

THE SYNTHETIC PYRETHROID ECTIBANTM PERMETHRIN AS A
TREATMENT IN THE PEST MANAGEMENT OF FLIES IN CAGED-LAYER
POULTRY HOUSES

by

Lee Hill Townsend, Jr.

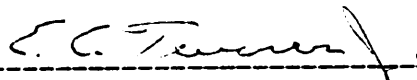
Dissertation submitted to the Graduate Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Entomology

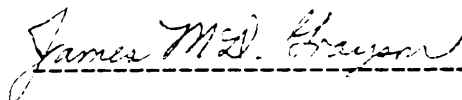
APPROVED:



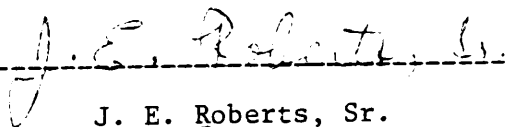
E. C. Turner, Jr., Chairman



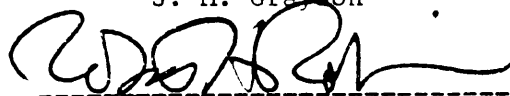
W. A. Allen



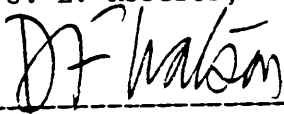
J. M. Grayson



J. E. Roberts, Sr.



W. H. Robinson



D. F. Watson

December, 1977

Blacksburg, Virginia

LD
568
Y856
1977
T-95
c.2

ACKNOWLEDGMENTS

I appreciate the encouragement and guidance of my advisory committee: Dr. E. C. Turner, Jr., chairman, and Drs. W. A. Allen, J. M. Grayson, J. E. Roberts, Sr., and W. H. Robinson of the Department of Entomology, and Dr. D. F. Watson, Department of Veterinary Science. Their contribution to my education cannot be overstated.

Mrs. Frank Rock and Cecil Kessinger provided invaluable assistance in all phases of the study. Their sincere interest was greatly appreciated. I wish to thank Mr. Don Simonet for help with the computer program for probit analysis. Also, Dr. W. L. Beane and Mr. Charles Orange of the Poultry Science Department provided facilities, assistance, and birds for the feed through portion of the project.

This research was supported by grants from ICI Americas, Inc. Their assistance and guidance in the persons of Drs. G. B. Braithwaite and F. S. Downing deserves my special thanks.

I am especially indebted to my wife, Jane, for her help and encouragement throughout my graduate training.

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
LITERATURE REVIEW	6
GENERAL MATERIALS AND METHODS	17
ECTIBAN AS A LARVICIDE	20
Comparison with other insecticides using a dip test . .	20
Toxicity of Ectiban sprays on chicken manure	32
Toxicity of Ectiban in fly breeding media	34
Toxicity of manure from chickens fed Ectiban-treated rations	38
Fate of Ectiban as a toxicant in the gut of a rooster .	45
EFFECT OF ECTIBAN ON CERTAIN NONTARGET ARTHROPODS	53
ECTIBAN AS AN ADULTICIDE	62
Topical application of Ectiban to female house flies .	62
The effect of surfaces on the efficacy of Ectiban . . .	64
Ectiban impregnated cotton cords for fly control . . .	73
FLY RESTING SITE STUDY	77
CONCLUSIONS	86
LITERATURE CITED	87
VITA	95

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1 Comparative toxicity of selected insecticides to third-stage Stauffer-strain house fly larvae using a dip technique.	23
2 House fly production from pans of poultry manure seeded with house fly eggs following topical treatment with Ectiban at the rate of 1 gallon/100 ft ²	33
3 House fly production from first-stage larvae reared on Purina ^r CSMA fly larvae media containing selected concentrations of Ectiban.	36
4 House fly production from second-stage larvae reared on Purina ^r CSMA fly larvae media containing selected concentrations of Ectiban.	37
5 House fly production from first-stage larvae reared on chicken manure containing selected concentrations of Ectiban.	39
6 Manure output of White Leghorn hens consuming rations containing encapsulated Ectiban at selected rates.	41
7 House fly production from first-stage house fly larvae seeded on manure from hens fed rations treated with selected concentrations of encapsulated Ectiban.	43
8 Corrected mean house fly mortalities resulting from bioassay of extracts of 50 ppm Ectiban-treated feed.	48
9 Sample weights and acetone extract volumes from samples collected for Ectiban bioassay of the gut contents of a rooster.	49
10 Percentage mortalities of female house flies exposed to residue extracts of samples from a rooster fed 50 ppm Ectiban-treated feed.	50
11 Percentage mortality of full grown <u>Alphitobius diaperinus</u> larvae following a 48 hr exposure to Ectiban-treated media.	60

<u>Table</u>	<u>Page</u>
12 Mean mortalities of groups of 10 house flies exposed for 4 hours to Ectiban-treated surfaces (2mg/ft ²).	68
13 Mean percentage knockdown and 24 hr mortality of groups of 45 female house flies following a 1 hr exposure to cotton cords treated with a 1% or 5% solution of Ectiban in xylene.	75
14 Mean numbers of flies per panel following resting site study, Montgomery Co., Va., 1977.	80
15 Mean numbers of fly specks per panel following fly resting site study, Montgomery Co., Va., 1977.	82

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Skeletal structure of permethrin.	5
2	Response of third-stage Stauffer and Wild-strain house fly larvae to diazinon.	24
3	Response of third-stage Stauffer and Wild-strain house fly larvae to supona.	25
4	Response of third-stage Stauffer and Wild-strain house fly larvae to dimethoate.	27
5	Response of third-stage Stauffer and Wild-strain house fly larvae to stirofos plus dichlorvos.	28
6	Response of third-stage Stauffer and Wild-strain house fly larvae to stirofos.	29
7	Response fo third-stage Stauffer and Wild-strain house fly larvae to SD 43775.	30
8	Response of third-stage Stauffer and Wild-strain house fly larvae to Ectiban	31
9	Response of first-stage house fly larvae to manure from hens fed Ectiban-treated rations	44
10	Response of groups of 10 female house flies to Ectiban residues in glass vials	46
11	Schematic representation of the fate of Ectiban in the digestive tract of a rooster.	52
12	Response of <u>Macrocheles muscaedomesticae</u> to Ectiban	56
13	Response of <u>Mormoniella vitripennis</u> to Ectiban.	57
14	Response of adult Stauffer and Wild-strain house flies to topical applications of Ectiban.	63
15	Response of adult Stauffer and Wild-strain house flies to topical applications of stirofos	65
16	Mean percentage mortalities of house flies exposed for 4 hours to surfaces treated with 2 mg of Ectiban WP per ft ²	69

Figure		Page
17	Mean percentage mortalities of house flies exposed for 4 hours to surfaces treated with 2 mg of Ectiban EC or WP per ft ²	71
18	Experimental design for the fly resting site study. . .	78

I. INTRODUCTION

From 1945 to 1970 the egg-production industry in the United States moved from small farm flocks of roosting birds to commercial flocks of thousands of caged layers. This change was accompanied by a sharp decrease in mature-bird size and a shift in emphasis from egg production per bird to return on investment (Acker 1971). The resulting high density/low area approach to poultry management has the problem of coping with large volumes of manure.

Poultry manure is a combination of feces and kidney excretions. A chicken voids about 20 times per day (Tyler 1958), totaling approximately 90 gms of wet manure daily from a 2.3 kg bird. About 70% of this weight is water. More than 12 million m³ of manure are produced annually from egg-laying chickens; an additional 21 million m³ comes from fryers (Hart 1963).

Chickens do not use feed efficiently (Hart 1963). Thus, their manure contains a great deal of organic matter. One of the most important biological features of this manure is its suitability as a larval breeding media for synanthropic flies, especially Musca domestica Linnaeus (Diptera: Muscidae).

Teotia and Miller (1973) observed house fly development in chicken manure between 20° and 38° C. As the temperature of the media was increased, development time from eggs to pupae decreased from 11 to 5 days. Conditions in the warmer months are favorable for the production of large fly populations, especially when additional water from leaky troughs or diarrheal birds increases the moisture content

of the manure (Hoffman and Monroe 1965). House flies subjected only to normal environmental stresses in the field usually result in a threefold rate of increase from generation to generation (Weidhaas and LaBrecque 1971; LaBrecque et al. 1972). In the absence of adequate pest management procedures, synanthropic flies may compete with eggs and manure as the main product of caged-layer facilities.

Anderson (1966) stated that the basic biological information on how to prevent house fly development has been known for over 40 years (i.e., rendering the breeding sites unsuitable for oviposition or larval development). However, there is some difference of opinion regarding the primary responsibility for filth-fly abatement. Anderson (1966) expressed incredulity that the principal source of professional guidance in control of these pests came from entomologists. He felt that the problem more properly involved adequate building design, prompt manure removal, and disposal or utilization. Anderson considered this the province of the agricultural engineer.

In contrast, Axtell (1967) stated that perfection in manure disposal was an unrealistic goal. He believed that the volume of manure was too large to be rendered unsuitable for breeding at all times. Axtell called for entomologists to continue to seek methods of reducing fly populations.

Populations of synanthropic flies pose several potential problems. Flies have demonstrated two attributes necessary for vectors of disease: mobility and a burden of bacteria. They may harbor well over 100 species of pathogenic organisms, the number of human and animal diseases exceeds

65 (Greenberg 1965). One such pathogen is Streptococcus gallinarum (Klein) (Eubacteriales: Lactobacillaceae), which causes white diarrhea of chickens. This organism passes into fly larvae that are feeding on contaminated manure. It remains in the insect during metamorphosis and chickens contract the disease after eating larvae or adult flies (Sacca 1964).

It is not disease transmission by flies, but rather human annoyance that precipitates most control attempts. A current trend of man's dispersal from urban to rural areas has resulted in closer contacts with flies produced from agricultural wastes. In California, Bureau of Vector Control surveys of domestic flies established that poultry operations were a prominent, but not sole contributor to the growing statewide fly problem (Peters 1963).

As long as the main problem stems from human annoyance, control approaches will be directed toward reductions in fly intensity rather than eradication attempts. A lesser degree of control is acceptable under non-disease circumstances (Fay and Kilpatrick 1958). Serious disease threats or measurable production losses correlated to specific fly densities will necessitate stringent control efforts. Also, nuisance levels associated with fly populations vary. Often a producer will have a higher fly tolerance threshold than hired workers or nearby residents.

The data base on synanthropic flies is broad and growing as research efforts continue. Fundamental work on population dynamics and behavior in relation to control practices contributed to the

all understanding of these pests. The importance of acarine and insect parasites and predators as population regulators has been emphasized, along with cultural practices regarding manure removal and composting. These investigations have been incorporated into integrated control programs which emphasize a coordinated approach to fly control (Anderson 1965; Axtell 1968, 1970a; DeFoliart 1963; Matthyse and McClain 1973; Legner and Olton 1968; and Wicht and Rodriguez 1970). Strategies include selective chemical treatments, which utilize data on the residual characteristics of the insecticides, and behavior and biology of pest and beneficial species.

The objective of my research was to evaluate the synthetic pyrethroid permethrin (Ectibantm permethrin, ICI, Americas, Inc.) (Fig. 1) as a potential treatment in the integrated control of synanthropic flies in poultry houses. I used a variety of application techniques including feed additive, direct topical application to manure for larval control, and residual sprays for adult control. In addition to investigating the effects of the pyrethroid on the house fly, I determined its effect on selected nontarget parasites and predators which may occur in chicken houses. The goal of the research was to define guidelines for judicious usage of this potent insecticide compatible with an integrated control approach for synanthropic flies.

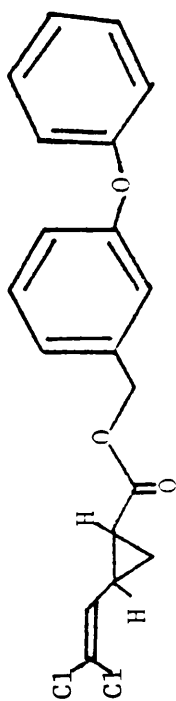


Figure 1. Skeletal structure of permethrin.

II. LITERATURE REVIEW

Pyrethrins and the development of synthetic pyrethroids. Persians apparently found the insecticidal properties of two pyrethrum flowers, Chrysanthemum roseum Web. and Mohr and C. carneum M. B. (Compositae). Secrecy surrounded early use and processing, so it is difficult to determine a specific date of discovery. Traders brought pyrethrum powders, the ground flower heads, to Europe in the early 1800's. About 1840, growers in a region of Yugoslavia along the Adriatic Sea began producing C. cinerariaefolium (Trev.), which superceded the Persian species as a pyrethrum source. More efficient kerosene extracts of pyrethrum began to replace the powdered form about 1919 (Gnadinger 1933). A search for more suitable growing conditions, changing world politics, and economic considerations combined to cause shifts of pyrethrum production to Japan and eventually to Kenya.

Pyrethrins are the only naturally occurring insecticide used widely today (Elliott 1974). They are broad spectrum contact toxicants acting on the insect's central nervous system to produce a rapid paralysis. This knockdown effect makes pyrethrins an effective space spray for flying insects. Natural pyrethrins are suitable for the control of insects of public health importance because they are safe for use with mammals under normal conditions. Although unstable when exposed to light, air or moisture, the lack of residual effect was not considered to be important (Barlow and Hadaway 1975).

The strategy of insect control began to change during the 1940's. The advent of synthetic insecticides resulted in cheaper, more stable

compounds. Surface deposits of these materials, chiefly chlorinated hydrocarbons, retained their toxicities for long periods of time. Cost and inherent stability of pyrethrins competitively excluded them from this type of application. But, the development of insecticide resistant species, concern about redistribution and subsequent contamination of the environment with toxicants directed investigators toward insecticides possessing adequate residual effect where applied, while remaining innocuous in the general environment (Barlow and Hadaway 1975).

Koehler (1974), reporting on the theme of an international conference on insect control, stated that the future of world agriculture would depend on the availability of proper kinds of insecticides in adequate quantities. It was assumed that insecticides would probably continue to provide the backbone of pest control in the developed nations. Current trends indicated that organophosphates and carbamates would be the principal control agents.

Conference participants emphasized the need to develop compounds which were selective between insect species and insects and mammals. Modifications of naturally-occurring insecticidal materials were recognized as a potential source of new toxicants (Koehler 1974).

Recent developments in the synthesis of pyrethroid compounds are encouraging. Several members of this group are among the most toxic compounds known for the species tested to date (Elliott 1974). Many pyrethroids retain the low mammalian toxicity characteristic of natural pyrethrins, yet are stable in light and are as long-lasting as insecticides of other chemical types. It is unlikely that they will remain

unchanged in the general environment and thus become a cause of pollution (Barlow and Hadaway 1975).

The insecticidal action of pyrethrins occurs on the nerve membrane. They are not enzyme inhibitors as are the organophosphates and carbamates. This should be an advantage in controlling populations of insects which are resistant to the latter two groups of toxicants.

Barlow and Hadaway (1975) provide several factors that may prove detrimental to pyrethroids. Among these are: relatively high cost, greater mammalian toxicity for some compounds than natural pyrethrins, and an irritant effect. The latter may stimulate insects to leave a treated surface before receiving a fatal dose. This may be true especially when lower, more economical concentrations are used.

Structure and insecticidal toxicity of pyrethroids. The insecticidal compounds in pyrethrum extracts are esters of cyclopropane carboxylic acids with alkenylmethyl cyclopentolones (Crombie and Elliott 1961). These are combinations of two different acids (chrysanthemum monocarboxylic acid and chrysanthemum dicarboxylic acid monomethyl ester) with two alcohols (pyrethrolone and cinerolone) (Fujitani 1909, Yamamoto 1923, and Staudinger and Ruzicka 1924). The amount of each present in flowers varies with the strain, environmental conditions during growth, and processing methods.

The two important constituents of the pyrethrum extract are pyrethrin I (pyrethrolone plus chrysanthemum monocarboxylic acid) and pyrethrin II (pyrethrolone plus chrysanthemum dicarboxylic acid monomethyl ester). Pyrethrin I provides much of the killing power in the

natural mixture, but has less rapid knockdown than the closely related pyrethrin II. Although both compounds are lipophilic, the slightly greater polarity of pyrethrin II may be associated with its better knockdown action.

Apparently, the greatest activity of natural and synthetic pyrethroids requires polarities falling within a narrow range. This seems to promote rapid penetration to their common site of action (Elliott 1974). Elliott (1970) stated that these compounds appear to act against insects as intact esters. This action seems to require an ester bond that is difficult to cleave. Also, the bond may provide a position of appropriate polarity at the center of the molecule.

Research on these materials led to the development of allethrin (cis, trans, -⁽⁺⁾-2,2-dimethyl-3-(2-methylpropenyl) cyclopropane carboxylic acid ester with ⁽⁺⁾-2-allyl-4-hydroxy-3-methyl-2-cyclopenten-1-one), the first synthetic pyrethroid (Schechter et al. 1949a, 1949b; Schechter et al. 1951). Mitlin and Babers (1955) found that allethrin was as toxic as pyrethrins when applied topically to DDT-resistant and non-resistant house flies. Ensuing structural modifications, polarity measurements, and accurate assessments of toxicity of additional synthetic analogs enabled deductions concerning moieties in the molecules which affected insecticidal action. Much of this work was done by Elliott and coworkers at the Rothamsted Experimental Station, Herfordshire, England.

The different side chains of pyrethrins I and II seem to influence the speed of action. Mortality depends on two important centers present

in both compounds and all substantially active synthetic isomers. These are the gem-dimethyl-cyclopropane carboxylate group on the acid and the unsaturated center on the alcohol side chain. The cyclopropane ring, ester link, and planar alcoholic ring maintain the necessary spatial relationships.

These requirements for insecticidal potency can be satisfied in many structures. Modification of the acid side chain of pyrethrin I resulted in synthesis of resmethrin, (\pm)-cis, trans-(5-benzyl-3-furyl) methyl 2,2-dimethyl-3-(2-methyl(propenylcyclopropane carboxylate) (Elliott et al. 1967). Elliott stated that this compound was more than 20 times as toxic to house flies as the natural pyrethrins. Resmethrin-like other chrysanthemic esters, is a mixture of stereoisomers. The (-) isomers have negligible toxicities. Bioresmethrin, the (+)-trans-chrysanthemate of resmethrin, is 55 times as toxic to adult female house flies as the mixed esters of the natural pyrethrins, nearly three times as toxic as parathion (0,0-diethyl o-(p-nitrophenyl) phosphorothioate) and more than five times as toxic as diazinon (0,0 diethyl 0-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate) (Elliott et al. 1967).

Median lethal doses (MLD) of resmethrin and its analogs demonstrated that the (+)-cis isomer (cismethrin) was more than twice as toxic as the (+)-trans isomer (Barlow and Hadaway 1975). Other cis, trans pairs have always shown the same superiority of the cis isomer, although MLD ratios may differ. While exhibiting adequate toxicity, resmethrin did not possess suitable residual properties. Additives to protect insecticides with short residual action from degradation

would have to be persistent and mixed with it at the molecular level. This is an impractical solution to the problem (Barlow and Hadaway 1975). Structural modification of the pyrethroid molecule appeared to be the efficacious approach (Elliott et al. 1973).

Synthesis was directed toward developing materials possessing a longer residual effect. Substituting 3-phenoxy-benzyl alcohol for the 5-benzyl-3-furylmethyl alcohol of bioresmethrin resulted in esters 10 to 100 times more stable in light and air than previous pyrethroids, but with reduced insecticidal action (Elliott et al. 1973a). Stability was improved also by eliminating the furan ring. Ueda et al. (1974) confirmed that this ring was subject to photosensitized attack by oxygen. Elliott et al. (1973a) reported that toxicity was restored in esters of the dichlorovinyl acid instead of chrysanthemic acid. This change removed the other known photosensitive center. The resulting compound (3-phenoxybenzyl (*)-cis, trans-2,2-dimethyl-3-(2,2-dichlorovinyl)-cyclopropane carboxylate) was tentatively named permethrin (Elliott et al. 1973b). The insecticide evaluated in this research project, Ectibantm permethrin, contained a 20:80 cis-trans ratio. Permethrin is also termed FMC 33297, S3151, SBP 1513, BW21z and NRDC 143.

At this early stage in its development, published research data concerning permethrin are limited. Much of the initial work has involved biting and nonbiting flies. Permethrin sprays and dusts have provided good control of tabanids on horses and cattle (Harris and Oehler 1976, Bay et al. 1976). Topical applications of this

pyrethroid in the laboratory showed it to be toxic to the face fly Musca autumnalis DeGeer (Diptera: Muscidae) (Robinson et al 1976), and against Stomoxys calcitrans (Linnaeus) and Haemotobia irritans (Linnaeus) in spot-tests and whole animal sprays of steers (Schmidt et al. 1976). This material showed a high degree of activity as a mosquito larvicide (Mulla and Darwazeh 1976) and as a nonthermal adulticide (Boike and Rathburn 1975).

Permethrin has been evaluated against a variety of household and agricultural pest species. The material has shown promise against the boll weevil, Anthonomus grandis Boheman; the confused flour beetle, Tenebrio confusum du Val; and the Japanese beetle, Popillia japonica Newman (Sullivan et al. 1975). It was not effective against the German cockroach, Blattella germanica Linnaeus, showing some indication of producing an avoidance reaction (Grayson 1975). The pyrethroid showed much higher efficacy against Alabama argilacea (Hubner) than did selected organophosphates and carbamates (Almeida and Takematsu 1975). Carter and Duffield (1976) found permethrin to be a potential agent for use against the clothes moth Tineola bisselliella Hummel and the carpet beetle Anthrenus flavipes LeConte. Also, permethrin was effective against the codling moth Laspeyresia pomonella (Linnaeus) (Hameed and Allen 1976). These reports emphasize the broad spectrum toxicity of this synthetic pyrethroid.

Certain compounds have the effect of extending the toxicity of pyrethrins, so that much less pyrethrum is needed in a spray with synergists to achieve the usual knockdown of flies. Perhaps the most widely used synthetic pyrethrin synergist is piperonyl butoxide

(a-(2-(2-butoxyethoxy)ethoxy)ethoxy)-4,5-methylenedioxy-2-propyl-toluene). Its effectiveness is cited as around a tenfold increase in pyrethrum toxicity when mixed with pyrethrin in a 10:1 ratio (Matsamura 1975).

The synergistic effect of piperonyl butoxide when used with synthetic pyrethroids is beginning to receive attention. Robinson et al. (1976) tested combinations of permethrin and piperonyl butoxide topically on face flies. The degree of synergism was markedly lower than that often observed for natural pyrethrum in other insects. However, it was sufficient to make the combination the most effective of the insecticides evaluated.

Mode of action of pyrethrins. Pyrethrins are potent neurotoxins. An insect intoxicated with it quickly develops hyperexcitation and tremors, which are followed by paralysis. No enzymatic inhibition, a salient feature of organophosphate and carbamate poisoning, is known to account adequately for the neurotoxic action of pyrethroids (Narahashi 1971).

Much of the research toward elucidating the activity of synthetic pyrethroids has been done with allethrin. Three main effects of allethrin have been noted on the giant axons of cockroaches: an increase in negative after-potential, repetitive after-discharge, and conduction block. These factors can account for the hyperexcitation and paralysis of a poisoned insect (Narahashi 1962a, 1962b).

Narahashi (1971) demonstrated that the actions of allethrin on the arthropod nerve fiber could be interpreted in terms of the

permeability of nerve membranes to sodium and potassium ions. The movement of these ions is the mechanism by which nerve excitation occurs. Differential permeability of these ions is disrupted by allethrin. It appears that the size and shape of the insecticidal compounds are critical factors for pyrethroid-like action on nerves (Berteau et al. 1968).

Much of the mammalian toxicity data concerning insecticides is derived from laboratory work with rats. Essentially all of the metabolites of permethrin are identified in rat excreta (Gaughan 1976). Six-month feeding studies with rats revealed a no effect level of 1500 ppm daily in the diet. Toxic symptoms together with a slight increase in liver weight were noted at a dose of 3000 ppm (Kadota et al. 1976).

Rats receiving 0.5 to 2.9 mg/kg oral doses of radio-carbon labelled permethrin eliminated 76% to 95% of the dichloro (^{14}C) vinyl acid or 3- (^{14}C) phenoxybenzyl alcohol in the excreta after four days. Most was eliminated during the first 24 hours (Elliott et al. 1976). Four days following treatment, residues of permethrin in most body tissues of the rat were below 0.01 ppm. Exceptions were 0.12 to 0.40 ppm in fat and 0.01 to 0.06 ppm in the kidneys and liver. The findings indicated that permethrin, its hydrolysis products, and metabolites are excreted from the body in a short time and are not retained to an unusual extent in the tissues.

In general, chlorinated hydrocarbon insecticides are metabolized slowly in mammals with the original compounds or metabolites being stored in fatty tissues. These residues are eliminated over a long

period of time. Permethrin is similar to these materials in that it is highly lipophilic and contains chlorine. While these properties are important to the very high insecticidal activity of the pyrethroid, they do not appear to limit its biodegradability (Elliott et al. 1976). Elliott et al. (1976) stated that permethrin metabolites appear to be formed rapidly by hydroxylation at methyl and phenoxy groups and by ester cleavage. The parent compound, these metabolites, their conjugates, or further oxidation products are eliminated quickly from mammals.

Integrated fly control in poultry houses. Integrated control of fly pests by poultry producers is a balanced use of manure management, farm sanitation, chemical control, mechanical control, and biological control (Anderson et al. 1968). Anderson (1965) and Axtell (1970b) emphasized maintaining populations of predatory mites and other biological control agents by properly timed, partial manure removal. This would be supplemented by selective treatment of adult resting areas and poison baits.

Geographical considerations, however, may greatly influence integrated control strategy. In regions characterized by short fly seasons, larvicides appear to be the best approach. Matthyse and McClain (1973) in New York suggested combining larval and adult control, thereby delaying insecticidal resistance through a drastic reduction of the gene pool. In Kentucky, Rodriguez and coworkers (1970) suggested using LD₅₀ toxicity data for selective insecticides to allow larviciding with a margin of safety for the beneficial fauna.

Control methods which utilize behavioral responses of pest and beneficial species deserve consideration. Ethological studies in

California showed that while populations of most fly species were dispersed widely about poultry ranches during the day, two aggregations were noted at night (Anderson and Poorbaugh 1964). About 15% of the estimated population of flies was found outside at night, mainly on tree branches and shrubs. Almost all of the indoor segment, about 85% of the estimated population, occurred on the ceiling areas of poultry houses. Thus, methods which utilize behavioral responses of pest and beneficial species are important.

Cords treated with insecticides provide a selective means of exerting control pressure against adult flies with a minimum disruption of populations of beneficial species (Kilpatrick and Schoof 1956, Schoof and Kilpatrick 1957, Mathis and Schoof 1965, and Williams 1973). Treated panels designed and placed for maximum attractiveness as night resting sites for flies also may be effective. Keiding (1965) reported that flies begin occupying night resting places in late afternoon. The attractiveness of narrow hanging objects in areas not exposed to strong air movements was apparent. Surface texture (rough versus smooth) and brightness are important, too. However, the relative contributions of these and other factors are not understood fully (Arevad 1965).

A variety of application techniques using new insecticides should be evaluated so that they may be used to best advantage in integrated fly control strategies. This serves to maximize and prolong their effectiveness against pest species noted for their ability to respond successfully to insecticidal challenge.

III. GENERAL MATERIALS AND METHODS

Rearing and handling of house flies. The two house fly strains used in this research project were a Stauffer strain obtained from the University of Illinois and a field-collected strain taken from a commercial chicken house in western Virginia in 1975. These flies were maintained at the Price's Forks Research Station, Blacksburg, Virginia, using the standard rearing procedures outlined by Keiding and Arevad (1964).

Purina^r Fly Larvae Media (#5060), dry, powdered Brewer's yeast, and water provided a suitable breeding substrate for fly larvae. When treated media was required for a test, Ectiban stock solutions were prepared from an emulsifiable concentrate formulation (2 lb/gal) and distilled water. The requisite volume of stock solution in a total of 700 ml of water was added to plastic bags containing 300 gm of dry media and a small portion of yeast. Plastic bags containing selected amounts of these treated media preparations were put in individual emergence containers (Breedon et al. 1975) and seeded with house fly eggs or larvae.

Cups of sour media were placed in adult cages to obtain eggs for sustaining the colony and for toxicity tests. For the latter, a moist camels-hair brush was used to transfer eggs or first stage larvae from the oviposition media to small squares of wet paper towel. When the required number of batches were prepared, they were washed onto the test substrate with small amounts of distilled water.

When second- or third-stage larvae were needed, portions of colony rearing cultures were placed in Tulgren funnels. Heat from light bulbs drove the larvae into collecting trays. These larvae were sorted and transferred with light-weight forceps.

Adult flies were collected from colonies of the desired age using a plastic bag and ultraviolet (UV) light. The cage was covered with a dark cloth with the trapping bag covering the cage opening. A UV light was turned on and positioned behind the bag. These captured flies were lightly anesthetized with CO₂ and shaken from the bag onto a funnel connected to a CO₂ tank. Light-weight forceps were used to transfer the flies into exposure cages. If necessary, the flies were sorted by sex.

Depending on the experimental design employed, the flies were anesthetized again for transfer to recovery cages. These cages were pint cardboard containers which had been provided with screen-topped lids. Dental wicks, which had been dipped in a sucrose solution, were provided during the recovery period. These cages were held in environmental chambers for 24 hours prior to mortality assessment.

Mortality criteria. Larval mortality at the termination of treated media and dip tests was determined by comparing successful adult development from treatment and control replicates. In tests with adult house flies, those individuals unable to remain upright and perform coordinated movements were considered to be dead. These data were corrected for control mortality using Abbott's formula (Abbott 1925). Mortality criteria for nontarget species varied and are discussed under experimental procedure.

Statistical procedure. Data from the residual panel spray and resting site study were compared by analysis of variance techniques. Means found to be significantly different ($P > 0.05$) were separated using a multiple range test (Duncan 1955). Dose-response curves for the toxicity data were computed by the SAS probit procedure (Barr et al. 1976). This program was modified to correct for control mortality using Abbott's formula.

IV. ECTIBAN AS A LARVICIDE

Poultry droppings from laying hens confined in suspended cages may accumulate in shallow gutters beneath the cage banks. This manure is removed at intervals depending on the gutter depth and rate of buildup. Frequently the time between cleaning operations is sufficient to allow several generations of flies to be produced. Mechanical breakdowns or more pressing needs for labor may interfere with manure removal schedules. Thus, several insecticides are registered for topical application to droppings to kill larvae of manure-breeding flies. Ectiban was evaluated in a series of experiments as a larvicide.

Comparison of Ectiban with other insecticides using a dip test.

Dipping is a standard method for screening contact insecticides. This technique has been used widely against plant feeding or stored product pests (Shepard 1958). Lennox (1940) used a dip test to evaluate insecticides against larvae of Phaenicia cuprina (Weidemann), the greenbottle fly. The LC_{50} (concentration causing death of 50% of the test population) and LC_{95} values may be calculated and compared to other toxicants or population strains. These data can provide evidence of resistance to an insecticide in addition to indicating the intrinsic toxicity of materials.

Third stage larvae from the Stauffer and wild strain were dipped in concentrations of one of seven insecticides. The organophosphates dimethoate (0,0-dimethyl S-(N-methylcarbamoylmethyl) phosphorodithioate), supona (2-chloro-1-(2, 4-dichlorophenyl) vinyl diethylphosphate), stirofos (2-chloro-1-(2,4,5 tri-chlorophenyl) vinyl dimethyl phosphate),

and Ravap^r (23% stirofos plus 5.7% dichlorvos) (2,2-dichlorovinyl dimethyl phosphate), were chosen because they are recommended by the VPI&SU Cooperative Extension Service as larvicides for poultry producers (Roberts 1977). Diazinon (0,0-diethyl 0-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate) was used because it had been shown to be an effective larvicide in field and laboratory evaluations (Bailey et al. 1968, Axtell 1966). The remaining materials, Ectiban and SD 43775 (cyano(3-phenoxyphenyl)methyl-4-chloro-alpha-(1-methylethyl)benzeneacetate, Shell Development Corp.), were experimental pyrethroids.

All insecticides, except for a 50% wettable powder formulation of stirofos, were emulsifiable concentrates. A series of serial dilutions of each toxicant was prepared in distilled water on a weight-volume basis.

Dippers used for immersing the larvae were made from the tops of pint cardboard containers. The center insert was removed and fine mesh Saran^r screen was glued to the rings. Groups of 20, third-stage larvae were placed in these dippers and immersed for 1 minute in a Syracuse dish containing 100 ml of the insecticide concentration. Eight replicates were dipped in each solution, beginning with the lowest dilution.

After immersion, the larvae were transferred from the dippers onto moist filter paper on the bottoms of pint cardboard containers by means of light-weight forceps. These containers were put in a chamber regulated at $24 \pm 1^{\circ}$ C and 80% relative humidity. Small quantities of distilled water were added to the filter paper to prevent desiccation prior to pupariation.

The effectiveness of the seven insecticides against Stauffer strain larvae is reflected by the respective LC_{50} and LC_{95} values

(Table 1). Diazinon, supona, and Ravap were the most toxic, followed by dimethoate, stirofos, and Ectiban. Shell SD 43775 produced the highest LC_{95} .

House fly populations lose a degree of resistance when insecticide pressure is removed. Pickens and Miller (1975) selected two colonies of stirofos-resistant house flies by pressuring adult flies of one group and larvae of the other. The selection pressures were removed after 50 generations. Larval pressured flies lost 81% of their resistance and the adult-pressured strain lost 68% of their resistance after 16 additional generations.

The wild strain flies in my experiments had completed over 15 generations in our laboratory before the dipping experiments were begun. Therefore, it may be assumed that some degree of insecticide resistance had been lost. It is also possible that some accidental cross-breeding may have occurred between the wild and Stauffer strains. However, the results of the dipping experiments indicated that such contact was slight. Distinguishable differences between the strains were evident.

Diazinon was the most toxic insecticide tested (Fig. 2). The Stauffer strain LC_{50} was comparable to the LC_{50} value determined by placing third-stage house fly larvae in cups of treated media for 24 hours (Axtell 1966). In my experiments, the ratio of LC_{50} 's (LC_{50} wild strain/ LC_{50} Stauffer strain) was 2.2 : 1; the LC_{95} ratio was 10 : 1.

Supona was next in effectiveness against the wild and Stauffer strain larvae. The LC_{50} and LC_{95} ratios were 4 : 1 and 10 : 1, respectively (Fig. 3). Supona is a recommended larvicide in Virginia.

Table 1. Comparative toxicity of selected insecticides to third-stage Stauffer-strain house fly larvae using a dip technique.

Insecticide	LC ₅₀ (% conc)	LC ₉₅
diazinon	0.001 - 0.003*	0.03
supona	0.001 - 0.004	0.02
stirofos	0.001 - 0.02	0.1
Ravap**	0.002 - 0.007	0.02
dimethoate	0.003 - 0.02	0.3
Ectiban	0.003 - 0.03	0.2
SD 43775	0.005 - 0.04	1.0

* 95% CI

** 23% stirofos plus 5.7% dichlorvos

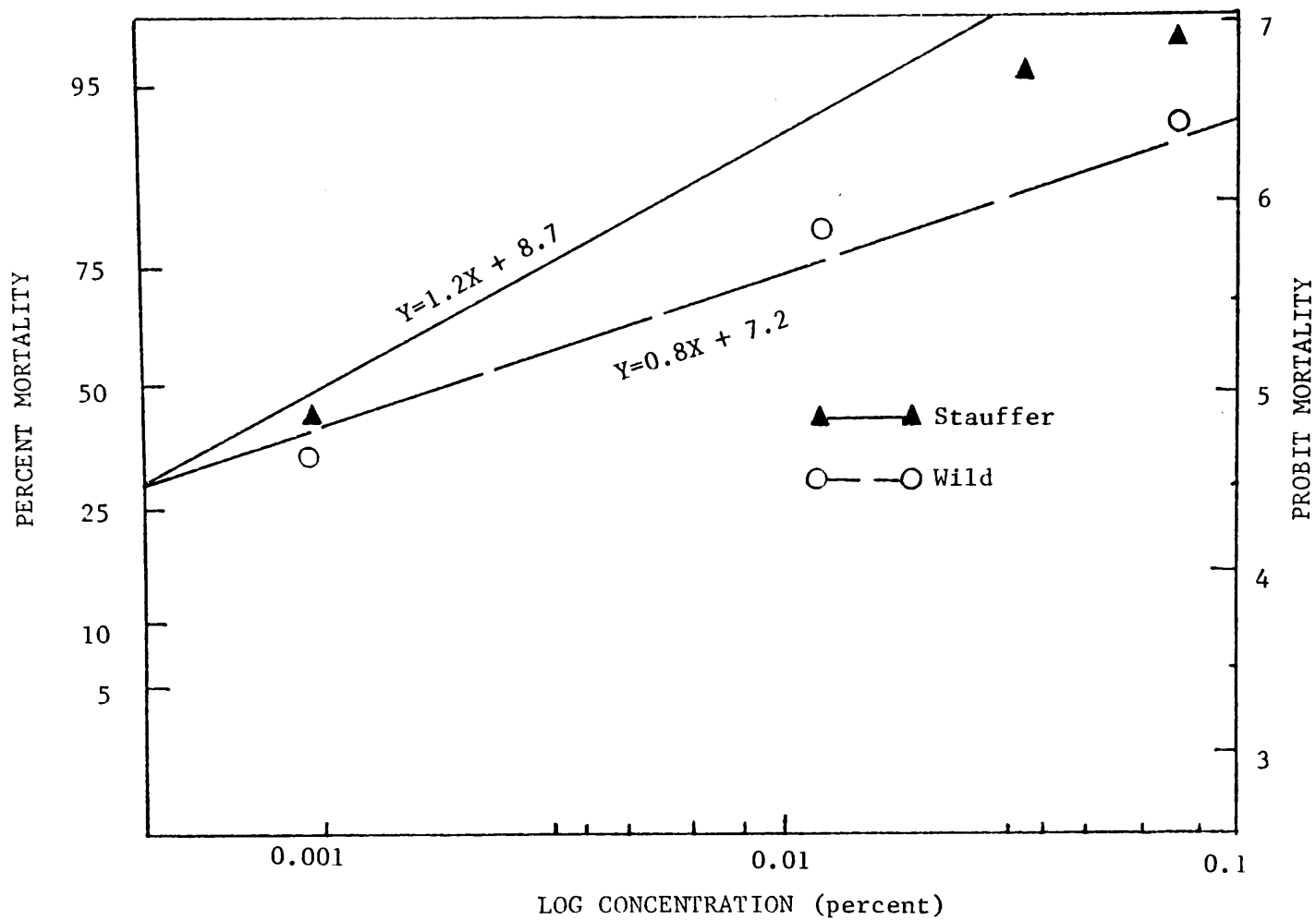


Figure 2. Response of third-stage Stauffer and Wild-strain house fly larvae to diazinon.

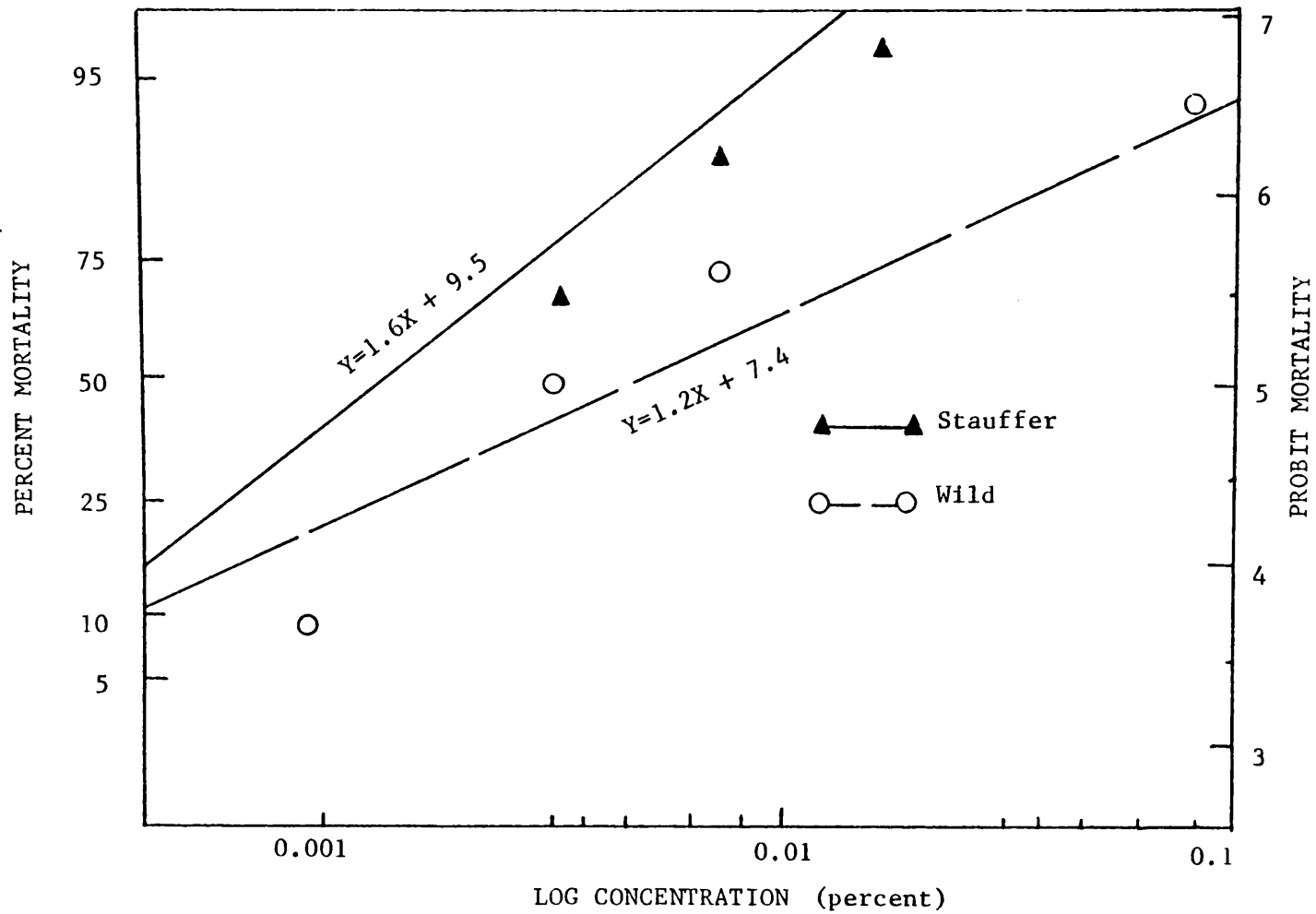


Figure 3. Response of third-stage Stauffer and Wild-strain house fly larvae to supona.

This may explain the higher ratios as compared to diazinon. However, the application history of the chicken house from which the wild flies were collected is not known.

Dimethoate was uniformly toxic to both house fly strains (Fig. 4). Sherman and Ross (1960) showed that dimethoate was among the most effective of 23 insecticides tested for larvicidal properties. This insecticide was found to have a degree of selective toxicity to house fly larvae over the predatory mite Macrocheles muscaedomesticae (Scopoli) (Acarina: Macrochelidae) (Axtell 1966).

The greatest LC_{50} ratios resulted from dipping tests with Ravap (Fig. 5). The respective ratios were 6.7 : 1 and 25 : 1. Ravap is recommended as a larvicide, residual spray, in resin strips, and in poison baits. It is possible that both larval and adult house flies may be exposed to the material. This would result in more intense selection pressure against a population.

Stirofos, one of the active ingredients of Ravap, also may be used as a larvicide and adulticide in Virginia. The LC_{50} ratio for wild versus Stauffer flies was 3.3 : 1, while the LC_{95} ratio was 1.5 : 1 (Fig. 6). The wettable powder formulation may have been less suitable for evaluation in a dip test than an emulsifiable concentrate. However, stirofos was not available in the latter form.

The log dose-response plots for SD 43775 and Ectiban appear in Figures 7 and 8. While Ectiban was slightly more effective, slopes of these lines show no great differences in intrinsic toxicities of the two pyrethroids between strains.

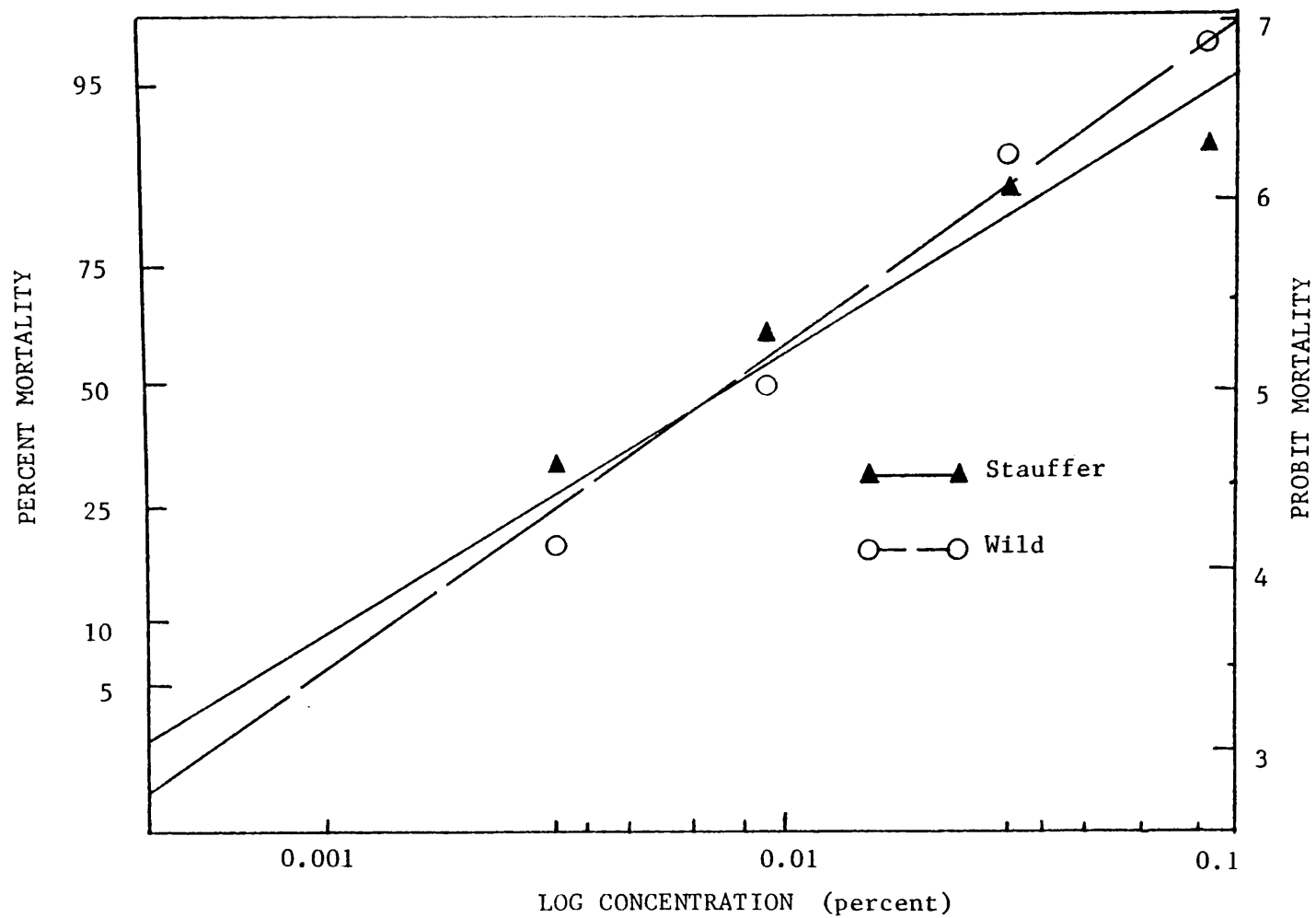


Figure 4. Response of third-stage Stauffer and Wild-strain house fly larvae to dimethoate.

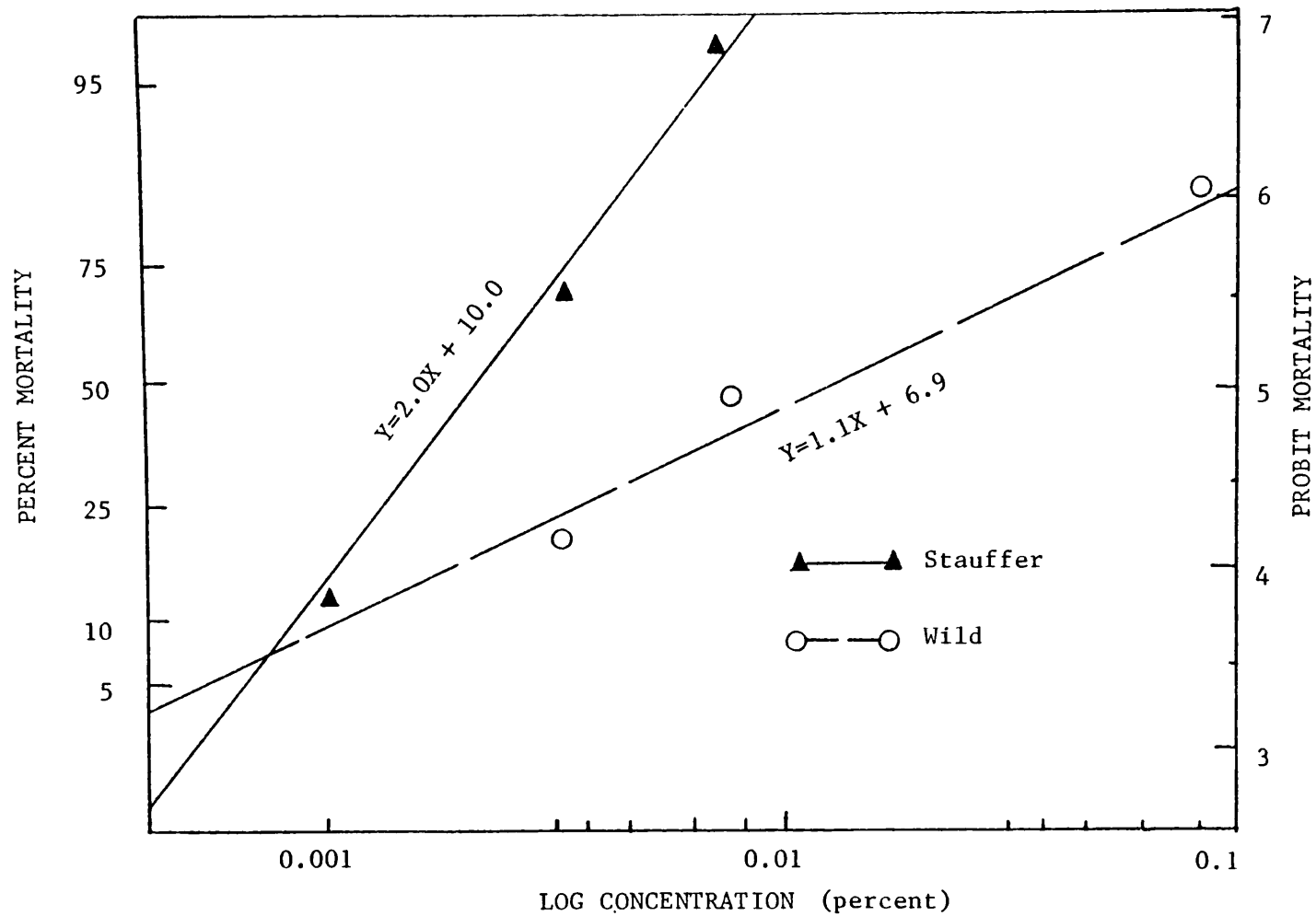


Figure 5. Response of third-stage Stauffer and Wild-strain house fly larvae to stirofos + dichlorvos.

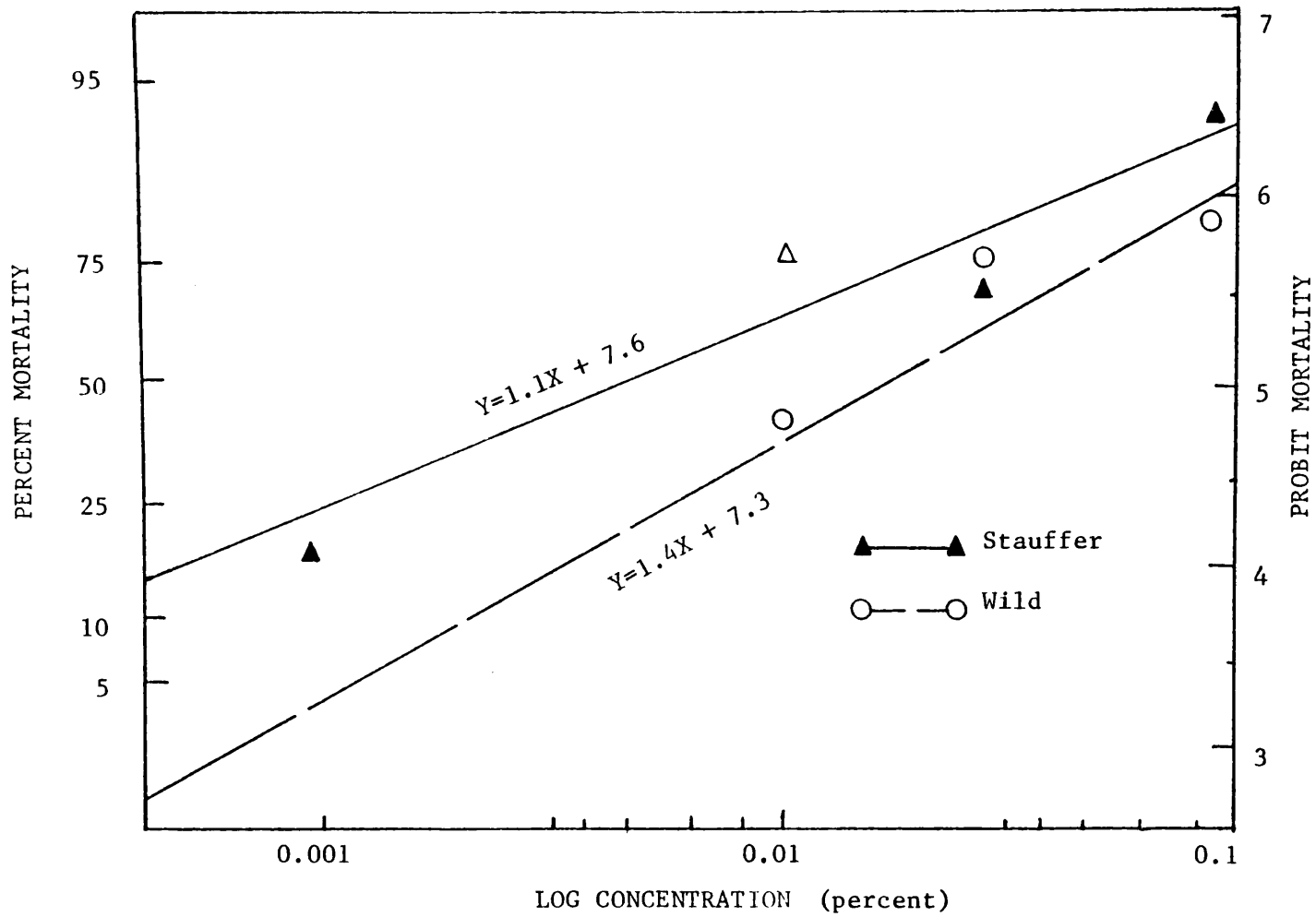


Figure 6. Response of third-stage Stauffer and Wild-strain house fly larvae to stirofos.

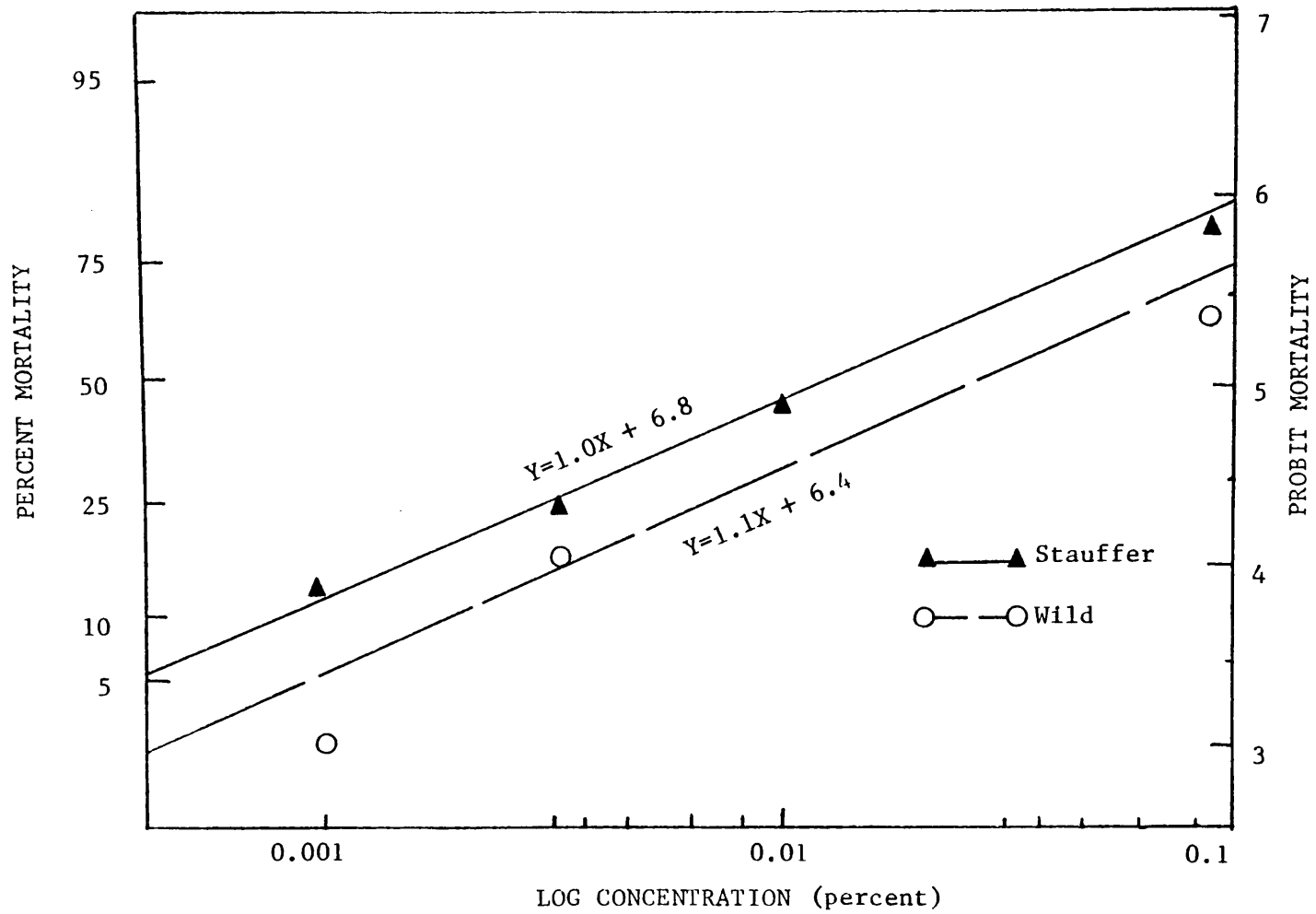


Figure 7. Response of third-stage Stauffer and Wild-strain house fly larvae to SD 43775.

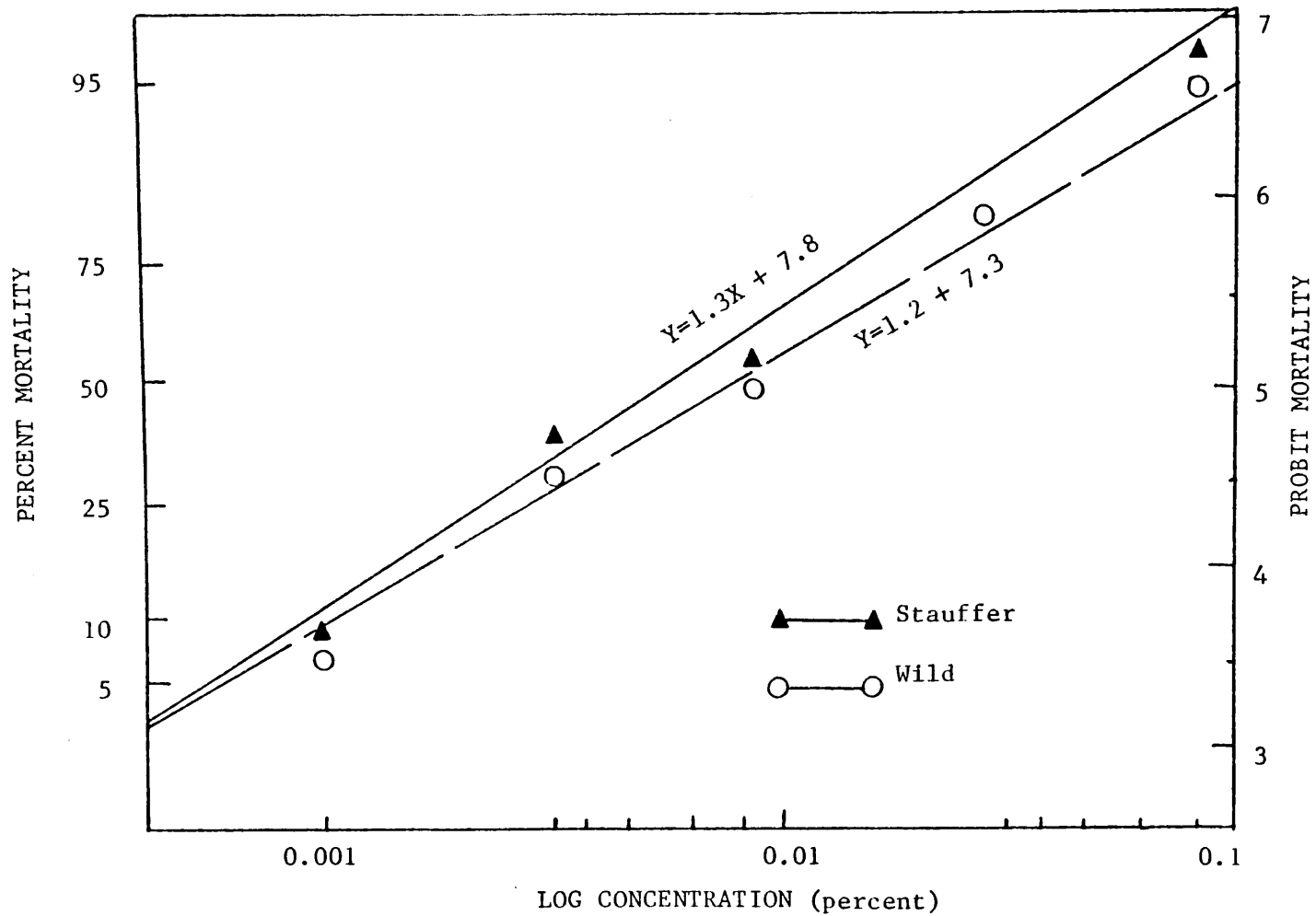


Figure 8. Response of third-stage Stauffer and Wild-strain house fly larvae to Ectiban.

Toxicity of Ectiban sprays on chicken manure. Data from the dip tests showed the larvicidal activity of Ectiban to be comparable to that of currently used materials. Therefore, the pyrethroid was evaluated as a topical larvicide.

Chicken manure collected from the VPI&SU Poultry Science Center was placed in 50 x 20 x 10 cm galvanized trays and frozen to kill any insects present in the droppings. After three days, the trays were thawed and Ectiban at 0, 0.0625, 0.125, and 0.25% active ingredient (w/w) was applied at the rate of 0.4 l per m² (1 gal/100 ft²).

Two trays were sprayed with each concentration. After treatment, they were seeded liberally with Stauffer strain house fly eggs. These trays were incubated at 26^o C until numerous pupae were seen on the surface of the control manure. The contents of each tray were divided into eight emergence cartons and examined for flies.

Fly production from samples of chicken manure treated with selected rates of Ectiban appear in Table 2. The pyrethroid was effective as a topical manure spray. Most larvae hatching from eggs seeded on the manure probably received a lethal amount of the insecticide as they crawled over the surface of the manure.

One disadvantage of the tray test is reflected in the large standard error of the control means. The larvae tend to congregate in areas of the pans to pupariate. The resulting aggregation created samples which contained diverse numbers of pupae. However, the technique is satisfactory for determining the effectiveness of a maintenance-type spray application. In this case, the target is the newly-hatched larvae. The goal is to prevent the larvae from entering the manure

Table 2. House fly production from pans of poultry manure seeded with house fly eggs following topical treatment with Ectiban at the rate of 1 gallon/100 ft².

Percentage conc (w/v)	Mean no. flies produced
0.25	0.4 ± 0.2*
0.125	1.3 ± 0.4
0.0625	1.1 ± 0.3
0	92.8 ± 29

* Mean ± SE

where they are more difficult to control. This application may be justified on piles of manure which are awaiting disposal, or as spot treatments.

Toxicity of Ectiban in fly breeding media. Under the proper conditions, larvicides may be an effective means of achieving fly control. However, numerous factors influence the degree of success. First, the moisture content of the manure is important in determining the amount of penetration of the insecticide. Under conditions of moderate moisture, the material may be effective to a depth of 7 cm. This may be reduced to 0.8 cm in dry manure. Also, fresh manure is being deposited continuously. These untreated feces will cover the area treated and provide breeding substrate. This necessitates frequent reapplications to achieve lasting results (Sampson 1956).

The feed additive approach to larviciding provides adequate mixing of the manure and toxicant. It also eliminates the need for spraying equipment needed to apply conventional larvicides topically (Miller 1970).

This series of experiments were designed to evaluate the effectiveness of Ectiban as a feed additive for the control of manure-breeding flies. Initially, Ectiban was added to a commercial larval media and to chicken manure to determine concentrations of the pyrethroid lethal to house fly larvae. These data aided in the selection of dosages to be used in a feed through experiment.

CSMA tests. Approximately 100 first-stage larvae were seeded onto 300 gm portions of CSMA media containing Ectiban in concentrations of 0, 3, 5, 10, 25, and 50 ppm active ingredient. Doses were replicated four

times. Also, 50, second-stage larvae were placed on each of five, 200 gm replicates of CSMA media containing 0, 5, 10, 25, 50, or 100 ppm Ectiban.

Since the manure samples from the feed through experiment would be collected daily and frozen until use, four additional replicates of 0, 10, and 50 ppm media were prepared and frozen at 0° C for 145 days. Then, these samples were thawed and seeded with approximately 100 first-stage larvae to determine if freezing would affect the pyrethroid.

Fly production data from first-stage larvae reared on treated media appear in Table 3. The lowest concentrations, 3 and 5 ppm, resulted in 49% and 96% reductions in fly production, respectively. No adult flies developed from the media which had been frozen after the addition of Ectiban. This indicated that no insecticidal activity was lost as a result of freezing.

Mold growth on these samples was a problem. While fly development was not impeded, it was difficult to process the replicates to recover adult flies. Born (1954) recommended placing a layer of sand on the surface of the fly media to alleviate the problem and to provide a pupariation site for the larvae. This suggestion was followed in all subsequent rearing experiments

Table 4 contains mean house fly production from media seeded with second-stage larvae. Survival of this stage was greater than that of first-stage larvae at the lower concentrations of active ingredient.

Chicken manure test. Manure from a commercial chicken house was frozen in 500 gm lots in plastic bags to kill those larvae present. After thawing, the desired amount of a stock solution of Ectiban was

Table 3. House fly production from first-stage larvae reared on Purina^r CSMA fly larvae media containing selected concentrations of Ectiban.

Ectiban (ppm a.i.)	Mean no. adults (4 reps)	Percentage reduction
50	0a*	100
25	0a	100
10	0a	100
5	5.0a	96
3	63.3b	50
0	125.5c	0

* Means within columns not showing a common letter are significantly different at the 5% level.

Table 4. House fly production from second-stage larvae reared on Purina^r CSMA fly larvae media containing selected concentrations of Ectiban.

Ectiban (ppm a.i.)	Mean no. adults (5 reps)	Percentage reduction
100	0.2a*	99
50	1.2a	97
25	3.4a	93
10	7.2a	84
5	25.8b	44
0	45.8c	0

* Means within columns not showing a common letter are significantly different at the 5% level.

added to obtain four replicates of 0, 1, 5, 10, 50, and 100 ppm active ingredient concentrations. The bags were kneaded to mix the insecticide and manure. Each sample was seeded with approximately 200 first-stage larvae.

Fly production data from the Ectiban manure mixes are summarized in Table 5. Fly production from the 5 and 10 ppm doses of Ectiban was greater than the corresponding results in the artificial media tests. Probably, this was due to incomplete mixing of the insecticide in the thick manure.

From these data, I selected three rates of Ectiban: 5, 10, and 50 ppm a.i. for feed treatment in the caged-layer experiment. The 5ppm level was expected to provide partial control, while the 10 and 50 ppm levels were expected to be sufficiently toxic to house fly larvae to prevent development.

Toxicity of manure from chickens fed Ectiban-treated rations. An encapsulated formulation of 20% Ectiban was mixed into commercial breeder mash containing by weight: 536 parts yellow corn meal, 100 parts pulverized oats, 50 parts wheat flour midlings, 25 parts wheat bran, 25 parts alfalfa meal, 30 parts fish meal and bone scraps, 80 parts soybean oil meal (49% protein), 20 parts stabilized fat, 4 parts iodized salt, 70 parts ground limestone, 5 parts defluorinated phosphate, 0.25 parts manganese sulfate, and 5 parts of a vitamin premix. The required amount of Ectiban in 25 ml of distilled water was applied with a chromatography sprayer as layers of feed were added to a large mixing bowl. A Model H600 Hobart bakery mixer blended the rations.

Table 5. House fly production from first-stage larvae reared on chicken manure containing selected concentrations of Ectiban.

Ectiban (ppm a.i.)	Mean no. adults (4 reps)	Percentage reduction
100	0.8*	99
50	12.7a	94
10	70.2b	67
5	187.5c	9
1	192.0c	6
0	205.1c	0

* Means within columns not showing a common letter are significantly different at the 5% level.

The treated feed was consumed by 19-week-old White Leghorn hens which were fed and watered in groups of five. There were three replicates of five birds for each treatment rate. They consumed treated feed for seven days.

All the manure was taken daily from each replicate, placed in plastic bags, and frozen immediately at 0° C. After completion of the seven day experiment, all samples were weighed, thawed, and placed in emergence containers. About 75 house fly eggs were placed on each manure sample.

Feed consumption rates (gm/bird/day) during the trials were 0 ppm- 79.1, 5 ppm- 76.6, 10 ppm- 82.8, and 50 ppm- 72.7. These were determined by weighing the feed bags before and after the tests. Feed trays were only half-filled to reduce waste, but some feed was spilled by the birds. The computed daily intakes of Ectiban were 0.4 mg for hens consuming 5 ppm feed, 0.8 mg from 10 ppm feed, and 3.6 mg from 50 ppm feed.

Manure output from the test birds increased during the first six days of the test (Table 6). These hens had been housed on the floor prior to being confined in individual cages for the experiment. Although the test began three days after they were caged, it is evident that the birds were still adjusting to the new environment. Seven day mean manure outputs for the 0, 5, 10, and 50 ppm treatments were not significantly different ($P > 0.05$).

Many hens came into laying condition during the test, but not enough to provide reliable data on egg production. Ectiban is relatively nontoxic to birds. The acute oral LD₅₀ for the Japanese quail is in

Table 6. Manure output of White Leghorn hens consuming rations containing encapsulated Ectiban at selected rates.

Day manure collected	Treatment rates in feed			
	0 ppm	5 ppm	10 ppm	50 ppm
1	44.4*	37.4	46.9	35.1
2	61.5	47.8	56.2	46.3
3	68.0	60.5	70.4	60.2
4	72.8	64.0	76.3	67.4
5	73.4	70.8	80.4	76.7
6	91.9	86.9	92.4	87.1
7	74.7	74.3	84.0	74.3
1 - 7	69.5	62.7	72.4	63.9

* Mean of three replicates

excess of 13,500 mg/kg; the LD₅₀s for the mallard duck and pheasant exceed 23,000 mg/kg (ICI 1977). As expected, no birds died during the trial, and none exhibited gross ill-effects from the Ectiban-treated rations.

Mean fly production for the seven treatment days and grand means appear in Table 7. The results were somewhat erratic, however, overall fly production from the manure of birds fed encapsulated Ectiban at 10 ppm and 50 ppm rates were lower and significantly different from the 0 and 5 ppm data. Ectiban concentrations and percentage reduction of overall treatment means based on the control mean were: 5 ppm, 12.1; 10 ppm, 25.8; and 50 ppm, 37.8.

Undoubtedly, increased levels of Ectiban in the ration would have caused greater mortality of the house fly larvae. However, a log dose probit plot of the percentage reduction versus the three Ectiban concentrations used in the feed through indicated that about 100 ppm would be necessary for 50% control (Fig. 9). The preceding media experiments showed that the toxicity of Ectiban was greater than that demonstrated in the feed trial.

The efficiency of the encapsulated formulation in protecting the pyrethroid was unknown prior to the test, so that the 10 and 50 ppm feed rates seemed to allow for some loss of activity. The wall polymer, which encapsulated Ectiban, was essentially a polyurea. The chemical release was based on vapor diffusion through this wall. The rate of release was a function of the permeability of the polymer. The formulation excipients remain confidential to the manufacturer.

Table 7. House fly production from first-stage house fly larvae seeded on manure from hens fed rations treated with selected concentrations of encapsulated Ectiban.

Day manure collected	Treatment rates in feed			
	0 ppm	5 ppm	10 ppm	50 ppm
1	76.7a*	88.3a	91.7a	88.3a
2	116.0a	77.0a	79.3a	31.0a
3	56.0a	35.7a	33.0a	31.0a
4	68.3a	62.7a	65.0a	21.3b
5	37.0a	40.0a	35.3a	63.7a
6	70.0a	80.0a	62.7a	52.3a
7	73.7a	64.0a	20.7	12.3b
2 - 7	72.8a	64.0a	54.0b	45.3b

* Means within rows not showing a common letter are significantly different at the 5% level.

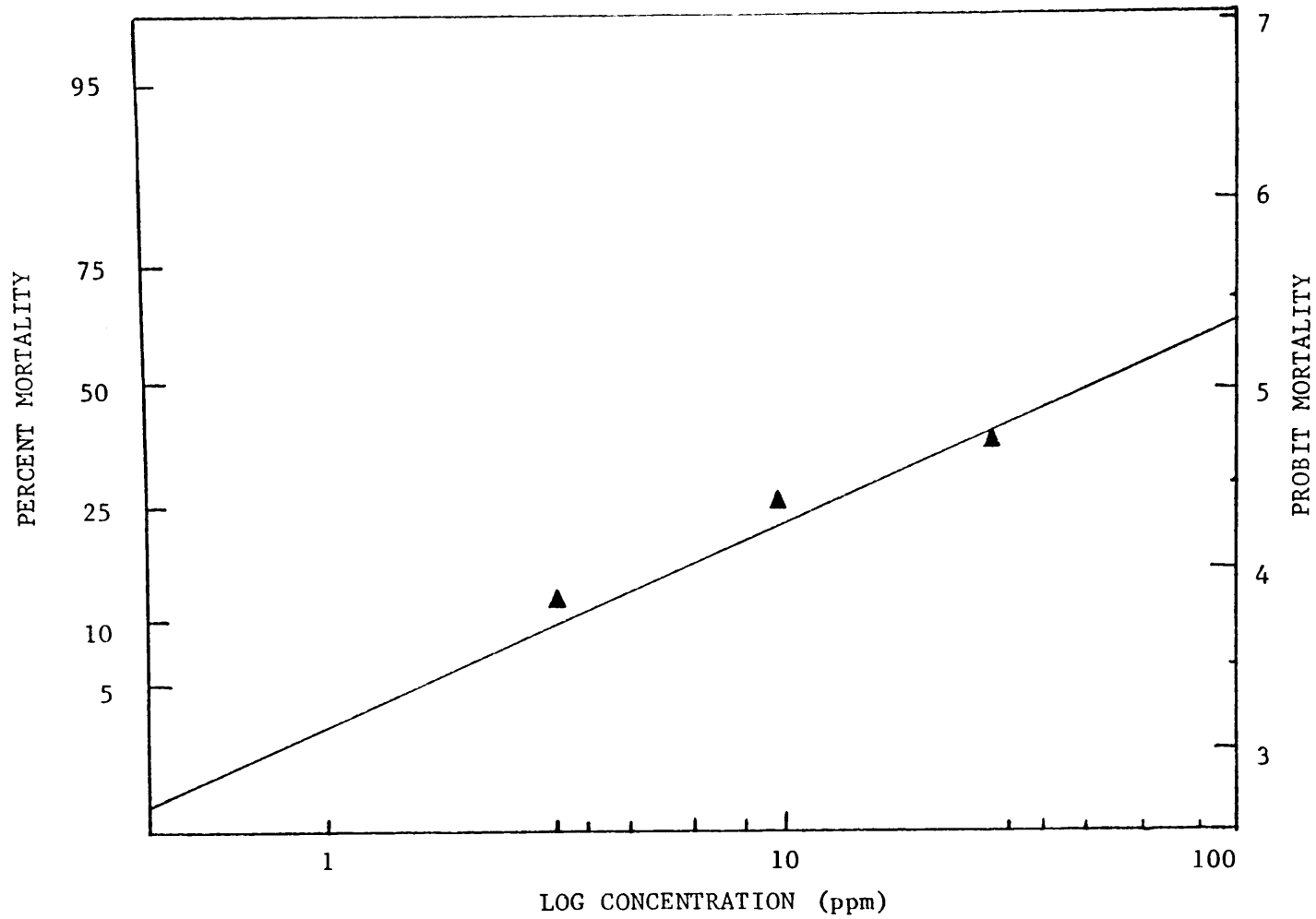


Figure 9. Response of first-stage house fly larvae to manure from hens fed Ectiban-treated rations.

The fate of Ectiban as a toxicant in the gut of a rooster. The limited effect on house fly breeding indicated that only small quantities of Ectiban were active in the manure. Possible explanations included: 1) incorrect preparation of treated feed; 2) premature release of the pyrethroid in the birds; 3) failure of the encapsulating material to release the insecticide in the manure; and 4) a combination of these factors. These alternatives were examined in the following series of bioassay experiments.

Acetone solutions of technical grade Ectiban were used to establish 0, 0.1, 0.5, 1.0, 2.5, and 5.0 μg m residues of the pyrethroid on the inner surface of 12 dram glass vials. One ml of each concentration per vial was used to prepare eight replicates of each dose. The vials were laid on a table and rotated slowly so that the material was deposited evenly inside the vials. Then, the vials were dried in front of a fan for one hour. Subsequently, 10, 4 to 6-day-old female Stauffer strain house flies were put in each vial for one hour. This exposure period was used in all bioassay tests.

The standard curve resulting from analysis of the mortality data from the vial residue tests appear in Figure 10. The slope of the log dose-probit plot was 3.3. This curve enabled estimation of Ectiban quantities in acetone extracts of feed, gut contents, and manure samples from a test bird

Feed bioassay. Two, one gram samples of 50 ppm feed were placed in vials with 10 ml of acetone. The calculated Ectiban concentration in this extract was about 5 μg m/ml. At this strength, the dosage would

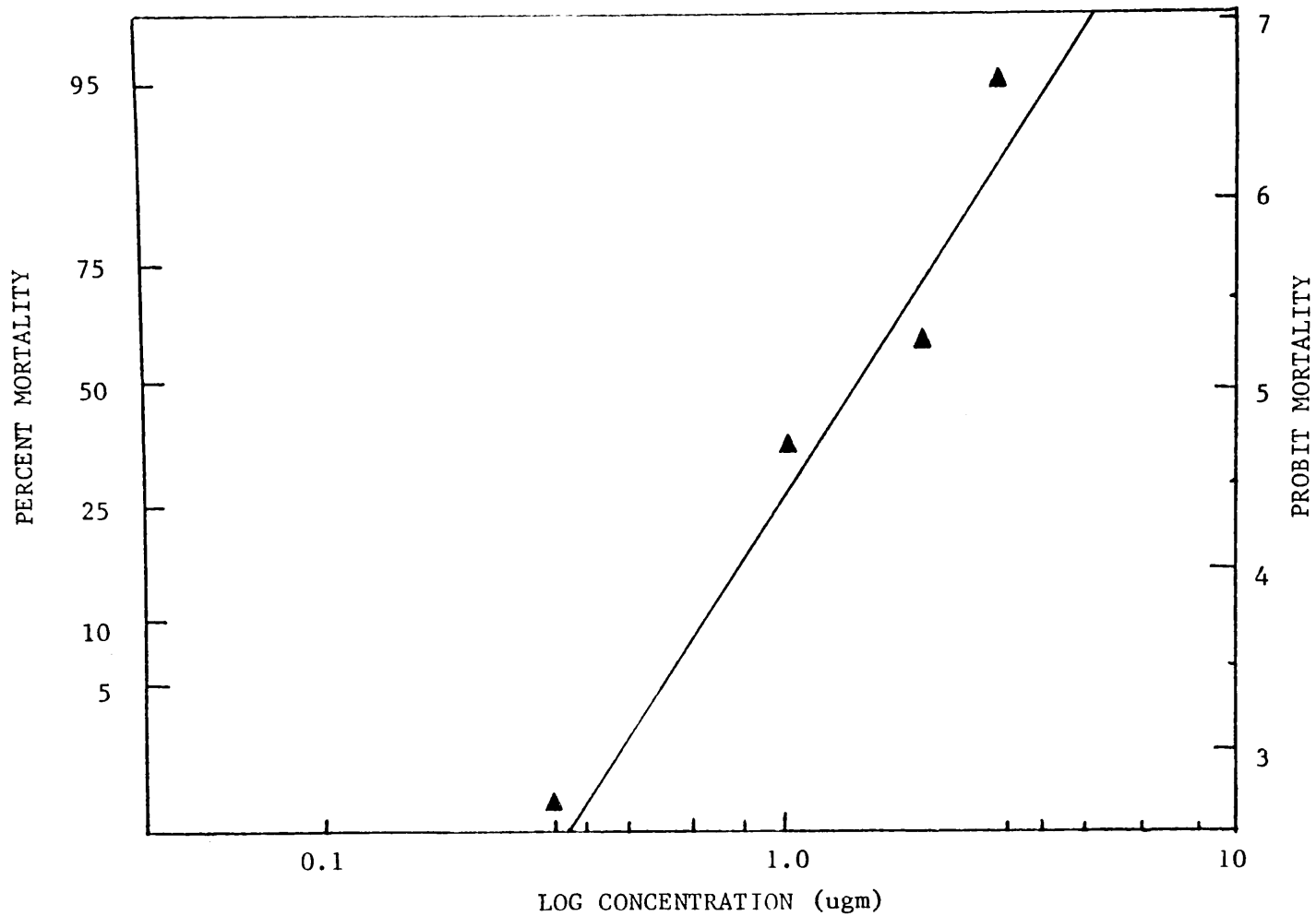


Figure 10. Response of groups of 10 female house flies to Ectiban residues in glass vials.

kill 100% of the exposed flies (Fig. 10). Therefore, portions of these extracts were drawn off and diluted further with acetone. Eight replicates of the following dilutions were prepared: 1:2, 1:3, 1:4, and 1:6 (i.e., 1 ml extract + 1 ml acetone + 1:2).

The house fly mortalities from this bioassay are summarized in Table 8. The equivalent Ectiban concentrations were calculated as follows: The mortality from exposure to the 1:2 dilution of Sample A was 79%. This value was converted to μgm of Ectiban by use of Figure 10, about 3 μgms . The 3 μgms must be multiplied by 20 to arrive at $\mu\text{gm/gm}$ (ppm), since the original extract was diluted by this factor. The same procedure was followed for the other dilutions and the final concentrations averaged to arrive at a final value. The calculations from Samples A and B indicated that the mean level of Ectiban in the ration was about 60 ppm. Thus, the pyrethroid was present at approximately the desired dosage.

Gut content bioassay. A 1-year-old White Leghorn rooster was given 50 ppm Ectiban-treated feed for four days. The bird was killed and samples were taken from the crop, proventriculus, two locations along the small intestine, each cecum, and the rectum. Feed and manure samples were collected from the cages. The gut content and manure samples were dried prior to extraction with acetone.

Sample weights and acetone volumes appear in Table 9. The number of replicates prepared varied depending on the sample available. Bioassay analyses indicated that the presence of Ectiban in the feed, crop, proventriculus, small intestine, and manure extracts diminished. The house fly mortalities are summarized in Table 10.

Table 8. Corrected mean house fly mortalities resulting from bioassays of extracts of 50 ppm Ectiban-treated feed.

Sample A		Sample B	
<u>Dilution</u>	<u>% mort.</u>	<u>Dilution</u>	<u>% mort.</u>
1:2	79 ± 7*	1:2	83 ± 2
1:3	67 ± 6	1:3	72 ± 8
1:4	35 ± 10	1:4	63 ± 9
1:6	9 ± 9	1:6	27 ± 10

* Mean ± SE

Table 9. Sample weights and acetone extract volumes from samples collected for Ectiban bioassay of the gut contents of a rooster.

Sample	Sample weight (gm)	Acetone volume (ml)
Feed	1.0	10
Crop	1.0	10
Proventriculus	0.5	5
Small intestine 1	0.6	5
Small intestine 2	1.0	10
Cecae	0.8	5
Rectum	0.2	4
Manure	1.0	10

Table 10. Percentage mortalities of female house flies exposed to residue extracts of samples from a rooster fed 50 ppm Ectiban-treated feed.

Sample	No. reps	Mean mortality
Control	3	0
Feed	5	100
Crop	5	100
Proventriculus	4	90
Small intestine 1	5	54
Small intestine 2	3	10
Cecae	5	0
Rectum	3	0
Manure	5	8

The relative concentrations of Ectiban in these samples, as reflected by fly mortalities decreased as the feed progressed along the digestive tract (Fig. 11). A slight reduction is noted between the crop and proventriculus. The first sample from the small intestine (SI 1) was taken from the duodenum. The second sample (SI 2) came from the posterior third of the intestine. By SI 1, fly mortality from the acetone extract had decreased by 40%. The SI 2 sample extracts produced a 10% mortality, in contrast to 90% from the crop sample. Apparently, the greatest loss of the toxicant occurred along the small intestine.

There was no fly mortality from exposure to cecal and fecal extract residues. The rectum is short, and only a 0.2 gm sample was present. Assuming a 90% loss of the pyrethroid by this point, the remaining concentration would be below the sensitivity range of the bioassay procedure.

The mortality difference between SI 2 and the manure samples suggests that no further loss of insecticidal activity occurs prior to elimination of the feces. In chickens, the major part of all digestion occurs in the small intestine (Card and Nesheim 1972). While my data indicated that the insecticidal properties of Ectiban were inactivated in this region, it does not infer that digestive enzymes were the principal cause. Ectiban is unstable at alkaline pH (Tsuda 1976). The hind gut of a chicken provides such an environment.

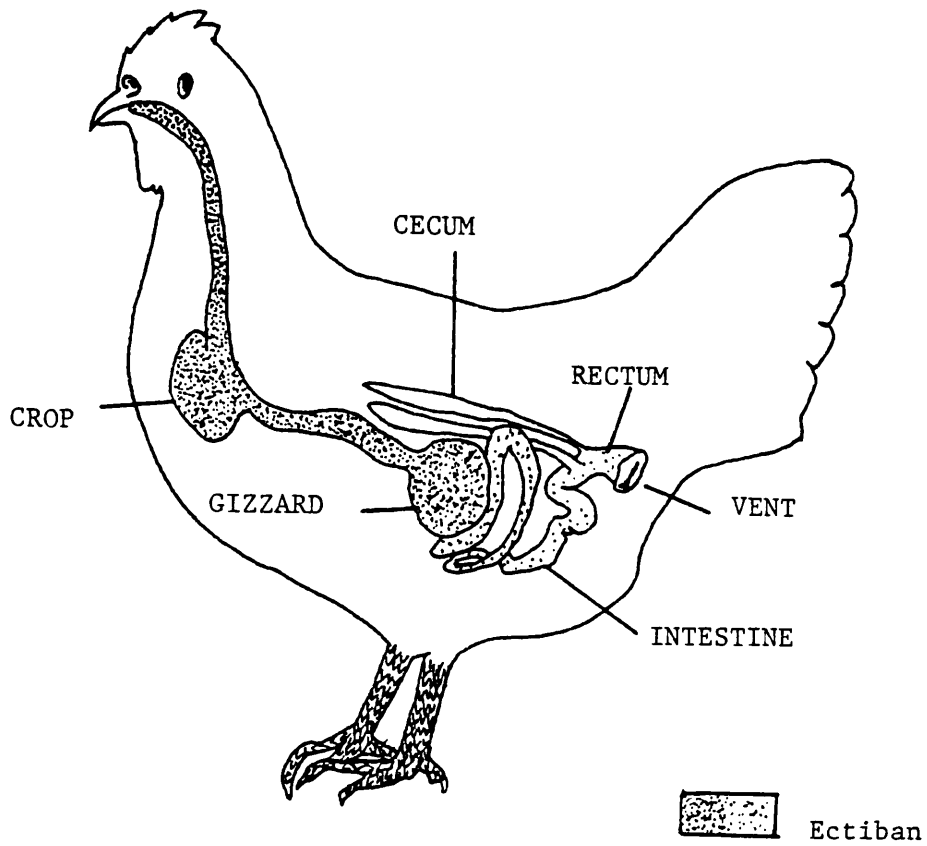


Figure 11. Schematic representation of the fate of Ectiban in the digestive tract of a rooster.

V. EFFECTS OF ECTIBAN ON CERTAIN NONTARGET ARTHROPODS

There is a varied fauna associated with chicken manure. In addition to the filth-breeding synanthropic flies, several species of hymenopterous parasites, predaceous beetles, flies, and mites may be abundant. Many of these organisms consume or parasitize fly eggs, larvae, or pupae, and some act indirectly to render the breeding matter unsuitable for fly development.

Most of the insecticides used for fly control are toxic to a spectrum of nontarget insects and mites. Often, the fly population may recover more rapidly from applications than do beneficial species (Anderson 1965). Therefore, it is important to consider representative biological control agents when assessing the toxicity of a compound. These data aid in selecting application techniques which will minimize the effects on nontarget organisms. The following toxicity tests were conducted by exposing Macrocheles muscaedomesticae, Mormoniella vitripennis (Walker) (Hymenoptera: Pteromalidae), and Alphitobius diaperinus Panzer (Coleoptera: Tenebrionidae) to Ectiban.

The Macrochelidae are the most abundant of five acarine families collected from domestic animal manure (Axtell 1963a). Macrocheles muscaedomesticae is usually the only macrochelid found in chicken manure and is a predator of house fly eggs and first-stage larvae (Wade and Rodriguez 1961; Axtell 1963a, 1963b). The importance of manure inhabiting mites on house fly production has been documented (Axtell 1963b, 1967). Fly control practices should be designed to minimize the disruption of these populations.

Mormoniella vitripennis was found parasitizing Fannia femoralis (Diptera: Muscidae) and Phormia regina (Meigen) (Diptera: Calliphoridae) in southern California (Legner 1966). However, this parasite was reared infrequently from field collections of house fly pupae (Legner 1967). Legner suggested that the inability of the wasp to locate host pupation sites in the manure prevented it from being effective in regulating house fly populations. Also, Varley and Edwards (1957) noted the random searching behavior of M. vitripennis adversely affected the wasp's effectiveness as a parasite. Natural hosts of this pteromalid seem to be limited to fly species that habitually pupariate near the surface of their breeding material (i.e., Fannia spp., Lucilia spp., and Calliphora spp.).

This type of parasite spends much time on fly breeding surfaces and may be subjected to larvicides. Its general size and habits are representative of several hymenopteran parasites of dung-breeding Diptera. Therefore, it is a suitable organism for toxicity tests involving nontarget organisms. These wasps were obtained from a wild strain maintained by Carolina Biological Supply Co., Burlington, North Carolina.

Procedure. The above nontarget species were tested using a pipet technique. This involved depositing an insecticide residue inside standard Pasteur pipets and exposing test organisms for uniform time periods (Foulk and Matthyse 1964).

Bolting cloth (100 mesh) was glued over the large end of the pipet with epoxy cement. Groups of 20 pipets were immersed in one of several

acetone solutions of technical Ectiban. The graded solutions were prepared on a weight-volume basis. Pipets for controls were immersed in acetone. Each dose was replicated eight times.

Twenty adult Macrocheles muscaedomesticae from a laboratory colony were drawn into each tube using an electric pump set to deliver a light vacuum. Then, the open end of the pipet was plugged with modeling clay. The same procedure was used for the hymenopteran parasite. Twenty adult females were placed in each tube. About 0.5 cm of the tip of each pipet was broken off so that these larger insects could enter easily.

All pipets were held in an environmental chamber at 27°C and 80% relative humidity and mortality was assessed after 24 hours using a stereomicroscope. The criterion of death was the cessation of movement.

The tests using Ectiban against Mormoniella vitripennis produced an LC₅₀ of 0.003%, while the LC₅₀ against Macrocheles muscaedomesticae was 0.002%. The flatter slope of the latter plot, 0.5 compared with 1.3, indicated that Ectiban may be intrinsically less toxic to the mite (Figs. 12 and 13).

Axtell (1966) evaluated the toxicities of 17 insecticides against third-stage house fly larvae and adult female Macrocheles muscaedomesticae. Only five materials were more toxic to fly larvae than to the mites. The two exhibiting the greatest selectivity for house fly larvae were Kepone^r (decachlorooctahydro-1,3,4-metheno-2H-cyclobuta-(cd)pentalen-2-one) and dimethoate. While the latter is recommended as a larvicide in Virginia, Kepone is not suitable for use.

Control strengths of insecticides, frequently about 0.5% a.i., exceed the discriminating dosage levels (about 0.005% a.i.) at which

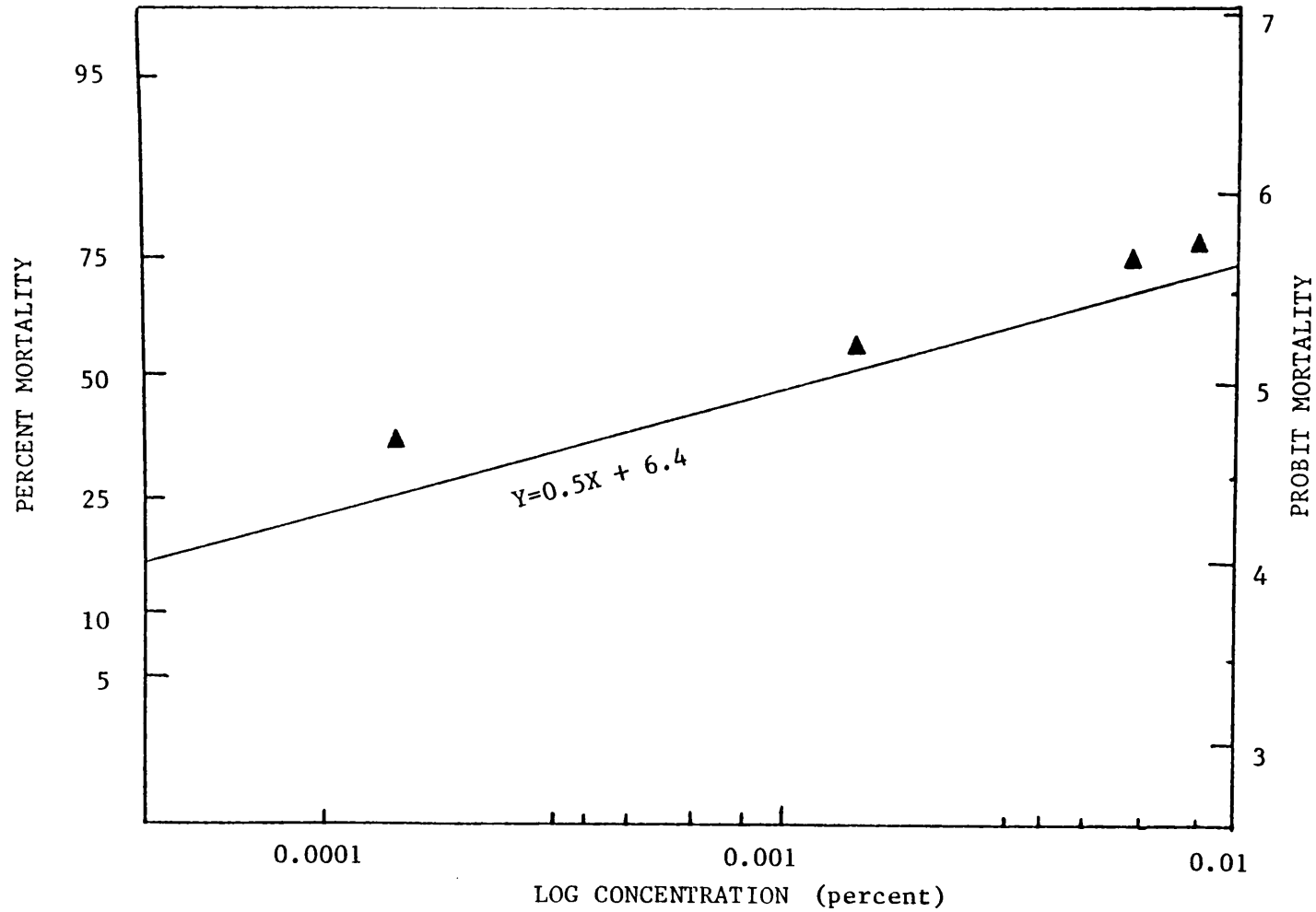


Figure 12. Response of *Macrocheles muscaedomesticae* to Ectiban.

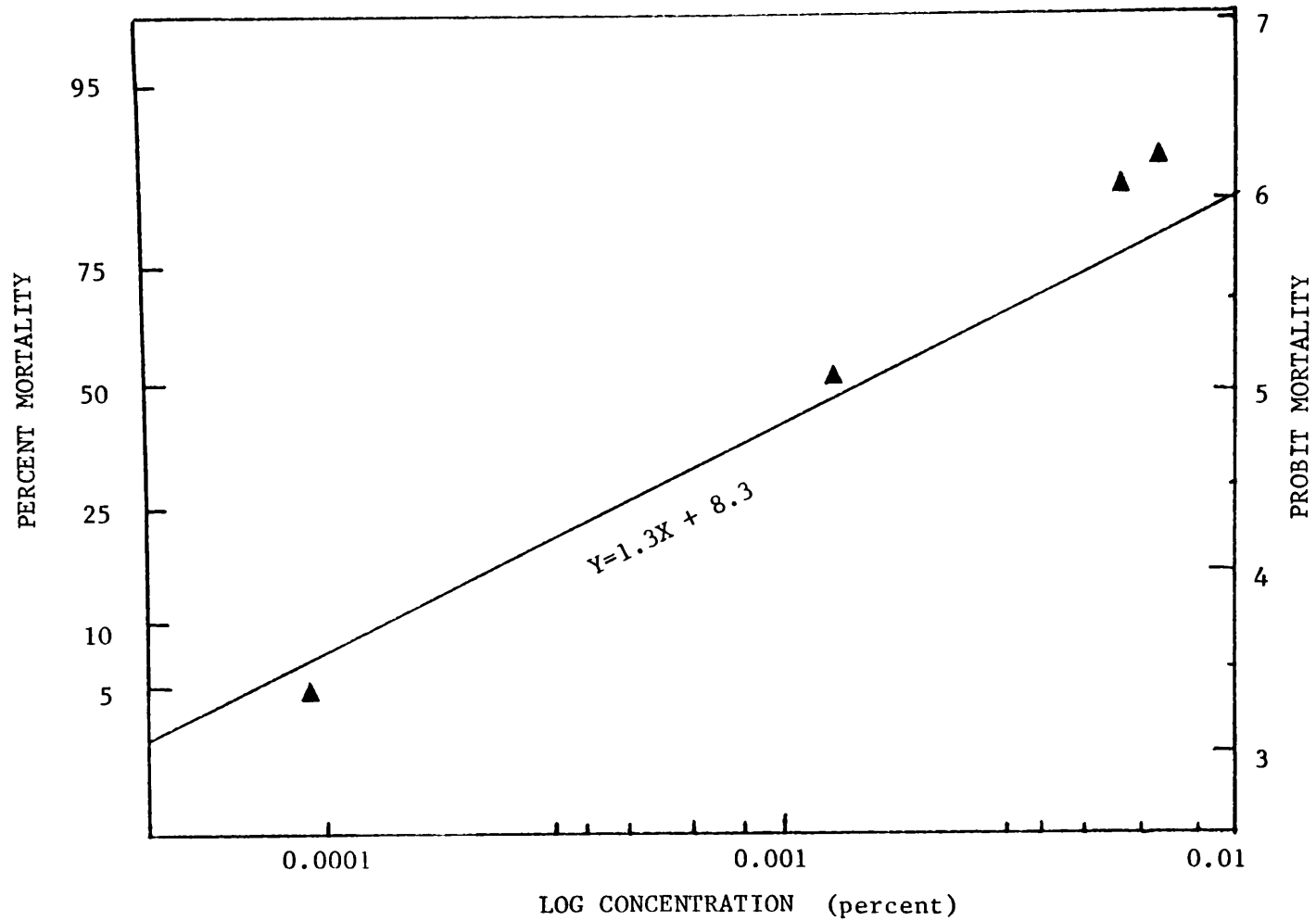


Figure 13. Response of *Mormoniella vitripennis* to Ectiban.

selective toxicity between pest and nontarget species may be of value. Axtell (1968) reported that when 12 insecticides, which showed selective toxicity to fly larvae in the laboratory, were tested on poultry manure for fly control, no selective advantage was noted. The few chemicals which did not destroy mite populations gave very little control of fly larvae, while those that gave some fly control were deleterious to the mite populations. The mites recovered slowly from these treatments, in contrast, numbers of fly larvae increased rapidly. He considered selective application methods for adult fly control to be preferable.

Alphitobius diaperinus, the lesser mealworm, may occur in great numbers in chicken litter or droppings. The larvae and adults are active in the breeding matter. Their burrowing activities promote drying of the manure and impede fly development. Under these circumstances, the species may be considered a biological control agent of manure-breeding flies (Legner and Olton 1968).

Alphitobius diaperinus has been reported as a predator of Dermanyssus gallinae Redi (Acarina: Dermanyssidae), the chicken mite (Kozlov 1970). However, this insect is not entirely beneficial. It has been incriminated as a host for the common cecal worm of poultry in Hawaii (Alicata 1939). The beetle can transmit acute avian leukosis, also (Edison et al. 1966). The first detailed biology of the species was reported by Lancaster and Simco (1967). They suspected it to be a reservoir of avian leukosis. The larvae may feed on the flesh of moribund and dead chicks (Harding and Bissell 1958). Their potentially large populations and the propensity to disperse makes them an effective

potential dissiminator of pathogenic bacteria. In addition, the beetles may cause structural damage in chicken houses as they tunnel into styrofoam insulation.

Ectiban-treated media tests against *Alphitobius diaperinus* larvae.

An emulsifiable concentrate formulation of Ectiban was added to a combination of CSMA house fly media, Brewer's yeast, and water at the rate of 0, 5, 10, 20, 30, and 45 ppm active ingredient. Three, 300 gm portions of the media were placed in wax-lined paper cups. Twenty full-grown larvae, each about 2 cm in length, were placed on the media, and a screened top was placed over the container to confine the larvae.

After 48 hours on the media, the larvae were removed, observed for signs of intoxication, and placed in cardboard chambers. Mortality counts were made after a 24 hour recovery period and are summarized in Table 11. All larvae placed on treated media remained on the surface. Unlike larvae on the untreated controls, they had not burrowed into the media. These larvae rolled and twisted violently when touched with forceps. Control larvae did not exhibit this exaggerated response.

These toxicity data indicate an LC_{50} of about 0.003% a.i. This is comparable to the LC_{50} values for Ectiban against house fly larvae, *Macrocheles muscaedomesticae*, and *Mormoniella vitripennis*, the latter two after a 24 hour exposure. These results emphasize the broad spectrum toxicity of Ectiban. Coupled with inherent limitations of larviciding in general, the use of the pyrethroid in this manner should be discouraged.

Toxicity of residual deposits of Ectiban to lesser mealworm adults.

Five groups of 10, 1 to 2-month-old adults were held for one hour in

Table 11. Percentage mortality of full grown Alphitobius diaperinus larvae following a 48 hr exposure to Ectiban-treated media.

ppm ai	percent mortality
0	0
2	0
5	1.7 \pm 1.7*
10	2.2 \pm 1.3
20	23.2 \pm 8.5
30	58.3 \pm 9.7
45	60.0 \pm 6.7

* Mean \pm SE

glass vials containing 0.001, 0.01, 0.1, or 1.0 mg residues of Ectiban. Knockdown counts were made as the beetles were transferred to recovery cages. Mortality counts were made after 24 hours. Ectiban concentrations and percentage knockdowns (\pm S.E.) following a one hour exposure to residues in glass vials were: 0.001 mg, 74 ± 4.1 ; 0.01 mg, 98 ± 2.0 ; and 0.1 mg, 100.

These concentrations were about 10x greater than those causing corresponding mortality percentages of adult house flies using the same technique. Knockdown frequently resulted in the beetles turning on their backs and the elytra prevented additional penetration of the pyrethroid into the insect. House flies had no such protection and the insecticide continued to be absorbed after knockdown. This and differences in body mass and physiology probably account for the differences noted.

VI. ECTIBAN AS AN ADULTICIDE

Topical applications of Ectiban to female house flies. Ectiban and stirofos were applied topically to 4 to 6-day-old female Stauffer and wild strain house flies. An ISCO microapplicator was used to put 1 μ l of various acetone solutions of the technical grade insecticide on the pronotum of each fly. Four replicates of 50 flies were treated with each concentration as recommended by Dahm and coworkers (1961). Two control groups were used. One group was treated with acetone, the second, untreated.

The log dose-probit plot of the mortality data for Ectiban is depicted in Figure 14. Ectiban was equally effective against both house fly strains. The 95% confidence intervals for the Stauffer and wild strain LD_{50} s were 6 to 16, and 8 to 14 ngm/fly, respectively. This is comparable to the 9 ngm/fly LD_{50} obtained by English workers (Elliott et al. 1973a). Robinson et al. (1976) reported an LD_{50} of 9 ngm/fly following topical application of Ectiban to the face fly (Musca autumnalis DeGeer) (Diptera: Muscidae). The synthetic pyrethroid NRDC 161 ((S)- α -cyano-3-phenoxybenzyl cis-(1R, 3R) 2,2-dimethyl-3-(2,2,-dibromovinyl)cyclopropane carboxylate), the most active insecticide known to date, has an LD_{50} of about 0.3 ngm/fly (Elliott et al. 1974).

Stirofos was chosen as the standard in the experiment because many of the poultrymen in western Virginia are serviced by the Ralston Purina Co. As a result, they rely on the company for products in addition to chicken feed. This includes pesticides for fly control. Frequently, this material is stirofos.

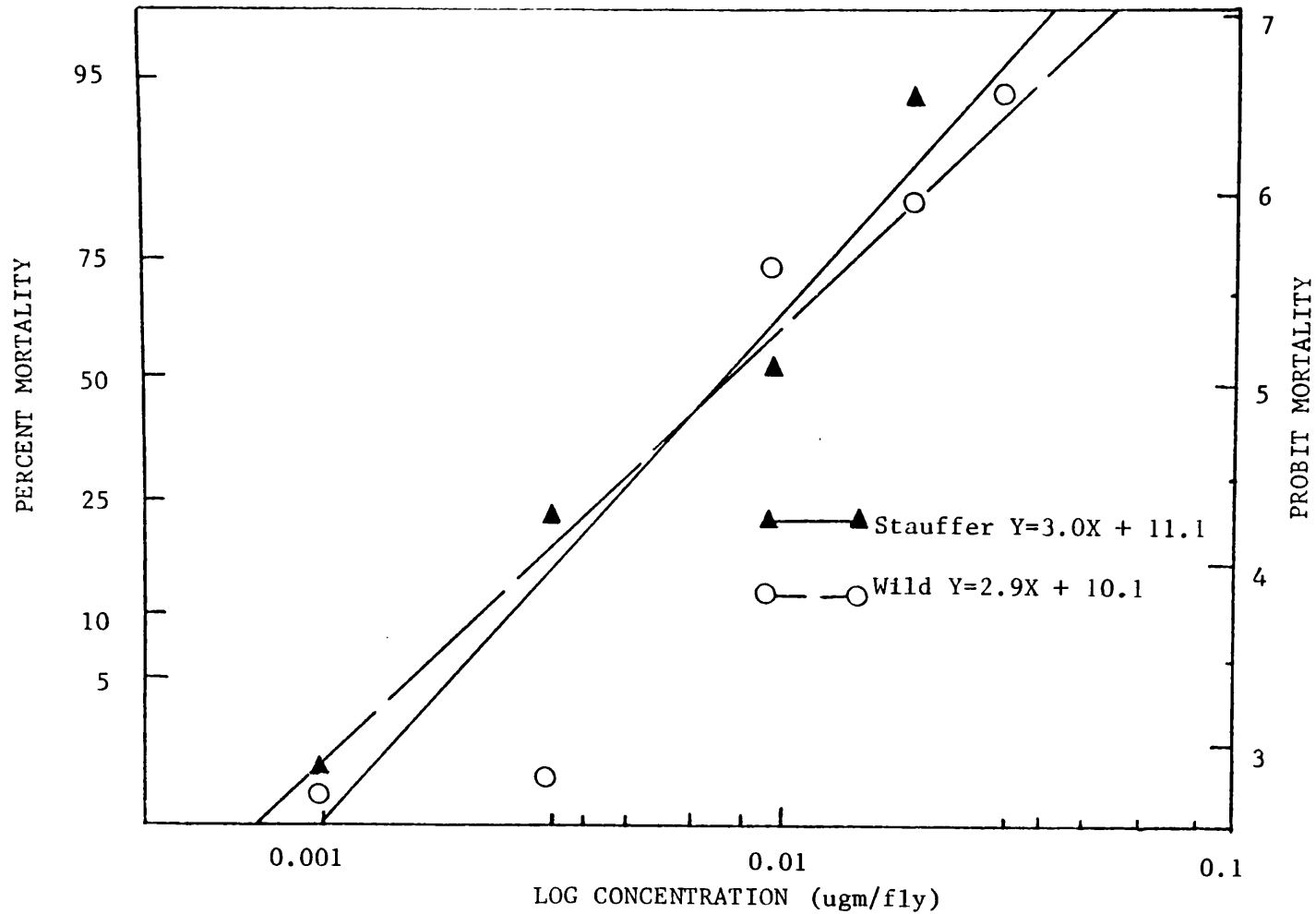


Figure 14. Response of adult Stauffer and Wild-strain house flies to topical applications of Ectiban.

The log dose-probit plot of mortality for this organophosphate insecticide is depicted in Figure 15. Stirofos was more effective against the Stauffer strain than it was against the wild strain flies. The wild to Stauffer LC_{50} and LC_{95} ratios were 5 : 1, and 7.6 : 1, respectively. While differences between the wild and lab strains were noted for stirofos, there was no notable differential susceptibility to the synthetic pyrethroid. Thus, this new insecticide shows promise against organophosphate resistant fly populations. Care must be used to forestall or minimize the development of resistance to this compound.

The effect of surfaces on the efficacy of Ectiban. Surfaces and surface coverings may limit the use of insecticides. Many materials, which were effective in the laboratory, failed when applied to a variety of surfaces in the field (Slominski and Gojmerac 1972). Sometimes, the problem can be circumvented by formulation changes. Data indicated that the emulsifiable concentrate (EC) formulation was not effective on painted surfaces (ICI, unpubl. data). It was necessary to confirm these findings and to determine whether or not the problem could be alleviated with a wettable powder (WP) formulation. Unpainted and painted plywood panels and styrofoam were treated with either the 2 lb/gal EC or the 25% WP to assess surface effects as reflected by house fly mortality.

Ectiban is very stable in light and air. Experimental data indicated that it had adequate residual properties for potential field use (Elliott et al. 1973). Adequate control of several dipteran species was obtained for over 200 days using permethrin at a rate of 1 gm/m^2

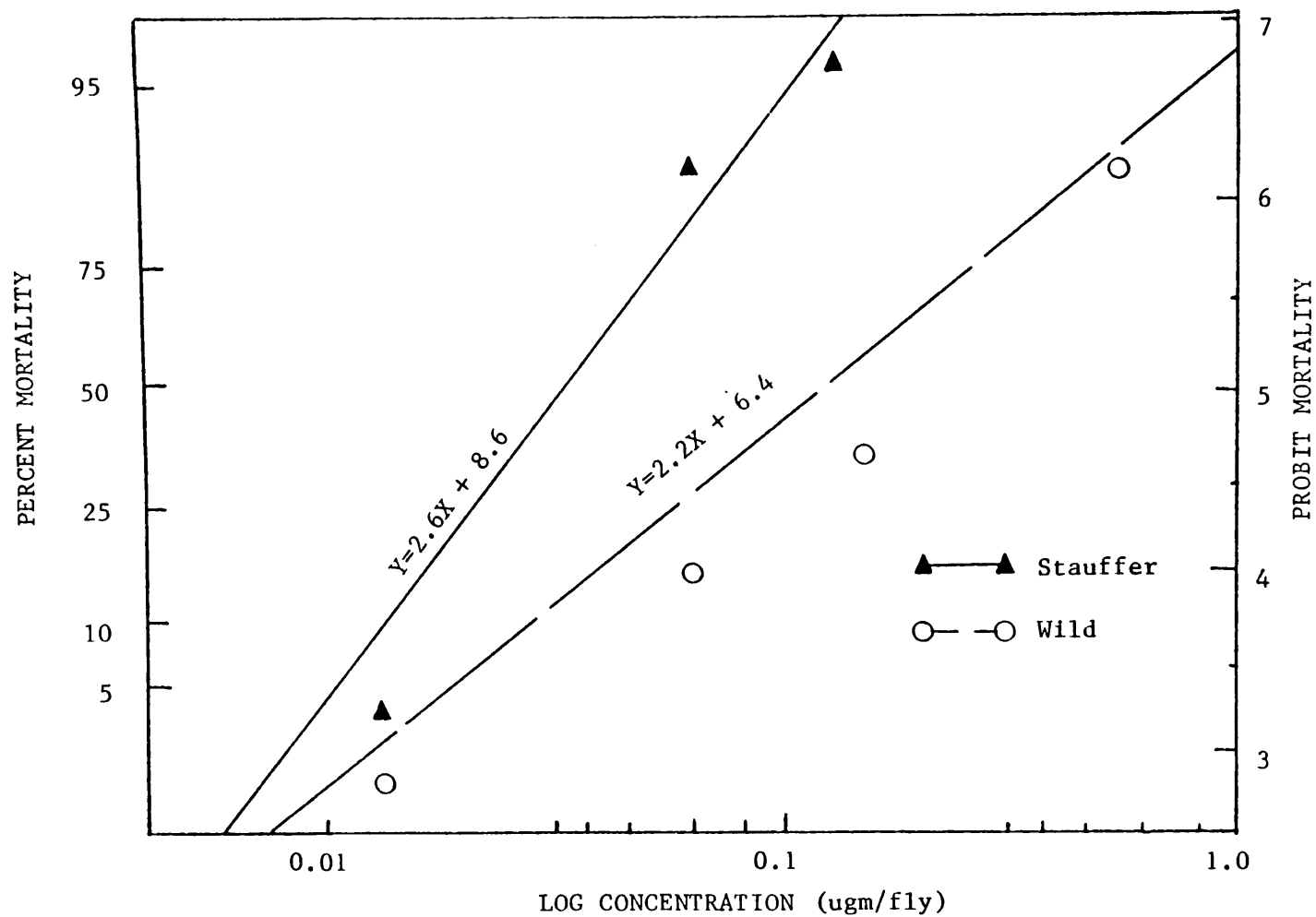


Figure 15. Response of adult Stauffer and Wild-strain house flies to topical applications of stirofos.

and insect exposures of one hour. Surface residue studies frequently invol applications of 1 to 2 gm/m² and relatively short insect exposures. I felt that using a small quantity of the pyrethroid (20 mg/m²) and a long exposure of the test insect (4 hours) would provide a sensitive procedure for determining surface/formulation interactions.

Panels (929 cm²) were cut from sheets of 0.6 cm interior-grade plywood. One group of panels received two coats of a semi-gloss interior-exterior enamel (ENA) (# 18 A, Sampson Paint Co., Richmond, Virginia). The second group was covered with one liberal coat of Sampson 1-B Vinal-A-Tex paint (LAT). A third group remained unpainted (PLY). Styrofoam (STI) represented insulation sheeting present in many recently constructed caged-layer houses.

Residual treatments were applied using a hand-operated B&G 3-gallon sprayer set to deliver a pressure of 0.6×10^{-2} newtons/m² (40 psi). All panels were sprayed at the rate of 0.4 l/m² (1 gal/100 ft²). Sprayer output was calibrated and timed using a stop watch to insure uniform treatment of each panel. Six panels were prepared for each replicate. Control panels were sprayed with water.

Toxicity of the Ectiban residues was assessed at intervals using both Stauffer and wild strain house flies. Three groups of 10, 4 to 6-day-old unsexed flies from each strain were exposed to eac panel for four hours. The flies were anesthetized lightly with CO₂, placed on the panels and covered with screen-topped cardboard rings (9 cm ID x 2 cm high). Therefore, the flies after recovering from the anesthesia, could move onto the rings and were not continuously exposed to the treated

surface. Mortality counts were made after the four hour exposure period. Temperatures and humidities in the laboratory during the tests were 21° to 24° C and 60% to 70% relative humidity. The panels were stored on shelves between tests. They were not exposed to weathering nor to direct sunlight during these periods.

Mean house fly mortalities from the eight surface/formulation combinations, assayed one day after treatment and corrected for control mortality, were separated statistically into three groups (Table 12). The EC formulation residues were ineffective on the two types of paints. These mortalities were not statistically different from the mean control mortality ($P < 0.05$). The wettable powder killed over half the flies exposed on both painted surfaces. The WP-latex and EC-plywood combinations did not produce mortalities in excess of 75%.

One difference was evident in the day-7 data. The WP-latex combination treatment produced a greater mortality than on day-1. The EC-plywood treatment remained at about 70% mortality. Again, the emulsion/paint combination treatments were ineffective.

House fly mortality resulting from exposure to the wettable powder on latex-painted panels had declined by day-20. This trend continued with mortality falling below 50% by about day-27 (Fig. 16). No mortality was observed on day-105.

This increase and subsequent decrease in insecticidal activity may have indicated a movement of the pyrethroid due to the application rate of 1 gal/100 ft². Generally, surface sprays are applied at 1 gal/750-1000 ft². In my test, the spray beaded on the enamel-coated surfaces.

Table 12. Mean mortalities of groups of 10 house flies exposed for 4 hours to Ectiban-treated surfaces (2 mg/ft²).

Day	Mean Mortalities							
	EC STI	WP ENA	WP STI	WP PLY	EC PLY	WP LAT	EC ENA	EC LAT
+1	9.7a	9.7a	9.3a	9.0a	7.3b	6.9b	1.0c	0.1c
	WP ENA	EC STI	WP LAT	WP STI	WP PLY	EC PLY	EC ENA	EC LAT
+7	9.8a	9.2a	9.2a	8.9a	8.9a	7.1b	0.8c	0.7c
	WP STI	WP ENA	WP PLY	EC STI	EC PLY	WP LAT		
+20	9.4a	9.3a	9.2a	9.2a	9.0a	8.2b		
	EC STI	WP PLY	WP STI	WP ENA	WP LAT			
+30	8.7a	8.4a	7.4ab	6.0b	2.9c			
	WP PLY	WP STI	EC STI	EC PLY	WP ENA	WP LAT	EC ENA	EC LAT
+50	9.5a	9.3ab	8.1bc	6.8c	3.3d	1.0e	0.0f	0.0f
	EC PLY	WP PLY	WP STI	WP ENA	WP LAT			
+105	8.6a	6.4b	5.0b	0c	0c			
	EC PLY	WP PLY	WP STI	EC STI				
+175	9.2a	8.8a	3.6b	3.1b				

* means within rows showing a common letter are not significantly different at the 5% level.

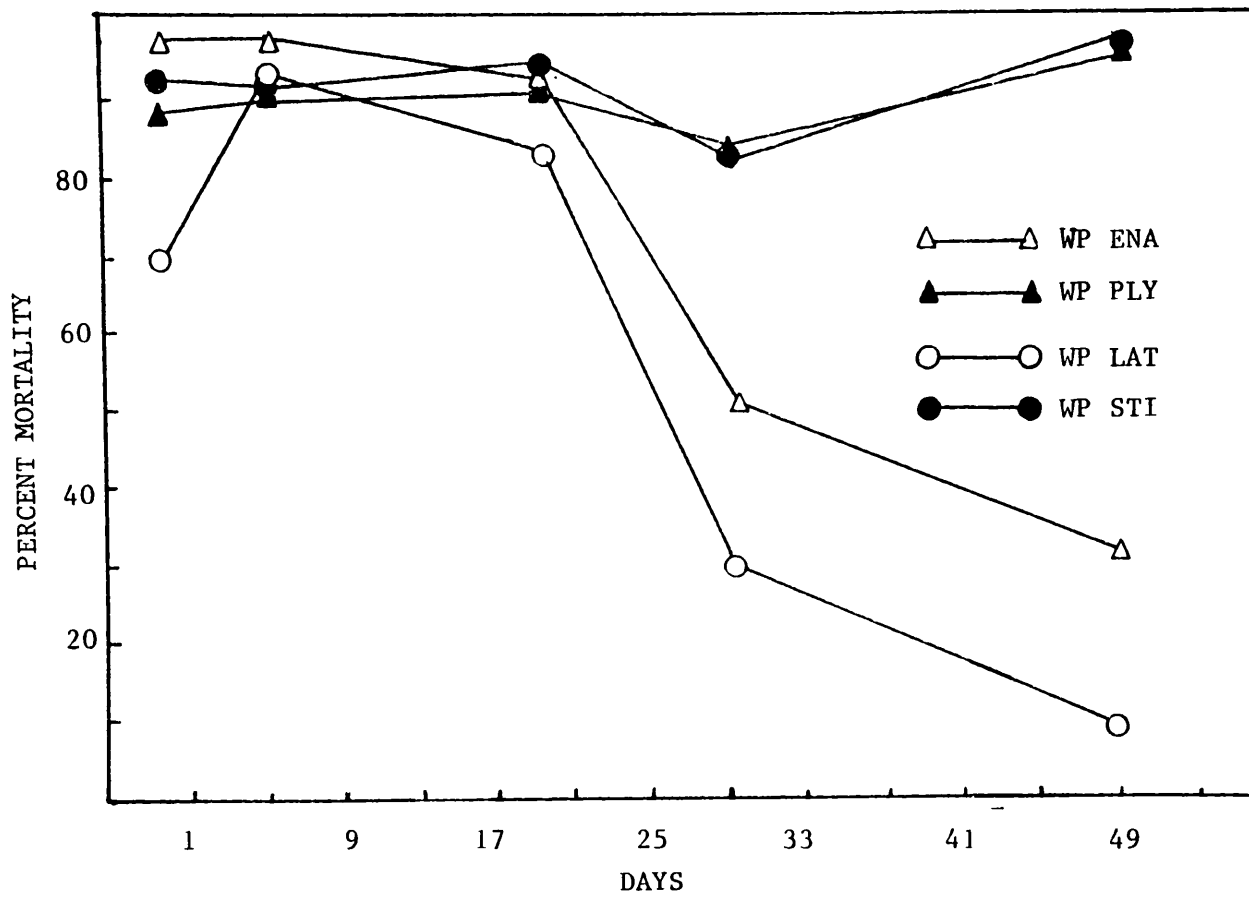


Figure 16. Mean percentage mortalities of house flies exposed for 4 hours to surfaces treated with 2 mg of Ectiban WP per ft².

Water solubility of the latex paint may have allowed the active ingredient to move into the paint with the water carrier, while they were confined to the surface of the enamel-painted panels. There was no comparable latent increase in fly mortality over time with the latter panels. However, the wettable powder was effective on enamel for about the same length of time. Mortality on this surface was zero on day-105.

Both Ectiban formulations were more effective residually on unpainted plywood and styrofoam (Fig. 17). The emulsifiable concentrate on plywood produced 84% mortality of flies when the test was terminated at 315 days. Teoita and Dahm (1950) noted better performance on wood when testing some organophosphate insecticides on plywood, whitewash, and painted panels. The wettable powder and emulsifiable concentrate formulations on styrofoam produced mortalities in excess of 50% for 15 and 18 weeks, respectively.

General discussion. The data of Wilson and coworkers (1975) demonstrated the variation in insecticide performance which may occur on different surfaces. They tested deposits of several insecticides on latex-painted plasterboard and enamel-painted wood. Generally, the materials were more effective on latex. Using the mosquito Anopheles quadrimaculatus (Say) (Diptera: Culicidae), phoxim (phenylglyoxyonitrile oxime 0,0-diethyl phosphorothioate) applied to latex paint caused mortalities in excess of 70% for 22 weeks. However, phoxim applied to enamel was effective for only two weeks. In contrast, chlorophoxim (0-chlorophenyl) glyoxylonitrile oxime 0,0-diethyl phosphorothioate) was effective on latex for one week and on enamel for 14 weeks. DDT

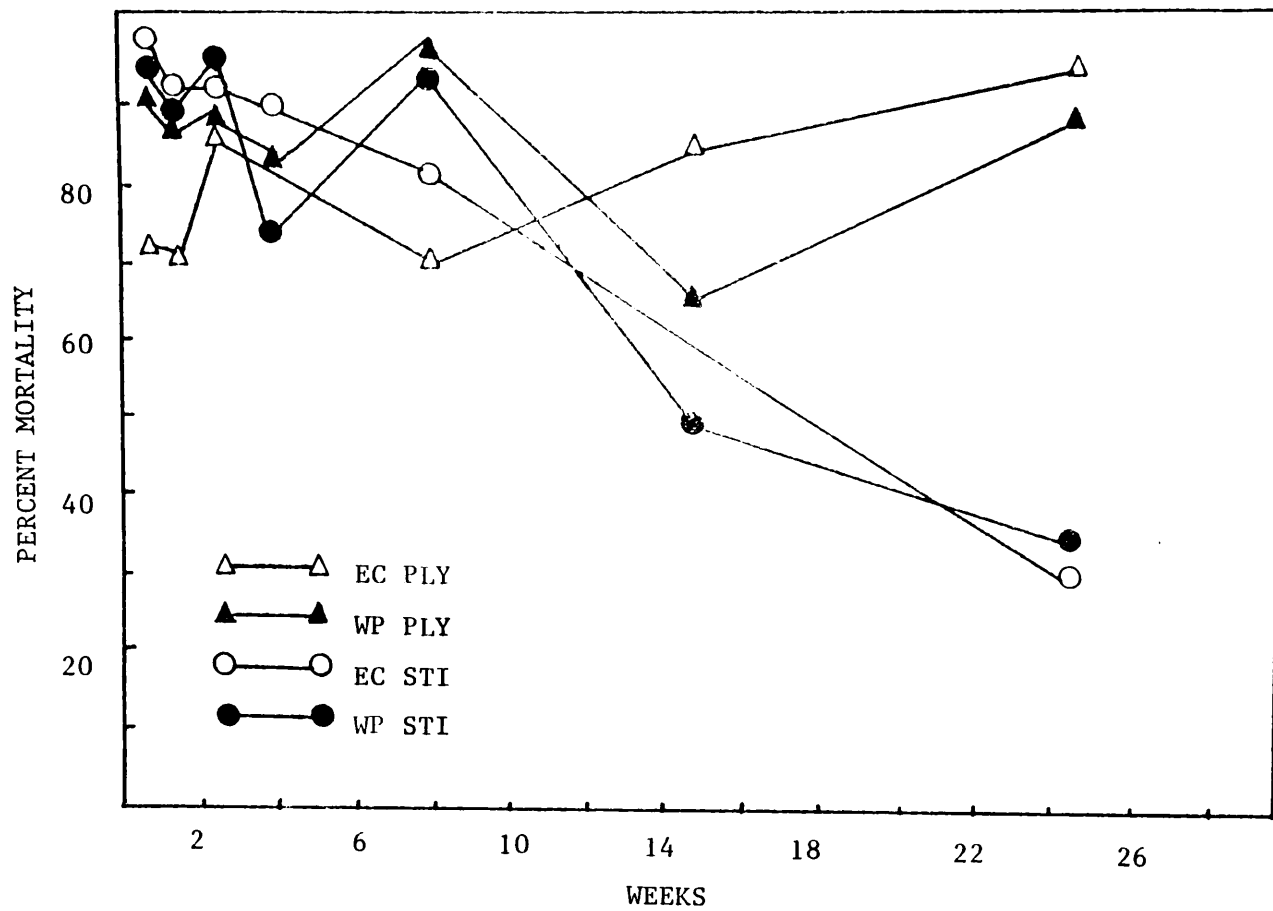


Figure 17. Mean percentage mortalities of house flies exposed for 4 hours to surfaces treated with 2 mg of Ectiban EC or WP per ft².

(1,1,1,-trichloro-2,2-bis(p-chlorophenyl)ethane) and malathion (diethyl mercaptosuccinate S-ester with 0,0-dimethyl phosphorodithioate) were relatively ineffective, lasting for only five weeks. Some of these differences may have been due to the surfaces as well as the paints.

Sanitation practices such as whitewashing dairy barns and milk houses, or painting egg rooms, may alter surface characteristics sufficiently to affect the residual efficacy of a toxicant. Gojmerac (1967) found that talc-based wall whiteners prolonged the activity of ronnel (0,0-dimethyl 0-(2,4,5-trichlorophenyl) phosphorothioate) when compared to ronnel residues on unpainted plywood. Slominski et al. (1971) showed the effects of surfaces and time on deposits of bromophos (0-(4-bromo-2,5-dichlorophenyl)0,0-dimethyl phosphorothioate) and ronnel. Data from applications of malathion against the black carpet beetle (Attagenus megatoma Fabrcius) (Coleoptera: Dermestidae) to a wide variety of surfaces are presented by Slominski and Gojmerac (1972).

The use of styrofoam insulation to reduce heat loss and to prevent moisture condensation is common in many recently-constructed chicken houses. Applications of insecticides to this surface may be necessary for fly control or to prevent tunneling in the material by the lesser mealworm. Slominski et al. (1970) found that expanded styrofoam appeared to be very sensitive to mixtures of several emulsifiable concentrate insecticides. The surface was dissolved or etched by dosages less than those required for residual insect control. Extruded styrofoam appeared to be less reactive. They did not determine whether or not the action was due to the insecticide, solvent, emulsifier, or any other component

of the formulated product. No such reaction was noted with Ectiban on styrofoam. The undiluted emulsifiable concentrate did dissolve both expanded and extruded styrofoam. However, no reaction was noted when 0.5% Ectiban was placed on these surfaces.

Wettable powder formulations tend to be more effective than emulsions initially, and often retain their toxicity for many weeks. However, when loss of insecticidal activity begins, it may proceed rapidly. Emulsion formulations may be less toxic initially, but frequently lose their effectiveness more slowly. This can result in the emulsion being the most satisfactory formulation for long-term control (Harris et al. 1976). An additional factor in loss of effectiveness of a residue on a porous surface is demonstrated with materials which are liquid at ambient temperatures, these include diazinon, malathion, bioresmethrin, and permethrin. Hadaway et al. (1970) reported that insecticides of this type tended to separate from the inert carrier and penetrate with the water phase into a porous surface.

The wettable powder formulation of Ectiban solved to some extent the loss of active ingredient of the pyrethroid into paints. However, it is evident from the data that loss still occurs. Research is needed on formulation changes that will lessen or curtail this phenomenon.

Ectiban impregnated cotton cords for fly control. Cylindrical test cages for exposing flies to the cords were constructed after the design of Fay and Lindquist (1954). They were made from $\frac{1}{2}$ -gallon cardboard containers (15.8 cm tall x 12.7 cm dia.). The cardboard insert in the top was replaced by a piece of 2 mm mesh wire screen. A

second screened container top replaced the bottom insert. This facilitated air circulation and allowed access to the cages from either end. Two opposing 11 x 15 cm holes were cut in the sides of each container. A 12 x 15 cm frame made from 2.5 cm wooden strips was placed inside each cage and stapled to the sides of the containers. Saran wrap^r was placed around the outside of the cages to allow entry of light and to facilitate observations during the exposures.

The cotton cords, 1 cm in diameter and 25 cm long, were immersed for four hours in 1% or 5% Ectiban-xylene solutions. Three cords of each strength were prepared along with control cords with and without xylene. One Ectiban-treated cord of the desired dosage was placed in each of three cages. Each cord was looped over the wooden frame and secured with wire so that the two lengths were oriented vertically in the cages.

Groups of 45, 4 to 6-day-old female house flies were placed in each cage for one hour. Counts of knocked-down flies were made at ten-minute intervals. The cages were jarred sharply between counts to disturb the flies.

Percentage knockdown of flies during a one-hour exposure to cotton cords immersed in 1% or 5% xylene-Ectiban solutions and the subsequent 24 hour mortalities are summarized in Table 13. These data are corrected for control mortality.

Except for the 1%-treated cords on day-1, knockdown of flies was in excess of 90% at the end of the test. A noticeable increase in 24 hour mortality occurred over the three test dates. This smaller effect on

Table 13. Mean percentage knockdown and 24 hr mortality of groups of 45 female house flies following a 1 hr exposure to cotton cords treated with 1% or 5% solutions of Ectiban in xylene.

Days	1% cords						24 hr mortality
	Percentage knockdown						
	Minutes of exposure						
	10	20	30	40	50	60	
+1	1	9	28	50	62	76	45.2 ± 3.9*
+7	0	7	30	61	82	96	60.7 ± 10.9
+55	0	10	28	53	81	94	70.0 ± 8.4

	5% cords						
+1	9	42	69	82	93	95	63.0 ± 6.8
+7	2	7	30	61	82	96	74.8 ± 3.3
+55	1	16	38	75	88	94	100

* Mean ± SE of three replicates

day-1 may have been due to a repellent effect of the xylene. The odor was strong 24 hours after the cords had been immersed in the solution for four hours. The odor dissipated as the solvent evaporated. In all tests and controls, most flies remained on the screen tops of the exposure cages. They moved onto the cords for short periods of time immediately after the cage was jarred. Although the numbers of flies on the cords were counted at 10-minute intervals, these were low and no differences were noted between numbers of flies resting on treated, untreated, or xylene-treated cords.

Fay and Lindquist (1954) used xylene to prepare parathion and diazinon treated cords for a similar series of tests. However, they waited four weeks before exposing them in cages, so no repellent effect was noted. Their cords were smaller, 0.2 cm in diameter, and were immersed in the solutions for only one minute. I tested 1 cm diameter cords because this size was shown to be most attractive to house flies Fay and Lindquist (1954).

The Ectiban-treated cords provided satisfactory knockdown of house flies. The 5% cords produced the greatest 24 hour mortality in this artificial situation. A field test of this control technique was not conducted due to a lack of tolerance permit. This may prove to be an effective way to expose the pyrethroid while minimizing the hazard to nontarget species. The design of such a method is discussed in the resting site study.

VII. FLY RESTING SITE STUDY

This study was conducted in a sheep barn on a VPI&SU farm. The structure, a metal-roofed quonset hut (9 m wide X 18 m long), was oriented north to south with the eastern exposure open. It was heavily infested with house flies. Eight Dorset ewes were housed in the building on a wire floor, which was suspended over a manure pit.

A choice of resting sites was provided, including three types of 30.5 cm x 61 cm plywood panels. They were: 1) plain plywood; 2) plain plywood with lengthwise black plastic tape strips 2 cm wide, spaced 2 cm apart; and 3) panels with 2 cm wide ridges separated by 1.5 cm grooves which were 1 cm deep. Cotton cords (1 cm diameter window sash) 35 cm in length were used also. In addition, curtains of these cords were constructed as follows: 35 cm lengths of cord spaced at 2.5 cm intervals were wired at one end to 61 cm long strips of wood. The wooden strips were hung horizontally so that the loose ends hung vertically. Except for the curtains, the various panels and strands of cord were oriented both horizontally and vertically in each replicate.

Figure 18 depicts the site placement within the barn. The three rows, representing replicates, were spaced 1.5 m apart: panels and cords within a replicate were suspended about 1 m apart by light wire. Vertical panels were oriented so that test surfaces (Grooved or striped) were facing eastward. All were about 2.35 m above the wire floor.

The panels remained in place for 25 days (July 21 to August 16, 1977). Two counts were made during the late afternoon (about 1700 hrs). The evening counts (about 2000 hrs), made on the same date, were taken

C= CURTAIN H= HORIZONTAL V= VERTICAL R= CORD
 PANELS G= GROOVED P= PLAIN S=STRIPED

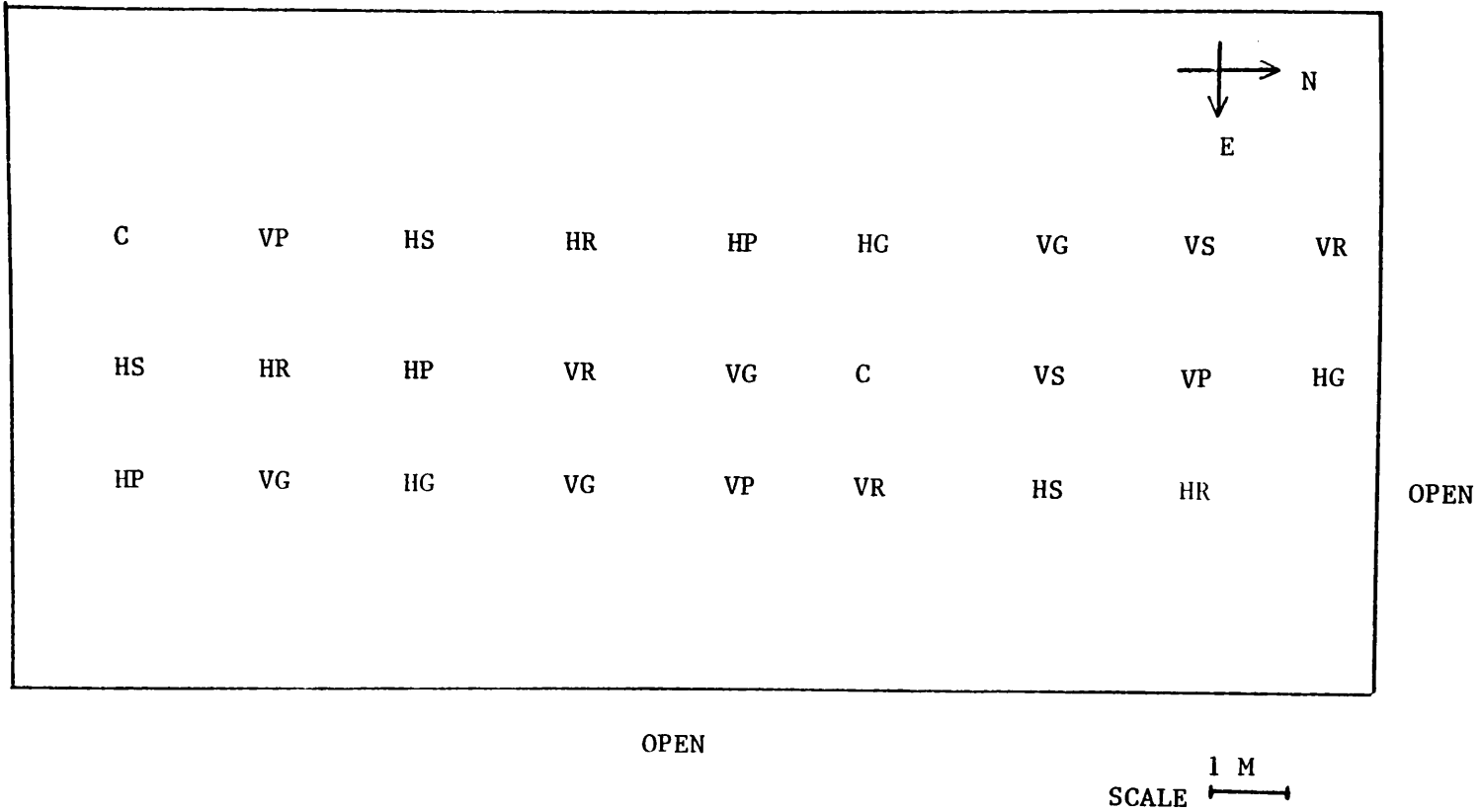


Figure 18. Experimental design for the house fly resting site study.

during the period to determine the numbers of flies resting on each cord and panel. Flies on the outer two cm of the panels were disregarded. The temperature and relative humidity on count days were recorded by a Bendix-Hygro-Thermograph. The panels were removed from the shed on the 35th day and the numbers of fly specks on the panels were counted. Mean numbers of flies and fly specks were analyzed using analysis of variance techniques.

Flies resting on the plywood panels and cotton cords were counted before dusk and after sunset on the same evenings. Pre-dusk temperatures ranged from 25° to 30° C; evening temperatures were 24° to 27° C. Humidity was greater than 60%.

The barn chosen for this study was being used as an untreated control in a premise spray experiment. House flies were abundant in and around the building. While no fly breeding was evident in the manure, flies were attracted to the sheep, fresh feces, and spillage around the feed and water troughs. Unfortunately, the animals were removed from the building the same day the panels were hung. The water and feed troughs were emptied, and fresh feces were no longer present.

Fly count data for the panels are summarized in Table 14. The mean numbers of flies per panel at the four sample intervals were not significantly different at the 5% level. Also, there were no significant differences between the three row replicates, means from vertical versus horizontal panels, or for the three panel types.

Many flies were present when the first pre-dusk and night counts were made. Most were resting on curved metal roof beams and along

Table 14. Mean numbers of flies per panel following resting site study, Montgomery, Co. Virginia, 1977.

Category	Mean no. flies/panel			
Orientation	Day 1	Day 2	Night 1	Night 2
Horizontal	2.3a*	1.1a	1.3a	0.9a
Vertical	1.9a	1.4a	0.8a	0.4a
Replicate				
Row 1	2.5a	1.0a	1.0a	0.3a
Row 2	2.0a	2.0a	1.5a	0.7a
Row 3	1.8a	0.8a	0.7a	1.0a
Panel type				
Grooved	2.3a	2.1a	1.5a	0.2a
Plain	1.5a	0.5a	0.8a	0.7a
Striped	2.5a	1.0a	0.8a	1.2a

* Means within rows having a common letter are not significantly different at the 5% level.

electrical wires. Few flies were seen on these surfaces during the day. Most visited the feces, wire floor, sheep, and wooden fences dividing the floor space into smaller pens.

The second pair of counts were made three days later. A decrease in the numbers of flies visiting the building was evident. Since few flies were present on the panels even when flies were abundant, I terminated the counts. The panels and cords were left in place to allow accumulation of fly specks.

Fecal spotting of paper strips and cords can supplement direct counts and provide a useful index of fly activity. The numbers of specks on the test surfaces of the 18 panels were counted after the panels had been removed from the barn. These data were a cumulative representation of fly visits during the 25 day experiment. As with fly counts per panel results, no significant difference ($P < 0.05$) was found between the mean number of specks on horizontal versus vertical panels, nor between row replicates. However, there was a significant difference between the mean number of specks deposited on the six surface/orientation combinations ($P < 0.10$) (i.e., horizontal grooved, vertical plain). greatest means were from the vertical and horizontal striped panels (Table 15). When these data were combined by panel type without regard to orientation, the fly speck means per striped panel were greater and significantly different ($P < 0.05$) from the means representing grooved and plain panels. More fly specks were deposited on the black stripes of the panels (14.4 ± 2.1) than on the plain stripes (5.3 ± 0.8). This may have been indicative of the importance of visual cues in site selection.

Table 15. Mean numbers of fly specks per panel following fly resting site study, Montgomery Co., Va. 1977.

Panel orientation	Panel type		
	Grooved	Plain	Striped
Horizontal	30 ± 7*	56 ± 4	157 ± 31
Vertical	55 ± 5	46 ± 5	112 ± 27

* Mean ± SE of three replicates

Horizontal and vertical cords provided suitable resting sites for flies. Mean flies per cord from the two pre-dusk counts were: vertical, 1.5 ± 0.8 ; and horizontal, 0.8 ± 0.3 . These means were in the same range as mean flies per panel from the pre-dusk period. Greater numbers of flies selected the cords for night resting. Night means for vertical and horizontal cords were 6.5 ± 3.9 , and 4.0 ± 2.6 flies per cord, respectively. The cord curtains were the most attractive surface tested. Mean flies per curtain during the pre-dusk counts were 11.5 ± 5.8 , the night mean was 68.3 ± 27.8 .

These trends were reflected in the fly speck counts from the single cords and curtains. Mean specks per single cord were: horizontal- 60 ± 12.6 ; vertical 85 ± 52.8 . Mean specks per cord of the curtain, based on counts of 10 cords, was 85 ± 21.5 . Fly specks were most numerous on the bottom portions of the cords, particularly the frayed ends.

Insecticide-treated cords have been used successfully for fly control in dairy barns and military dining halls (Kilpatrick and Schoof 1956; Schoof and Kilpatrick 1957). These trials involved the use of 0.2 cm diameter cotton cords which had been immersed in xylene solutions of parathion or diazinon. Cords were installed singly at the rate of 25 to 30 lineal feet per 100 ft² of floor area. Mathis and Schoof (1968) obtained good house fly control in milking parlors using impregnated cords at the rate of 15 lineal feet per 100 ft² of floor area. Treatments were supplemented with dichlorvos bait dispensers.

Ordinary and composite insecticide-treated cords containing dimethoate (30% w/v), ronnel (12%), trichlorfon (dimethyl (2,2,2-tri-

chloro-1-hydroxyethyl) phosphonate) (6.5%), and to a lesser extent diazinon (20%) were shown to be capable of giving season-long control of Fannia canicularis (Linnaeus) (Diptera: Muscidae) (Williams 1973). These cords were installed at the rate of 0.98 m cord/m² of floor space.

Williams noted the following advantages of treated cords over other chemical methods of fly control: 1) specific action by utilizing the propensity of flies to rest on suspended objects; 2) suitable for use in most poultry houses irrespective of management system or building fabric; 3) birds disturbed only at the time of installation; and 4) insecticide relatively nonhazardous to birds or workers when exposed in this manner.

Disadvantages to such systems include labor involved to make and hang the cords and the hazard to workers treating the cords with rather high concentrations of insecticides. The latter problem could be eliminated if commercially prepared cords were available. Also, cords should be placed carefully for best effect. This requires some general knowledge of fly behavior and some study of their distribution in the individual buildings. The cord curtains, which were attractive in the resting site study, require more time and materials than do the single cords.

Based on the resting site study data, the use of treated wood panels for fly control may be a less desirable alternative. The additional cost of wood would add to the overall cost. Research along these lines may lead to a more effective surface or design.

DeFoliart (1963) found that five gallons of spray per barn, regardless of size, would control flies if the first application was made prior to the buildup of fly populations, and if subsequent treatments were applied based on known residual characteristics of the insecticide used. The panel data indicate that portions of ceilings could be striped with tape and spot-treated. This would eliminate the need for panels per se, but could gain selective advantage by increasing the attractiveness of defined areas in a barn or chicken house. The persistence and high insecticidal activity of Ectiban permethrin make it suitable for such a control strategy.

VIII. CONCLUSIONS

Ectibantm permethrin, a potent synthetic pyrethroid, demonstrated potential in the laboratory for use in an integrated fly control program for chicken houses. Its toxicity to house fly larvae was comparable to that of currently used organophosphate insecticides. Ectiban was most effective when applied topically to chicken manure. However, an encapsulated formulation of the pyrethroid did not give satisfactory larval control as a feed additive in a ration for laying hens. Most insecticidal activity was lost as the treated feed passed through the bird's digestive tract.

The broad spectrum toxicity of Ectiban to selected nontarget manure-dwelling arthropods was evident. No differential toxicity was noted between house fly larvae and adult Macrocheles muscaedomesticae, Mormoniella vitripennis, or Alphitobius diaperinus larvae. The potential hazard of this insecticide to parasites or predators of manure-breeding flies indicated that larvicidal applications should be limited.

Ectiban was very effective as a house fly adulticide. While an emulsifiable concentrate formulation was not active on latex and enamel-painted plywood, a wettable powder formulation was. Both formulations were found to be suitable for use on unpainted plywood and styrofoam.

A fly resting site study emphasized the desirability of using behavior patterns of pest species to advantage when applying control measures. Curtains of cotton cord, single cords, and striped plywood panels attracted resting flies. Insecticidal treatment of such preferred surfaces would provide a selective means of exposing the pyrethroid.

IX. LITERATURE CITED

- Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. *J. Econ. Entomol.* 18:265-7.
- Acker, D. 1971. *Animal science and industry*. Prentice-Hall, Inc., Englewood Cliffs, N. J. 604 pp.
- Alicata, J. E. 1939. Preliminary note on the life history of Subulura brumpti, a common cecal nematode of poultry in Hawaii. *J. Parasitol.* 25:179-80.
- Almeida, P. R., and A. P. Takematsu. 1975. Acao dos piretroides contra a "curuquere"- Alabama argilacea (hubn. 1823)- em algodoeiro. *O Biologico* 41:299-302.
- Anderson, J. R. 1965. A preliminary study of integrated fly control on northern California poultry ranches. *Proc. Ann. Conf. Calif. Mosq. Cont. Assoc.* 33:42-4.
- Anderson, J. R. 1966. Recent developments in the control of some arthropods of public health and veterinary importance. *Bull. Entomol. Soc. Amer.* 12:342-8.
- Anderson, J. R., A. S. Deal, E. F. Legner, E. C. Loomis, and M. H. Swanson. 1968. Fly control on poultry ranches. *Univ. Calif. Agric. Ext. Ser. Publ. AXT-72. Rev.* 13 pp.
- Anderson, J. R., and J. H. Poorbaugh. 1964. Observations on the ethology and ecology of various Diptera associated with northern California poultry ranches. *J. Med. Entomol.* 1:131-47.
- Arevad, K. 1965. On the orientation of house flies to various surfaces. *Entomol. exp. and Appl.* 8:175-88.
- Axtell, R. C. 1963a. Effect of Macrochelidae (Acarina: Mesostigmata) on house fly production from dairy cattle manure. *J. Econ. Entomol.* 56:317-21.
- Axtell, 1963b. Acarina occurring in domestic animal manure. *J. Econ. Entomol.* 56:628-33.
- Axtell, R. C. 1966. Comparative toxicities of insecticides to house fly larvae and Macrocheles muscaedomesticae, a mite predator of the house fly. *J. Econ. Entomol.* 59:1128-30.
- Axtell, R. C. 1967. Macrochelidae (Acarina: Mesostigmata) as biological control agents for synanthropic flies. *Pro. Internat. Congr. Acarol.* 2:401-16.

- Axtell, R. C. 1968. Integrated house fly control: populations of fly larvae and predaceous mites, Macrocheles muscaedomesticae, in poultry manure after larvicidal treatment. J. Econ. Entomol. 61: 245-9.
- Axtell, R. C. 1970a. Integrated fly-control for caged poultry houses. J. Econ. Entomol. 63:400-5.
- Axtell, R. C. 1970b. Fly control in caged-poultry houses: comparison of larviciding and integrated control programs. J. Econ. Entomol. 63:1734-7.
- Barlow, F., and A. B. Hadaway. 1975. The insecticidal activity of some synthetic pyrethroids against mosquitoes and flies. Pest Art. News Sum. 21:233-8.
- Barr, A. J., J. H. Goodnight, J. P. Sail, and J. T. Helwig. 1970. A user's guide to SAS-76. Sparks Press, Raleigh, N. C. pp. 206-7.
- Bay, D. E., N. C. Ronald, and R. L. Harris. 1976. Evaluation of a synthetic pyrethroid for tabanid control on horses and cattle. Southwest. Entomol. 1:198-203.
- Berteau, P. E., J. E. Casida, and T. Narahashi. 1968. Pyrethroid-like biological activity of compounds lacking cyclopropane and ester groupings. Science 161:1151-3.
- Boike, A. H., Jr. and C. B. Rathburn. 1975. Laboratory non-thermal aerosol tests of insecticides for the control of adult mosquitoes. Mosq. News 35:488-90.
- Born, D. E. 1954. Mold control in fly rearing media. J. Econ. Entomol. 47:367.
- Breeden, G. C., E. C. Turner, Jr. and W. L. Beane. 1975. Methoprene as a feed additive for control of the house fly breeding in chicken manure. J. Econ. Entomol. 68:451-2.
- Card, L. E., and M. C. Nesheim. 1972. Poultry production. Lea and Febigei. Philadelphia, Pa. 392 pp.
- Carter, S. W., and P. A. Duffield. 1976. A preliminary evaluation of the pyrethroid NRDC 143 as an industrial mothproofer. J. Textile Indust. 67:77-81.
- Crombie, L., and M. Elliott. 1961. Synthetic pyrethroids. Fortschr. Chem. org. Nat. Stoffe. 19:120-64.
- Dahm, P. A., J. Gurland, I. Lee, and J. Berlin. 1961. A comparison of some house fly bioassay methods. J. Econ. Entomol. 54:343-7.

- DeFoliart, G. R. 1963. Preventive spraying schedules for dairy farm fly control. *J. Econ. Entomol.* 56:649-54.
- Duncan, D. B. 1955. Multiple range and multiple F tests. *Biometrics* 11:1-42.
- Edison, C. S., S. C. Schmittle, R. B. Goode, and J. B. Lai. 1966. Induction of leukosis tumors with the beetle Alphitobius diaperinus. *Amer. J. Vet. Res.* 27:1053-7.
- Elliott, M. 1970. The relationship between the structure and the activity of pyrethroids. *Bull. Wld. Hlth. Org.* 44:315-24.
- Elliott, M. 1974. Structure activity studies- natural and synthetic pyrethroids. *Chem. Indust.* 24:78-80.
- Elliott, M., A. W. Farnham, N. F. Janes, P. H. Needham, and B. C. pearson. 1967. 5-benzyl-3-furyl chrysanthemate: a potent new insecticide. *Nature* 240:493-4.
- Elliott, M., A. W. Farnham, N. F. Janes, P. H. Needham, D. A. Pulman, and J. H. Stevenson. 1973a. NRDC 143, a more stable pyrethroid. *Proc. 7th British Insectic. Fungi. Conf.* pp 721-8.
- Elliott, M., A. W. Farnham, N. F. Janes, P. H. Needham, D. A. Pulman, and J. H. Stevenson. 1973b. A photostable pyrethroid. *Nature* 246:169-70.
- Elliott, M., A. W. Farnham, N. F. Janes, P. H. Needham, and D. A. Pulman. 1974. Synthetic insecticide with a new order of activity. *Nature* 248:710-1.
- Elliott, M., N. F. Janes, D. A. Pulman, L. C. Gaughan, T. Unai, and J. E. Casida. 1976. Radiosynthesis and metabolism in rats of the 1R isomers of the insecticide permethrin. *J. Agric. Food Chem.* 24: 270-6.
- Fay, R. W., and J. W. Kilpatrick. 1958. Insecticides for control of adult Diptera. *Ann. Rev. Entomol.* 3:401-20.
- Fay, R. W., and D. A. Lindquist. 1954. Laboratory studies on factors influencing the efficiency of insecticide impregnated cords for house fly control. *J. Econ. Entomol.* 47:975-80.
- Foulk, J. D., and J. G. Matthyse. 1964. Tests with mites in treated glass pipettes. *J. Econ. Entomol.* 57:602.
- Fujitani, J. 1909. Chemistry and pharmacology of insect powder. *Arch. exp. Path. Pharm.* 61:47-75.

- Gaughan, L. C., T. Unai, and J. E. Casida. 1976. Comparative permethrin metabolism: rat, cow, bean, and cotton. Paper No. Pest 36, 172nd ACS Meet. San Francisco. (Abstract).
- Gnadinger, C. B. 1933. Pyrethrum flowers. McLaughlin Gormley King Co. Minneapolis. 380 pp.
- Gojmerac, W. L. 1967. Wall whitening agents, their effect on residual activity of ronnel to house flies. *J. Econ. Entomol.* 60:872-3.
- Grayson, J. M. 1975. Cockroach control research in 1974. *Pest Control* 43:17-20.
- Greenberg, B. Flies and disease. *Sci. Amer.* 231:92-9.
- Hadaway, A. B., F. Barlow, J. E. H. Grose, C. R. Turner, and L. S. Fowler. 1970. Evaluation of compounds for insecticidal activity on adult mosquitos. 1. Response of adult mosquitos to some new insecticides. *Bull. WHO* 42:353-68.
- Hameed, S. F., and J. G. Allen. 1976. Toxicity and persistence of some organophosphorous insecticides and permethrin on apple fruits for control of codling moth Laspeyresia pomonella (L.). *J. Hort. Sci.* 51:105-15.
- Harding, W. C, Jr., and T. L. Bissell. 1958. Lesser mealworms in a brooder house. *J. Econ. Entomol.* 51:112.
- Harris, E. G., J. E. H. Grose, and L. J. Saliba. 1976. Control of farm flies in Malta- II. Residual effectiveness of insecticide formulations on various surfaces to Musca domestica and Stomoxys calcitrans. *Pest. Art. News Sum.* 22:207-14.
- Harris, R. L., and D. D. Oehler. 1976. Control of tabanids on horses. *Southwest. Entomol.* 1:194-7.
- Hart, S. A. 1963. Fowl fecal facts. *World's Poul. Sci. J.* 19:262-72.
- Hoffman, R. A., and R. E. Monroe. 1956. Control of house fly larvae in poultry droppings. *J. Econ. Entomol.* 49:704-5.
- ICI 1977. Ectibantm pyrethroid insecticide technical report. 2 pp.
- Kadota, T., Y. Okuno, H. Kohda, and J. Miyamoto. 1976. Mammalian toxicological study of permethrin, 3-phenoxybenzyl (-)cis,trans,-2,2-dimethyl-3-(2,2-dichlorovinyl)-cyclopropane-1-carboxylate. *Botyu-Kagaka* 41:143-8.
- Keiding, J. 1965. Observations on the behavior of the house fly in relation to its control. *Rivista Di Parassitologia* 26:45-60.

- Keiding, J., and K. Arevad. 1964. Procedure and equipment for rearing a large number of house fly strains. Bull. WHO 31:527-8.
- Kilpatrick, J. W., and H. F. Schoof. 1956. The use of insecticide treated cords for house fly control. Pub. Hlth. Rpt. 71:144-50.
- Koehler, C. S. 1974. Insecticides for the future: needs and prospects. Science 186:654-5.
- Kozlov, V. I. 1970. The tenebrionid Alphitobius diaperinus, a predator of Dermanyssus gallinae. Parazitologiya 4:363-\$. (Abstract)
- LaBrecque, G. C., D. W. Meifert, and D. E. Weidhaas. 1972. Dynamics of house fly populations. Fla. Entomol. 55:101-6.
- Lancaster, J. L. Jr., and J. S. Simco. 1967. Biology of the lesser meal worm, a suspected reservoir of avian leukosis. Univ. Ark. Agric. Exper. Stat. Rept. 159:1-12.
- Legner, E. F. 1966. Parasites of the house fly and other filth-breeding Diptera in southern California. J. Econ. Entomol. 59:999-1001.
- Legner, E. F. 1967. The status of Nasonia vitripennis as a natural parasite of the house fly, Musca domestica. Can. Entomol. 99: 308-9.
- Legner, E. F., and G. S. Olton. 1968. The biological method and integrated control of house and stable flies in California. Calif. Agric. 22:2-4.
- Lennox, F. G. 1940. Studies of the physiology and toxicology of blow flies. 4. The action of contact larvicides on Lucilia cuprina. Austral. Counc. Sci. Indust. Res. Pam. 101:69-131.
- Mathis, W., and H. F. Schoof. 1965. Studies on house fly control. J. Econ. Entomol. 58:291-3.
- Mathis, W., and H. F. Schoof. 1968. Chemical control of house flies in dairy barns and chicken ranches. J. Econ. Entomol. 61:1071-3.
- Matthysse, J. G., and D. MaAlain. 1973. House fly control in climate-controlled caged-layer houses. J. Econ. Entomol. 66:927-33.
- Miller, R. W. 1970. Larvicides for fly control- a review. Bull. Entomol. Soc. Amer. 16:154-8.
- Mitlin, N., and H. F. Babers. 1955. Relative toxicity of topically applied allethrin and pyrethrins to house flies and cockroaches. J. Econ. Entomol. 48:747-8.

- Mulla, M. S., and H. Darwazeh. 1976. Field evaluation of new mosquito larvicides and their impact on some nontarget insects. *Mosq News* 36:251-6.
- Narahashi, T. 1962a. Effect of the insecticide allethrin on some nerve membrane potentials of cockroach giant axons. *J. Cell Comp. Physiol.* 59:61-65.
- Narahashi, T. 1962b. Nature of the negative after-potential increased by the insecticide allethrin in cockroach giant axons. *J. Cell. Physiol.* 59:67-76.
- Narahashi, T. 1971. Mode of action of pyrethroids. *Bull. WHO* 44:337-45.
- Peters, R. F. 1963. Urbanization's impact on the poultry industry. *Calif. Vector Views* 10:69-71.
- Pickens, L. G., and R. W. Miller. 1975. Development of resistance in house fly adults and larvae pressured with stirofos. *J. Econ. Entomol.* 68:39-40.
- Roberts, J. E., Sr. 1977. Fly control for poultry producers. *In* Virginia pest management guide. *Pest Manag. Ser.* 1:37-8.
- Robinson, J. V., H. W. Chambers, and R. L. Combs. 1976. Topical toxicity of ten insecticides to laboratory-reared Musca autumnalis. *J. Econ. Entomol.* 69:89-90.
- Rodriguez, J. G., P. Singh, and B. Taylor. 1970. Manure mites and their role in fly control. *J. Med. Entomol.* 7:335-41.
- Sacca, G. 1964. Comparative bionomics of the genus Musca. *Ann Rev. Entomol.* 9:341-58.
- Sampson, H. 1956. Insecticides used to control house fly larvae. *J. Econ. Entomol.* 49:74-7.
- Schechter, M. S., N. Green, and F. B. LaForge. 1949a. The synthesis of cyclopentenolones of the type cinerolone. *J. Amer. Chem. Soc.* 71:1517.
- Schechter, M. S., N. Green, and F. B. LaForge. 1949b. Constituents of the pyrethrum flowers. XXIII. Cinerolone and the synthesis of related cyclopentenolones. *J. Amer. Chem. Soc.* 71:3165-73.
- Schechter, M. S., F. B. LaForge, A. Zimmerliand, and J. M. Thomas. 1951. Crystalline allethrin isomer. *J. Amer. Chem. Soc.* 73:3541-2.

- Schmidt, C. D., J. J. Matter, J. H. Meurer, R. E. Reeves, and B. K. Shelley. 1976. Evaluation of a synthetic pyrethroid for control of stable flies and horn flies on cattle. *J. Econ. Entomol.* 69: 484-6.
- Schoof, H. F., and J. W. Kilpatrick. 1957. House fly control with parathion and diazinon impregnated cords in dairy barns and dining halls. *J. Econ. Entomol.* 50:24-7.
- Shepard, H. H. 1958. Methods of testing chemicals on insects. Burgess Publishing Co. Minneapolis, Minn. 356 pp.
- Sherman, M., and E. Ross. 1960. Toxicity to house fly larvae of droppings from chicks given Dipterex-treated water. *J. Econ. Entomol.* 53:1066-70.
- Slominski, J. W., and W. L. Gojmerac. 1972. The effect of surfaces on the activity of insecticides. *U. Wisc. Res. Rpt.* 2376: 8 pp.
- Slominski, J. W., W. L. Gojmerac, and W. E. Buckholder. 1970. The reaction of styrofoam to insecticides. *J. Econ. Entomol.* 63: 998-9.
- Slominski, J. W., W. L. Gojmerac, and W. E. Burkholder. 1971. Toxicity of residues of bromophos and ronnel to house flies as influenced by several surfaces. *J. Econ. Entomol.* 64:550-1.
- Staudinger, H., and L. Ruzicka. 1924. Isolation and constitution of the active portion of Dalmation insect powder. *Helv. Chim. Acta.* 7:177-201.
- Sullivan, W. N., M. S. Schechter, B. M. Cawley, and J. Kennedy. 1975. Promising pyrethroid and organophosphate insecticides with low mammalian toxicity. *Soap, Cosmet. Chem. Spec.* 51:44-6.
- Teotia, J. S., and B. F. Miller. 1973. Environmental conditions affecting the development of house fly larvae in poultry manure. *Environ. Entomol.* 2:329-33.
- Teotia, T. P. S., and P. A. Dahm. 1950. The effect of temperature, humidity, and weathering on the residual toxicities to the house fly of five organic insecticides.
- Tsuda, S., Y. Okuno, T. Yamaguchi, H. Ouchi, and C. Hirose. 1976. Studies on S-3151 (1) Basic studies on insecticidal activities of new insecticidal compound, 3-phenoxybenzyl (-) cis, trans, 2,2-dimethyl-3-(2,2-dichlorovinyl)-cyclopropanecarboxylate (S3151, permethrin). *Botyu-Kagaku* 41:90-9.

- Tyler, C. 1958. The influence of the zero hour and length of the time unit on the variation of dry matter excretion in balance experiments with poultry. *J. Agric. Sci.* 51:243-7.
- Ueda, K., L. C. Gaughan, and J. E. Casida. 1973. Photodecomposition of resmethrin and related compounds. ACS Meet. Chicago. (Abstract).
- Varley, G. C., and R. L. Edwards. 1957. The bearing of parasite behavior on the dynamics of insect host and parasite populations. *J. Anim. Ecol.* 26:471-7.
- Wade, C. F., and J. G. Rodriguez. 1961. Life history of Macrocheles muscaedomesticae (Acarina: Macrochelidae), a predator of the house fly. *Ann. Entomol. Soc. Amer.* 54:776-81.
- Weidhaas, D. E., and G. C. LaBrecque. 1971. Studies on the population dynamics of the house fly Musca domestica L. *Bull. WHO* 43:721-5.
- Wicht, M. C., Jr., and J. G. Rodriguex. 1970. Integrated control of muscid flies in poultry houses using predator mites, selected pesticides and microbial agents. *J. Med. Entomol.* 7:687-92.
- Williams, J. P. R. 1973. The control of Fannia canicularis (L.) in poultry houses using impregnated cords. *Br. Poult. Sci.* 547-50.
- Wilson, H. G., G. C. LaBrecque, and J. Thomas. 1975. Effectiveness of four insecticides on painted surfaces against Anopheles quadrimaculatus Say. *Mosq. News* 35:85-6.
- Yamamoto, R. 1923. Insecticidal principle in Chrysanthemum cinerariaefolium II and III. *J. Chem. Soc. Japan* 44:311-30.

X. VITA

Lee Hill Townsend, Jr. was born in Lexington, Kentucky, on October 23, 1946, to Lee H. and Louise Talbott Townsend. He entered the University of Kentucky as a 1964 graduate of Lexington Henry Clay High School. He graduated in 1968 with a B. S. degree in zoology and was commissioned a 2nd Lieutenant in the U. S. Air Force Reserve. Upon completion of four years active duty, he enrolled as a graduate student at Virginia Polytechnic Institute and State University. He completed a M. S. degree in entomology in June 1975 with financial support from a Graduate Teaching Assistantship. He is a student member of the Entomological Society of America and member of the Entomological Society of Washington, Gamma Sigma Delta, Phi Kappa Phi, Phi Sigma, and Sigma Xi. He was married to Jane Voellinger, daughter of Otto Richett and Edith Strayer Voellinger of Dothan, Alabama, on June 10, 1972. They have a son, Scott Richett Townsend.


Lee Hill Townsend, Jr.

THE SYNTHETIC PYRETHROID ECTIBANTM PERMETHRIN AS A TREATMENT
IN THE PEST MANAGEMENT OF FLIES IN CAGED-LAYER
POULTRY HOUSES

by

Lee Hill Townsend, Jr.

(ABSTRACT)

Ectibantm permethrin was evaluated as a feed additive, topical larvicide, residual surface spray, and on cotton cords for potential use as a fly control agent in caged-layer poultry houses. Also, its toxicity to representative nontarget arthropods was determined.

Ectiban at 5 and 10 ppm active ingredient in larval media controlled first and second-stage house fly larvae. However, an encapsulated formulation of the pyrethroid did not produce comparable results when fed in the rations of laying-hens at 50 ppm ai. A bioassay of acetone extracts of feed samples from a test bird indicated that most insecticidal activity was lost in the small intestine. However, fly production was greatly reduced in trays of manure seeded with fly eggs following topical applications of the pyrethroid at 24, 48, and 96 mg ai/ft². Mortality data from the nontarget species emphasized the broad spectrum toxicity of Ectiban.

Ectiban was effective as a residual house fly adulticide. The efficacies of a wettable powder and emulsifiable concentrate formulation of the insecticide applied to unpainted, latex- and enamel-painted plywood panels and styrofoam were compared. Residual activity was determined by exposing adult flies to the unweathered panels at

selected posttreatment intervals. The emulsion was effective on styrofoam for 126 days and in excess of 315 days on plywood, but was ineffective on the painted panels. The wettable powder was effective on latex for 30 days, on enamel for 45 days, on styrofoam for 112 days, and on plywood in excess of 315 days.

Caged house flies were exposed for one hour to cotton cords treated with 1% or 5% Ectiban-xylene solutions. Mortality data indicated that 5% Ectiban-treated cords would be suitable as an application method for exposing the pyrethroid for control of adult flies.

Ectiban permethrin demonstrated potential as a tool in the pest management of flies in poultry houses.