THE USE OF OILS IN INSECT MANAGEMENT
IN COTTON IN THE BLACKLANDS OF TEXAS

A Thesis

by

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ABSTRACT

The Use of Oils in Insect Management in Cotton in the Blacklands of Texas (December 1990)

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Field studies were conducted to determine the toxicity of a mineral oil, cottonseed oil and soybean oil applied alone and combined with insecticides for the control of several cotton pest insects. A study was performed to determine if various rates of oils applied had any effect on cotton yield. Also, a cage study was conducted to determine the toxicity of oils alone and in combination with insecticides to adult boll weevils, *Anthonomus grandis grandis* (Boheman). Applications of water and oil:water emulsions both with and without insecticides were made with a conventional hydraulic-atomization spraying system. Ultra low volume applications of oils with and without insecticides were made with a controlled droplet application system.

Oils applied conventionally as 10:1 water emulsions provided better control of tarnished plant bug (TPB) nymphs, *Lygus lineolaris* (Palisot de Beauvois), and cotton fleahopper (CFH) adults and nymphs, *Pseudatomoscelis seriatus* (Reuter), than ultra low volume application of oils. The addition of methomyl did

not improve control of either adults or nymphs of CFH or TPB. Orchex 796 apparently reduced numbers of beneficial insects but the vegetable oils did not.

The toxicity of cypermethrin to TPB and CFH was enhanced by the addition of oils. Soybean oil was as effective as any cypermethrin treatment in reducing numbers of TPB and CFH adults but not nymphs. This suggests that soybean oil repelled the adult insects.

Oils enhanced the toxicity of cypermethrin to adult boll weevils. The toxicity of azinphosmethyl, methyl parathion and oxamyl to boll weevil adults was not enhanced by the addition of oil.

There were no significant differences determined among the four rates of mineral oil and cottonseed oil tested on cotton yield. Lint qualities of cotton treated with oils were determined to be statistically the same and not different from a water control.

DEDICATION

This thesis is dedicated to my parents, Bud and Ouita McCaa, for their love, patience, dedication and help throughout this study and throughout the years. Their encouragement and understanding has seen me through many tough times and helped me to learn valuable lessons about life. I am also very grateful for the love and friendship of my wife, Chris. She provided needed encouragement, help and understanding during my graduate career and for that I will always be grateful and thankful.

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INTRODUCTION

Cotton

Upland cotton, Gossypium hirsutum L., is a fiber crop of major economic importance for most of the world, valued for both its lint and oil. The average world-wide production of cotton in the late 1970's was 63.5 million bales/year (Niles and Feaster 1984). The world's leading cotton producing nations are the People's Republic of China, the U.S.S.R., and the United States of America (Metzer 1985).

The cultivation of cotton and its use dates back several millenia to pre-Incan Peru in the New World and to ancient India in the Old World (Crawford 1924). Cotton and its cultivation have influenced the agricultural, industrial, commercial, social and political history in the western world (Scherer 1916, Crawford 1924, Cohn 1956, Lewis and Richmond 1968, Lee 1984). Cotton has particularly affected the history and the social and economic development of the southern United States.

Approximately 3,890,000 ha of cotton were grown in the United States in 1983 (Anonymous 1983). Texas remains one of the primary cotton producing states in the United States. The average annual production of upland cotton in Texas during the years of 1980-1984 was 3.54

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million bales which was approximately 30% of the average annual cotton production for the United States for that same period (Anonymous 1984). The average monetary value for Texas upland cotton for the 1980-1984 period was $923,467,750/year (Anonymous 1984).

Cotton Insects in Texas. Several arthropod pests may be found in cotton ecosystems in Texas (Adkisson 1984). The major cotton pests include the cotton fleahopper (CFH), *Pseudatomoscelis seriatus* (Reuter); the tarnished plant bug (TPB), *Lygus lineolaris* (Palisot de Beauvois); the boll weevil, *Anthonomus grandis grandis* Boheman, the bollworm, *Heliothis zea* (Boddie), the tobacco budworm, *Heliothis virescens* (F.), and the pink bollworm, *Pectinophora gossypiella* (Saunders).

The pink bollworm is mainly a pest of the Trans-Pecos region of Texas. The cotton fleahopper and the boll weevil are considered to be key pests for most cotton production areas of the state except for the High Plains region. A key pest is any pest which normally requires action to keep the populations from reaching levels which cause economic damage (Reynolds et al. 1982, Adkisson 1984). Greater than 30% yield losses have been estimated if no control measures are implemented for populations of cotton fleahoppers and boll weevils in cotton (Schwartz and Klassen 1981). The complex of *Heliothis* spp. may cause an estimated 4% loss in annual cotton production in the United States (Anonymous 1976). *Heliothis* spp.

infestations of sufficient size may cause even greater cotton yield losses (Adkisson et al. 1964). Heliothis spp. are, nevertheless, considered a secondary pest of cotton. Natural controls will, under most circumstances, keep Heliothis populations from causing economic losses in cotton. Problems associated with Heliothis spp. are usually encountered when the environmental conditions are favorable for population build-up over naturally occurring enemies (omnivorous insect predators and parasites) or when the said enemies are destroyed by the use of insecticides (Walker et al. 1979, Reynolds et al. 1982, Adkisson 1984).

All of the aforementioned pests of cotton have been control targets of cotton producers in Texas for over 75 years. There have been many failures in the traditional system of cotton production and plant protection in Texas as they too often depend heavily on multi-applications of insecticides (Newsom and Brazzel 1968, Bottrell and Adkisson 1977, Walker et al. 1979, Reynolds et al. 1982). Cotton pests must be controlled with alternate strategy programs. Walker (1984) reported that approximately 95% of all Texas cotton was involved in some type of ecologically-based and sound alternate control strategy program.

Pest Management in Texas Cotton

A prime example of integrated pest management (IPM) in Texas is the short season production program which relies on additional chemical and cultural tactics (Reynolds et al. 1982, Adkisson 1984). IPM is an approach to pest control which relies on both suppressive and preventive tactics which when evaluated and combined will result in a strategy which avoids allowing pest populations to reach densities where economic damage occurs and where there is little or no damage to the environment (Luckmann and Metcalf 1982).

In Texas, IPM strategies for cotton include part if not all of the following control tactics: 1) escape in time through the use of short-season management, the appropriate varieties and manipulated planting dates; 2) stalk destruction at the close of the production season; 3) conservation of natural enemies of pests through the use of pesticides which are selective; and 4) the timely use of insecticides through the use of simple decision making models and from the data acquired through insect scouting programs (Bottrell and Adkisson 1977, Frisbie 1977, Allen et al. 1985, Drees 1985).

This strategy for pest management in Texas cotton is directly related to the short season production which occurs in a large portion of the state (Walker et al. 1977, Adkisson 1984). The ultimate aim of this system is to achieve an early and adequate yield without the economic and ecological problems associated with mid-season and late-season attempts at pest control through the use of insecticide applications.

Role of Insecticides in Cotton IPM

Per-acre cotton lint yields in the United States by 1966 had almost doubled from the yields of the 1930's but there has been little improvement or increase in yields since that time. Increasingly difficult or expensive control of insect pests is frequently cited as a major reason for the lack of further improvement (Lee 1984).

Insecticides have been, and still are, the strategy most often used for the control of cotton insect pests. With the introduction of DDT in 1945, it appeared that synthetic organic insecticides would provide complete and inexpensive control of insect pests. But extensive use of these insecticides brought about the development of resistance to insecticides in many insect species. Genetic variations among individuals of a species allow for survival of a few individuals exposed to normally lethal doses of insecticides. These survivors reproduce and give rise to successively more resistant generations. Development of insecticide resistance did not originate with the use of synthetic organic insecticides, but their widespread use accelerated the natural process (Quraishi 1977).

Use of insecticides may cause other problems in addition to the development of resistance in insect populations. Release of secondary pests from their normal control mechanisms is a major shortcoming associated with the use of insecticides. As previously mentioned Heliothis spp. are considered secondary pests but often increase in number to a point past the economic injury level so that control measures must be implemented. Herbivorous insects, such as Heliothis spp., have well developed detoxifying mechanisms for metabolizing plant secondary compounds. Multi-function oxidases are common in polyphagous herbivores such Heliothis spp. Plapp and Vinson (1977) determined that these microsomal oxidases are the primary means by which insects detoxify phosphorothionate, carbamate, formamidine, and pyrethroid insecticides. Therefore, herbivores are better able to develop insecticide resistance than natural enemies and under selection pressure caused by the use of insecticides may increase in number to a population level where economic damage may occur.

Along with other control strategies, insecticides may be successfully used in IPM (Ripper 1944, van den Bosch and Stern 1962, Brazzel 1965). In this scheme for insect control, insecticides are considered to be an important and a major component of Texas cotton IPM programs (Anonymous 1969, Reynolds et al. 1982).

The use of insecticides should be judicious and selective so as to avoid any unwanted side effects from their use and to maximize their advantages. Selectivity exists through the use of different application methods and different insecticidal carriers.

LITERATURE REVIEW

Insecticides have conventionally been applied as emulsifiable concentrates (EC) using water as the carrier. The ultra-low volume (ULV) application technique for pesticides was developed in the 1960s as an alternative to EC application strictly in water. ULV application of insecticides most often uses very low volumes of water or an oil carrier. Diesel oil, ethylene glycol, molasses, toxaphene, vegetable and petroleum oils have all been used as ULV carriers. Southwick et al. (1986) reported that ULV applications may be less costly to growers and applicators due to the application of smaller spray volumes.

Insecticides applied as ULV may be more effective than when applied as EC. Some of the advantages of ULV formulations are increased residual activity of insecticides (MacCuaig 1966, Awad et al. 1967, McDaniel 1980), decreased spray drift and increased canopy penetration (Brazzel et al. 1968, McDaniel 1980, McDaniel et al. 1983) and increased insecticide penetration across the insect cuticle (Awad and Vinson 1968).

Toxaphene was one of the first insecticides used in combination with other insecticides to increase residues for the control of cotton insect pests. Ware et al. (1979) reported that the addition of toxaphene increased both the initial residue and the residual activity of methyl parathion. Toxaphene is a slightly volatile solvent which is thought to decrease the volatility of methyl parathion as well as reducing its hydrolytic and photolytic decomposition (Ware et al. 1979). Bigley et al. (1981) reported that camphene and cedar oil may increase the persistence of methyl parathion, but not to the extent as when combined with toxaphene. Their data also suggests that the beneficial attributes of toxaphene may be due to the physical effect of increasing the surface residues of methyl parathion. Molasses also increases the toxicity of methyl parathion to cotton insect pests (Nemec and Adkisson 1967, Ware et al. 1980). Hooper et al. (1979) suggested that toxaphene was possibly mutagenic and its ban followed shortly thereafter. The search for suitable ULV carriers led researchers to explore vegetable and petroleum oils as possible substitutes for toxaphene.

Oils as Insecticide Carriers

The use of oils as insecticide additives is not a new technology. Woglum (1926) found that white oil emulsions, characterized by high viscosity and low volatility, were the most effective spray type for control of insect and mite pests in California citrus trees. De Ong (1926) explored the technical aspects of petroleum oils and oil-water emulsions on insects and on plants. Dawsey (1933) devised a laboratory method for determining the approximate evaporation of petroleum spray oils under field conditions.

More recently, Southwick et al. (1986) reported that vegetable oils such as cottonseed oil and soybean oil exhibit the desirable ULV characteristics of low volatility and low phytotoxicity. Vegetable oils are not as volatile as some other insecticide diluents but remain for days as slowly diminishing sticky droplets (Akesson et al.1983). Cottonseed oil used as the insecticide carrier increased the residual activity of four pyrethroids, a phosphorothionate, and a carbamate on cotton foliage (Ware et al. 1983). Chalfant and Young (1984) showed that the addition of peanut oil to encapsulated methyl parathion for application via chemigation significantly improved the insecticide's toxicity to cowpea curculio, Chalcodermus aeneus Boheman, when compared to the conventional aqueous formulation. Luttrell and Wofford (1984) reported that soybean oil enhanced the toxicity of permethrin to Heliothis virescens (F.) larvae. Womack et al. (1985) reported that soybean oil was superior to water as the insecticide carrier for the control of bollworms in cotton. Two pyrethroids, fenvalerate and permethrin, were shown to have increased toxicity when applied with petroleum oil or with cottonseed oil to both house flies and tobacco budworm larvae (Ochou et al. 1986). Treacy et al. (1986) reported that soybean oil used as the carrier, applied both ULV and conventionally in emulsions, increased the initial toxicity and residual activity of several insecticides to boll weevils.

The efficacy and residual activity of insecticides is not always improved by the addition of vegetable or petroleum oils. The toxicity of carbaryl to southern armyworm, Spodoptera eridania (Cramer), larvae was reduced when combined with several solvents (Brattsten and Wilkinson 1977). Ochou (1985) reported that the addition oil did not improve the efficacy of two organophospates, ethyl parathion and methyl parathion, nor that of a carbamate, methomyl.

The effect of an oil carrier on the insecticide depends on the type of insecticide and it solubility in the carrier (Schouest et al. 1983, Treacy et al. 1985, Ochou 1985). Ochou (1985) found that the more oil-soluble pyrethroids generally had enhanced toxicity when combined with oils but the organophospahtes and the carbamate he tested were not enhanced as they are not as oil-soluble relative to the pyrethroids tested. Synergism of an insecticide and its oil carrier may be due to more rapid transport of the insecticide dissolved in oil across the insect cuticle (de Licastro et al. 1983).

Insecticidal Qualities of Oils

Vegetable and petroleum oils not only increase the toxicity and the residual activity of insecticides but may, themselves, be toxic to insects. Chapman (1967) reported that the use of oils has three advantageous qualities over insecticides: 1) oils are relatively harmless to humans, 2) arthropods are less likely to develop resistance to oils when compared to insecticides, and 3) oils are generally less expensive relative to the high cost of insecticides.

Mineral or petroleum oils have long been used in citrus orchards for the control of insect and mite pests (Woglum 1926, De Ong 1926, Dawsey 1933). Petroleum oils, more so than vegetable oils, are used to control insect pests and to kill dormant insect eggs (Schoonhoven 1978). Schroeder and Green (1983) reported that two different oils applied to a plant leaf surface affected the bonding ability of eggs of Diaprepes abbreviatus (L.), a sugarcane rootstalk borer, and allowed for natural removal of the eggs. Szatmari-Goodman and Nault (1983) reported that JMS stylet oil significantly reduced the transmission of maize dwarf mosaic, an aphid-borne disease of sweet corn. They also found that aphid stylet probing was delayed on oil-sprayed corn leaves where the aphids had difficulty in anchoring their tarsi compared to the untreated control. Messina and Renwick (1983) found that five different oils, (three vegetable oils, a mineral oil, and polyethylene glycol), equally reduced the survivorship of eggs of the cowpea weevil, Callosobruchus maculatus (F.). They determined that the lack of oil-specific activity indicated that the protective properties of the oils tested were physical rather than chemical. Schoonhoven (1978) reported that the significant differences in control of the Mexican bean weevil, Zabrotes subfasciatus (Boheman), provided by different oils and different purities of the oils suggest that the oils have a different mode of action from oxygen starvation. Hill and Schoonhoven (1981) reported that 1 ml vegetable oil/kg bean seed was effective in controlling the Mexican bean weevil infesting stored dry beans. The authors determined the active oil fraction to be the triglyceride component.

Four different vegetable oils were effective in protecting stored wheat from the granary weevil, Sitophilus granarius (L.) (Qi and Burkholder 1981). The same oils were also shown to have repellent qualities which were determined by the number of insects leaving the treated stored wheat. Qi and Burkholder (1981) suggested that vegetable oils may influence early insect development or larval eclosion in addition to affecting adult survival. Su et al. (1972) reported that the peel oils from eight different citrus fruits were effective in the control of the cowpea weevil in black-eyed peas. Dennettia oil, a plant oil, was significantly more toxic to the American cockroach and a grasshopper than the insecticides diazinon, lindane or propoxur (Iwuala et al. 1981).

The following experiments were conducted to determine the relative toxicity and efficacy of vegetable and

and mineral oils alone and as additives or carriers to insecticides for the control of cotton insect pests in the northern Blackland prairie region of Texas.

Experiments were designed to reach the following objectives:

1) To determine the influence of various rates of mineral oil and vegetable oils on the yield of cotton.

2) To determine the relative toxicity of mineral oil and vegetable oils to cotton insects.

3) To determine the relative efficacy of mineral oil and vegetable oils as additives or carriers for insecticides used in the control of cotton insect pests.

4) To compare the conventional application of insecticides as EC in water to the ULV application method of insecticides.

MATERIALS AND METHODS

All studies were conducted at the Texas A&M Research and Extension Center located in northern Dallas County. The soil at this location is predominantly Austin silty clay which is typical of the northern Blackland Prairies. All treatments were applied to cotton planted May 11 ('G&P 3774') and May 22 ('Paymaster 145') in 1984, and on May 7 ('Paymaster 145') in 1985. Row spacing in both study years was 102 cm. All replicated treatments were made to individual test plots eight rows wide by 18.3 m long.

The following oils were used in the course of the studies: 1) Orchex 796, a highly paraffinic petroleum spray oil (Exxon Corporation, Houston, Tex.); 2) soybean oil (SBO) (refined and bleached, Anderson Clayton and Company, Richardson, Tex.); and 3) cottonseed oil (CSO) (once-refined, Valco Chemicals, Harlingen, Tex. in 1984; Anderson Clayton and Company, Richardson, Tex. in 1985). Appendix Table 22 reports the physical characteristics of the oils. These oils were used either alone as a treatment or as a carrier for an insecticide treatment.

Experimental Methods

Applications of oil treatments were made by a tractor-mounted Sprayrite Ground Plane (Sprayrite Manufacturing Company, West Helena, Ark.) traveling at 2.39 m/sec. The sprayer used eight hydraulically-driven controlled droplets applicators (CDA) on a mounted boom so that each applicator was directly over a row and ca. 0.3 m above the plant canopy when spraying. The rotation speed of the CDA sprayer units was calibrated at 4000 rpm. This rotation speed delivered droplets 120 to 140 um in diameter for the oil carriers alone and 101 to 105 um in diameter for the water-oil emulsions. Droplet size of all oil carriers and water-oil emulsion carriers was determined by the method of Maksymiuk (1978). A sample of the ULV spray of each carrier was taken from a line of white kromekote cards held horizontally ca. 0.45 m above bare ground. An oil soluble dye having a known spread factor was added to the carriers to improve droplet imagery. Measurement of oil stain diameters were made with an ocular lens and are reported in Appendix Table 23. Because each oil had a different flow rate, the air pressure used to force the oil into the CDA sprayer units was changed accordingly to provide the desired finished spray rate. This calibration procedure was repeated before each experiment was performed to account for changes in temperature and wear on the application equipment.

Applications of insecticides in water as emulsifiable concentrates (EC) were made with a Hahn Hi-boy sprayer (Hahn Incorporated, Evansville, Ind.) operating at 2.39 m/sec. The EC-water treatments were applied at 517.5 kPa with a finished spray rate of 46.75 liters/ha.

During mid-season, the effect of oils and of insecticides on the numbers of insects were determined by collection of insects with a D-Vac Vacuum Insect Net (Riverside, Calif.). Fifty 0.09 m^2 "sweeps" were randomly taken from the center six rows of each plot to avoid drift from adjacent plots. Insects were then killed by asphyxiation with ethyl acetate, sorted as to family and species if possible, and the numbers recorded for statistical analysis.

The insects collected in D-Vac samples were classified as pestiferous or beneficial insects. The two pest insects identified were CFH and TPB. There were 16 beneficial insect groups identified. They were grouped as follows: 1) predatory Coleoptera including Hippodamia convergens Guerin-Meneville, Scymnus spp. and Collops spp.; 2) predatory Hemiptera, including various spp. of Reduviidae and Nabidae, Geocoris spp., and Orius spp.; and predatory Neuroptera including Chrysopa spp. and Micromus spp..

After initial fruit set, whole plant inspections were made on 0.0004 ha in each treatment plot. Numbers of Heliothis spp. eggs and larvae, insect damage, and numbers of squares and bolls were recorded.

Experimental Design and Procedures

Oil Rate Study. This study was made to determine if varying amounts of oils applied to cotton had any effect on the yields or caused any phytotoxicity.

In 1984, four rates each of Orchex 796 and CSO and an unsprayed control were arranged in a randomized complete block design with four replications. The finished spray rates of the oil treatments were 4.68, 9.35, 14.03 and 18.70 liters oil/ha. The oil treatments were applied July 23 and 30, 1984. To determine the effect of any phytotoxicity on yield, the center two rows of each treatment plot were mechanically-stripped of seed cotton on September 25, 1984 and the weights were recorded for statistical analysis.

Mid-season Insecticide Study. This experiment was performed to determine if Orchex 796 and CSO alone and as water:oil emulsions were toxic to pestiferous hemipteran pest insects and to beneficial insects found in cotton during the middle of the growing season. For comparison, methomyl was added to the oils and oil:water emulsions to determine if oils enhanced the insecticide's toxicity.

On July 10, 1984, seven treatments were applied to cotton ('G&P 3774') arranged in a randomized complete block design with four replications. The treatments were: 1) 4.68 liters Orchex 796/ha; 2) 4.68 liters CSO/ha;

3) 46.75 liters water-Orchex 796/ha (10:1) plus 5% Armul 535 non-ionic emulsifier (DeSoto Incorporated, Harahan, La.) by oil volume; 4) 46.75 liters water-CSO/ha (10:1) plus 5% Armul 535 by oil volume; 5) methomyl at 0.14 kg [AI]/ha in 4.68 liters Orchex 796/ ha; 6) methomyl at 0.14 kg [AI]/ha in 4.68 liters CSO/ha and 7) an unsprayed control. D-Vac samples were taken on July 11, 12, and 13, 1984.

Oil:Insecticide Efficacy Study. The purpose of this study was to determine if oils had any effect on the performance and toxicity of cypermethrin to both pest and beneficial insects found in cotton. Samples of insects found in the cotton plots during the middle of the growing season were taken and whole plant inspections of cotton were made to determine any effect which the oils may have had.

In 1984, eight treatments were randomly assigned in a split-plot design having four replications. Main plot treatments were the carriers (Orchex 796, SBO, CSO, and water) with the sub-plot treatments being cypermethrin applied at 0.03 kg [AI]/ha or no added insecticide. Treatments were applied July 19 and 31, and August 8, 1984. D-Vac samples were then taken July 20 and 23. Boll weevils were obtained from the Robert T. Gast Rearing Laboratory, Mississippi State, Miss. Fifteen adults were released in the center of each treatment plot during the night of July 25. This release was made because severe cold during the winter of 1984 and destruction of the boll weevil's natural overwintering habitat on the Research Center had reduced the natural population to a level at which no damage could be found. Whole plant inspections were made August 3 and 10, 1984. Two full rows of cotton were hand-picked of lint from each plot at the end of the growing season and the resulting seed cotton was weighed.

The same split-plot design used in 1984 was repeated in the 1985 study with the exception that CSO was not included so that there were six total treatments. Treatments were applied July 1, 15 and 26. D-Vac samples were taken July 4 and 6. Whole plant inspections were made on July 19. The center two rows of each treatment plot were mechanically stripped of lint on September 9, 1985 and the burr cotton was weighed. Burrs were removed by hand and the seed cotton was then ginned and the gin turnout calculated. Lint samples from each treatment plot were sent to the Textile Research Center at Texas Tech University, Lubbock, Texas, for determination of micronaire, length and strength.

Boll Weevil Cage Study. This study was designed to determine the effect which oils have on the toxicity of insecticides to adult boll weevils. Boll weevils were placed on cotton at four, 24, and 48 h following insecticide treatment.

In both 1984 and 1985, blooming cotton

('Paymaster 145') was assigned to one of the following treatments: 1) an unsprayed check; 2) 4.68 liters Orchex 796/ha; 3) 4.68 liters CSO/ha; 4) 4.68 liters Orchex 796 plus insecticide; 5) 4.68 liters CSO/ha plus insecticide; and 6) 46.75 liters water/ha plus insecticide. The insecticides used in 1984 were: 1) azinphosmethyl at 0.28 kg [AI]/ha; and 2) cypermethrin at 0.045 kg [AI]/ha. In 1985, the insecticides used were: 1) azinphosmethyl at 0.28 kg [AI]/ha; 2) cypermethrin at 0.034 kg [AI]/ha; 3) methyl parathion at 0.56 kg [AI]/ha; and 4) oxamyl at 0.14 kg [AI]/ha. The oxamyl used in the 1985 study was applied as an oil-water (1:1) emulsion using 5% and 10% Sponto AK31-53 non-ionic emulsifier (Witco Chemical Corporation, Houston, Tex.) by oil volume of Orchex 796 and CSO, respectively, with a finished spray rate of 4.65 liters/ha. The physical characteristics of Sponto AK31-53 are reported in Appendix Table 22.

Boll weevils obtained from the Robert T. Gast Rearing Laboratory, Mississippi State, Miss., were reared to maturity in growth chambers with 14:10 (L:D) photoperiod maintained at 30+/-1 °C. Upon emergence as adults, the boll weevils were held at room temperature (22 +/-3 °C) and fed cotton ('Paymaster 145') squares for a minimum of four days prior to use in this study.

Muslin sleeve cages were placed over the individual cotton plants at four, 24 and 48 hours after spraying treatments. Five to ten adult boll weevils were placed in each of three to five muslin sleeve cages per treatment. Forty-eight hours after initial exposure of the boll weevils to the treatment residues, the caged plants were cut at ground level with pruning shears and the removed to the laboratory for determination of mortality. A boll weevil was considered to be dead if it failed to respond to squeezing of its proboscis with forceps (Treacy et al. 1985).

Statistical Analyses

Multiway analysis of variance was used to determine if differences existed in insect numbers, insect damage, cotton fruit numbers, lint yields, and lint qualities in all replicated studies except the oil rate study. Differences in treatment mean arrays were separated using the least significant differences (LSD) for the oil rate study and the mid-season insecticide study and by using Student-Newman-Keul's multiple comparison test for the oil: insecticide efficacy study.

Percent mortality of boll weevils from the cage study was analyzed by one-way analysis of variance, as there were no true blocks in this study. Treatment means were seperated using the Bonferroni procedure (Miller 1981).

All missing plot data were calculated by the method for the specific experimental design according to Steel and Torrie (1980).

RESULTS AND DISCUSSION

Oil Rate Study

This study was performed to determine if there were differences in the yield of cotton when varying amounts of oils were applied during the growing season. Visual inspections of cotton plants in the plots were made throughout the growing season to determine if the oils were causing phytotoxicity.

Cotton lint yields are reported in Table 1. There were no yield differences found among the different rate treatments of oils or the control. Visual inspection of treatment plots did not reveal oil-related phytotoxicity of the cotton plants during the course of this particular study.

Mid-Season Insecticide Study

The purpose of this test was to determine if Orchex 796 and CSO alone and as a water:oil emulsion were toxic to pestiferous hemipteran insects and beneficial insects which are found in cotton during the middle of the growing season. For comparison, methomyl, a commonly used cotton insecticide, was applied in Orchex 796 and in CSO to determine if the oils enhanced the toxicity of the insecticide to the insects collected.

Table 1. Yield as kg cotton lint/ha on September 25, 1984.

Oil Rate (liters/ha)	Yield Orchex 796	Yield CSO
0.00	499.3	499.3
4.68	465.0	455.5
9.36	474.5	447.9
14.04	474.5	476.5
18.70	470.0	486.0

There were no significant differences in cotton yield among the treatments, P=0.05.

Numbers of TPB adults and nymphs collected by D-Vac in fifty 0.09m ^{2} sweeps per plot are reported in Table 2. None of the treatments controlled TPB adults over the three day sampling period. However, the use of oil:water emulsions with both Orchex 796 and CSO resulted in consistently lower numbers of adults than the oil only and the oil:insecticide treatments. On the third day after application, all treatments except 4.68 liters Orchex 796/ha had reduced the number of TPB nymphs by a statistically significant amount. Addition of methomyl to CSO did not improve control. The two water-oil emulsions reduced the number of TPB nymphs slightly more than any of the other treatments. Based on these results, Orchex 796 and CSO as a 10:1 water emulsion were the most effective treatments tested.

The numbers of CFH collected in the same test are shown in Table 3. A significant reduction in adult CFH

Table 2. Numbers of tarnished plant bugs collected in 50 0.09 m^2 D-Vac samples following spray on July 10, 1984.[a]

Treatment	Finished spray rate (liters/ha)	Adults: Days after application 1	2	3	Nymphs: Days after application 1	2	3
Orchex 796	4.68	6.25	10.75	6.75	3.50	4.50	7.00
Orchex 796 + 0.14 kg [AI] methomyl/ha	4.68	3.50	9.50	7.00	3.25	4.75	4.00*
Water-Orchex 796 (10:1) emulsion	46.75	2.75	8.25	4.25	2.25	5.75	3.25*
CSO	4.68	3.75	10.25	7.50	4.00	7.75	3.50*
CSO + 0.14 kg [AI] methomyl/ha	4.68	3.75	12.00	10.75	1.75	3.50	4.25*
Water-CSO (10:1) emulsion	46.75	2.75	6.75	6.25	1.00	2.50	2.00*
Control	-	4.00	7.25	7.25	3.25	4.50	9.50

[a] Means within columns followed by * differ significantly from the control, P=0.05.

Table 3. Numbers of cotton fleahoppers collected in 50 0.09 m^2 D-Vac samples following spray on July 10, 1984.[a]

		Adults			Nymphs		
	Finished spray	Days after application			Days after application		
Treatment	rate (liters/ha)	1	2	3	1	2	3
Orchex 796	4.68	9.00	12.25	13.50	6.00*	11.00	10.25
Orchex 796 + 0.14 kg [AI] methomyl/ha	4.68	4.25	9.25*	11.00*	6.00*	5.75	7.00*
Water-Orchex 796 (10:1) emulsion	46.75	3.25	11.50	10.75*	8.25	12.00	6.00*
CSO	4.68	4.50	17.75	17.25	7.50	12.00	8.75
CSO + 0.14 kg [AI] methomyl/ha	4.68	5.75	14.00	15.25	7.50	11.75	9.75
Water-CSO (10:1) emulsion	46.75	5.75	10.25	10.75*	4.50*	12.50	8.75
Control	-	6.50	16.00	17.25	9.50	17.25	16.50

[a] Means within columns followed by * differ significantly from the control, P=0.05.

numbers was obtained with 4.68 liter Orchex 796 plus 0.14 kg [AI] methomyl/ha on the second and third days of sampling. A similar reduction in CFH numbers was observed with the two water-oil emulsions on the third sampling date. Significantly fewer CFH nymphs were collected in the water:CSO emulsion plot on the first sampling date compared to the other treatments. On that same sampling date, significant effect was obtained with 4.68 liters Orchex 796/ha with and without the addition of 0.14 kg [AI] methomyl/ha. The addition of methomyl did not improve the control of either CFH adults or nymphs.

Effects of the treatments on numbers of a predaceous hemipteran were also measured. The mean numbers of adult big-eyed bugs (BEB), Geocoris spp., were significantly reduced by 4.68 liters Orchex 796/ha two and three days after treatment application (Table 4). The water-Orchex 796 emulsion provided significant reduction of BEB on the second sampling date but was no more effective than the Orchex 796 alone treatment. The addition of methomyl to either Orchex 796 or CSO did not significantly reduce the numbers of BEB.

Effects of treatments on numbers of a predaceous coleopteran were measured. The mean numbers of adult Scymnus spp. were reduced by 4.68 liters Orchex 796/ha two and three days following treatment application (Table 5). Addition of 0.14 kg [AI] methomyl to Orchex

Table 4. Numbers of Geocoris spp. adults collected in 50 0.09 m^2 D-Vac samples following spray on July 10, 1984. [a]

Treatment	Finished spray rate (liters/ha)	Days after application 1	2	3
Orchex 796	4.68	0.50	1.00*	0.50*
Orchex 796 + 0.14 kg [AI] methomyl/ha	4.68	0.50	2.00	0.75
Water-Orchex 796 (10:1) emulsion	46.75	1.00	1.00*	1.50
CSO	4.68	0.50	1.50	1.50
CSO + 0.14 kg [AI] methomyl/ha	4.68	0.75	2.00	1.50
Water-CSO (10:1) emulsion	46.75	0.25	2.50	1.00
Control	-	1.00	3.25	2.00

[a] Means wihtin columns followed by * differ significantly from the control, P=0.05.

Table 5. Numbers of *Scymnus* spp. adults collected in 50 0.09 m^2 D-Vac samples following spray on July 10, 1984. [a]

Treatment	Finished spray rate (liters/ha)	Days after application 1	2	3
Orchex 796	4.68	4.75	5.25*	5.00*
Orchex 796 + 0.14 kg [AI] methomyl/ha	4.68	2.50*	11.50	6.25*
Water-Orchex 796 (10:1) emulsion	46.75	6.50	11.75	9.00*
CSO	4.68	9.25	17.50	11.00
CSO + 0.14 kg [AI] methomyl/ha	4.68	5.00	13.75	7.75*
Water-CSO (10:1) emulsion	46.75	3.00	15.25	12.00
Control	-	7.75	17.25	17.50

[a] Means within columns followed by * differ significantly from the control, P=0.05.

796 significantly reduced the numbers of adults on the first and third sampling dates, but had no effect on the second sampling date. The water-Orchex 796 emulsion significantly reduced Scymnus spp. numbers on day three as did 4.68 liters CSO plus 0.14 kg [AI] methomyl/ha.

The reduction of both TPB nymphs and CFH adults and nymphs with both oils applied conventionally as emulsions suggests that this method provides better control than ULV oil application. Fewer numbers of the beneficial insects, BEB and Scymnus spp., were found in the treatments using Orchex 796 compared to those treatments using CSO. This suggests that CSO may be safer than Orchex 796 to the beneficial insect species collected.

Oil:Insecticide Efficacy Study

The purpose of this study was to determine if oils had any effect on the toxicity and performance of the pyrethroid insecticide, cypermethrin, to both pestiferous and beneficial insects during the course of the cotton growing season. To determine this effect, samples of insects were taken during the middle of the growing season and whole plant inspections of cotton plants were made.

1984 Study. All treatments significantly reduced CFH numbers one and four days after treatment application. The treatment of 4.68 liters SBO/ha had the lowest number of CFH adults at one day after application (Table 6). Four days after application 0.03 kg [AI] cypermethrin/ha in CSO and in SBO had significantly reduced the numbers of CFH adults (Table 6). There was significant reduction of numbers of CFH nymphs four days after treatment with both SBO alone and Orchex 796 alone indicating some of the control was apparently due to the oils alone. On both dates there were significant oil-carrier interactions which indicates that oil type did affect insecticidal control of CFH adults. Oils were superior to water as carriers of cypermethrin.

The number of CFH nymphs collected in the CSO plus cypermethrin treatment one day after treatment application was significantly less than the water control

Table 6. Mean numbers of cotton fleahopper adults and nymphs collected in 50 0.09 m^2 D-Vac samples following treatment application on July 19, 1984.[a]

		Adults		Nymphs	
		Days after application			
Treatment	Carrier	1	4	1	4
Cypermethrin (0.03 kg [AI]/ha)	CSO[b]	3.25*	4.50*	3.25*	4.25*
	SBO[b]	3.75*	4.50*	4.50*	2.50*
	Orchex 796[b]	9.50*	5.50*	5.25	2.00*
	Water[c]	9.75*	12.75*	5.75	7.25
No insecticide	CSO[b]	17.75*	24.75*	13.50	8.00
	SBO[b]	3.00*	6.50*	7.00	3.75*
	Orchex 796[b]	11.50*	12.50*	6.75	4.75*
	Water[c]	34.25	41.25	12.00	9.50

[a]Means within columns followed by * differ significantly from the water-no insecticide treatment (P=0.05) by LSD.

[b]Applied by CDA at 4.68 liters/ha.

[c]Applied conventionally at 46.75 liters/ha.

(Table 6). Four days after application, the cypermethrin in oil treatments significantly reduced the number of CFH nymphs compared to the water control, however cypermethrin in water was not significantly different from the control. Carrier-treatment interaction was not significant on either date. The carrier main effect was not significant one day after treatment application but was significant four days after application, thereby indicating that oils may have become more effective over time. Effect of insecticide was significant on both sampling dates.

There were no significant differences found among treatment means for TPB or 16 beneficial insect spp. statistically analyzed from the D-Vac samples collected on July 20 and 23, 1984.

This study shows quite clearly that combinations of cypermethrin with oil were more effective than cypermethrin without oil. Further, there were differences between oils. SBO alone was superior to the other oils in reducing adult CFH. This was not true with nymphs, suggesting the effect of SBO was to repel, not kill, CFH adults.

Numbers of *Heliothis* spp. larvae in the same plots are reported in Table 7. At four days after the application made on July 31, 1984, cypermethrin in SBO and in water were the only treatments which had significantly fewer larvae than the water control. Two

Table 7. Mean numbers of *Heliothis* spp. larvae on 0.0004 ha as determined by whole plant inspection on August 3 and August 10, 1984.[a]

Treatment	Carrier	Date: August 3	Date: August 10
Cypermethrin (0.03 kg [AI]/ha)	CSO[b]	0.75	0.50
	SBO[b]	0.00*	0.25*
	Orchex 796[b]	0.50	1.00
	Water[c]	0.00*	0.00*
No insecticide	CSO[b]	1.75	1.25
	SBO[b]	0.25	0.00*
	Orchex 796[b]	0.50	0.00*
	Water[c]	1.25	1.50

[a]Means within columns followed by * differ significantly from the water-no insecticide treatment (P=0.05) by LSD.

[b]Applied by CDA at 4.68 liters/ha.

[c]Applied conventionally at 46.75 liters/ha.

days after the application made on August 8, 1984, cypermethrin in SBO and in water, and the treatments of SBO and Orchex 796 alone had significantly fewer larvae than the water control. On both dates, SBO was the carrier in which cypermethrin reduced the mean number of larvae. Overall, insect numbers were too low for meaningful interpretation of the data.

The numbers of Heliothis-damaged squares and bolls indicates that SBO was the superior carrier for cypermethrin and the superior carrier in the no insecticide treatments other than water and cypermethrin (Table 8). Only cypermethrin in SBO and in water and SBO only significantly reduced the number of damaged bolls compared to the water control.

The mean numbers of cotton squares and the mean numbers of bolls for this experiment are reported in Table 9. There were no significant differences determined among either of these counts by whole plant inspection.

Means of treatment yields are reported in Table 10. All treatment means were slightly lower than the water control mean. Cypermethrin in CSO was the only treatment which significantly reduced the yield compared to the control. The poor boll set on August 3, 1984 may explain this reduction (see Table 9). The reduced yield was probably due to chance.

Based on the data, insect numbers were low during

Table 8. Mean numbers of *Heliothis*-damaged squares and bolls on 0.0004 ha as determinded by whole plant inspection on August 3 and August 10, 1984, respectively.[a]

Treatment	Carrier	Squares	Bolls
Cypermethrin (0.03 kg [AI]/ha)	CSO[b]	1.25	4.75
	SBO[b]	0.75*	1.75*
	Orchex 796[b]	1.75	5.25
	Water[c]	1.50	4.25*
No insecticide	CSO[b]	2.75	8.00
	SBO[b]	1.00	2.25*
	Orchex 796[b]	2.25	7.25
	Water[c]	3.50	7.75

[a]Means within columns followed by * differ significantly from the water-no insecticide treatment (P=0.05) by LSD.

[b]Applied by CDA at 4.68 liters/ha.

[c]Applied conventionally at 46.75 liters/ha.

Table 9. Total numbers of cotton squares and bolls on 0.0004 ha as determined by whole plant inspection on August 3, 1984.[a]

Treatment	Carrier	Squares	Bolls
Cypermethrin (0.03 kg	CSO[b]	94.75	149.50
[AI]/ha)	SBO[b]	85.25	173.00
	Orchex 796[b]	100.25	173.50
	Water[c]	87.00	173.50
No insecticide	CSO[b]	82.75	164.25
	SBO[b]	103.75	187.00
	Orchex 796[b]	73.75	168.75
	Water[c]	86.25	168.25

[a]There were no significant differences in numbers of squares or bolls among the treatments.

[b]Applied by CDA at 4.68 liters/ha.

[c]Applied conventionally at 46.75 liters/ha.

Table 10. Yield as kg lint cotton /ha on September 25, 1984.[a]

Treatment	Carrier	Yield
Cypermethrin (0.03 kg [AI]/ha)	CSO[b]	1842.9*
	SBO[b]	2038.4
	Orchex 796[b]	1991.1
	Water[c]	2100.6
No insecticide	CSO[b]	1976.1
	SBO[b]	1983.6
	Orchex 796[b]	1983.6
	Water[c]	2123.0

[a] Means within columns followed by * differ significantly from the water-no insecticide treatment (P=0.05) by LSD.

[b]Applied by CDA at 4.68 liters/ha.

[c]Applied conventionally at 46.75 liters/ha.

the 1984 growing season and their control did not effect yield. However, it was obvious that oil:cypermethrin combinations were more effective than cypermethrin and water. SBO, either alone or in combination with cypermethrin, was more effective than the other oils.

1985 Study. The purpose of this study was the same as that for the 1984 study: to determine if oils had any effect on the toxicity and performance of cypermethrin. The only difference between the 1984 study and this study was the deletion of CSO as an oil carrier.

The number of CFH adults collected three and five days after treatment application on July 1, 1985 are reported in Table 11. On both dates all cypermethrin treatments had significantly fewer adults than the water control. SBO gave a significant reduction in number of CFH adults three days after application but not at five days after application. There were significant effects due to treatment on both sampling dates. There was a significant oil-treatment interaction three days after application indicating that oils were affecting insecticide performance.

Cypermethrin (0.03 kg [AI]/ha) in 4.68 liters Orchex 796/ha was the only treatment which significantly reduced the number of CFH nymphs compared to the water control three days after treatment application (Table 11). Five days after application, the treatments

Table 11. Mean numbers of cotton fleahopper adults and nymphs collected in 50 0.09 m2 D-Vac samples following treatment application on July 1, 1985.[a]

		Adults		Nymphs	
		Days after application			
Treatment	Carrier	3	5	3	5
Cypermethrin (0.03 kg [AI]/ha)	SBO[b]	2.00*	2.75*	1.00	0.25*
	Orchex 796[b]	0.00*	0.75*	0.00*	0.00*
	Water[c]	1.00*	3.75*	1.00	2.50
No insecticide	SBO[b]	2.75*	7.00	1.25	1.25
	Orchex 796[b]	5.00	9.25	1.25	2.25
	Water[c]	6.68	9.43	2.33	2.83

[a]Means within columns followed by * differ significantly from the water-no insecticide treatment (P=0.05) by LSD.

[b]Applied by CDA at 4.68 liters/ha.

[c]Applied conventionally at 46.75 liters/ha.

cypermethrin in Orchex 796 and in SBO had significantly fewer nymphs compared to the water control (Table 11). On both sampling dates, the insecticide effect was significant. Oils, in the case of CFH nymphs, were more effective than water as a carrier.

SBO reduced the numbers of CFH adults but not the numbers of nymphs. This suggests that SBO may be repelling the CFH adults rather than killing them.

Mean numbers of TPB adults collected three and five days after application in the same test plots are reported in Table 12. On both dates all cypermethrin treatments and the treatment of 4.68 liters SBO/ha significantly reduced the number of adults compared to the control. The insecticide effect was significant on both sampling dates, however the carrier-treatment interaction was sig nificant five days after application. This indicated that carriers were affecting insecticide performance. This may be because on both sampling dates SBO was significantly different from the control while Orchex 796 and CSO were not significantly different. Again, the data suggest repellency of TPB adults due to SBO.

Numbers of minute pirate bugs (MPB), Orius spp., a beneficial predaceous hemipteran insect, collected by D-Vac five days after treatment application are reported in Table 13. Cypermethrin (0.03 kg [AI]/ha) significantly reduced MPB numbers in all carriers compared to the

Table 12. Mean numbers of tarnished plant bug adults collected in 50 0.09 m^2 D-Vac samples following treatment application on July 1, 1985.[a]

		Days after application	
Treatment	Carrier	3	5
Cypermethrin (0.03 kg [AI]/ha)	SBO[b]	0.50*	0.50*
	Orchex 796[b]	0.00*	0.50*
	Water[c]	0.00*	1.00*
No insecticide	SBO[b]	0.75*	0.50*
	Orchex 796[b]	4.25	4.50
	Water[c]	3.68	5.00

[a]Means within columns followed by * differ significantly from the water-no insecticide treatment (P=0.05) by LSD.
[b]Applied by CDA at 4.68 liters/ha.
[c]Applied conventionally at 46.75 liters/ha.

Table 13. Mean numbers of minute pirate bug adults collected in 50 0.09 m^2 D-Vac samples five days after treatment application on July 1, 1985.[a]

Treatment	Carrier	Number of minute pirate bug adults
Cypermethrin (0.03 kg [AI]/ha)	SBO[b]	1.00*[a]
	Orchex 796[b]	0.25*
	Water[c]	1.00*
No insecticide	SBO[b]	3.25
	Orchex 796[b]	2.25*
	Water[c]	5.93

[a]Means followed by * differ significantly from the water-no insecticide treatment (P=0.05) by LSD.

[b]Applied by CDA at 4.68 liters/ha.

[c]Applied conventionally at 46.75 liters/ha.

water control. SBO at 4.69 liters/ha was the only carrier without insecticide which significantly reduced the number of MPB.

All other insect species collected by D-Vac sampling were either too low in number for statistical analysis or upon analysis showed no statistical differences among treatments.

The only significant differences determined by whole plant inspection on July 19, 1985 were among the number of *Heliothis* spp. eggs (Table 14). Cypermethrin in SBO and in water reduced the number of eggs compared to the control. Orchex 796 alone was the only oil treatment which significantly reduced *Heliothis* egg numbers. SBO also reduced egg numbers, but the effect was not statistically significant. The addition of cypermethrin to Orchex 796 or to SBO did not result in reduction of *Heliothis* egg numbers.

Hot temperatures (38 ^{o}C) during the following week reduced the survival of larvae and a damaging population did not develop. Only one whole plant inspection was made due to the dry conditions in the later part of July which resulted in rapid maturity of the cotton. No insect of economic importance was found.

None of the treatments significantly reduced the yield of cotton in 1985 (Table 15). Lint micronaire, length, and strength were all determined to be statistically equal among treatments. The means of these

Table 14. Mean numbers of *Heliothis* spp. eggs on 0.0004 ha as determined by whole plant inspection on July 19, 1985.[a]

Treatment	Carrier	Number of *Heliothis* spp. eggs
Cypermethrin (0.03 kg	SBO[b]	9.50*
[AI]/ha)	Orchex 796[b]	15.00
	Water[c]	1.00*
No insecticide	SBO[b]	8.50
	Orchex 796[b]	5.50*
	Water[c]	23.50

[a]Means followed by * differ significantly from the water-no insecticide treatment (P=0.05) by LSD.

[b]Applied by CDA at 4.68 liters/ha.

[c]Applied conventionally at 46.75 liters/ha.

Table 15. Yield as kg cotton/treatment plot and cotton fiber qualities.[a,b]

Treatment	Carrier	kg cotton/ plot	Micro- naire	Length[c]	Strength[d]
Cypermethrin (0.03 kg [AI]/ha)	SBO[e]	13.3	4.588	23.59	22.75
	Orchex 796[e]	12.4	4.650	23.86	21.50
	Water[f]	13.6	4.463	23.57	21.25
No insecticide	SBO[e]	13.4	4.763	23.69	22.56
	Orchex 796[e]	14.0	4.938	23.61	21.06
	Water[f]	13.6	5.263	23.80	20.69

[a]There were no significant differences in cotton yield or lint quality among the treatments (P=0.05) by LSD.

[b]Cotton fiber samples sent to the Textile Research Center at Texas Tech Univeristy, Lubbock, Tex.

[c]Length measured in mm.

[d]Strength measured in grams Tex.

[e]Applied by CDA at 4.68 liters/ha.

[f]Applied conventionally at 46.75 liters/ha.

lint quality measurements are reported in Table 15. All oil treatments produced lint which was equal in quality to cotton produced using conventional insecticide application in water.

Boll Weevil Cage Study

Cage Experiment One. The purpose of this experiment was to determine the effect of oils on the toxicity of cypermethrin to adult boll weevils. Boll weevils were placed in whole plant cages and exposed to treatment residues at three different times following initial treatment application.

CSO and Orchex 796 alone at 4.68 liters/ha produced the greatest boll weevil mortality of the 4 h residues applied August 14 (Table 16). Mortality was similar with Orchex 796. The addition of 0.03 kg [AI]

Table 16. Percent mortality of adult boll weevils exposed for 48 h on individual treated cotton plants at 4, 24 and 48 h after treatment application on August 14, 1984. Cage Exp. 1.

Carrier	Volume (liters/ha)	kg insecticide [AI]/ha	Mean % 48 h mortality from insecticide residues (h post application)		
			4	24	48
Orchex 796	4.68	None	69.17[ab]	53.33[abc]	23.33[a]
CSO	4.68	None	85.00[a]	40.00[abc]	23.33[a]
Orchex 796	4.68	0.045 cypermethrin	25.00[c]	71.67[a]	20.00[a]
CSO	4.68	0.045 cypermethrin	45.00[bc]	13.33[c]	15.00[a]
Water	46.75	0.045 cypermethrin	35.00[bc]	66.67[ab]	34.81[a]
Control	-	None	15.00[c]	15.00[bc]	10.74[a]

Means followed by the same letter within columns are not significantly different at the P=0.05 level, by the Bonferroni comparison.

cypermethrin/ha reduced control oil carrier only at 4 h and was not different from water as the carrier. At 24 h, cypermethrin in Orchex 796 produced the greatest mortality at 24 h and was significantly different from the control. Oils alone and combined cypermethrin improved control of boll weevil adults. At 48 h, there were no differences between treatments.

Cage Experiment Two. This experiment was performed to determine the effect oils have on the toxicity of azinphosmethyl to adult boll weevils. Boll weevils were exposed to residues as in the first cage experiment.

Mortality of insects placed on plants 4 h after treatment was significantly different for the 0.28 kg [AI] azinphosmethyl/ha treatments in Orchex 796 and in water, and also for the Orchex 796 oil treatment compared to the control treatment (Table 17). CSO plus cypermethrin and CSO alone did not differ from the control treatment. There was no significant difference between azinphosmethyl in water or in Orchex 796 and both treatments produced significant control at all three times. CSO treatments with and without the addition of azinphosmethyl did not produce significant boll weevil mortality during the three day study. This suggests an interaction between the CSO and azinphosmethyl which inhibited the effectiveness of the insecticide in controlling boll weevils. The additive effect of Orchex 796 with insecticide suggests that Orchex 796 was toxic to the boll weevil.

Cage Experiment Three. This experiment was performed to determine the effect of oils on the toxicity of azinphosmethyl to adult boll weevils. No treatments of oils alone were included in the cage study applied July 9, 1985. Boll weevils were exposed to treatment residues as previously described in preceding cage experiments. All azinphosmethyl treatments produced mortality which was significantly greater than the control mortality throughout the study (Table 18). There was no statistical difference among the azinphosmethyl treatments.

Cage Experiment Four. This study was made to measure the effect of oils on the toxicity of cypermethrin to adult boll weevils. Boll weevils were exposed to

Table 17. Percent mortality of adult boll weevils exposed for 48 h on individual treated cotton plants at 4, 24 and 48 h after treatment application on August 22, 1984. Cage Exp. 2.

Carrier	Volume (liters/ha)	kg insecticide [AI]/ha	Mean % 48 h mortality from insecticide residues (h post application)		
			4	24	48
Orchex 796	4.68	None	96.67^{a}	60.00^{ab}	53.33^{ab}
CSO	4.68	None	44.44^{b}	26.67^{b}	16.67^{b}
Orchex 796	4.68	0.28 azinphosmethyl	100.00^{a}	96.67^{a}	87.50^{a}
CSO	4.68	0.28 azinphosmethyl	45.18^{b}	27.41^{b}	12.00^{b}
Water	46.75	0.28 azinphosmethyl	100.00^{a}	96.67^{a}	93.33^{a}
Control	-	None	27.41^{b}	20.00^{b}	16.67^{b}

Means followed by the same letter within columns are not significantly different at the P=0.05 level, by the Bonferroni comparison.

Table 18. Percent mortality of adult boll weevils exposed for 48 h on individual treated cotton plants at 4, 24 and 48 h after treatment application on July 9, 1985. Cage Exp. 3.

Carrier	Volume (liters/ha)	kg insecticide [AI]/ha	Mean % 48 h mortality from insecticide residues (h post application)		
			4	24	48
Orchex 796	4.68	0.28 azinphosmethyl	98.00[a]	84.00[a]	72.00[a]
CSO	4.68	0.28 azinphosmethyl	98.00[a]	73.78[a]	92.00[a]
Water	46.75	0.28 azinphosmethyl	96.00[a]	100.00[a]	98.00[a]
Control	-	None	20.22[b]	10.67[b]	0.00[b]

Means followed by the same letter within columns are not significantly different at the P=0.05 level, by the Bonferroni comparison.

treatment residues as in the other cage experiments.

Addition of 0.034 kg [AI] cypermethrin/ha to either CSO or Orchex 796 did not enhance control of boll weevils exposed to the 4 h residues (Table 19). Both CSO and Orchex 796 increased boll weevil mortality compared to the control at 4 h but did not do so at 24 h or at 48 h. There were no significant differences demonstrated among the treatments at 24 and 48 h. Cypermethrin was used at less than optimal rates for boll weevil control in this experiment and thus poor control was obtained. The reduced rates were used to aid in separation of additive effects.

Cage Experiment Five. This experiment was performed to determine the effect oils have on the toxicity of oxamyl to adult boll weevils. Oil-water emulsions were used in this experiment because oxamyl is not soluble in oil. Boll weevils were exposed to treatment residues as in the other cage experiments.

There were no significant differences among the boll weevil mortalities with four h residues of oxamyl applied July 30, 1985 (Table 20). Orchex 796 gave slightly better control than CSO and both oils were better than the control at four h. The oxamyl treatments were significantly better than CSO while Orchex 796 was statistically equal in controlling boll weevils. There were no significant differences at 24 h among the oxamyl treatments, however these treatments were significantly

Table 19. Percent mortality of adult boll weevils exposed for 48 h on individual treated cotton plants at 4, 24 and 48 h after treatment application on July 25, 1985. Cage Exp. 4.

Carrier	Volume (liters/ha)	kg insecticide [AI]/ha	Mean % 48 h mortality from insecticide residues (h post application)		
			4	24	48
Orchex 796	4.68	None	100.00^{a}	4.00^{a}	8.00^{a}
CSO	4.68	None	33.78^{a}	8.44^{a}	16.89^{a}
Orchex 796	4.68	0.034 cypermethrin	14.22^{bc}	14.00^{a}	32.67^{a}
CSO	4.68	0.034 cypermethrin	32.44^{b}	23.56^{a}	40.00^{a}
Water	46.75	0.034 cypermethrin	16.44^{bc}	16.67^{ab}	46.00^{a}
Control	-	None	0.00^{c}	0.00^{a}	18.00^{a}

Means followed by the same letter within columns are not significantly different at the P=0.05 level, by the Bonferroni comparison.

Table 20. Percent mortality of adult boll weevils exposed for 48 h on individual treated cotton plants at 4, 24 and 48 h after treatment application on July 30, 1985. Cage Exp. 5.

Carrier	Volume (liters/ha)	kg insecticide [AI]/ha	Mean % 48 h mortality from insecticide residues (h post application)		
			4	24	48
Orchex 796	4.68	None	56.89^{a}	12.00^{b}	22.00^{ab}
CSO	4.68	None	50.89^{b}	22.22^{b}	4.22^{b}
Orchex 796	4.68	0.14 oxamyl[x]	93.56^{a}	90.00^{a}	58.22^{a}
CSO	4.68	0.14 oxamyl[y]	98.00^{a}	94.00^{a}	58.00^{a}
Water	46.75	0.14 oxamyl	82.48^{a}	78.00^{a}	38.00^{ab}
Control	-	None	18.00^{c}	10.00^{b}	8.00^{b}

Means followed by the same letter within columns are not significantly different at the P=0.05 level, by the Bonferroni comparison.

[x]Applied as oil:water (1:1) emulsion using 5% Sponto AK31-53 emulsifier by oil volume.

[y]Applied as oil:water (1:1) emulsion using 10% Sponto AK31-53 emulsifier by oil volume.

better than the oils alone which were no better than the controls at this time. The 48 h residues of oxamyl in Orchex 796 and in CSO were not significantly better than the oxamyl in water treatment but both of these oxamyl-oil emulsion combinations gave control while the oxamyl in water treatment did not. Thus, oil emulsions enhanced the residual activity of oxamyl.

Cage Experiment Six. This study was made to measure the effect of oils on the toxicity of methyl parathion to adult boll weevils. Boll weevils were exposed to treatment residues as previously described in the preceding cage experiments.

Methyl parathion (0.56 kg [AI]/ha) in 4.68 liters CSO/ha was the most toxic treatment applied July 30, 1985 (Table 21). There were, however, no significant differences between methyl parathion applied in water or CSO. Orchex 796 alone and CSO alone gave equal boll weevil mortality (Table 21). There were no significant differences among the treatments at 24 and 48 h. Methyl parathion in CSO was the most toxic treatment at 24 h, but methyl parathion in water was the most toxic treatment at 48 h.

The data from the boll weevil cage studies concur with that of Ochou (1985), where the more oil-soluble pyrethroid insecticides have enhanced toxicity when combined with oils while the less oil-soluble organophosphate and carbamate insecticides were not enhanced

Table 21. Percent mortality of adult boll weevils exposed for 48 h on individual treated cotton plants at 4, 24 and 48 h after treatment application on July 30, 1985. Cage Exp. 6.

Carrier	Volume (liters/ha)	kg insecticide [AI]/ha	Mean % 48 h mortality from insecticide residues (h post application) 4	24	48
Orchex 796	4.68	None	56.89^{b}	12.00^{a}	22.00^{a}
CSO	4.68	None	50.89^{bc}	22.22^{a}	4.22^{a}
Orchex 796	4.68	0.56 methyl parathion	54.89^{b}	14.00^{a}	12.22^{a}
CSO	4.68	0.56 methyl parathion	94.00^{a}	48.89^{a}	12.00^{a}
Water	46.75	0.56 methyl parathion	72.06^{ab}	40.00^{a}	24.44^{a}
Control	-	None	18.00^{c}	10.00^{a}	8.00^{a}

Means followed by the same letter within columns are not significantly different at the P=0.05 level, by the Bonferroni comparison.

when combined with oils.

SUMMARY AND CONCLUSIONS

Cotton yield and lint quality were not affected by the application of oils regardless of the volume applied, up to 18.70 liters oil/ha.

Numbers of nymphal TPB and both adult and nymphal CFH were reduced more effectively with conventionally applied oil:water emulsions compared to ULV application of oils alone. CSO was apparently safer to two beneficial insects than was Orchex 796.

The toxicity of oils was additive to that of cypermethrin to both hemipterous pest insects and to the boll weevil. The toxicity of organophosphate and carbamate insecticides was not enhanced by the addition of oils. SBO was the most effective oil tested for reducing the number of adult and nymphal hemipterous pest insects in cotton. This finding suggests that SBO was apparently repelling the adult insects; and thus, there were fewer numbers of nymphs found.

The equal performance of conventionally applied oil:water emulsions compared to the ULV application of oils through a CDA system indicates that the expensive changeover to a CDA spraying system was not justified.

From this study, mineral and vegetable oils were found to possess qualities which make them suitable for addition to certain insecticide applications for the control or repellency of insect pests. Further research should be performed to more clearly define the apparent repellent nature of vegetable oils when used on plants which are different from the oil's source.

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APPENDIX

Table 22. Physical characteristics of oils and an emulsifier. [a]

Physical characteristics	Carrier: Orchex 796	CSO[b]	SBO[c]	Sponto AK31-53 [d]
Aniline point (°C)	98.4	2.2	0.6	93.4
Surface tension (dynes/cm)	33.4	53.4	53.6	-
Specific gravity (g/ml)	0.85	0.92	0.92	1.00
Viscosity, cst.				
37.8 °C	14.1	37.0	32.8	-
25.0 °C	24.2	62.5	32.8	-
20.0 °C	30.0	74.3[e]	62.7	-

[a]Data from Exxon Corporation, Houston, Tex.

[b]Cottonseed oil (once-refined, Valco Chemicals, Harlingen, Tex.).

[c]Soybean oil (once-refined and bleached, Anderson Clayton and Company, Richardson, Tex.).

[d]Data from Witco Chemical Corporation, Houston, Tex.

[e]Viscosity determined at 21°C.

Table 23. Mean droplet diameter of oils and water-oil emulsions at 30°C.

Carrier	No. of cards measured	Diameter (um)
Orchex 796	12	137.88
CSO	8	138.83
SBO	10	120.77
Water + Orchex 796 emulsion	6	104.54
Water + CSO emulsion	6	101.53

VITA

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