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Minimizing Environmental Hazards During Dormant Spraying of Almond Orchards and Other Crops

Progress Report

December 18, 1992

To: Almond Board of California

From: Barry W. Wilson, Principle Investigator

Introduction

Organophosphates (OPs) and a light oil are used as a winter dormant spray to control insects such as Peach Twig Borer and San Jose Scale in the more than a half a million acres of almond, peach, prune and other stone fruit orchards in the Central Valley of California. Drift of pesticides onto non-target crops and exposure of Red-tail Hawks to the (OPs) during dormant spray season are addressed by two projects from our laboratories. One is a two year study that is drawing to a close on the impact of three OPs (parathion, diazinon and methidathion) to hawks in the orchards. The research was initiated to answer specific questions raised by California Department of Food and Agriculture (CDFA) and is funded by a consortium of chemical companies working with the Almond Board of California. The second project - reported here - focuses on the development of spray applicators and application regimes to reduce both drift and exposure of birds during dormant spraying. It is funded by smaller grants from PIAP, the Almond, Prune and Cling Peach Boards of California.

Red-tail Hawk Study Update

The study site of the Red-tail Hawk project is a 50 square mile region south east of Modesto, California. The field studies are over and the laboratory work is nearing completion. Live-trapped and radiotagged Red-tail Hawks and American Kestrels were sampled for blood cholinesterases (ChE) and excretory metabolites of OPs and then tracked to determine their home ranges. Land use, pesticides sprayed and air levels of pesticides were ascertained and entered into a GIS computer program (CAMRIS) for analysis. The field work established that hawks have small (often less than 1-2 square miles) home ranges in the winter, and they exhibit exposures to and blood enzyme levels consistent with pesticide use in their home ranges. Examination of the pesticide residues on ground squirrels captured during the second season is in progress to help us understand the routes of exposure of the birds to the OPs. Laboratory studies of the behavior of kestrels (a small captive-bred raptor) after exposure to low levels of OPs, and studies of the toxicity of the OPs and oils to pigeons and kestrels are underway. In general, we found that parathion was the most toxic, diazinon second and methidathion the least toxic chemical when delivered via oral or dermal routes. There was a large difference in the ability of the OPS to reduce blood ChEs after dermal dosing; ChE depressions due to parathion took more than a week to recover; ChE activity recovered more rapidly after diazinon treatment and was hardly depressed after application of methidathion.

Sprayer Application Research

In their letter requesting study of dormant sprays, CDFA did not request research on spray applications or of OPs other than parathion, diazinon and methidathion, limiting the support from the consortium to studies directly concerning the hawks. Our finding that chlorpyrifos, a widely used OP, was also involved led to a letter asking that it be studied too. During the studies, parathion use was banned as of January 1, 1992 by order of the EPA, and carbaryl, a carbamate pesticide, recently has been approved for use in dormant sprays.

The project supported by the commodity groups and PIAP is a vital component of our research to reduce hazards of people and wildlife to dormant sprays by examining both toxicity to birds and efficacy of insect control of different spray applications. Ground and air application of dormant sprays are tested in small orchard sites, pigeons are placed in cages in the orchards as surrogates for the birds that live there. Acute toxicology studies are carried out in the laboratory, and air, ground and target exposure studies of the pesticides are undertaken in the orchards. The sprayer research focuses on a comparison of an air curtain sprayer (Curtec), a conventional fan sprayer (Oma) and helicopter application, using diazinon and Volck oil as the test chemicals.

A multiyear update is presented here. Several studies were in almond orchards near Modesto; last year's study was in a site west of Fresno. The data suggest that spraying with the air curtain sprayer reduce both volume (cutting down drift) and in active ingredient (AI), (cutting down exposure to the hawks) without loss of efficacy.

Specific Objectives of Sprayer Studies

1. Measure drift of the chemicals during operation of conventional and mast sprayers in dormant almond orchards.
2. Determine deposition of the chemicals on twigs and branches in a dormant almond orchard.
3. Assess the efficiency of pest control of the treatments.
4. Examine the exposure of caged pigeons when appropriate during the treatments.

Methods

Pesticide: The model OP chosen was diazinon (O,O-diethyl O-(2-isopropyl-6-methyl -4-pyrimidinyl) phosphorothioate). It is widely used, less toxic than parathion, and less sensitive to weather conditions than chlorpyrifos. This year we will include carbaryl, recently being marketed as a dormant spray, in the studies.

Birds: The "sentinel bird" we study is the domestic pigeon, in reality a domestic Rock Dove (Columba livia), raised in the Central Valley of California for the restaurant trade. It is closely related to the wild species, and relatively inexpensive to obtain and keep. Using it as a surrogate to wild birds avoids many of the difficulties inherent in treating wild birds with pesticides in the field and in the laboratory.

Parameters: The parameters determined include: spray residues in soil, plants and air, and on the feet and feathers of caged sentinel birds; blood and brain levels of cholinesterases; and insect numbers. Currently, different rates and volumes/acre of the dormant sprays are under study.

During each test, fallout is collected on mylar sheets placed on the orchard floor at distances from the center of the plot. Typical placement was 37.5, 75, and 150 meters from the center; actual placement depends upon the size and shape of the orchard. Drift samples are collected by high volume air samplers at the same locations. Twig samples are collected from within the plot and analyzed for diazinon and carbaryl deposition, quantified in micrograms/ square centimeter of twig area.

Pest Monitoring: Both San Jose Scale and Peach Twig Borer are monitored following each treatment. Relative population levels of San Jose Scale are determined with sticky tape and pheromone traps. Populations are also sampled directly by removing infested twigs. Peach Twig Borer populations are evaluated in each treatment by counting the number of strikes on each of 10 trees following emergence from hibernacula (which occurs in February).

Progress: Spray Application Study

In the winter of 1988 - 1989, before funding of this project began, a preliminary trial of Asai and Steinke compared a conventional orchard sprayer and an experimental, over-the-row sprayer, specifically built for this trial. The experimental unit consisted of a mast, extended to approximately 20 feet above the ground, and a boom. cantilevered from the mast, reaching over half of the row width. By passing down both sides of a row of trees, the sprayer could apply material over an entire row.

In 1989 - 1990, the first year of this project, another test was conducted in Stanislaus County, again using a conventional orchard air carrier sprayer as the baseline for comparison. This trial was conducted using a sprayer with an 18 foot mast, and four fans, each with a rotary atomizer mounted on the fan spindle. The fans were arranged along the height of the mast and directed horizontally into the trees. Again it was necessary to spray both sides of the tree.

For the 1990 - 1991 tests, we were loaned a Curtec sprayer, manufactured by BEI Inc. of South Haven, Michigan. The sprayer has four crossflow fans mounted on a central mast, with the axis of rotation oriented vertically. The output from these fans is directed horizontally into the trees. A rotary atomizer is placed in the output, with the axis of rotation horizontal, perpendicular to the fan output, and parallel to the direction of travel. Each rotary atomizer is supplied with liquid from its own positive displacement peristaltic pump and is powered by a hydraulic motor. Each fan is also powered by a hydraulic motor.

The commercially available Curtec has four fans facing to each side, (a total of eight fans), spraying the equivalent of one row per pass. The unit is self contained, being powered by a diesel engine mounted forward of a 400 gallon mix tank. The central mast is approximately 18 feet high. The Curtec loaned to us had fans on only one side, and was power take-off driven. The mast was lengthened by four feet in recognition of the taller nut trees found in California when compared to Midwestern fruit trees. In addition, another fan without an atomizer was added to the top of the mast to help move the airstream horizontally through the orchard canopy and reduce entrainment of the spray droplets into the overhead fog.

The 1990 - 1991 trial compared the performance of a conventional orchard sprayer (brand name Oma), the Curtec, a helicopter, and the Curtec modified to reduce fan speed. The first trial showed the fan output to be far too powerful for dormant orchards. Spray material was blown through several rows of leafless trees and into adjacent plots and directly into the stations measuring drift. The reduced fan speed was intended to reduce the effect of the fan output on drift.

The same Curtec unit was used for 1991 - 1992 tests, but the topmost fan had an atomizer added to it. In addition, the hoses in the peristaltic pumps were changed to those of a smaller diameter, thus reducing the minimum application rate to 15 to 20 gallons per acre. The additional atomizer and pump were operated from the existing hydraulic system with some changes in plumbing. Throttling valves were introduced into the control system for each fan. By setting these valves, the fan rotational speed, and thus output could be reduced without reducing the atomizer rotational speed. Reducing atomizer rotational speed is directly related to droplet size, thus reduction in speed results in increased droplet sizes.

Results

The pilot study of Asai and Steinke showed a reduction in drift from the over-the-row sprayer of approximately 10 to 25%. However, the sprayer also deposited high amounts of material on the ground, rather than the tree. This design was not used for further trials; the cantilevered boom was an obvious worker safety hazard; it had a potential to contact electrical transmission lines and inherent structural weaknesses in design.

The sprayer used for the first year of this project showed the feasibility of using several points for distributing the liquid and also for putting fans vertically along the mast. Deposition uniformity from high to low was increased. The results were not encouraging for this particular brand however, and it was not used for any further testing.

Deposition

The results from the 1990 - 1991 tests are shown in Figure 1. Twig samples were taken, as in previous years, and analyzed for the presence of diazinon residue. Twig areas were then measured, and the residue normalized to a unit of micrograms/sq. cm, plotted on the vertical axis in Figure 1. The method of application used is on the x-axis, with position of the twigs on the tree as the y-axis. The rows were oriented north to south in this orchard. From each tree, samples were collected at two heights, approximately 1.5 meters (5 feet, L) and 3 meters (10 feet,H) above ground. At each height, samples were taken within the row, that is on the north and south sides of each tree and combined into samples labelled N as the first code letter. The portions of the tree between rows, thus closest to the sprayer and facing east or west, were also sampled and designated as W for the first code letter.

Each sample consisted of one twig from each of the two sides designated. Eight twigs per tree were sampled and segregated into four samples per tree: NL - north and south sides low; NH - north and south sides high; WL - east and west sides low; and WH - west and east sides high. Each treatment was contained within a separate plot. Six trees were sampled for each treatment. All tests were completed with the same active ingredient rate per acre. Total volume varied, being 100 gpa for the Oma and 40 gpa for both Curtec applications and the helicopter trial.

The average for all sprayers was 8.4 $\mu g/cm^2$. Over all locations on the tree, the Curtec average was 13.6 $\mu g/cm^2$, the modified Curtec trial average was 9.8 $\mu g/cm^2$, the Oma average was 8.4 $\mu g/cm^2$, and the helicopter deposited an average of 4.2 $\mu g/cm^2$. The largest value found was from the Curtec at position NL, with deposition of 21.0 $\mu g/cm^2$. The lowest value was for the helicopter sampled at position WL with a value of 3.4 $\mu g/cm^2$. Comparisons are given in Table 1 for the Curtec versus the Oma conventional air carrier sprayer.

During 1991 - 1992 trials were completed using the Curtec, modified as described above. Only a reduced rate (1 lb of formulated diazinon 50 WP) was completed before rains eliminated access to the study site. Results confirmed the general trend shown in earlier year's data, but no statistical conclusions were drawn.

The percentage of droplet sizes above a diameter of 100 μm (the preferred range) and below 10 μm (the range most likely to be entrained in fog) were comparable for the Curtec and the conventional fan sprayer.

In general, the Curtec and the Modified Curtec consistently deposited several times the diazinon on the trees compared to the conventional fan sprayer (Table 1). This leaves open the possibility of reduced rates, and even eliminating output from one or more of the Curtec fans in order to deliver material only to sites on the tree where it is necessary.

Drift

The deposition of OP on fallout sheets on the ground indicated that the drift offsite 60 meters and beyond the spray application was less for the Curtec sprayer (Figure 2).

Insect Control

In addition to showing the Curtec mast sprayer yielded increased deposition of the OP on trees, we also found it provided satisfactory control of insects (Figure 3).

Pigeon Exposures

Pigeons in the orchards show decreased blood cholinesterase levels when they were directly in line with the sprayer, approximately 70% of control values. Pigeons that were 37 meters downwind of the spray plot showed no depression. Dermal exposure to OPs by birds perching on sprayed trees is believed to be a major route of exposure. A striking finding in the laboratory studies was that the blood ChEs of birds dosed dermally on their feet with parathion and to a lesser extent diazinon took many days, often weeks to recover. It was as if there were some depot for the pesticides, perhaps under the scales, or elsewhere in the skin of the birds (Figure 4).

Discussion

The results of the studies strongly indicate that air curtain sprayers may provide better targeting of chemical and permit reduced amounts of AI. The Curtec sprayer deposited spray in the upper portions of the trees at a level higher than conventional sprayers, and generally provided good deposition of the spray and insect kill (Figure 5). The use of reduced gallonage per acre reduced the potential of drift off target. Integrated Pest Management Director Dr. Frank Zalom, on sabbatical in Spain, FAXed a message during the preparation of this report in which he said, "The work is really important...I wish we had more information...on efficacy and deposition with the application techniques.." With regard to experimental design, Zalom said "The application rates and gallonage data is useful and...has a high probability of adoption if... (it)... works as well as the conventional spray yet reduces environmental problems."

Grower Questions: When these results were presented at spray applicator and grower meetings, one question often asked was how mast sprayers like the Curtec could be used in older orchards with trees that overhang the aisles. One way is to lower or tilt the mast, retaining much of the benefit of the sprays by turning the fans to point slightly upward, but still in a general horizontal direction so that the mast would fit between the rows and under the point where the canopy has grown together. Another question asked concerned the utility of reducing sprayer volumes below 100 gallons per acre. The rationale for use of low volumes has to do with the lack of leaf cover of the trees in a dormant orchard. If a dormant tree cannot hold a large (> 200 gpa) volume of water, the excess, and the pesticide suspended or dissolved in it, simply runs off onto the ground. When the water carrier remaining on the tree evaporates, it leaves less pesticide on the tree than if an amount of water less than the capacity of the tree to retain was used. By using less material more efficiently, it should be possible to reduce pesticide and carrier costs and improve field efficiency of the sprayer at the same time. Finally, growers often ask about the use of electrostatics. Electrostatics are an enhancement, rather than a stand alone technique, working best under situations in which the spray is close to its target. Unfortunately, it also is most effective on small size droplets, those that are most readily captured by fog.

All cultural practices are a compromise between cost and yields. Controlling pests has been an important factor in the equation. In the future, the increasing urbanization of the Central Valley, and the mounting concern of Californians for the health of wildlife make it inevitable that more consideration be given to the safety of the sprays, and their impact off-target. Specifically there is a need for continuing research on sprays less toxic to non-target organisms, and to technology that will deliver the materials more uniformly over the entire tree height, improving pest control, reducing drift and reducing total material applied per acre.

To date the project has established:

1. The usefulness of air curtain mast sprayers to apply dormant sprays at low volumes during the dormant season.
2. The usefulness of pigeons as surrogate birds in field and laboratory studies.
3. The possibility that dermal exposures to pesticides are more long-lasting than oral exposures to birds that roost in orchards.

Next steps in the research reported here are to validate the conclusions reached in the studies, expand the experiments to include the toxicity of carbaryl to birds and parameters such as droplet size and volume specifically to reduce drift.

Participants

Major participants in the project to date are:

Dr. Barry W. Wilson, Environmental Toxicology and Avian Sciences , Principal Investigator
Dr. William E. Steinke, Agricultural Engineering, Coprincipal Investigator
Dr. James N. Seiber, Environmental Toxicology*, Coprincipal Investigator
Dr. Frank Zalom, Integrated Pest Management, Coprincipal Investigator
John D. Henderson, Staff Research Associate, Avian Sciences, Biochemical Toxicologist
Michael McChesney, Staff Research Associate, Analytical Toxicology**
Wesley Asai, Farm Advisor, Stanislaus County, Cooperating Investigator
Richard Coviello, Fresno County, Cooperating Investigator

* Dr. Seiber has recently relocated to the University of Nevada at Reno. His place on the project will be taken by Dr. Taka Shibamoto, Environmental Toxicology.

** Mr. McChesney has recently taken early retirement and will be replaced by a staff member working with Dr. Shibamoto.

Table 1
Comparison of Diazinon Deposition in Trees

Sprayer	Sample Position*	Deposition μg/cm²
Curtec	NS	16.5
	EW	10.7
	High	10.7
	Low	16.6
Modified Curtec	NS	11.4
	EW	8.1
	High	10.2
	Low	9.3
Oma	NS	6.4
	EW	5.8
	High	7.6
	Low	4.6
Helicopter	NS	4.8
	EW	3.7
	High	4.8
	Low	3.7

* NS and EW sample positions incorporate the high and low samples from the North-South and East-West locations on the trees, respectively. High and Low sample positions incorporate samples from all sides of the tree.

Figure 1

Diazinon deposition on twigs by position on tree and sprayer used for application.

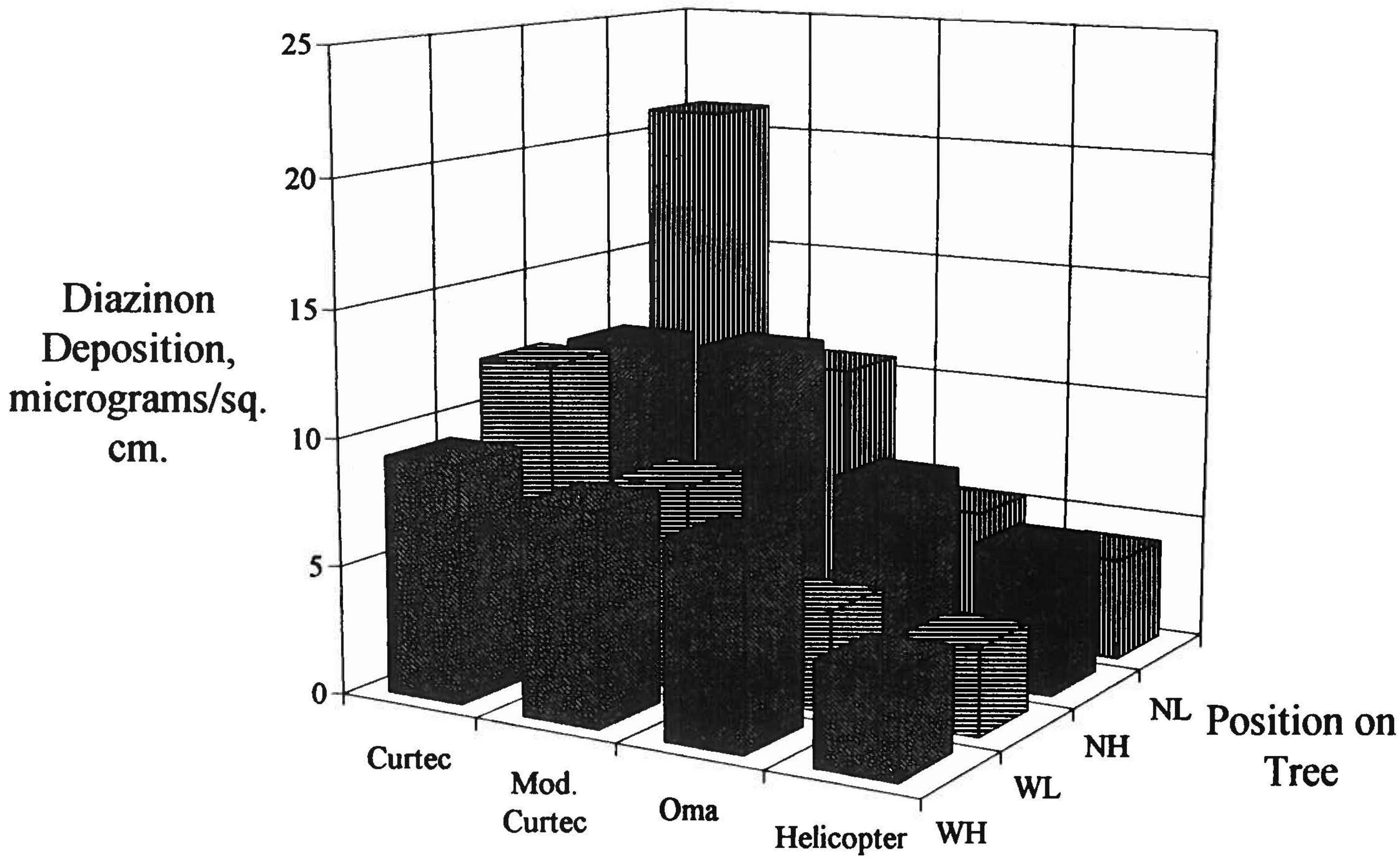

Figure 2

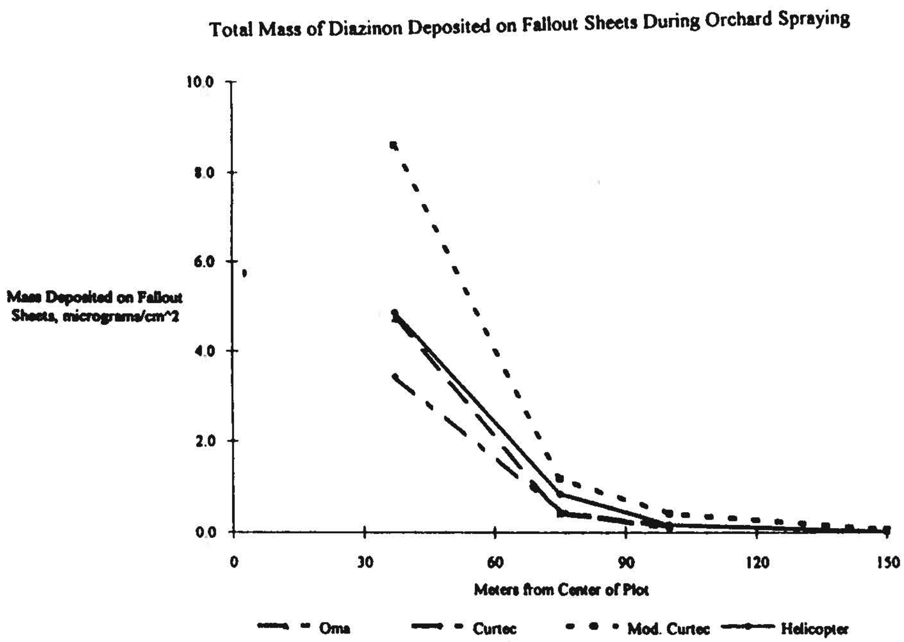

Figure 3

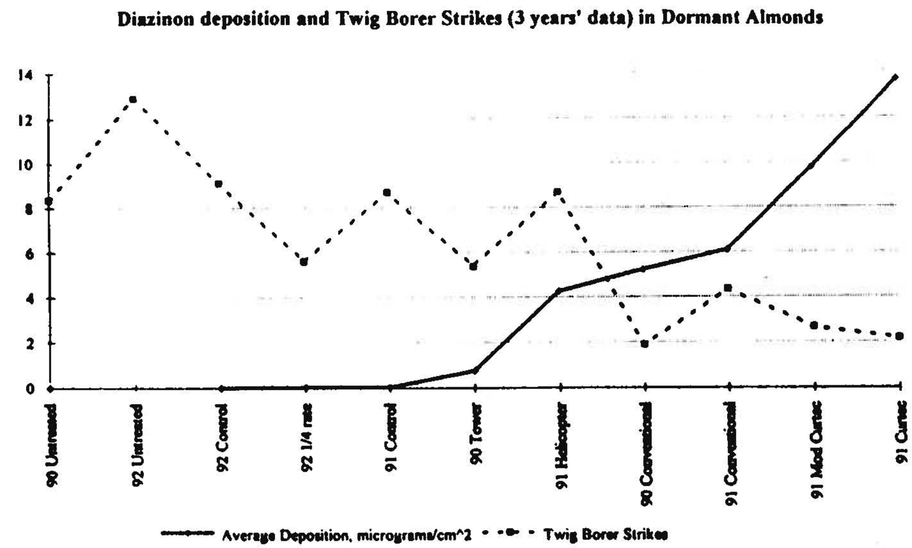

Figure 4

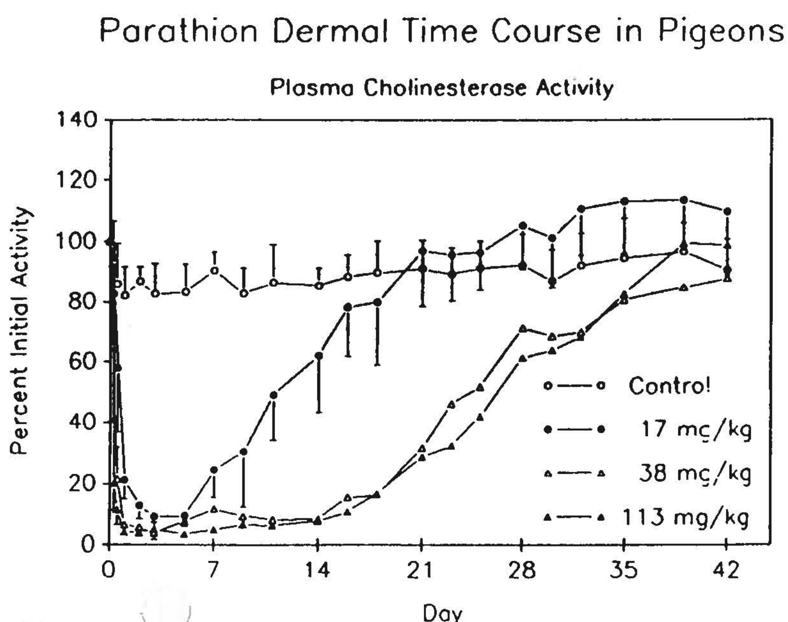

Figure 5