PLANT AND MINERAL OILS: EFFECTS AS INSECTICIDE ADDITIVES AND DIRECT TOXICITY TO TOBACCO BUDWORM[1/] LARVAE AND HOUSE FLY[2/] ADULTS

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ABSTRACT

Both plant and mineral oils synergized synthetic pyrethroid insecticides against the tobacco budworm, *Heliothis virescens* (F.), and the house fly, *Musca domestica* L. The same oils were less synergistic or even antagonistic with the more water-soluble organophosphate and carbamate insecticides. The effects of oils on insecticide toxicity were demonstrated in both dose-mortality and time-mortality tests, indicating that either method can be used to analyze the influence of oils on insecticide activity. When oils alone were used against eggs and larvae of the tobacco budworm, mineral oils produced higher mortalities than plant oils.

INTRODUCTION

Most of the insecticide used to control insects is wasted. This occurs because much of the initial dose applied to plants is dissipated into the air, broken down by sunlight, or taken into the leaves of plants instead of remaining on plant surfaces (Metcalf 1982, Southwick et al. 1983). If ways to increase the life of insecticide residues on plant surfaces can be found, better insect control may be obtained or, at least, the same level of control may be obtained more inexpensively.

For years most insecticides applied to cotton in the United States, particularly methyl parathion, were used in combination with toxaphene. Toxaphene has been shown to decrease the loss of methyl parathion residues on cotton (Ware et al. 1975, 1978, 1980, Bigley et al. 1981). However, toxaphene was banned on the basis of mutagenicity, and research is now being conducted to find substitutes for it. This had led to interest in the use of plant and mineral oils as adjuvants for insecticides. In fact, with the development of ultra low volume application of insecticides, non-volatile oils are used as insecticide carriers in many agricultural production systems.

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The present experiments measured the effects of plant and mineral oils as insecticide adjuvants and determined their effects when combined with different types of insecticides. We also measured the direct toxicity of oils to eggs and larvae of a major cotton insect pest.

MATERIALS AND METHODS

Test insects were eggs and first instar larvae of the tobacco budworm, Heliothis virescens (F.) and adult male house flies, Musca domestica L. The tobacco budworms were reared on artificial diet (Vanderzant et al. 1962) and originated from eggs collected on the Texas A&M University Experimental Farm, College Station. House flies were of the Rutgers Diazinon-R strain which is resistant to organophosphate insecticides. The colony was fed a sugar:milk mixture (1:1 volume ratio). Three- to six-day-old male flies were used because of their availability and for homogeneity of data as compared to using mixtures of male and female flies.

Two pyrethroid insecticides, fenvalerate and permethrin, two organophosphates, methyl and ethyl parathion, and a carbamate, methomyl, were tested alone and in combination with oils. All are commonly used at the present time. They were all obtained as technical grade, i.e. at least 90% pure, samples from the manufacturers. Solutions of the insecticides were prepared in acetone on a weight-per-volume basis and were stored in the dark in a freezer until use.

Several plant and mineral oils were tested alone or in combination with the insecticides. Plant oils included a crude cottonseed oil (100%), a once-refined cottonseed oil, and the soybean oil, Numade®. Mineral oils included Orchex® 796, Isopar® V and ER-7110. All oils were prepared as weight-per-volume acetone solutions and were stored in the laboratory at room temperature.

The effect of oils on insecticide activity was tested by exposing insects to residues of known amounts of insecticides alone or in combination with oils at a 1:10 insecticide:oil ratio on the inner surface of 20 ml glass vials of the type used for liquid scintillation counting (Plapp and Vinson 1977). Required amounts of all chemicals were pipetted into vials from their respective stock solutions or dilutions; the total volume of solvent was adjusted to 0.5 ml, and the vials were rolled on their sides until the solvent evaporated. Diet and test insects were added to each vial which was then plugged with cotton. First instar tobacco budworm larvae were tested in groups of 5-10 insects per vial and male house flies were tested in groups of six per vial. Mortality was determined 24 hours after exposure was initiated.

Effectiveness of oil additives was measured by determining effects on the dose of insecticide required to produce 50% mortality. Synergism or antagonism of insecticide by oils was calculated by the following ratio: LC_{50} insecticide alone/LC_{50} oil-insecticide mixture. Ratios >1 indicate synergism while ratios <1 indicate antagonism.

The influence of oils on the speed of knockdown by insecticides was tested on male adult house flies using the same 1:10 insecticide: oil ratio as in toxicity tests. For this test a given dose of insecticide that produced knockdown in 30-60 min was used. Flies were observed continually, and the time required to produce 50% knockdown (KD_{50}) was recorded for each treatment. Each test was conducted in duplicate and replicated at least four times. These tests were performed with 1:10 ratios of insecticide to oil.

Several oils were tested alone for toxicity to tobacco budworm eggs and neonate larvae. Groups of ten newly laid eggs were exposed to residues of known amounts of oils in 20 ml glass vials. Each test was conducted in duplicate and replicated at least six times. Nontreated vials were used as controls to determine natural mortality of eggs under the experimental conditions. Number of larvae hatched was recorded on the fourth day after exposure to oil residues was initiated. Mortality was corrected using Abbott's (1925) formula. Mortality among neonate larvae that emerged from treated eggs was also recorded to determine if oils were toxic to newly emerged larvae.

Toxicity tests were analyzed by an SAS analysis system. LC_{50}, LC_{90} and slope values were determined from computer output. Data on the knockdown time tests were analyzed using the PROC GLM statistical procedure (Helwig and Council 1979). Statistical differences between KD_{50} means were determined using Duncan's New Multiple Range Test (Duncan 1955).

RESULTS

Data on toxicity of 1:10 insecticide:oil combinations to tobacco budworm larvae are summarized in Table 1. LC_{50} values and synergism ratios are listed. Generally the oils were synergistic with the pyrethroids, but synergism levels were low, 2-fold or less. Crude cottonseed oil appeared to be most active, but there were no significant differences in effectiveness between any of the oils. Oils were usually antagonistic with methyl parathion and methomyl. The antagonism was greater with methyl parathion. Again, no particular oil appeared to be different from the others in producing antagonism.

Table 1. Toxicity of Insecticides and Insecticide:Oil (1:10) Combinations to First Instar Larvae of the Tobacco Budworm.

Combination	Fenvalerate		Permethrin		Methyl parathion		Methomyl	
tested	LC50 [a]	S.R. [b]	LC50	S.R.	LC50	S.R.	LC50	S.R.
Insecticide (I) only	1.62	-	1.77	-	0.08	-	0.13	-
I + Orchex 796	1.18	1.37	1.72	1.03	0.29	0.28	0.18	0.72
I + Crude Cottonseed Oil	0.87	1.86	0.88	2.01	0.18	0.47	0.14	0.92
I + Refined Cottonseed Oil	1.18	1.37	1.75	1.03	0.11	0.73	0.15	0.87
I + Soybean Oil	1.40	1.15	1.00	1.77	0.26	0.31	0.09	1.44

a/ LC50 values are in micrograms per 20 ml glass vial after 24 h exposure.
b/ Synergist Ratio (S.R.) = LC50 insecticide only divided by LC50 for insecticide plus oil.

Data on toxicity to house flies of 1:10 insecticide:oil mixtures are summarized in Table 2. The results were generally similar to those with the tobacco budworm. All oils tested synergized both pyrethroid insecticides, but no oil was particularly outstanding. Fenvalerate, which was less toxic than permethrin, was synergized to a greater extent. Ethyl parathion toxicity was antagonized by vegetable oil. Methomyl was synergized against flies by all oils tested, but the extent of synergism was low, 1.4-fold or less.

Table 2. Toxicity of Insecticides and Insecticide:Oil (1:10) Combinations to Adult Male House Flies.

Combination tested	Fenvalerate LC50[a]	Fenvalerate S.R.[b]	Permethrin LC50	Permethrin S.R.	Ethyl parathion LC50	Ethyl parathion S.R.	Methomyl LC50	Methomyl S.R.
Insecticide only	1.74	-	0.33	-	2.73	-	0.64	-
I + Orchex 796	1.04	1.67	0.22	1.50	-	-	0.53	1.21
I + Crude Cottonseed Oil	1.11	1.57	0.23	1.43	-	-	0.46	1.37
I + Refined Cottonseed Oil	0.85	2.05	0.27	1.22	-	-	0.57	1.12
I + Soybean Oil	1.37	1.27	-	-	5.10	.54	0.46	1.39

a/ LC50 values are in micrograms per 20 ml glass vial after 24 h exposure.
b/ Synergist Ratio (S.R.) = LC50 insecticide only divided by LC50 for insecticide plus oil.

A fast way to test for insecticide:oil interactions involves exposing insects to a lethal dose of insecticide only or to a combination of insecticide plus oil. Synergism is evidenced as a decrease in knockdown time. Data on responses of male house flies to such mixtures are summarized in Table 3. The results show all pyrethroid:oil mixtures were synergistic. Orchex 796 appeared to be the most effective oil tested. No effect was observed when ethyl parathion was mixed with soybean oil. With methomyl, there was a slight antagonism with soybean oil, a result similar to those seen in the 24 h toxicity tests.

Table 3. Effects of Oils on Speed of Insecticide Action for Male House Flies Exposed to a Toxic Dose of Insecticide Only or Insecticide Plus Oil at 1:10 Ratios.

Combination tested	Minutes until 50% knockdown for: Fenvalerate[a]	Permethrin[a]	Ethyl Parathion[a]	Methomyl[a]
Insecticide only	35.63 ± 2.18	33.13 ± 1.87	41.5 ± 2.8	15.0 ± 1.0
I + Orchex 796	17.06 ± 2.68	13.5 ± 6.2		
I + Crude Cottonseed Oil	21.90 ± 2.14	21.8 ± 3.29		
I + Refined Cottonseed Oil	24.27 ± 1.84	24.7 ± 2.08		
I + Soybean Oil	24.96 ± 1.97	24.0 ± 2.56	39.3 ± 1.2	19.25 ± 4.0

a/ Insecticide doses = 5, 6, 30 and 10 micrograms per vial for fenvalerate, permethrin, ethyl parathion and methomyl, respectively.

The toxicity of oils to tobacco budworm eggs and larvae hatching from treated eggs are shown in Table 4. The mineral oils, Orchex 796, Isopar V and ER-7110, were all more toxic to eggs and neonate larvae than any of the plant oils. All oils were much less toxic to eggs than any of the insecticides tested against larvae. These results indicate that oils are useful additives to insecticides and that oils are not direct toxicants.

Table 4. Toxicity of Mineral and Plant Oils to Eggs and Neonate Larvae of the Tobacco Budworm.

	Eggs		Neonate Larvae	
Oil tested	24 h LC50 in μg/vial	Fiducial limits	96 h LC50 in μg/vial	Fiducial limits
Orchex 796	340	157-427	176	87-259
Isopar V	108	76-139	213	-
ER-7110	449	267-619	325	164-464
Soybean Oil	978	712-1359	1278	1091-1522
Cottonseed Oil	> 5,000	-	-	
Refined Cottonseed Oil	> 6,000	-	-	

DISCUSSION

The data presented here clearly demonstrated that oils synergized pyrethroid insecticides against both the tobacco budworm larvae and adult house flies. In contrast, oils were less synergistic, or even antagonistic, with the organophosphate and carbamate insecticides tested.

In the 24 h toxicity tests mineral oils and plant oils were similarly effective as pyrethroid synergists. In the knockdown time tests, Orchex 796, a mineral oil, was more effective than the plant oils. Similarly, mineral oils were more active as ovicides than the plant oils. Reasons for the differences are not known.

The mechanism of insecticide synergism by oils is unclear, but probably relates to polarity of the test insecticides. The more polar (more water soluble) organophosphate and carbamate insecticides were less synergized than the less polar pyrethroids. This suggests that oils, themselves very non-polar chemicals, are more likely to be effective as synergists with insecticides of similar solubility properties. These results are very similar to those reported earlier by Nettles and Betz (1975) for DDT:toxaphene synergism with the boll weevil, *Anthonomus grandis* Boheman.

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