractor speeds for control of the bollworm complex and the boll weevil is summarized in Table III and IV, respectively. Phosvel at 1.5 lb of active ingredient per acre was used in all treatments.

Results from the Heliothis spp. test (Table III) showed that tractor speed greatly influenced control in both methods of applications. Control was more effective at 3 mph than at 9 mph. Conventional sprays were more effective than the accutrol air-emulsion sprays, although both reduced the infestations of the bollworm complex significantly below that of the check. The conventional spray applied at a application speed of 3 mph was the most effective for control of the bollworm complex. In this treatment damaged squares totaled 8.2%, compared with 44.0% in the check. Conventional sprays applied at application speeds of 6 and 9 mph were less effective.

Square damage resulting from the accutrol air-emulsion sprays when applied at application speeds of 3, 6, and 9 mph were not economically feasible although they were significantly below that of the check.

The air-emulsion sprays were examined closely while spraying and later after the material had been deposited on the plant. From visual observations it appeared that the accutrol air-emulsion sprays failed to penetrate the plant foliage and enter areas where the *Heliothis* complex was found. Other observations showed spray particles to be uniform in size and equally distributed on the leaf surface. It was felt that this method of application would be more effective for control of leaf feeding insects or in the use of herbicides. Several advantages were observed when using the air-emulsion system. One was that very little drift was noted when spraying in moderate wind. In addition, spray pattern and particle distribution on the leaf surface were easily observed several minutes after application.

Boll weevil damage is summarized in Table IV. Although the accutrol air-emulsion spray applied at the application speed of 9 mph was significantly better than the other treatments, it was felt that the population was too low to make an adequate evaluation.

Population Studies of the Bollworm Complex

Seven hundred and twenty-one larvae were collected in the treatment area (Test 1 and 2) between August 12 and September 28. *Heliothis zea* was the most predominant species collected. The population range from 66.7% to 100% with a seasonal average of 83.8% over the 48 day period. The population of *Heliothis virescens* larvae present in the field over this same period ranged from 0.0% to 47.1% with an average of 16.2%. Populations of *H. virescens* increased substantially during the latter part of the season (Table V). In this same field, Price and Young (1969) reported *H. virescens* population reached 75%.

Lingren and Bryan (1965) reported that *H. zea* is the dominant species on cotton in Oklahoma and mentioned that *H. virescens* may contribute 10-20%, to bollworm complex infestations during certain periods of the cotton growing season.

Effect of Insecticides on Parasites in Treatment Area

Bollworm larvae collected for species determination were also checked for parasites. The parasite most commonly collected from field collected larvae was a braconid, *Microplitis croceipes* (Cresson). Several unidentified tachinid flies and parasitic hymenopterans were also collected.

The percent of bollworm larvae parasitized over this 48 day period ranged from 14.9% to 41.7% with a seasonal average of 29.0%. The parasitism rate was fairly consistent as seen in Table IV throughout the treatment period. The tobacco budworm parasitism was lower than the bollworm and ranged from 0.0% to 23.8% with an average parasitism rate of 7.5%.

Bottrell et al. (1968) found that 7% of bollworms (1086) and 16% of tobacco budworms (69) collected in Oklahoma in 1966 from cotton were parasitized. Sixteen percent of the *H. zea* collected from alfalfa were parasitized.

The parasitism rate for the bollworm complex was surprisingly high although insecticides were applied over this area except for the checks on August 12, 13, 19, 24, 30, and September 3. Other cotton on the station was also sprayed during this period. One item that should be kept in mind is that a large number of these larvae came from the check which were randomly distributed in the treatments and from the treatments that failed to give control. In addition, an alfalfa field bordered the South side of the plots, although growth in this field was very poor due to the dry wather. There is a possibility that these two factors might have contributed to this high parasitism rate. However, additional research on parasitism needs to be investigated for the significant informations.

SUMMARY AND CONCLUSION

Eight compounds and compound combinations were evaluated for control of the bollworm, Heliothis zea (Boddie), the tobacco budworm, Heliothis virescens (F.), and the boll weevil, Anthonomus grandis (Boheman), in field experiments conducted at South Central Research Station, Chickasha, Oklahoma, during the summer of 1971.

For conventional sprays several chemicals, except two herbicides; Dow General and Premerge, reduced the infestations of the bollworm complex significantly below that of the check. Azodrin at 1.0 lb. per acre gave the best control after four applications.

The conventional sprays were superior to the accutrol air-emulsion spray system at the three different tractor speeds used for bollworm-budworm control. The tractor speed also affected control; damage was greater as the speed of the tractor increased.

The boll weevil population were so low that an adequate evaluation of chemicals could not be made.

The seasonal average of the bollworm and the tobacco budworm larvae collected between August 12 and September 28, were 83.8% and 16.2%, respectively. The average parasition rate of the bollworm was 29.0%, compared with 7.5% of the tobacco budworm. The parasite most commonly found from field collected larvae was Microplitis croceipes (Cresson).

Additional research on using selective insecticides and new techniques of applications is urgently needed to develop better control measures for the bollworm and the tobacco budworm.

LITERATURE CITED

Adair, H. M., R. T. Kincade, M. L. Laster, and J. R. Brazzel. 1967. Low-volume aerial spraying of several insecticides for cotton insect control. J. Econ. Entomol. 60(6): 1121-7.

Adler, V. E., A. H. Yeomons, and E. S. Fields. 1965. Low-volume ground insecticide applicator. J. Econ. Entomol. 58(4): 780-1.

Awad, T. M., and S. B. Vinson. 1968. The pick-up and penetration of ultra-low-volume and emulsifiable concentrate malathion formations by tobacco budworm larvae. J. Econ. Entomol. 61(1): 242-5.

Awad, T. M., S. B. Vinson, and J. R. Brazzel. 1967. The effect of environmental and biological factors on the persistance of malathion applied in ultra-low-volume or emulsifiable concentrate form to cotton plants. J. Agr. Food Chem. 15: 1009-13.

Adkisson, P. L. 1967. Development of resistance by the tobacco budworm to mixtures of toxaphene or strobane plus DDT. J. Econ. Entomol. 60(3): 788-91.

Adkisson, P. L., and S. J. Nemec. 1966. Comparative effectiveness for killing bollworms and tobacco budworms. Tex. Agr. Exp. Sta. Bull. 1048. 4p.

Adkisson, P. L., and S. J. Nemec. 1967. Insecticides for controlling the bollworm, tobacco budworm, and boll weevil. Tex. Agr. Exp. Sta. MP-837. 7p.

Adkisson, P. L., E. S. Vanderzant, D. L. Bull, and W. E. Allison. 1960. A wheat germ medium for rearing the pink bollworm. J. Econ. Entomol. 53(5): 759-62.

Bartlett, B. R. 1963. The contact toxicity of some pesticides residues to hymenopterous parasites and coccinellid predators. J. Econ. Entomol. 56(5): 694-8.

Berger, R. S. 1963. Laboratory techniques for rearing *Heliothis* species on artificial medium. USDA ARS-33-84, 4p.

Bishopp, F. C. 1929. The bollworm or corn earworm as a cotton pest. USDA Farm. Bull. 1595, 14p.

Bottrell, D. G., J. H. Young, R. G. Price, and R. H. Adams. 1968. Parasites reared from *Heliothis* spp. in Oklahoma in 1965 and 1966. Ann. Entomol. Soc. Amer. 61(5): 1053-5.

Brasher, C., J. A. Mullins, and S. E. Bennet. 1971. Electrostatic ULV spraying for control of the boll weevil. J. Econ. Entomol. 64(6): 1537-41.

Brazzel, J. R. 1963. Resistance to DDT in Heliothis virescens. J. Econ. Entomol. 56(5): 571-4.

Brazzel, J. R. 1965. Research for better insect control. Miss. Farm. Res. 28(8): 8.

Brazzel, J. R., L. D. Newsom, J. S. Roussel, C. Lincoln, F. J. Williams, and G. Branes. 1953. Bollworm and tobacco budworm as cotton pests in Louisiana and Arkansas. La. Agr. Exp. Sta. Tech. Bull. 482, p. 1-47.

Bryan, D. E. 1961. Cotton insect control in Oklahoma. Okla. Agr. Exp. Sta. Pro. Ser. P-396, 14p.

Burt, E. C., E. P. Lloyd, D. B. Smith, W. P. Scott, J. R. McCoy, and F. C. Tingle. 1970. Boll weevil control with insecticide applied in sprays with narrow-spectrum droplet sizes. J. Econ. Entomol. 63(2): 365-70.

Burt, E. C., D. B. Smith, and E. P. Lloyd. 1966. A rotary disc device for applying ultra-low-volume (undiluted) pesticides with ground equipment. J. Econ. Entomol. 59(6): 1487-9.

Carter, F. L., and J. R. Phillips. 1968. Methyl parathion resistance in a laboratory strain of the bollworm. J. Econ. Entomol. 61(6): 1716-8.

Chamberlin, F. S., and J. N. Tenhet. 1926. The seasonal history and food habits of the tobacco budworm, Heliothis virescens Fab., in the southern tobacco-growing region. J. Econ. Entomol. 19(4): 611-4.

Cherry, E. T., and C. D. Pless. 1971. Effect of carbofuran and disfulfoton on parasitism of tobacco budworms and hornworms on burley tobacco. J. Econ. Entomol. 64(1): 187-90.

Cleveland, T. C., W. P. Scott, T. B. Davich, and C. R. Parencia, Jr. 1966. Control of the boll weevil on cotton with ultra-low-volume (undiluted) technical malathion. J. Econ. Entomol. 59(4): 973-6.

Cowan, C. B., Jr., and J. W. Davis. 1968. Field tests with conventional low-volume or ultra-low-volume sprays for control of the boll weevil, bollworm, and tobacco budworm on cotton in 1967. J. Econ. Entomol. 61(4): 1115-6.

Ewing, K. P., and E. E. Ivy. 1943. Some factors influencing bollworm populations and damage. J. Econ. Entomol. 36(4): 602-6.

Falcon, L. A., R. Van den Bosch, C. A. Ferris, L. K. Stromberg, L. K. Etzel, R. E. Stinner, and T. F. Leigh. 1968. A comparison of season-long cotton pest-control program in California during 1966. J. Econ. Entomol. 61(3): 633-42.

Fletcher, R. K. 1929. The uneven distribution of Heliothis obsoleta (Fabricius) on cotton in Texas. J. Econ. Entomol. 22(4): 757-60.

Folsom, J. W. 1936. Note on little-known cotton insects. J. Econ. Entomol. 29(2): 282-5.

Fye, R. E. 1968. Populations of boll weevil in selected fields in Arizona in 1965 and 1966. J. Econ. Entomol. 61(2): 377-80.

Fye, R. E., and A. R. Hopkins. 1959. Comparative spray coverage of cotton plants with a conventional and a high-clearance sprayer. J. Econ. Entomol. 52(4): 592-6.

Gaines, R. C. 1942. Effect of boll weevil control and cotton aphid control on yield. J. Econ. Entomol. 35(4): 493-5.

Graves, J. B., J. R. Bradley, and J. L. Bagent. 1965. Laboratory evaluation of several organotin compounds against Heliothis spp. J. Econ. Entomol. 58(3): 583-4.

Graves, J. B., D. F. Clower, J. L. Bagent and J. R. Bradley. 1964. Bollworm increasing in resistance to insecticides. La. Agr. 7(3): 3, 16.

Graves, J. B., D. F. Clower, and J. R. Bradley, Jr. 1967a. Resistance of the tobacco budworm to several insecticides in Louisiana. J. Econ. Entomol. 60(3): 887-8.

Graves, J. B., J. S. Roussel, J. Gibbens, and D. Patton. 1967b. Laboratory studies on the development of resistance and cross-resistance in the boll weevil. J. Econ. Entomol. 60(1): 47-50.

Graves, J. B., J. S. Roussel, and J. R. Phillips. 1963. Resistance to some chlorinated hydrocarbon insecticides in the bollworm, Heliothis zea. J. Econ. Entomol. 56(4): 442-4.

Harrell, E. A., W. W. Hare, H. Womack, and J. B. O'Neil. 1970. Experiment ultra-low-volume ground equipment for insect control on cotton. J. Econ. Entomol. 63(4): 1074-6.

Harrell, E. A., W. W. Hare, and J. R. Young. 1966. Ground equipment for applying low-volume insecticide to sweet corn. J. Econ. Entomol. 59(2): 487-9.

Harrendorf, K. 1965. A modified high-clearance sprayer for plot use. J. Econ. Entomol. 58(5): 1014-5.

Hodges, J. W., R. J. Beshear, and C. M. Beckham. 1966. Relative seasonal abundance of bollworm and tobacco budworm larvae on cotton in Georgia. J. Econ. Entomol. 59(1): 128-31.

Hopkins, A. R., and H. M. Taft. 1964. Field experiments for control of the boll weevil, bollworm spp., and the cotton aphid on cotton in 1960-62. J. Econ. Entomol. 57(4): 509-11.

Hunter, W. D., and W. E. Hinds. 1905. The Mexican cotton boll weevil. USDA Bur. Entomol. Bull. 51, 181p.

Isely, D. 1946. The cotton aphid. Ark. Agr. Exp. Sta. Bull. 462, 29p.

Laster, M. L., and J. R. Brazzel. 1968. A comparison of predator populations in cotton under different control programs in Mississippi. J. Econ. Entomol. 61(3): 714-9.

Lincoln, C., and T. F. Leigh. 1957. Timing insecticide applications for cotton insect control. Ark. Agr. Exp. Sta. Bull. 588, 47p.

Lingren, P. D., and D. E. Bryan. 1965. Dosage-mortality data on the bollworm, Heliothis zea, and the tobacco budworm, Heliothis virescens, in Oklahoma. J. Econ. Entomol. 58(1): 14-8.

Lingren, P. D., and R. L. Ridgway. 1967. Toxicity of five insecticides to several insect predators. J. Econ. Entomol. 60(6): 1639-41.

Lingren, P. D., R. L. Ridgway, C. B. Cowan, Jr., J. W. Davis, and W. C. Watkins. 1968. Biological control of the bollworm and the tobacco budworm by arthropod predators affected by insecticides. J. Econ. Entomol. 61(6): 1521-5.

Lloyd, E. P., F. C. Tingle, M. E. Merkl, E. C. Burt, D. B. Smith, and T. B. Davich. 1967. Comparison of three rates of application of ultra-low-volume azinphosmethyl in a reproduction-diapause control program against the boll weevil. J. Econ. Entomol. 60(6): 1696-9.

Lowry, W. L. 1966. Bollworm and tobacco budworm resistance to some insecticides in lower Rio Grande Valley in 1964. J. Econ. Entomol. 59(2): 479-80.

Lowry, W. L., R. L. McGarr, O. T. Robertson, R. S. Berger, and H. M. Graham. 1965. Bollworm and tobacco budworm resistance to several insecticides in the lower Rio Grande Valley of Texas. J. Econ. Entomol. 58(4): 732-4.

Lukefahr, M. J. 1970. The tobacco budworm situation in the lower Rio Grande Valley and northern Mexico. Proc. 2nd Ann. Tex. Conf. on Insect, Plant Disease, Weed and Brush Control, Tex. A & M Univ. 140-5.

McGarr, R. L., and D. A. Wolfenbarger. 1969. Methyl parathion, toxaphene and DDT used alone and in combination for control of several cotton insect. J. Econ. Entomol. 62(5): 1249-50.

McGarr, R. L., A. J. Chapman, and D. F. Martin. 1965. Field tests with several insecticides for control of the pink bollworm, boll weevil, and bollworm. J. Econ. Entomol. 58(4): 693-4.

McGarr, R. L., and C. M. Ignoffo. 1966. Control of Heliothis spp. with a nuclear polyhedrosis virus, EPN, and two newer insecticides. J. Econ. Entomol. 59(5): 1284-5.

McGarr, R. L., and D. A. Wolfenbarger. 1970. Insecticides for control of four cotton insects in 1968. J. Econ. Entomol. 63(4): 1324-5.

Messenger, K. 1963. Low-volume aerial spraying will be boom to aerial applicators. Agr. Chem. 18:63-6.

Messenger, K. 1964. Low-volume aerial spray. Agr. Chem. 19:1961-4.

Mistric, W. J., Jr., B. M. Covington, and F. D. Smith. 1970. Effects on methyl parathion, DDT, and toxaphene on the boll weevil, bollworm, and cotton plant in North Carolina. J. Econ. Entomol. 63(2): 596-9.

Mistric, W. J., Jr., and F. D. Smith. 1969. Behavior of tobacco budworm larvae of flue-cured tobacco and possibilities of improving the effectiveness of insecticidal treatments applied mechanically for control. J. Econ. Entomol. 62(1): 16-21.

Murray, J. C. 1972. Introduction. In Distribution, abundance and control of Heliothis species in cotton and other host plants. So. Coop. Ser. Bull. 169, p. 1-2.

Nemec, S. J. 1971. Topical application and cage plant evolutions of insecticides toxicities to bollworms, tobacco budworm, and boll weevils. Tex. Agr. Exp. Sta. Pro. Rep. (in press).

Nemec, S. J., and P. L. Adkisson. 1966. Comparative effectiveness of low volume concentrate and water emulsion sprays of certain insecticides for cotton insect control. Tex. Agr. Exp. Sta. Misc. Pub. 813, 6p.

Nemec, S. J., and P. L. Adkisson. 1969. Laboratory tests of insecticides for bollworm, tobacco budworm, and boll weevil control. Tex. Agr. Exp. Sta. Pro. Rep. 2674, 10p.

Nemec, S. J., P. L. Adkisson, and H. W. Dorough. 1968. Laboratory tests of ultra-low-volume and conventional low-volume sprays for controlling the bollworm and the tobacco budworm. J. Econ. Entomol. 61(1): 209-13.

Newsom, L. D., and C. E. Smith. 1949. Destruction of certain predators by application of insecticides to control cotton pests. J. Econ. Entomol. 42(6): 904-7.

Pate, T. L., and J. R. Brazzel. 1964. Resistance of bollworms to poison tested. Miss. Farm. Res. 27(4): 1-3.

Peterson, A. 1946. Laboratory tests showing effect of DDT on several important parasitic insects. Ohio. J. Sci. 46(6): 323-6.

Peterson, A. 1959. Larvae of insects: Part I: lepidoptera and plant infesting hymenoptera. Edwards Brothers, Inc., Ann Arbor, Michigan, 315p.

Pfrimmer, T. R., R. E. Furr, and E. A. Stadelbacher. 1971. Material for control of boll weevils, bollworms, and tobacco budworm on cotton at Stoneville, Mississippi. J. Econ. Entomol. 64(2): 475-8.

Plapp, F. W., Jr. 1971. Insecticide resistance in *Heliothis*: Tolerance in larvae of *H. virescens* as compared with *H. zea* to organophosphate insecticides. J. Econ. Entomol. 64(5): 999-1002.

Price, R. G., and J. H. Young. 1969. Cotton insect control. Chickasha Cotton Res. Sta. Pro. Rep. P-622, 28p.

Quaintance, A. L., and C. T. Brunes. 1905. The cotton bollworm. USDA Bur. Entomol. Bull. 50, 155p.

Ridgway, R. L., and P. D. Lingren. 1972. Predaceous and parasitic anthropods as regulators of *Heliothis* populations. *In* Distribution, abundance and control of *Heliothis* species in cotton and other host plants. So. Coop. Ser. Bull. 169, p. 48-58.

Ridgway, R. L., P. D. Lingren, C. B. Cowan, and J. W. Davis. 1967. Populations of arthropod predators, and *Heliothis* spp. after application of systemic insecticides to cotton. J. Econ. Entomol. 60(4): 1012-6.

Rings, R. W., and C. R. Weaver. 1948. Effects of benzene hexachloride and DDT upon parasitization of the oriental fruit moth. J. Econ. Entomol. 41(4): 566-9.

Roussel, J. S., and D. F. Clower. 1957. Resistance to the chlorinated hydrocarbon insecticides in the boll weevil. J. Econ. Entomol. 50(4): 463-8.

Sherman, F. 1930. Results of airplane dusting in the control of cotton bollworm (*Heliothis obsoleta* Fab.) J. Econ. Entomol. 23(5): 810-3.

Smith, C. L., and B. F. Driggers. 1944. Toxicity of DDT to *Macrocentrus ancylivorus* Rohwer. J. Econ. Entomol. 37(4): 538.

Smith, G. L., T. C. Cleveland, and J. C. Clark. 1965. Field tests for control of overwintered boll weevils. J. Econ. Entomol. 58(2): 360-1.

Taft, H. M., and A. R. Hopkins. 1965. Fight insects with mist. Agr. Res. p. 5.

Taft, H. M., and A. R. Hopkins. 1967. Control of cotton pests with low-volume insecticides applied with a low-volume mist sprayer. J. Econ. Entomol. 60(2): 608-10.

Taft, H. M., A. R. Hopkins, C. E. Jernigan, and J. C. Webb. 1969. A new 8-row ground sprayer with auxiliary air for ULV application of pesticides to cotton. J. Econ. Entomol. 62(3): 570-4.

Thomas, C. A., Jr., and R. J. Goddard. 1966. Low-volume concentrated sprays applied by ground equipment for control of the boll weevil. J. Econ. Entomol. 59(1): 114-6.

Thurston, R. 1960. Effect of insecticidal sprays on hornworm and on Apanteles congregatus. J. Econ. Entomol. 53(5): 976.

Van den Bosch, R., H. T. Reynolds, and E. J. Dietrick. 1956. Toxicity of wildly used insecticides to beneficial insects in California cotton and alfalfa fields. J. Econ. Entomol. 49(2): 359-63.

Wheeler, E. H., and A. A. LaPlante. 1946. DDT and Ryanex to control Oriental fruit moth: Their effect upon parasite population. J. Econ. Entomol. 39(2): 211-5.

Whitten, C. J., and D. L. Bull. 1970. Resistance to orgonophosphorus insecticides in tobacco budworm. J. Econ. Entomol. 63(5): 1492-5.

Wilkes, L. H., P. L. Adkisson, and B. J. Cochran. 1961. Use of an air-carrier sprayer for cotton insect control. Tex. Agr. Exp. Sta. Pro. Rep. 2205, 3p.

Wilkes, L. H., and J. K. Walker, Jr. 1961. Modification of a commercial high-clearance sprayer for use in small plot spraying, J. Econ. Entomol. 54(3): 601-3.

Wolfenbarger, D. A. 1970. Toxicity of certain insecticides to three lipidopteran cotton insects. J. Econ. Entomol. 63(2): 463-6.

Wolfenbarger, D. A., R. L. McGarr, and W. L. Lowry. 1966. Carbamate-type insecticides for control of tobacco budworm and bollworm on cotton. J. Econ. Entomol. 59(6): 1458-61.

Wolfenbarger, D. A., A. A. Guerra, and W. L. Lowry. 1968a. Effects of organometallic compounds on lepidoptera. J. Econ. Entomol. 61(1): 78-81.

Wolfenbarger, D. A., W. L. Lowry, A. L. Scales, and C. R. Parencia, Jr., 1968b. Effect of 4'-(3,3-dimethyl-1-triazeno) acetanilide and other compounds on several lepidopterous pests of cotton. J. Econ. Entomol. 61(1): 235-8.

Wolfenbarger, D. A., and R. E. Redfern. 1968. Toxicity of five carbamate insecticides to the two-spotted spider mite and larvae of southern armyworm and the tobacco budworm. J. Econ. Entomol. 61(2): 580-1.

Wolfenbarger, D. A., and W. L. Lowry. 1969. Toxicity of DDT and related compounds to certain lepidopteran cotton insects. J. Econ. Entomol. 62(2): 432-5.

Wolfenbarger, D. A. 1970. Toxicity of certain insecticides to three lepidopteran cotton insects. J. Econ. Entomol. 63(2): 463-6.

Wolfenbarger, D. A., and R. L. McGarr. 1970. Toxicity of methyl parathion, and monocrotophos applied topically to populations of lepidopteran pests of cotton. J. Econ. Entomol. 63(6): 1762-4.

Wolfenbarger, D. A., R. L. McGarr, and W. L. Lowry. 1970. Toxicity of organophosphorus, aryl methylcarbanilate, methylcarbamate and carboxanilide insecticides against lepidopterans attacking cotton. J. Econ. Entomol. 63(6): 1943-7.

Wolfenbarger, D. A., M. J. Lukefahr, and H. M. Graham. 1971. A field population of bollworms resistant to methyl parathion. J. Econ. Entomol. 64(3): 755-6.

Young, D. F., Jr. 1969. Cotton insect control. 1st. ed. Oxmoor Press, Birmingham, Alabama, 185p.

A P P E N D I X

T A B L E S

TABLE I

PERCENT OF FRUITS DAMAGED BY *H. ZEA* AND *H. VIRESCENS* IN SMALL PLOT FIELD TESTS USING CONVENTIONAL SPRAYS, CHICKASHA, OKLAHOMA 1971

Chemical	Lbs. Actual Tox/A	Sampling Dates						
		8/12	8/18	8/23	8/30	9/3	9/8	Avg[1,2,3]
Azodrin	1.0	5.3	7.7	6.3	5.3	5.0	1.0	5.1[a]
Galecron + Methyl parathion	0.5+ 0.25	2.0	0.7	4.7	8.7	9.7	8.0	6.4[a]
Phosvel	1.5	1.7	5.7	6.3	13.0	7.3	3.0	7.1[a]
Galecron	0.5	3.3	5.3	7.7	11.3	11.7	6.3	8.5[a]
Toxaphene + Methyl parathion	2.0+ 1.0	3.0	0.3	6.0	17.0	18.0	14.7	11.2[a]
Pencap M	1.0	1.3	3.0	8.0	25.0	17.3	3.7	11.4[a]
Methyl parathion	1.0	2.0	2.0	12.3	20.3	31.7	11.7	15.6[a]
Premerge	0.125	2.0	14.0	35.3	66.3	68.0	48.3	46.4[b]
Check	--	2.0	10.7	31.7	65.3	74.3	51.7	46.7[b]
Dow General	0.125	4.3	20.0	36.7	72.3	70.3	58.3	51.5[b]

[1]Based on 100 fruits from each of three replicates on count date.

[2]8/12 count not included in seasonal average.

[3]Entries with any of the same letters had no significant difference (5% level of probability) measured by Duncan's multiple range test.

TABLE II

PERCENT OF FRUITS DAMAGED BY THE BOLL WEEVIL IN SMALL PLOT FIELD TESTS USING CONVENTIONAL SPRAYS, CHICKASHA, OKLAHOMA 1971

Chemical	Lbs. Actual Tox/A	Sampling Dates						
		8/12	8/18	8/23	8/30	9/3	9/8	Avg[1,2,3]
Premerge	0.125	0.0	1.7	0.3	0.0	0.7	1.0	0.7[a,c]
Azodrin	1.0	0.0	1.3	1.3	0.0	0.7	0.7	0.8[a,c]
Phosvel	1.5	0.7	0.7	1.0	0.7	0.7	1.7	1.0[a,c]
Methyl parathion	1.0	2.3	0.7	0.3	0.7	0.3	3.0	1.0[a,c]
Pencap M	1.0	1.0	0.7	1.3	1.3	1.0	1.0	1.1[a,c]
Galecron + Methyl parathion	0.5+ 0.25	0.7	0.3	0.0	0.7	1.7	2.7	1.1[a,c]
Galecron	0.5	0.7	1.0	0.3	2.7	2.0	0.7	1.3[a,c]
Toxaphene + Methyl parathion	2.0+ 1.0	0.7	2.3	0.3	1.0	1.7	3.7	1.8[b,c]
Dow General	0.125	0.7	2.3	1.7	0.3	2.7	3.7	2.1[b,c]
Check	--	0.5	2.0	1.0	0.7	3.0	8.3	3.0[b]

[1]Based on 100 fruits from each of three replicates on count date.

[2]8/12 count not included in seasonal average.

[3]Entries with any of the same letters had no significant difference (5% level of probability) measured by Duncan's multiple range test.

TABLE III

PERCENT OF FRUITS DAMAGED BY *H. ZEA* AND *H. VIRESCENS* USING CONVENTIONAL SPRAYS VS. AIR EMULSION SPRAYS AT DIFFERENT TRACTOR SPEEDS, CHICKASHA, OKLAHOMA 1971

Method of Application[1]	MPH	Sampling Dates 8/13	8/18	8/23	8/30	Avg[2,3,4]
Conventional	3	3.0	5.7	9.3	9.6	8.2[a,b,c,d]
	6	3.0	8.0	16.3	22.0	15.4[a,b,c]
	9	1.0	10.0	20.0	27.3	19.1[a,b,d]
Air-Emulsion	3	5.7	21.7	26.0	26.0	24.6[a,b,d]
	6	1.0	17.3	31.3	46.0	31.5[a,c]
	9	4.0	19.0	33.0	52.7	34.9[a,c]
Check	-	3.0	18.7	46.3	67.0	44.0[b]

[1]Phosvel at 1.5 lbs of actual toxicant per acre was used for all treatments.

[2]Based on 100 fruits from each of three replicates on count dates.

[3]8/13 count not included in seasonal average.

[4]Entries with any of the same letters had no significant difference (5% level of probability) measured by Duncan's multiple range test.

TABLE IV

PERCENT OF FRUITS DAMAGED BY THE BOLL WEEVIL USING CONVENTIONAL SPRAYS VS. AIR EMULSION SPRAYS AT DIFFERENT TRACTOR SPEEDS, CHICKASHA, OKLAHOMA 1971

Method Application[1]	MPH	Sampling Dates 8/13	8/18	8/23	8/30	Avg[2,3,4]
Conventional	3	1.0	1.0	4.7	1.3	2.3[b,c]
	6	1.7	2.3	5.3	0.3	2.6[b,c]
	9	1.7	2.0	4.7	1.0	2.6[b,c]
Air-Emulsion	3	1.0	1.3	7.0	0.0	2.8[b,c]
	6	3.7	4.7	6.7	0.7	4.0[b]
	9	3.7	2.3	3.0	0.0	1.8[a,c]
Check	-	1.7	1.7	7.0	1.3	3.3[b,c]

[1]Phosvel at 1.5 lbs of actual toxicant per acre was used for all treatments.

[2]Based on 100 fruits from each of three replicates on count dates.

[3]8/13 count not included in seasonal average.

[4]Entries with any of the same letters had no significant difference (5% level of probability) measured by Duncan's multiple range test.

TABLE V

PERCENT *H. ZEA* AND *H. VIRESCENS* LARVAE COLLECTED IN INSECTICIDAL PLOTS AND PERCENT OF LARVAE PARASITIZED, CHICKASHA, OKLAHOMA 1971

Dates Collected	No. of Larvae Collected	% *H. zea*	% *H. virescens*	% Parasitized *H. zea*	% Parasitized *H. virescens*
Aug. 12	74	100.0	0.0	14.9	0.0
19	95	88.0	12.0	27.4	0.0
24	142	92.3	7.8	23.7	18.2
30	187	88.8	11.2	25.3	23.8
Sept. 3	86	90.7	9.3	24.4	0.0
8	32	90.6	9.4	41.4	0.0
15	51	52.9	47.1	33.3	12.5
28	54	66.7	33.3	41.7	5.6
Total	721	--	--	--	--
Season Average	-	83.8	16.2	29.0	7.5

VITA

Sanit Ratanabhumma

Candidate for the Degree of

Master of Science

Thesis: FIELD EVALUATION OF INSECTICIDES USING TWO METHODS OF SPRAYING FOR CONTROL OF THE HELIOTHIS COMPLEX, BOLL WEEVIL AND THEIR EFFECT ON PARASITISM

Major Field: Entomology

Biographical:

Personal Data: Born in Bangkok, Thailand, February 17, 1945, the son of Varee and Chaleo Ratanabhumma.

Education: Received Bachelor of Science degree (Honor) from Kasetsart University, Bangkok, Thailand in July, 1968; completed requirements for Master of Science degree at Oklahoma State University in July, 1972.

Professional Experience: Employed as a Assistant Lecturer, Department of Entomology and Plant Pathology, Kasetsart University from November 1968 to May 1970; Graduate Research Assistant, Department of Entomology, Oklahoma State University, 1970-72.

Honors: Qualified as a member of President's Honor Roll, Oklahoma State University, for Fall semester 1970-71; Selected as a Thai Student Leader at Oklahoma State University, 1970-72.

Organizations: Thai Students' Association.