THE BIOLOGICAL EVALUATION OF SPRAY ADDITIVES AND SOLVENTS WITH *BLATTELLA GERMANICA* (LINN.) AND *PERIPLANETA AMERICANA* (LINN.)

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PREFACE

The effects of spray additives on pesticide formulations long have been a very important concern of people in the area of commercial pest control. When one considers the vast number of materials being used as ingredients of the various formulations, the concern becomes more evident.

Since this type of problem is very important in insect control, the National Pest Control Association offered to support a research program which would investigate the biological effects of many of the commonly used spray additives when applied to surfaces. With help from Dr. D. E. Howell, a research grant proposal was written and accepted by the National Pest Control Association for this project.

I wish to express my appreciation to my major adviser, Dr. D. E. Howell, for his guidance and encouragement throughout this research program and in preparation of this paper. Appreciation and sincere thanks are extended to Dr. Robert D. Morrison, Professor of Mathematics, for his continuous help and suggestions on statistical methods used during the research program and paper preparation. To Dr. R. R. Walton, Professor of Entomology, and Dr. James E. Webster, Professor of Biochemistry, gratitude is expressed for their valuable suggestions and criticisms of this thesis.

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INTRODUCTION

Spray additives are found in nearly all pesticide formulations and usually are classified as either synergists, surfactants, chemical deodorants, toxicants, or solvents. Numerous ingredients are added to spray formulations before adequate information on the biological activity has been obtained. If enough information were available, many of these materials probably would be shown to be of little value or possibly even detrimental to the pesticide formulation. Without this information control programs may be unsuccessful due to the use of some of these ingredients whose values have not been determined.

When a material is used in a formulation and the material acts as a repellent to the insects to be controlled, the result would be a lower per cent mortality or an unsuccessful control program. This in turn causes the cost of pest control to be higher due to the added application of insecticides which increases the problem of pesticide residues.

With these points in mind, this research program was initiated. Approximately 200 different pesticide formulations were tested for possible repellent action on _P_. _americana_ and _B_. _germanica_. All test materials were applied to plywood panels (white pine) and several different test designs were used. Many of the experiments were statistically evaluated.

In addition, the creep or spread of common pesticide solvents was studied. The effect surfactants have on the movement of solvents and the ability of the solvents to carry a toxicant were also investigated in this research program.

This research project was centered around the needs of workers in the area of commercial pest control. It is hoped that the results will be of value in the planning of their control programs for the insect pests which plague us today.

REVIEW OF THE LITERATURE

Insect response to chemical stimulation has been measured often on the basis of behavior patterns of the insects being tested. The patterns exhibited by the insects can be greatly influenced by environmental factors such as temperature, humidity, and light intensity. Other factors not so obvious are nutritional condition, amount of activity and disturbance, behavioral peculiarities, age, state of development, sex, and sample differences.

The uses, action, and history of spray additives on insects have been reviewed by Dethier (1947, 1956), Shambaugh et al. (1957), Taylor (1960), and others. The review presented in this paper will be limited to material involved in this particular research program.

Methods of Evaluation and Action of Spray Additives

Early materials were screened for repellency mostly against mosquitoes. Granett (1940) evaluated materials by application of the test chemicals to one arm or leg of a human subject and then determining the period of protection. To date, there have been many modifications of these procedures for testing on other insects such as the application of repellents as liquids or aerosols to coveralls, trousers, socks, gloves, and other surfaces.

Shaw et al. (1943) tested fly repellents and commercial sprays of known ingredients on dairy cattle. Base oil alone showed a highly significant repellent effect after the morning spraying but a nonsignificant effect after the afternoon spraying. Sprays containing 2.5% pyrethrins and 5.0% Thanite mixture in base oil caused a highly significant reduction of fly populations when compared with either the check or base oil.

Ribbands (1946) studied the action of pyrethrins and Lethane 384 sprays when they were applied to the surface of native huts. Anopheles mosquitoes were repelled for about four days after treatment with 0.1% pyrethrins in kerosene. In tests with 10% Lethane 384 in kerosene, the repelling action was gone after one night.

Granett et al. (1949) investigated the effectiveness of several compounds as livestock repellents. In their repellency rating of the materials tested, base oil had a rate of 20%.

Howell (1949) found that the only materials tested that exhibited significant repellent action to horse flies when used at safe concentrations were those that contained piperonyl butoxide or piperonyl cyclonene.

Laake et al. (1950) tested the relative effectiveness of various insecticides for control of house flies in dairy barns and horn flies on cattle. An emulsion spray containing 0.1% pyrethrins plus 1.0% piperonyl butoxide gave a residual protection of 6.6 days on treated surfaces of a barn. When this mixture was applied to the animal's entire body surface, it gave protection for 6.8 days from horn flies.

The action of piperonyl butoxide as a constituent of heavy oil sprays for the control of stored products insects was investigated by Hewlett (1951). He also studied piperonyl butoxide as a synergist for pyrethrins and its effects on the residual toxicity of pyrethrins. His results showed that there was no increased residual effect due to adding 2.5% piperonyl butoxide to the pyrethrins formulation. The effectiveness of the mixture became less toxic after nine days and lost most of its effectiveness in eighteen days. Pyrethrins alone was found to be the more toxic formulation after eighteen days. When wood and filter paper were compared, the insecticide on the filter paper surface had an eighteen day residual toxicity compared to fifteen days for the same treatment on wood.

A difference in the repellency to horn flies of 5.0% butoxypolypropylene glycol plus either 0.5% pyrethrins or 0.5% allethrins in various base oils was observed by Granett (1951) on the day of treatment and a day after treatment. Deobase, Bayol D, mineral seal oil, and proprietary oils A and B were used as solvents in the tests. The solvent found most repellent on the day of treatment and the day after treatment was proprietary oil A. When the formulation included 0.5% allethrins instead of pyrethrins, the solvent found most repellent and least repellent to horn flies on the day of treatment and the day after treatment were proprietary oil A and Deobase, respectively.

Sarkaria (1951), in his screening tests, divided liquid repellents into two classes—vapor and contact repellents—based on their activity in giving protection. He considered the contact repellents to be deficient in that they failed to remove the psychological hazard of swarming insects and allowed biting to occur on skin areas left uncovered by the application. The vapor repellents were thought to be deficient because they were lost rapidly by evaporation from the treated surface.

In a test with several materials, Pyrenone (10% piperonyl butoxide and 1.0% pyrethrins) was found to be the most repellent and the most economical for horse fly and horn fly control (Goodwin et al., 1952).

Goodhue et al. (1952) studied repellent actions of several chemicals to American cockroaches. They described methods for detecting both repellents and attractants. The method was based on the insects' habit of hiding in sheltered places away from light. In the tests the insects were given the choice of untreated shelter and treated shelter. If most of the insects were found in untreated shelters, the chemical in the treated one was considered repellent. This method also can be used to compare several chemicals or several concentrations of chemicals.

A laboratory method for testing repellents against biting flies was investigated by Starnes and Granett (1953). They found that Deobase had little or no repellency against house flies and stable flies. In the same tests, 5.0% Lethane 384 showed 95% repellency one day after treatment and 32% repellency seven days after treatment; whereas, 2.0% Pyrenone was 25% repellent on the first day after treatment and 38% repellent four days after treatment and after that exhibited no repellency.

Incho et al. (1953) evaluated insect-proofing paper treated with pyrethrins and piperonyl butoxide formulations. They found that eighteen months after treatment pyrethrins and piperonyl butoxide deposits on the paper showed no appreciable losses. They evaluated the residual effectiveness of the materials by letting cadelle larvae crawl on the surface of the treated papers. They found that the papers were protected for two months to a year from penetration by boring larvae.

Repellency of pyrethrins when applied to grain was investigated by Laudani et al. (1954). Their data indicated that adult flour beetles were repelled by treated corn and that the beetles were capable of detecting the difference between 0.1, 0.25, 0.3, and 0.37 ppm of pyrethrins.

Bruce and Decker (1955) found that the repellencies of 12 different fly spray formulations applied to beef cattle for protection from *Tabanus sulcifrons* were similar, ranging from 78.7% to 97.5%. Materials containing 1.0% pyrethrins were reported most repellent; and materials containing 1.0% allethrins, least repellent.

Granett and Haynes (1955) evaluated cyclethrins as livestock fly repellents. When cyclethrins were synergized with piperonyl butoxide or sulfoxide in an oil base spray, it was found that 1.5 to 2 times as much cyclethrins were needed as pyrethrins to provide effective repellency on the day of spraying against horn flies and stable flies.

The effects of insecticide additives on the behavior of the Japanese beetle were studied by Foster (1955). The results of his tests indicated that some solvents were repellent to the Japanese beetle. Odorless kerosene, So-Sol, benzene, xylene, Deobase, Shell insecticide base, Mistol, Ultrasene, regular run kerosene, No. 2 fuel oil, Velsicol AR-50, Velsicol AR-55, Velsicol AR-60, Sovacide 544-B, Sovacide 544-C, Sun solvent, and Shell E-407R were thought to have repellent action to the Japanese beetle. He found that some of the emulsifiers were repellent. These were Atlas E-1276, Emcol 74, and Emcol 77.

Lee (1957) reported that R-11 mixed with 0.075% pyrethrins, 0.15% piperonyl butoxide, and 0.25% MGK-933 developed a residual barrier that cockroaches would not cross for a period up to four weeks. When this repellent mixture was formulated with chlorinated hydrocarbon, the result was a scattering of the insects rather than an effective control.

Swank and Davis (1957) investigated the use of N-pentylphthalimide as a repellent for possible use on insect-resistant packaging. They found that 25 and 50 mg per square foot of N-pentylphthalimide had a lower repellency than pyrethrins plus piperonyl butoxide at 10 and 100 mg per square foot, respectively. At 100 and 200 mg per square foot, N-pentylphthalimide repelled more than the synergized pyrethrins.

Bruce and Decker (1957) indicated from their test results that a solvent such as Velsicol AR-50 when used as the solvent for R-326 and Tabutrex gave a longer period of repellency than activated pyrethrins to stable flies.

Hocking and Lindsay (1958) studied the reactions of insects to the olfactory stimuli from the components of an insecticide spray. They found that components such as diesel fuel oil, Velsicol AR-50, and Velsicol AR-55 were repellent, the Velsicol products being considerably more repellent than the fuel oil. This indicated that many additives found in sprays tend to defeat the object of the spray by inducing such reactions in insects exposed to their vapor that the insects will not come in contact with the toxicant. This provided an additional argument that aerial spraying, and sometimes in other methods of spraying, should move up wind on each successive pass; since by this procedure, insects repelled out of the later-treated swathes were most likely to move down wind into the area already sprayed. This also suggested that individuals surviving might be considered to have developed behavioral resistance to the insecticide being used.

Philips (1959) found that by spraying the surfaces of wheat being stored in ships with a 0.3% pyrethrins and 3.0% piperonyl butoxide combination, moths and beetles could be repelled for extended periods of time.

Goodhue (1960) described two new methods of screening repellents for cockroaches. The slanted card method was based on tendencies of the insects to rest on a slanting surface. The other method of testing was to place treated and untreated filter papers in two of three ground glass cylinders connected by a U-shaped opening. This kept the insects from climbing out and also forced them to stay on the filter papers or other surfaces at the bottom of the cylinder. The repellency in both tests was determined by comparing the number of cockroaches on the treated surfaces to the number on the untreated surfaces. These two methods were described as being easy to use and providing for the screening of a large number of chemicals under controlled conditions.

It was reported by Whiting (1960) that pyrethrins plus piperonyl butoxide repelled insects better than many repellents when applied to surfaces. He found that five days after application 0.4% pyrethrins plus 0.5% piperonyl butoxide repelled 88% of German cockroaches compared to 49% by R-440, 49% by Tabutrex, 48% by Crag fly repellent, and 34% by R-11. After nine weeks pyrethrins and piperonyl butoxide repelled 7.0%; R-440, 18%; R-11, 26%, Tabutrex, 0%; and Crag fly repellent, 0%.

Burden and Eastin (1960) found that German cockroaches were repelled by several compounds. Their tests indicated that deodorized kerosene repelled 45% of the insects one day after application. Tabutrex repelled 50% of the insects for a week. Paper cartons were used as test surfaces for the various treatments.

Pickthall (1960) investigated the effect of perfumery chemicals at 0.5% concentrations on the insecticidal efficiency of pyrethrins against the house fly. He reported the only compound which might have a detrimental effect on pyrethrins was phenylacetaldehyde dimethylacetal. The other materials tested were phenyl ethyl alcohol, phenyl ethyl acetate, geraniol, tetrahydrogeraniol, limonene, terpineol, terpinyl acetate, eugenol, ionone 100%, methyl eugenol, and citral.

Taylor (1960) found in his studies with surface repellents for a 30-day period that treated cotton string was the most effective. Plastic was the next most repellent surface with paper string third. The other materials and their descending order of repellency were glass, wire, painted wood, and unpainted wood.

Gouch and Smith (1962) investigated the effect of age and time of day on the avidity of *Aedes aegypti* (L). They found that in both the morning and afternoon tests, taken separately, the avidity increased rapidly with age for the first five or six days and then remained fairly uniform or increased slightly through the ninth day. However, the avidity each morning was much lower than during the previous afternoon despite the additional age. They concluded that in order to obtain maximum uniformity in repellent studies with this species, the mosquitoes should be seven to eight days old and the number of repellents small enough to complete testing in a morning or an afternoon. They also found that comparisons should not be made between morning and afternoon tests.

Roberts et al. (1963) reported that formulations containing various combinations of R-11, R-326, Tabutrex, butoxypolypropylene glycol, and piperonyl butoxide with 0.02% pyrethrins and without pyrethrins were less effective against stable flies and horn flies than 0.1% pyrethrins without additives. The effectiveness of treatments appeared to be more influenced by the quantity of pyrethrins in the formulation than by the presence or absence of additives.

Mode of Chemical Stimulation

Many efforts have been made to explain the mode of action of chemicals that act as repellents or attractants to insects. The sensilla on the legs of *Periplaneta americana* were shown to have no sensitivity to olfactory stimuli by Pringle (1938).

The palpi, hypopharynx, and ligula of P. americana were reported by Frings and Frings (1949) to be the locations of chemoreceptors. They also reported that the antennae and cerci have no chemoreceptors.

Roys (1956, 1958) studied the American cockroach by using behavioral and electrophysiological investigations. He found that nerve fibers and neurons in the tarsi and ventral nerve cord responded directly to application of salt, acid, sucrose, or quinine in concentrations as low or lower than the concentrations which had been reported as normal taste thresholds in behavioral studies. His findings suggested that the response to chemical stimuli might be found in many nerves in the insects rather than being limited to taste receptors.

Using electrophysiological tests, Price (1963) found that P. americana were stimulated by several repellents even though parts or all of the antennae had been removed.

Movement of Solvents

Brown et al. (1956) found that absorption of wood preservative solution was a complex and variable phenomenon. In dip treatments with ponderosa pine sapwood in a single solvent, the results of their tests indicated an absorption rate was 1:20 in an end to side surface ratio. In the tests, over half the total absorption occurred within fifteen seconds of immersion. Absorption also was found to vary inversely with the specific gravity of the wood.

The mechanisms involved in the flow of liquids into or through wood was investigated, and the non-polar nature of the solvent limited movement of the preservative solution to the gross capillary system of the wood. Flooding of the exposed cell lumens on the wood surfaces will explain the initial absorption. An increase in the moisture content reduced the initial absorption rate.

Cook and Ottes (1959) reported that a number of organic phosphate pesticides could be converted by ultraviolet light to less polar compounds.

Mitchell et al. (1960) reported that when chromatographic paper was used in tests where silver nitrate was used as a chromogenic agent a band or curtain appeared near the solvent front. This band contained silver reacting substances; and when the paper was sprayed with chromogenic agents, this curtain became dark and masked compounds which might have migrated into the area. To correct this, washed papers were used.

Mitchell (1960) described several methods of locating and identifying eleven organophosphates. Location and identification procedures for the compounds were as follows: (a) expose their quenched areas to ultraviolet light before and after exposure to bromine fumes and spraying with fluorescein; (b) spray with ammonical silver nitrate and expose to a germicidal light; (c) spray with 2-phenoxyethanol-silver nitrate and heat at 130-135 C for 30 minutes and expose to a germicidal light.

METHODS AND MATERIALS

Test Insects and Rearing Techniques

Blattella germanica and *Periplaneta americana* colonies were established from laboratory-reared adults available in the Oklahoma State University Department of Entomology Insectary. Both of the species were fed Purina Dog Chow and water throughout the tests. Nymphs and adults of both sexes were used in the tests. They were reared in 20-gallon metal garbage containers in which wooden shelves were used for resting sites. Half-pint paper cartons were used as containers for the dog food, and large test tubes filled with water and stopped with cotton served as the water source for the test animals. Both the food and water dispensers were placed on the top shelf in each of the rearing containers.

The temperature ranged from 65 F to 85 F in the rearing room. To help alleviate the problem of high humidity in the rearing chamber, two small openings were cut in the sides of the containers and covered with fine mesh wire. This allowed fresh air to circulate in the container, and the screening kept the insects from escaping.

Handling of Test Animals

Counting and handling of the cockroaches in all tests were facilitated by anesthetizing with CO_2. Eight to ten minutes passed after the anesthetized cockroaches were placed in the testing apparatus before the majority of the insects appeared to be fully revived. The actual testing of materials did not start until the eight to ten minutes had passed in each test.

Testing Procedures

Testing of all the spray additives used in this research program was carried out on ¼" x 4" x 6" white pine plywood panels. These panels were dipped for about one second in the chemicals to be tested at the start of each test and hung immediately on wire hangers. After all the panels of one treatment had been dipped and placed on hangers, they were hung in an open shelter so that air could pass over the surfaces of all the panels; but they did not come in contact with panels treated with other materials. All panels were kept in the same area throughout all the tests. When needed for testing, the number of panels to be used was removed from the hanging panels; and the rest were left until the next test period.

A turntable 18" in diameter that rotated at one revolution per minute was used in these tests. This testing apparatus was first used by Miesch (1964) for testing cockroach baits. This apparatus was thought to be helpful in cutting down the variations of temperature, humidity, and light. The outer cage surrounding the turntable was made of clear plastic about 18" in diameter and about 10" high. The inside surface of the plastic was covered with petroleum jelly to prevent the cockroaches from crawling out during the tests. The bottom of the apparatus was made of plywood 18" in diameter.

The panels were secured in a vertical position equidistant from each other on radii of the circle with the end of the panel one inch from the outer edge of the turntable. Each panel was held upright by four nails. Two nails were placed near the ends of the panels, one nail on either side. This enabled the panels to be easily slipped in and out for the tests with the least amount of contamination. The cockroaches were placed on the turntable after the panels were in position. The arrangement of the test panels allowed the cockroaches to move around on the paper-covered bottom of the test apparatus without touching any of the treated panels. The panels were tested by exposing them to a predetermined number of cockroaches and then counting the insects that appeared on each panel at specified counting times. After each count the cockroaches were forced from the panels with a jet of air. Four counts were made in a 30-minute period.

At the start of each test, a new group of treated panels was placed in the testing apparatus, the electric motor was started, and a new group of cockroaches was introduced. During the entire testing program, new insects, clean paper, and unused panels were used in every test. This was done to reduce contamination from chemicals and cockroaches.

Repellency of Pesticide Additive Combinations to *P. americana*

An incomplete block design with two replications and 121 treatments (Table 1. Common pesticide additive combinations) was used in these tests. All 121 treatment positions were assigned at random. Eleven different treatments could be tested per block with this design. The objective of the experiment was to determine what responses *P. americana* would have to surfaces treated with 1.0% concentrations of common pesticide additives when used as combinations. Evaluation was based on counting the number of cockroaches appearing on treated panels on the turntable and comparing the means of the treatments. Sixty American cockroaches were used for each test, one week, three weeks, and six weeks after the panels were treated.

Repellency of Selected Spray Additives Tested Individually with *P. americana* and *B. germanica*

Following the preliminary tests on common pesticide additive

TABLE 1. Spray additives and combinations used in the preliminary repellency tests with *P. americana*.

Treatments	Type*	Treatments	Type	Treatments	Type
R-440, Pyrethrins	R + T	R-326, Atlox 1045A	R + E	R-326, Triton X-100	R + E
R-326, MGK-264	R + Y	R-11, R-1357	R + R	Soltrol 170	S
R-326, MGK-933	R + T	Sulfoxide, R-1345	Y + R	Base Oil No. 1	S
Soltrol	S	R-1345, Pyrethrins	R + T	R-1345, I. M.	R + T
Atlox 1045A, Volpa-3	E + E	R-440	R	MGK-933	T
Velsicol AR-55	S	Kerosene (Conoco)	S	Volpa-3	E
R-1357, Volpa-3	R + E	R-1357	R	R-874, R-11	R + R
MGK-933, Atlox 1045A	T + E	Normal Hydrocarbon Blend	S	I. M.	T
R-1357, Pyrethrins	R + T	R-1345, MGK-264	R + Y	Sulfoxide, Pyrethrins	Y + T
R-874, R-440	R + R	R-440, Triton X-100	R + E	Sulfoxide, R-11	Y + R
R-874	R	Sulfoxide, R-874	Y + R	Volpa-3, I. M.	E + T
Volpa-3, Pyrethrins	E + T	R-874, Atlox 1045A	R + E	R-11, Volpa-3	R + E
R-874, Triton X-100	R + E	Triton X-100, I. M.	E + T	R-1345, Triton X-100	R + E
R-874, R-1357	R + R	Sulfoxide, Volpa-3	Y + E	R-1357, I. M.	R + T
MGK-264, Pyrethrins	Y + T	R-440, R-326	R + R	R-1357, MGK-264	R + Y
MGK-264, Triton X-100	Y + E	MGK-264, Atlox 1045A	Y + E	R-440, I. M.	R + T
n-Octane	S	Atlox 1045A	E	Sulfoxide	T
R-440, MGK-264	R + Y	R-1345, R-1357	R + R	R-874, R-1345	R + R
Atlox 1045A, Pyrethrins	E + T	MGK-933, Pyrethrins	T + T	R-1345, Atlox 1045A	R + E
R-1357, Triton X-100	R + E	MGK-933, MGK-264	T + Y	Apco 467	S
R-326, Pyrethrins	R + T	R-326, I. M.	R + T	R-874, Volpa-3	R + E
n-Decane	S	MGK-264, I. M.	Y + T	R-11, Atlox 1045A	R + E
Atlox 1045A, Triton X-100	E + E	Triton X-100	E	Velsicol AR-50	S
n-Dodecane	S	R-1345, R-326	R + R	R-1357, MGK-933	R + T
MGK-933, Triton X-100	T + E	I. M., Pyrethrins	T + T	R-326, Volpa-3	R + E
Volpa-3, Triton X-100	E + E	R-874, MGK-264	R + Y	Sulfoxide, R-1357	Y + R
R-874, I. M.**	R + T	R-874, MGK-933	R + T	R-440, Atlox 1045A	R + E
Velsicol AR-50G	S	R-1357, R-326	R + R	Sulfoxide, R-440	T + R

TABLE 1. (continued)

Treatments	Type	Treatments	Type	Treatments	Type
R-440, R-11	R + R	R-440, MGK-264	R + Y	R-874, R-326	R + R
R-1345, MGK-933	R + T	R-11, MGK-264	R + Y	R-11, Pyrethrins	R + T
R-326	R	Crag Fly Repellent	R	MGK-264, Volpa-3	Y + E
R-440, R-1357	R + R	MGK-933, I. M.	T + T	Sulfoxide, Atlox 1045A	Y + E
R-11, R-326	R + R	Soltrol 200	S	R-11, MGK-933	R + T
R-11	R	Apco 125	S	Pyrethrins	T
R-1357, Atlox 1045A	R + E	Sulfoxide, MGK-933	Y + T	Sulfoxide, I. M.	Y + T
R-440, Volpa-3	R + E	R-11, Triton X-100	R + E	Sulfoxide, R-326	Y + R
R-1345	R	MGK-933, Volpa-3	T + E	R-1345, Volpa-3	R + E
Atlox 1045A, I. M.	E + T	Triton X-100, Pyrethrins	E + T	MGK-264	Y
R-11, I. M.	R + T	R-440, R-1345	R + R	Sulfoxide, Triton X-100	Y + E
Sulfoxide, MGK-264	Y + Y	Base Oil No. 2	S	n-Hexadecane	S
R-874, Pyrethrins	R + T				

*Initials used to designate additives:
R=Repellent
T=Toxicant
Y=Synergist
S=Solvent
E=Emulsifier
**I. M. (Intermediate Mixture) = 10% Piperonyl Butoxide, 1.0% Pyrethrins

combinations to P. americana, several materials were selected for evaluation which had a high or low degree of repellency when used individually in Base Oil No. 1 or water (Tables 2 and 3). These materials were all tested at 1.0% concentration with P. americana and B. germanica. The results were obtained in this test in a different manner than the preliminary test described above. In this test only four panels of one treatment were placed on the turntable during each test. The procedure in counting and randomizing the placement of the treated panels was the same as described above. The total number of cockroaches appearing on a panel was recorded. This total was made up of four counts on each of the four panels. This gave sixteen observations for each treatment at each test period. Sixty American or 125 German cockroaches were used in each test of this series.

The main objective of this investigation was to select several of the additives for more extensive testing. The chemicals selected were those found to have above average or below average repellency after test periods of 7, 21, and 42 days. The selection was based on the average number of cockroaches that appeared on a treatment.

Repellency of Selected Spray Additives to P. americana and B. germanica Tested at Three Concentrations

A factorial design was used to study the effects of time, chemicals, and concentrations on repellency. Testing periods of 1, 7, 21, and 42 days after panel treatment were used on both species of cockroaches. The following materials were used: Lethane 384, MGK-264, pyrethrins, piperonyl butoxide, Atlox 1045A, Toximul-P, D-460, and D-41927. These were used at concentrations of 1.0%, 0.1%, and 0.01% formulated in Base Oil No. 1. The same number of observations was made for each treatment

TABLE 2. Selected spray additives and combinations used in repellency tests with *P. americana*.

Emulsifiers	Repellents	
Triton X-100	R-11**	R-874
Triton X-131	R-326	R-1357
Triton X-155		
Triton B-1956*		

Emulsifiers	Solvents
Triton X-131 & Toximul-P	Amsco (odorless kerosene W-2)
Emcol AD6-29	Espesol 5
Volpa-3	Espesol 5*
Atlox 1045A	Isopropyl Alcohol
Toximul-P*	Methylene Chloride
Igepal CO-890*	Trichloroethylene
Igepal CO-890 & Espesol-5 = Solvent	

Masking Agents		Synergists
D-458**	D-41925	MGK-264
D-460	D-41927	Piperonyl Butoxide
D-461	D-41928	
D-462	D-41968	

Masking Agents		Toxicants
D-463	D-41994	
D-464	D-42516	Lethane 384
D-465	Nilodor	MGK-933
D-878	Perfume 19	Pyrethrins

*1.0% additive in water. All other materials were used with Base Oil No. 1 (Phillips Petroleum Company).

**D=Insecticide Deodorants
R=Repellent

TABLE 3. Selected spray additives and combinations used in repellency tests with *B. germanica*.

Emulsifiers

Triton X-100
Triton X-131
Triton X-155
Triton X-700
Triton X-800*
Triton B-1956*
Triton X-131 & Toximul-P
Emcol AD6-29
Volpa-3
Atlox 1045A
Odor Sorb Emulsifier
Toximul-P*
Igepal CO-890*
Igepal CO-890 & Espesol-5 = Solvent

Masking Agents

D-458**	D-41927
D-460	D-41928
D-461	D-41968
D-462	D-41994
D-463	D-42516
D-464	Nilodor
D-465	Perfume 19
D-878	Odor Sorb 202
D-41925	Odor Sorb 201*

Repellents

R-11**	R-874
R-326	R-1357

Solvents

Amsco (odorless kerosene W-2)
Espesol-5
Isopropyl Alcohol
Methylene Chloride
Trichloroethylene
Gulf Livestock Oil
Gulf Fly Spray Oil
Apco 140

Synergists

MGK-264
Piperonyl Butoxide

Toxicants

Lethane 384
MGK-933
Pyrethrins

*1.0% additive in water. All other materials were used with Base Oil No. 1 (Phillips Petroleum Company).
**D=Insecticide Deodorants
R=Repellent

in the same manner as in tests already described. Only one treatment was tested on the turntable at a time. The number of cockroaches used in this test with each species was 70 American or 125 German.

Repellency of a Toxicant (Diazinon) Plus Selected Spray Additives to *P. americana* and *B. germanica*

Repellency Tests. These tests were also a factorial design involving time, chemicals, and concentrations and how they affect the toxicant in the formulation being tested. The procedure in obtaining the data was the same as in the other experiments except that there were two replications in this experiment with four panels in each replication and counts were made on each panel four times. The number of cockroaches used in these tests were 50 American or 100 German. Two concentrations (1.0% and 0.01%) of Lethane 384, MGK-264, pyrethrins, piperonyl butoxide, Atlox 1045A, Toximul-P, D-460, or D-41927 were used in a formulation with 1.0% Diazinon in these tests. A 0.01% Diazinon formulation also was tested. Evaluations were conducted 7, 21, and 42 days after panel treatment.

Mortality Tests. After the repellency part of these tests for each treatment had been completed, a treated panel was selected at random from the four in the test apparatus and was placed in a one-half gallon paper carton with the top covered with nylon netting. The anesthetized cockroaches used in the repellency tests were placed in the respective half-gallon cartons containing the treated panels. The panel was centered vertically on the bottom of the container so that the cockroaches could move around the sides without touching the treated surface. Thumbtacks were used to hold the panels in place.

The purpose of these tests was to investigate the per cent mortality after 12- and 24-hour periods of exposure to see if there were any correlation between the repellency and toxicity of a material. The number of cockroaches used in this test was 50 American or 100 German. Two replications and 1-, 7-, 21-, and 42-day test periods were used in the test.

Studies on the Movement of Common Pesticide Solvents

The objectives of these tests were threefold: (1) to investigate the ability of solvents to spread over or penetrate an area where they had been applied; (2) to study the effect of different surfactants on solvent movement; (3) to test the ability of solvents to carry Diazinon. The solvents listed in Table 4 were used with the following surfactants: Atlox 1045A, Volpa-3, Odor Sorb emulsifier, Triton X-100, Triton X-700, and Triton X-131. In preliminary studies different methods of solvent penetration of wood were investigated. These studies showed that solvent penetration in 1½" square blocks of white pine, redwood, cottonwood, and oak was extremely variable, as found by Brown et al. (1956). Solvent dyes were used to trace the movement of the solvents in wood blocks. This procedure was discontinued because of the extreme variability of results and replaced with the following test. Whatman No. 1 chromatography paper was used because of its high degree of purity (99% cellulose) and uniformity of structure. Ten microliters of each solvent formulation were applied to a 2½" x 18" strip of Whatman No. 1 chromatographic paper dyed red with an oil soluble dye. The solvents were formulated individually or with a 1.0% concentration of Triton X-100, Triton X-700, Volpa-3, Triton X-131, and Diazinon or Diazinon plus one of the surfactants. In the tests with solvents alone, one test was conducted at normal room conditions (temperature, 70-85 F); and the other test was carried out under

TABLE 4. Pesticide solvents used in solvent movement studies.

Kerosene	Soltrol 130	n-Hexadecane
Soltrol 200	Soltrol 170	Apco 140
Base Oil No. 1	Apco 170	Gulf Livestock Oil
n-Dodecane	Base Oil No. 2	Gulf Fly Spray Oil
AR-50	Normal Hydro-carbon Blend	Amsco
AR-50G		Trichloroethylene
AR-55	Benzene	Methylene Chloride
Diesel	n-Octane	Isopropyl Alcohol
Xylene	n-Decane	Espesol-5
Apco 462	Cottonseed Oil	

saturated (with chemical) conditions at room temperature. In the saturated test, the solvent treated strips were placed in a gallon jar in which an open pint jar of the test solvent had been deposited ten minutes earlier. The remaining tests involving solvents plus surfactants plus Diazinon were conducted under normal room conditions.

In all tests the strips of paper were hung to dry for two or three hours after being treated with a test material. Time intervals of two hours for fast evaporating solvents and three hours for slow evaporating solvents were used so that the data collected from these tests would indicate how far a given solvent formulation would spread after these time intervals.

To find the distance the solvents or solvent formulations moved, marks were placed at the furtherest extensions of the circle at the end of the two- or three-hour period. The distances between the marks were measured to the nearest 0.1 cm, and an average of thirty measurements was used as the creep distance for that particular test material.

The carrying ability of the solvents for Diazinon was measured by a method described by Mitchell (1960). In these tests undyed strips were used with the same application procedure for treatment as described above.

The evaporation period, however, was extended to 48 hours. This was necessary for all slower evaporating materials so that they would have sufficient time to evapoate before being dipped or sprayed.

The paper strips were dipped in a solution containing 170 mg of Ag NO_3 dissolved in 1 ml H_2O to which 5 ml of NH_4 OH was added. This mixture was diluted with 95% ethanol to 200 ml. After the strips had dried thoroughly, they were placed under a short wave (2537 A^o) ultraviolet light for 20 to 50 minutes. This caused a reaction to occur in which the chromatographic paper turned black due to the presence of Ag NO_3, and the Diazinon residue on the paper turned brownish-green. The distance covered by the Diazinon residue was measured and compared to that of the solvents by themselves.

RESULTS AND DISCUSSION

The use of various testing designs for the biological evaluation of common spray additives tested in combinations and individually with *B. germanica* and *P. americana* will be reported and described in this section.

Repellency of Pesticide Additive Combinations to *P. americana*

Preliminary studies were conducted with *P. americana* on 121 different spray additive combinations at 1.0% concentration by use of an incomplete block experiment. The chemicals used in these tests were nearly all common constituents of spray formulations used in the control of cockroaches or other insects.

Table 5 lists the average number of cockroaches found on each treatment after two replications for each of the three test periods. The data indicated that some of the spray additive combinations were more repellent than others. The formulations which appeared most repellent for the three test periods, one, three, and six weeks after treatment, contained one or more of the following materials: R-874, R-11, R-1357, pyrethrins, MGK-264, R-440, Atlox 1045A, Volpa-3, and Triton X-100. These materials and some in other formulations showed an indication of having increased the repelling action of other materials that they were combined with in the tests.

Many of the materials in the spray combinations appeared to be very repellent when used in certain combinations; but when the same materials were used in other combinations, they showed a lower degree of repellency.

The results of these tests showed that spray additives reacted differently in various combinations, so further testing of some of the more repellent materials seemed necessary.

Repellency of Selected Spray Additives Tested Individually with *P. americana* and *B. germanica*

In this study several of the more commonly used spray additives tested at 1.0% concentrations were found to be as repellent or more repellent to *P. americana* than some of the more common cockroach repellents. The results of these tests are shown in Table 6.

The mean number of cockroaches for the treatments at the seven-day test period ranged from 4.87 per panel for R-1357 to 9.81 for Igepal, an emulsifier. In general, the materials showing the highest repellency were repellents commonly used in cockroach control. Materials like piperonyl butoxide, pyerthrins, and deodorants were found to be highly repellent to the American cockroach. At the end of the seven-day test period, two emulsifiers, Triton X-155 and Triton B-1956, seemed to be somewhat repellent along with several insecticide deodorants.

After the 21-day test period, the materials that appeared to be the most repellent at 7 days were again high on the list of repellents. Two, R-1357 and R-874, were again the most repellent treatments. The next most repellent materials were synergists, piperonyl butoxide and MGK-264. The repellency of pyrethrins was consistent from the 7- to the 21-day test period since it ranked as the sixth or seventh most repellent material each time. Several of the insecticide deodorants and two of the surfactants also were among the 20 materials shown to be most repellent at this test period.

The 42-day test reading indicated that the repellency of most of the materials was somewhat less than at the end of the 7-day test period. However, the same materials generally were shown to be the most repellent to the American cockroach at 42 days after treatment as at the other test periods. The most repellent chemicals again were R-1357, R-874, and R-326. Pyrethrins and three deodorants also were more repellent than most of the other materials. Piperonyl butoxide was about half way down the list of repellents at this period.

The results of these tests indicated that several spray additives used in formulating many of the common household insect sprays may be expected to exhibit a certain amount of repellency for several days after being applied to a surface. Taylor (1960) found this to be true on several different surfaces.

The results of the repellency tests using 49 spray additives with B. germanica demonstrated that several of the materials which were repellent in the American cockroach test also were repellent to German cockroaches (Table 7). However, several of the materials showed different degrees of repellency to the two species of cockroaches.

The seven-day counts indicated that German cockroaches were repelled by two insecticide deodorants, D-460 and D-41927, to about the same degree as they were by repellents, R-11, R-1357, and R-874. Other materials also found repellent after seven days were Lethane 384, pyrethrins, Nilodor, MGK-933 (1.5% pyrethrins, 3.0% piperonyl butoxide, 5.0% n-octyl bicycloheptene dicarboximide), and piperonyl butoxide.

At 21 days, the same materials as in the 7-day test period showed a high repellency. The most repellent were R-1357, R-11, and R-874 with D-41927 and D-460 having about the same degree of repellency. Lethane 384, MGK-933, and piperonyl butoxide also were near the top of the list of repellents. The repellency of pyrethrins fell to about the middle of the list.

After the 42-day test period, the same materials, R-1357, R-11, and R-874, were still some of the most repellent. Lethane 384 also showed a long period of repellency, but the insecticide deodorants that were found to be highly repellent in the first two test periods lost their action after 42 days. Very slight differences appeared in most of the other materials.

From both the American and German cockroach studies, it was observed that there was a greater spread in the means during the 7-day test period (German, 12.00-18.88 and American, 4.87-9.81) than with the 21-day test period (German, 12.81-18.82 and American, 7.25-11.00). However, the 42-day tests had a much narrower range of means in both species (German, 15.63-18.63 and American, 7.59-10.63). This indicated that spray additives such as those used in the above tests generally lost their effectiveness as repellents after about three weeks.

Repellency of this nature would be most desirable where the death of the insects would be of no benefit, such as Philips (1959) described in repelling insects from grain stored in the holds of ships. The materials that showed high repellency had a place in this type of control program where contamination of food products with insect bodies was restricted. But, if the control program were one in which high mortality rates were desired, the materials would then be a detriment to the spray formulation.

Repellency of Selected Spray Additives to *P. americana* and *B. germanica* Tested at Three Concentrations

The analysis of variance for the response of American and German cockroaches to surfaces treated with pyrethrins and piperonyl butoxide are presented in Tables 8 and 9, respectively. The F values for the main effect of days in the American cockroach test and concentrations and days in the German cockroach test were significant at the .01 level.

The response for the American cockroaches can be seen in Figs. 1 and 3. Fig. 1 shows a typical response for a repellent material (pyrethrins). The slope of lines abcd, ABCD, and A'B'C'D' showed that all concentrations had a lower repellency as the concentration decreased and as the time passed from 1 to 42 days after treatment except line ABCD where point D is lower than point C. The response shown in Fig. 3 for piperonyl butoxide indicated that seven days after treatment the 0.01% concentration (point B') exhibited as much repellency as one day after treatment (point A'). The response also showed that there was very little difference after one day in the amount of repellency of 0.1% (point A) and 1.0% (point a) concentrations.

Fig. 2 shows the response of German cockroaches to pyrethrins. This was very similar to the response shown in Fig. 4 (using piperonyl butoxide) and those for the same materials with American cockroaches. In nearly all instances the repellency decreased with the lower concentrations and with the passage of time.

Tables 10 and 11 show the analyses of variance for the response of American and German cockroaches to surfaces treated with MGK-264 and Lethane 384. The F values for the main effect of days in both species of insects were highly significant. Chemicals x concentrations, days x concentrations, days x concentrations x chemicals interactions were indicated by significant F values in both species.

In general, the response (Fig. 5 with MGK-264) for American cockroaches showed the typical decrease in repellency with lower concentrations (lines ABCD and A'B'C'D') and the decrease with time after treatment. The response shown in Fig. 7 with Lethane 384 for American cockroaches did not give a typical decrease in repellency at the longer time interval after treatment. The slope of line abcd indicated that at the 7-day test period point b of the material was less repellent than at the 21-day period for 1.0% concentration (point c). The response showed little difference in the repellency of 0.01% (line A'B'C'D') and 0.1% Lethane 384 (line ABCD) to American cockroaches except at the one- (points A' and A) and seven- (points B' and B) day test periods.

The response (Fig. 6 with MGK-264) for German cockroaches indicated several interactions. The most repellent concentration for one (point A) and seven (point B) days after treatment was 0.1% (line ABCD). Very little difference in the response could be observed after seven days in any of the concentrations. They all seemed to lose their repellency to about the same degree with time.

The response for German cockroaches to Lethane 384 is presented in Fig. 8. The response showed no extreme deviation from the normal response to repellents. Line ab (concentration, 1.0%) sloped more than line AB (concentration, 0.1%) and line A'B' (concentration, 0.01%).

The analyses of variance for the responses of American and German cockroaches to surfaces treated with surfactants Atlox 1045A and Toximul-P are presented in Tables 12 and 13. The F values for the main effects of chemicals and days in American cockroaches and the main effects of chemicals, concentrations, and days in German cockroaches were all significant. The chemicals x concentrations interaction in American cockroaches and the chemicals x concentrations, days x concentrations, days x concentrations x chemicals interactions in German cockroaches were indicated by significant F values (Tables 12 and 13).

The response shown in Fig. 9 for American cockroaches indicated that there was little difference in the repellency of Toximul-P over the four test periods for the three concentrations. The response for American cockroaches to Atlox 1045A is presented in Fig. 11. It can be seen from the response that the repellency of 0.1% Atlox 1045A one day (point B) after treatment was higher than the 1.0% concentration for the same time period (point b). Also the response after one day showed that the 0.1% concentration (line ABCD) tended to be almost as repellent as 1.0% concentration (line abcd) throughout the test period.

Fig. 10 shows the response for German cockroaches to Toximul-P. The response showed that the insects reacted to the three concentrations similarly except at the 42-day test period where the 0.1% concentration (point D) seemed to be the most repellent formulation. The response for German cockroaches to Atlox 1045A (Fig. 12) indicated the interaction effects. The 1.0% concentration (line abcd) showed that the least repellent treatment period was after 21 days (point c). The least repellent test period for 0.1% concentration (line ABCD) of Atlox 1045A was seven days (point B). But, the most repellent test period for this material at the 0.01% concentration (line A'B'C'D') was seven days (point B').

The analyses of variance for the response of American and German cockroaches to surfaces treated with insecticide deodorants D-41927 and D-460 are shown in Tables 14 and 15. It can be seen from these tables that the main effects of concentration and days were highly significant in both species. Some interaction was present as would be expected by highly significant F values for days x chemicals, days x concentrations, and days x chemicals x concentrations for German cockroaches and also for American cockroaches which had significant F values for days x concentrations and days x concentrations x chemicals.

Fig. 13 shows the response for American cockroaches to D-41927. This indicated that all concentrations were most repellent one day after treatment (points a, A, and A'). Both the 0.1% (line ABCD) and 1.0% (line abcd) concentrations still showed a high degree of repellency after seven days (points B and b). The response for American cockroaches to D-460 can be seen in Fig. 15. The most important feature of this graph is the fact that the most repellent surfaces were at the seven-day test period for the 1.0% concentration (point b) and the one-day test period for 0.01% and 0.1% concentrations (points A' and A). Also, little difference could be seen between 0.1% and 0.01% concentrations after seven days (points B and B').

The response of German cockroaches to D-41927 is presented in Fig. 14. This graph shows that the most repellent time period for all concentrations was the seven-day test period (points b, B, and B'). The 1.0% concentration was definitely the most repellent concentration for the first two test periods (points a and b). After 21 days, the 0.1% concentration (point C) seemed to be the most repellent.

It can be seen from Fig. 16 that D-460 was most repellent at the 1.0% (point b) and 0.1% (point B) concentrations to the German cockroach at the seven-day test period. The response otherwise showed little deviation from a normal surface for the other materials.

<u>Repellency of a Toxicant (Diazinon) Plus Selected Spray Additives to *P. americana* and *B. germanica*</u>

<u>Repellency Tests</u>. Table 16 shows the analysis of variance for the

response of American cockroaches to surfaces treated with 0.01% and 1.0% Diazinon individually and to surfaces treated with 1.0% Diazinon plus 0.01% and 1.0% of each of the following materials: pyrethrins, piperonyl butoxide, D-41927, D-460, Lethane 384, MGK-264, Toximul-P, and Atlox 1045A. Two of the main effects, types in other chemicals and days were significant. The F value for the interaction of days x types in other chemicals was highly significant. It can be seen from the F value for chemicals x concentrations that there were no significant differences in the concentrations of the chemicals. The response for the American cockroaches for the various treatments are shown in the following figures: Fig. 17, pyrethrins; Fig. 19, piperonyl butoxide; Fig. 21, D-41927; Fig. 23, D-460; Fig. 25, Lethane 384; Fig. 27, MGK-264; Fig. 29, Toximul-P; Fig. 31, Atlox 1045A; and Fig. 33, Diazinon. The responses indicated that all the test materials except the deodorants had very little effect on the spray formulation. It can be seen from these response graphs that all the treatments followed a pattern similar to Diazinon except D-41927 and D-460. Fig. 19 shows that D-41927 had a high repellency at the one-day test period at the 1.0% concentration (point A). The 0.01% concentration (line A'B'C'D') had a loss in repellency at each test period (points A', B', C' and D'). The only material tested against the American cockroach that showed this gradual loss in repellency was D-41927. The responses to all of the other materials showed an increase in repellency for each concentration at the three-week test period (points C and C'). The most logical explanation for this occurrence seemed to be the changes that occur in insects from season to season. Since this test was started in August and completed in October, there may have been enough changes in the test animals' activity to cause this type of response. This was the only test conducted during a period where a change in season occurred. A similar response will be reported later in this paper when the test animal is B. germanica.

Table 17 contains the analysis of variance for German cockroaches to surfaces treated with 0.01% and 1.0% Diazinon individually and 1.0% Diazinon combined with a 0.01% and 1.0% concentrations of the following materials: pyrethrins, piperonyl butoxide, D-41927, D-460, Lethane 384, MGK-264, Toximul-P, and Atlox 1045A. The F values for the main effects of types in other chemicals, Diazinon versus other chemicals, and days were highly significant. The interaction of days x types in other chemicals was significant. As with the American cockroach, the effect of concentrations x chemicals were not found significant in this test.

The response for German cockroaches to the various treated surfaces tested as repellents are shown in the following figures: Fig. 18, pyrethrins; Fig. 20, piperonyl butoxide; Fig. 22, D-41927; Fig. 24, D-460; Fig. 26, Lethane 384; Fig. 28, MGK-264; Fig. 30, Toximul-P; Fig. 32, Atlox 1045A; and Fig. 34, Diazinon. The responses presented in these figures indicated that most of the materials had little, if any, more repelling effect than Diazinon. The only materials having greater repellency than Diazinon were D-41927 and D-460. Both concentrations of both materials showed the most repellency at the one-day test period (points A and A').

The other test materials also were most repellent at the one-day test period (points A and A') and in some cases very little difference was observed between the two concentrations at the one-day test period.

After the one-day test period, generally all the materials gave a characteristic pattern of responses as can be seen in Figs. 18-34. This pattern showed that all the materials lost their repellency most rapidly between the 7- (points B and B') and 21- (points C and C') day test periods. However, the response showed that the materials were more repellent at the 42-day test period (points D and D') than at the 21-day test period (points C and C'). This response was somewhat different than that at the same test period for the American cockroaches. However, if the test dates for the four test periods for each of the species were considered, the 21-day test period (points C and C') for American cockroaches corresponded to the 42-day test period (points D and D') for German cockroaches. These two test periods showed the test materials to be more repellent than at the preceding test periods. Again, the most logical explanation for this type of response seemed to be the activity changes that occurred during the time interval. The test with German cockroaches was begun in early August and completed in mid-September; whereas, the test with American cockroaches was initiated in mid-August and completed in early October. This type of activity change in insects has been found to be more pronounced in species that hibernate or that go into an inactive state (diapause) due to adverse environmental conditions, but cockroaches have been shown to have a circadian rhythm. However, the changes that occur from season to season are not well understood. The results of this test indicated that this area of study should be investigated in more detail. It can be seen that results such as those presented in this paper from materials tested over a period of time may be affected greatly by this possible alteration in activity of the test animals during the period of study.

Mortality Tests. Table 18 gives the results of the toxicity test with American cockroaches. All the treatments tested one day after treatment except 0.01% Diazinon gave 90% or higher kill after the 12-hour check and 100% mortality after 24 hours. Seven days after treatment the per cent kill at the 12-hour check ranged from 62% to 95% except in 0.01% Diazinon, and after 24 hours the per cent mortality was from 83% to 100% except with 0.01% Diazinon which gave only 10% kill. Twenty-one days after treatment, the per cent mortality for the 12-hour check was from 12% to 72% except with 0.01% Diazinon which had 4.0% kill. At the 24-hour check, the per cent mortality ranged from 40% to 100% in all except 0.01% Diazinon. The 42-day test period for the treatments showed a per cent kill from 16% to 40% at the 12-hour check except with 0.01% Diazinon. After the 24-hour check, a range of 32% to 75% kill was observed except in the case of 0.01% Diazinon.

The materials tested at either concentration in combination with Diazinon seemed to have little effect on the mortality rate at either the 12- or 24-hour check one day after treatment. The test period of seven days after treatment indicated that all the materials would give 90% or more kill except the deodorant being tested. These materials also were shown in other tests to have some degree of repellency. The material shown by this test to be most effective after seven days was 1.0% piperonyl butoxide. It was the only material to give 100% mortality to the American cockroach. The results obtained from the 21- and 42-day test periods indicated that some of the spray additives did not increase the effectiveness of Diazinon but reduced it to some extent. The only formulations that showed increased mortality were in the case of some of the surfactants and 1.0% piperonyl butoxide.

The results of the toxicity test with German cockroaches are given in Table 19. The per cent mortality after one day ranged from 70% to 92%

at the 12-hour check to 95% to 100% at the 24-hour check. Pyrethrins at 1.0% concentration seemed to be most detrimental to the Diazinon at both the 12- and 24-hour checks. The deodorants seemed to have some repelling action at the 12-hour check. After seven days the mortality percentage ranged from 75% to 96% at the 12-hour check to 93% to 100% after 24 hours. Again, the pyrethrins and deodorants seemed to have lowered the mortality rate at both check periods.

The data from the 21- and 42-day periods after treatment indicated that the most effective materials again were surfactants. The rest of the materials at the 21-day treatment period did not increase the effectiveness of Diazinon, and the only material that showed a definite lower percentage kill was D-460. After 42 days the formulations all seemed to be as effective as Diazinon used individually.

This test indicated that a person involved in the controlling of insect pests should consider very carefully the spray additives being used in his spray formulation. This consideration may increase the mortality rate greatly, simply through selecting spray additives that have no repelling effect; and the pest will be more apt to be killed than repelled when it comes in contact with a treated surface. This type of action where an insect is repelled from a treated surface and is not killed is thought by many to be resistance. When this occurs a new insecticide is usually desired; but if a more detailed study had been conducted, the formulation that was thought to cause resistance may only have been acting as a repellent.

The repelling action of an insecticide formulation may explain the question brought up about the insects changing their habitats. If an insecticide is applied to a surface or area where a population of insects exists and the material repels the insects before it kills them, they in turn will seek a new area or surface as a habitat. Hocking and Lindsay (1958) have shown that spray additives such as AR-50G and AR-55 would repel mosquitoes from one area to another.

Studies on the Movement of Common Pesticide Solvents

The results from the preliminary studies in which wooden blocks were used indicated that solvent movement through white pine, redwood, cottonwood, and oak 1½" square blocks was extremely variable. Brown et al. (1956) reported similar results in their studies with wood preservatives. In these preliminary tests, solvents were observed to move through the end grain of the 1½" square blocks in as little as 10 to 15 seconds. This movement of the solvents through the blocks was very irregular.

Tables 20 and 21 represent the distance of spread for each solvent and solvent formulation. These results were obtained over a period of 12 months. However, each test such as Atlox 1045A plus all solvents was carried out in less than one week. All of the tests over a period of 12 months were conducted under similar laboratory conditions in a temperature range of 65-80 F. The variation of temperature and humidity over the 12-month period may have had some effect on the spread of the various solvent formulations. This must be considered in the interpretation of the data presented in Tables 20 and 21. In each table it can be seen that the solvents generally moved farther without a surfactant than when a surfactant was added. The results shown in Table 20 indicate that various surfactants caused solvents to spread different distances. Most of the slow evaporating solvents moved shorter distances when a 1.0% concentration of a surfactant was added. However, when some of the surfactants such as Atlox 1045A were added to the solvents that evaporate quickly—trichloroethylene, methylene chloride, and xylene—the distance of spread was increased.

The test surfactants were ranked on the basis of the effectiveness in altering the movement of solvents. The materials were ranked as follows: Atlox 1045A, Volpa-3, Triton X-700, Triton X-100, Triton X-131, and Odor Sorb emulsifier. This ranking is merely an indication of how these surfactants would affect solvents in the environment of the laboratory and should not be overemphasized since the different surfactants and solvent formulations were tested over a period of 12 months.

When the solvents were formulated with Diazinon and the various surfactants (Table 21), the results appeared similarly to those reported for the solvents plus various surfactants. The following ranking for the tests was observed: Triton X-100, Atlox 1045A, Triton X-131, Triton X-700, Volpa-3, and Odor Sorb emulsifier. Again, this ranking should not be considered as strong evidence that solvent movement will be reduced by a given surfactant due to the fact that these tests also were carried out over a 12-month period. However, it can be seen from the data from both tests that Atlox 1045A and Triton X-100 formulations appeared to more closely approximate the movement of solvents alone than any of the other surfactants tested; whereas, Odor Sorb emulsifier in both tests gave the least amount of spread for the solvents involved.

These results give an indication as to the effectiveness of the various solvents and surfactants. In tests such as these, the results would be more reliable if it were possible to conduct the tests under closely controlled environmental conditions.

In the tests designed to measure the ability of various solvents to move Diazinon, the results indicated that most of the solvents moved Diazinon the same distances as the solvents themselves moved. When Diazinon was dissolved in a few solvents, the color change resulting from the exposure to ultraviolet light and Ag NO_3 was less distinct than the normal reactions with the other solvent formulations. In these cases Diazinon movement was difficult to evaluate but apparently approximated that in the more clear cut reactions.

SUMMARY AND CONCLUSIONS

Repellency of Pesticide Additive Combinations to *P. americana*

One hundred twenty-one different treatments were tested against *P. americana* using an incomplete block experiment. These materials were tested one, three, and six weeks after treatment. The most repellent formulations contained the following materials: R-874, R-11, R-1357, pyrethrins, MGK-264, R-440, Atlox 1045A, Volpa-3, and Triton X-100. These materials increased the repellent action of other materials with which they were formulated.

Repellency of Selected Spray Additives Tested Individually with *P. americana* and *B. germanica*

Results of these tests indicated that several of the more common pesticide additives had a high degree of repellency for up to 21 days. Surfaces treated with materials such as piperonyl butoxide, pyrethrins, insecticide deodorants, and surfactants were repellent to both American and German cockroaches. The most repellent materials throughout the tests for both species were R-1357 and R-874.

The mean numbers for *P. americana* and *B. germanica* during the tests indicated that there was a wider range in the repellency of the materials at the 1- and 21-day test periods than at the 42-day test period. This type of response showed that most of the materials lost their repellency by the 21-day test period.

Repellency of Selected Spray Additives to *P. americana* and *B. germanica* Tested at Three Concentrations

These tests were designed as factorial experiments with time, concentrations, and chemicals being investigated. In the American cockroach test with pyrethrins and piperonyl butoxide, a difference was noted in the reactions of the chemicals and a loss in the repellency over the time period. In the German cockroach test with the same materials, a difference in the concentrations and time period was shown; but no difference between chemicals was observed.

There was a difference in repellency in the tests with MGK-264 and Lethane 384. Chemicals x concentrations interaction revealed a difference in the concentration effect on repellency of both species of test animals. The days x concentrations and days x concentrations x chemicals interactions indicated that the concentrations of these two materials did not give a typical upward slope with time. A 1.0% concentration of Lethane 384 at the 7-day test period was less repellent than at the 21-day test period in the American cockroach test. In the German cockroach test with MGK-264, the most repellent concentration one and seven days after treatment was the 0.1% formulation.

The response given by American cockroaches to the surfactants Toximul-P and Atlox 1045A was such that a slight difference could be detected between the materials. The most difference could be seen when comparing chemicals x concentrations. Atlox 1045A was the most repellent at the 0.1% concentration one day after treatment; whereas, Toximul-P was the most repellent at the 1.0% concentration seven days after treatment.

The tests with German cockroaches indicated a substantial amount of difference between the materials and the concentrations over the test period. Atlox 1045A appeared to be the more repellent material, and the most repellent concentration was 0.01% seven days after treatment.

The investigation of repellency of chemical deodorants with American cockroaches indicated no difference between D-41927 and D-460. However, there was a significant difference in the effectiveness of the concentrations of the two chemicals. All concentrations of both chemicals were most repellent one day after treatment except the 1.0% concentration of D-460 which was most repellent seven days after treatment. The 0.1% concentration of D-460 was more repellent throughout the tests than was 0.1% D-41927; otherwise, both materials were very similar in repellency.

The studies of the repellency of chemical deodorants with German cockroaches again indicated that there was no difference between the chemicals (D-41927 and D-460), but there was a highly significant difference between concentrations within each chemical. Days x concentrations indicated that there was a substantial difference in responses to the concentrations over time. The seven-day test period in both materials for all except the 0.01% concentration of D-460 was the most repellent. However, other than this, the materials had very similar reactions.

Repellency of a Toxicant (Diazinon) Plus Selected Spray Additives to *P. americana* and *B. germanica*

Repellency Tests. In the tests with American cockroaches, the repellency of the material with time was the most significant factor. The most repellent test periods were 1 and 21 days after treatment for all test materials except D-41927 (a chemical deodorant). The response showed that all the formulations except D-41927 and D-460 repelled the American cockroach in a manner similar to Diazinon alone. Of both concentrations D-41927 was the most repellent at the 1.0% concentration seven days after treatment.

In the tests using German cockroaches with the same materials, the results were very similar with the American cockroach tests showing a difference in repellency of the chemicals being tested. A slight difference was noted between Diazinon alone and when used with deodorants. The deodorants gave the formulation a more repelling effect compared to Diazinon used alone. Formulations with D-41927 and D-460 at both concentrations showed a very high repellency at the one-day test period with D-41927 much more repellent than D-460. Generally, the other materials gave a very similar response as in the American cockroach tests except that the lower repellency period was 42 days after treatment instead of 21 days. The only explanation presented was that the change in seasons affected the activity of the cockroaches in such a way as to make them less active and in turn caused the treated surfaces to appear to have increased their repellency. Again, it should be pointed out that the 21-day test period for American cockroaches and the 42-day test period for German cockroaches occurred the same week.

Mortality Tests. In the studies using American cockroaches, all the materials tested at either concentration with Diazinon gave about the same degree of kill as Diazinon used alone one day after treatment except D-41927 and D-460 which gave a lower per cent kill. The most effective formulation after seven days was 1.0% piperonyl butoxide. This material and the surfactants were the only materials that increased the mortality rate after 21 and 42 days over Diazinon alone.

The tests with German cockroaches indicated that formulations containing 1.0% pyrethrins and D-41927 and D-460 at both concentrations were the only materials that gave a lower per cent kill than 1.0% Diazinon. The same formulations gave a reduced mortality rate after seven days. However, 21 and 42 days after treatment the only material that showed a reduction in kill was D-460. The surfactants tested increased the mortality rate at these periods.

The data indicated that the repellency of a formulation using the various spray additives definitely had some effect on the per cent mortality of the formulation. In some cases better results could be obtained by using 1.0% Diazinon alone.

Studies on the Movement of Common Pesticide Solvents

Atlox 1045A and Triton X-100 seemed to be the least active in reducing the distance the solvent moved. Nearly all of the solvents moved farther without the 1.0% concentration of the surfactants except in the case of the faster evaporating solvents. The data gave some indication of which surfactant would be the most effective in altering the movement of solvents.

The distance that the various pesticide solvents moved Diazinon appeared to be the same distance as the solvents themselves moved. In some of the formulations, the movement was difficult to measure due to indistinct color changes caused by the formulation not reacting properly with $Ag\ NO_3$.

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APPENDIX

TABLE 5. Repellency of 121 spray additives and combinations to *P. americana*.

Mean Number of Cockroaches at Designated Periods After Treatment					
7 Days		21 Days		42 Days	
Atlox 1045A, Triton X-100*	11.09**	Volpa-3, Triton X-100	16.98	R-1357, Atlox 1045A	19.00
R-874, R-11	11.28	R-1357, Atlox 1045A	17.05	R-874, Atlox 1045A	19.50
I. M.***	11.31	Triton X-100, Atlox 1045A	17.44	R-1345, I. M.	21.00
R-1357, Volpa-3	14.01	Sulfoxide, Atlox 1045A	17.57	R-874, MGK-933	21.50
R-11, Pyrethrins	14.24	Sulfoxide, Volpa-3	19.03	R-440, Volpa-3	21.50
R-874, Volpa-3	15.01	Atlox 1045A, I. M.	19.09	R-440, Pyrethrins	23.00
MGK-264, Atlox 1045A	15.27	Atlox 1045A, Pyrethrins	19.41	R-1345, Volpa-3	23.00
R-874, R-1357	15.50	R-874, Volpa-3	19.52	R-1345, Atlox 1045A	23.50
R-326, Atlox 1045A	16.36	I. M.	19.91	R-326, Volpa-3	23.50
R-1345, Atlox 1045A	16.58	Sulfoxide, Triton X-100	19.97	R-874, Triton X-100	24.00
R-440, Triton X-100	16.64	R-326, Triton X-100	20.42	R-874, Volpa-3	24.00
R-1357, Triton X-100	16.67	R-1345, Atlox 1045A	20.98	R-874, R-440	25.00
R-11, Volpa-3	17.14	MGK-933, MGK-264	21.05	Atlox 1045A	25.00
MGK-933	17.77	R-11, Atlox 1045A	21.44	Sulfoxide, Triton X-100	25.00
R-11, Atlox 1045A	18.68	R-874	21.97	Volpa-3, Triton X-100	25.50
Sulfoxide, R-874	18.77	Triton X-100, Pyrethrins	21.98	R-874, R-1357	26.00
MGK-933, Triton X-100	19.14	R-874, Atlox 1045A	22.03	MGK-933, Pyrethrins	26.00
Atlox 1045A	19.50	R-440, Triton X-100	22.59	MGK-264, I. M.	26.00
R-440, Pyrethrins	19.72	R-874, R-1357	22.97	R-1357, Triton X-100	26.50
R-1345, R-11	20.14	R-1345, R-1357	23.00	Triton X-100	26.50
Velsicol AR-50G	20.76	Atlox 1045A	23.48	MGK-933	26.50
R-1357, Atlox 1045A	20.91	R-1357, Triton X-100	23.96	R-326, MGK-933	27.00
Sulfoxide, R-440	20.98	R-440, Atlox 1045A	24.08	MGK-264, Triton X-100	27.00
Sulfoxide, Triton X-100	22.14	R-874, R-326	24.92	Kerosene	27.00
I. M., Atlox 1045A	22.18	n-Hexadecane	24.94	R-1357	27.00
I. M., Volpa-3	22.41	MGK-264, Atlox 1045A	25.00	Base Oil No. 1	27.00
R-326, Triton X-100	22.46	R-1345, Volpa-3	25.00	Sulfoxide, MGK-933	27.50
Soltrol 130	22.48	MGK-364, I. M.	25.03	Sulfoxide, I. M.	27.50

TABLE 5. (continued)

Mean Number of Cockroaches at Designated Periods After Treatment					
7 Days		21 Days		42 Days	
Triton X-100, Pyrethrins	22.88	R-326, I. M.	25.04	MGK-264, Atlox 1045A	28.00
Sulfoxide, R-11	23.23	MGK-264, Pyrethrins	25.46	R-326, Triton X-100	28.00
I. M., Pyrethrins	23.48	R-1345, R-326	25.48	Crag Fly Repellent	28.00
MGK-933, Volpa-3	23.85	R-440, Volpa-3	25.59	Atlox 1045A, Pyrethrins	28.50
MGK-933, Atlox 1045A	23.86	R-1345	25.60	R-11, R-1357	28.50
Pyrethrins, Atlox 1045A	24.59	R-326, Atlox 1045A	25.93	R-440, R-1357	28.50
R-440, Atlox 1045A	24.62	Atlox 1045A, Volpa-3	26.08	MGK-264, Pyrethrins	29.00
R-874, R-326	24.71	Sulfoxide, R-440	26.44	R-1345, R-1357	29.00
MGK-933, R-326	24.77	Sulfoxide	27.02	Volpa-3	29.00
R-11, I. M.	24.81	R-11, Volpa-3	27.35	I. M.	29.00
Volpa-3, Triton X-100	24.85	Sulfoxide, R-1345	27.43	R-1345, Triton X-100	29.00
R-1357, Pyrethrins	24.94	Base Oil No. 1	27.47	MGK-264	29.00
n-Dodecane	25.06	Base Oil No. 2	28.02	R-326, Pyrethrins	29.50
n-Decane	25.07	n-Decane	28.35	R-440, I. M.	29.50
R-1345, MGK-933	25.16	Soltrol 170	28.42	MGK-933, I. M.	29.50
Atlox 1045A, Volpa-3	25.61	MGK-264, Triton X-100	28.46	R-440, R-1345	29.50
Atlox 1045A, Sulfoxide	25.79	Sulfoxide, R-11	28.46	n-Hexadecane	29.50
R-1357, MGK-933	25.86	Pyrethrins, R-11	28.52	MGK-933, Triton X-100	30.00
Volpa-3	25.91	MGK-264, Volpa-3	28.56	Sulfoxide, MGK-264	30.00
R-874, Atlox 1045A	26.14	Volpa-3, I. M.	28.88	R-326, MGK-264	30.50
Sulfoxide, MGK-933	26.35	MGK-933, Triton X-100	28.99	n-Octane	30.50
R-1345, Volpa-3	26.38	R-11, R-326	28.99	I. M., Pyrethrins	30.50
R-326	26.50	R-1357, MGK-264	29.04	R-874, R-326	30.50
Crag Fly Repellent	26.54	Velsicol AR-50G	29.07	Sulfoxide, Atlox 1045A	30.50
R-440, R-1345	26.73	Volpa-3	29.46	n-Decane	31.00
R-874, R-326	26.84	Sulfoxide, R-1357	29.53	Volpa-3, Pyrethrins	31.50
R-326, Volpa-3	26.84	MGK-933, Pyrethrins	29.54	R-11, MGK-933	31.50
R-11, R-1357	26.88	Velsicol AR-50	29.92	Atlox 1045A, MGK-933	32.00

TABLE 5. (continued)

Mean Number of Cockroaches at Designated Periods After Treatment					
7 Days		21 Days		42 Days	
Volpa-3, Pyrethrins	26.95	Triton X-100	29.98	R-874, I. M.	32.00
R-11	26.99	Triton X-100, R-1345	29.99	R-1345, Pyrethrins	32.00
R-440, I. M.	27.05	Pyrethrins	30.05	R-440, R-326	32.00
MGK-933, I. M.	27.08	R-11, MGK-933	30.06	R-874, R-11	32.00
R-326, MGK-264	27.19	R-440, R-1357	30.07	Atlox 1045A, Volpa-3	32.50
R-11, MGK-264	28.31	Sulfoxide, R-1357	30.09	Sulfoxide, R-1345	32.50
Sulfoxide, Volpa-3	28.52	R-440, MGK-264	30.41	Sulfoxide, R-874	32.50
R-1357, I. M.	28.76	R-874, R-11	30.41	R-1357, I. M.	32.50
R-11, Triton X-100	28.98	Volpa-3, Pyrethrins	30.42	Sulfoxide	32.50
R-1345, R-1357	29.34	R-1345, I. M.	30.47	MGK-933, Volpa-3	32.50
R-874, I. M.	29.48	n-Dodecane	30.48	R-874, MGK-264	33.00
Sulfoxide, R-1357	29.91	R-874, R-1345	30.48	R-11	33.00
R-1345	29.96	R-11, I. M.	30.58	Soltrol 130	33.50
R-1345, I. M.	30.06	MGK-933, Volpa-3	30.98	Atlox 1045A, Triton X-100	33.50
R-440, R-326	30.10	MGK-933, Sulfoxide	31.03	MGK-933, MGK-264	33.50
R-1345, Pyrethrins	30.31	MGK-933, R-326	31.10	R-1357, MGK-264	33.50
Apco 467	30.43	MGK-933, R-874	31.45	R-1357, Sulfoxide	33.50
R-874, MGK-933	30.73	MGK-933	31.46	Base Oil No. 2	33.50
Base Oil No. 2	30.81	R-11, Triton X-100	31.52	Sulfoxide, R-440	33.50
R-326, Pyrethrins	30.84	R-440, I. M.	31.53	R-1357, Volpa-3	34.00
R-326, I. M.	31.10	R-440, R-326	31.58	R-874, R-1345	34.00
R-874, MGK-264	31.56	R-874, I. M.	31.97	R-11, Pyrethrins	34.00
Sulfoxide, I. M.	32.51	R-874, MGK-264	32.03	R-874	34.50
MGK-264, I. M.	32.73	MGK-264	32.05	n-Dodecane	34.50
MGK-933, Pyrethrins	32.81	R-874, Sulfoxide	32.08	Sulfoxide, Pyrethrins	34.50
Triton X-100, I. M.	33.17	R-326, Pyrethrins	32.38	R-11, R-326	34.50
Triton X-100, R-1345	33.29	R-11, R-1357	32.43	R-11, MGK-264	34.50
R-1357, R-326	33.56	R-11	32.47	R-11, Triton X-100	34.50

TABLE 5. (continued)

Mean Number of Cockroaches at Designated Periods After Treatment					
7 Days		21 Days		42 Days	
Sulfoxide, Pyrethrins	33.65	R-440, R-1345	32.48	R-326, Atlox 1045A	35.00
R-874, R-1345	34.06	Sulfoxide, R-326	32.51	R-440	35.00
Kerosene	34.21	R-1357, Volpa-3	32.53	R-1345, R-326	35.00
n-Hexadecane	34.37	R-440, R-11	32.53	R-11, Atlox 1045A	35.00
R-1345, MGK-264	34.43	R-1345, MGK-933	32.53	R-1345, MGK-264	36.00
R-11, MGK-933	34.50	R-874, Triton X-100	32.97	Sulfoxide, Volpa-3	36.50
R-874, R-440	34.61	R-1357, I. M.	33.53	R-11, Volpa-3	36.50
MGK-264, R-440	34.74	Triton X-100, I. M.	33.54	Atlox 1045A, I. M.	36.50
MGK-264, MGK-933	35.39	Apco 125	33.54	MGK-264, Volpa-3	36.50
R-874, Triton X-100	35.42	Normal Hydrocarbon Blend	33.59	Triton X-100, R-440	37.00
Velsicol AR-50	35.42	R-440	33.89	Triton X-100, I. M.	37.00
MGK-264	35.46	R-1345, Pyrethrins	34.98	R-1345, MGK-933	37.00
Soltrol 200	36.56	Velsicol AR-55	35.03	R-11, I. M.	37.50
R-440, R-1357	36.58	Crag Fly Repellent	35.47	R-874, Pyrethrins	38.50
R-440, R-11	37.13	R-326	35.52	Soltrol 170	39.50
R-1357, MGK-264	37.84	R-1357, R-326	35.53	Volpa-3, I. M.	39.50
R-440, Volpa-3	37.89	R-440, Pyrethrins	35.55	R-1345, R-11	39.50
Base Oil No. 1	37.99	R-326, MGK-264	35.59	Apco 125	39.50
Sulfoxide, R-326	39.04	Sulfoxide, Pyrethrins	35.91	Velsicol AR-55	40.00
Sulfoxide, R-1345	39.23	R-874, Pyrethrins	36.03	R-1357, Pyrethrins	40.00
R-440	39.48	MGK-933, I. M.	36.49	Velsicol AR-50	40.00
Apco 125	39.64	Sulfoxide, MGK-264	36.53	R-326	40.00
Sulfoxide	39.68	R-1357	36.55	R-1357, R-326	40.00
Pyrethrins	40.14	R-1345, MGK-264	36.60	Normal Hydrocarbon Blend	40.50
MGK-264, Volpa-3	40.22	I. M., Pyrethrins	36.98	R-1357, MGK-933	40.50
Normal Hydrocarbon Blend	40.35	R-1357, Pyrethrins	37.08	Triton X-100, Pyrethrins	40.50
Velsicol AR-55	40.48	Soltrol 130	37.09	Sulfoxide, R-11	41.00
n-Octane	40.72	Kerosene	37.37	R-440, Atlox 1045A	41.00

TABLE 5. (continued)

Mean Number of Cockroaches at Designated Periods After Treatment					
7 Days		21 Days		42 Days	
MGK-264, Triton X-100	43.34	R-874, R-440	38.00	R-326, I. M.	41.50
R-1357	43.37	R-326, Volpa-3	38.08	R-1345	41.50
R-11, R-326	43.76	R-11, MGK-264	39.00	Pyrethrins	41.50
R-1345, R-326	44.13	R-1357, MGK-933	39.04	R-440, MGK-264	42.50
R-874, Pyrethrins	44.21	n-Octane	39.41	Soltrol 200	42.50
Triton X-100	46.11	Sulfoxide, I. M.	39.50	Velsicol AR-50G	43.50
MGK-264, Pyrethrins	46.71	Apco 467	39.98	Apco 467	45.50
Soltrol 170	47.51	R-1345, R-11	40.08	Sulfoxide, R-326	47.00
Sulfoxide, MGK-264	47.68	Soltrol 200	40.53	R-440, R-11	49.50

*Treatments ranked from the most repellent to least repellent material for each test period.

**Average number of cockroaches appearing on a panel for two replications with six observations per replication.

***I. M. (Intermediate Mixture) = 10% Piperonyl Butoxide, 1.0% Pyrethrins.

TABLE 6. Repellency of 42 spray additives to *P. americana*.

Mean Number of Cockroaches at Designated Periods After Treatment

7 Days		21 Days		42 Days	
R-1357*	4.87**	R-1357	7.25	R-1357	7.59
MGK-264	5.28	R-874	7.37	R-874	7.86
R-874	5.81	Piperonyl Butoxide	7.59	D-463	8.37
D-458	6.00	MGK-264	7.65	R-326	8.50
Piperonyl Butoxide	6.06	D-465	7.75	Pyrethrins	8.68
Pyrethrins	6.37	Pyrethrins	7.80	Perfume 19	8.71
Triton X-155	6.50	Atlox 1045A	7.86	D-41968	8.77
Triton B-1956	6.69	Lethane 384	7.93	Volpa-3	8.85
R-326	6.75	Volpa-3	8.44	Espesol-5 & Water	8.85
Atlox 1045A	6.78	D-462	8.44	Lethane 384	8.92
Methylene Chloride	6.81	D-464	8.56	MGK-933	8.98
D-462	7.00	D-41925	8.58	Nilodor	9.10
D-41928	7.06	D-42516	8.71	Trichloroethylene	9.16
D-878	7.09	D-463	8.73	MGK-264	9.23
D-41994	7.19	D-461	8.80	D-462	9.29
D-42516	7.25	Methylene Chloride	8.92	D-41994	9.29
Nilodor	7.31	Nilodor	8.92	D-460	9.36
R-11	7.41	Triton X-131	8.95	D-42516	9.49
Triton X-100	7.44	D-878	8.99	Espesol-5 & Oil	9.52
D-41968	7.46	Trichloroethylene	9.02	R-11	9.56
D-461	7.46	Igepal & Espesol-5	9.04	Amsco	9.59
D-460	7.50	Espesol-5 & Water	9.13	Igepal	9.63
D-41925	7.52	Igepal	9.18	D-41968	9.63
Lethane 384	7.54	D-41968	9.20	Triton X-155	9.66
Triton X-131 & Toximul-P	7.54	D-41928	9.26	Triton X-131 & Toximul-P	9.69
D-465	7.58	Emcol	9.29	Emcol	9.75
Espesol-5	7.59	Perfume 19	9.51	D-461	9.78

TABLE 6. (continued)

Mean Number of Cockroaches at Designated Periods After Treatment					
7 Days		21 Days		42 Days	
D-41927	7.63	Triton B-1956	9.58	Piperonyl Butoxide	9.90
Amsco	7.69	Triton X-100	9.71	Igepal & Espesol-5	9.94
MGK-933	7.71	D-41994	9.72	Isopropyl Alcohol	9.97
D-464	7.75	R-11	9.74	Toximul-P	9.99
Perfume 19	7.81	Triton X-131 & Toximul-P	9.74	Triton B-1956	10.00
Isopropyl Alcohol	7.87	MGK-933	9.81	D-878	10.00
Triton X-131	8.00	D-458	9.87	D-41927	10.06
D-463	8.06	R-326	9.93	D-458	10.14
Emcol	8.13	Amsco	10.00	Triton X-131	10.19
Espesol-5 & Water	8.19	D-460	10.06	D-464	10.26
Volpa-3	8.37	D-41927	10.09	Methylene Chloride	10.39
Trichloroethylene	8.44	Isopropyl Alcohol	10.23	Triton X-100	10.43
Igepal & Espesol-5	8.50	Espesol-5 & Oil	10.56	D-41925	10.46
Toximul-P	9.37	Triton X-155	10.56	D-465	10.49
Igepal	9.81	Toximul-P	11.00	Atlox 1045A	10.63

*Treatments ranked from the most repellent to least repellent material for each test period.
**Average number of cockroaches appearing on one panel after 16 observations.

TABLE 7. Repellency of 49 spray additives to *B. germanica*.

Mean Number of Cockroaches at Designated Periods After Treatment					
7 Days		21 Days		42 Days	
D-460*	12.00**	R-1357	12.81	R-1357	15.63
D-41927	12.13	R-11	13.06	Lethane 384	15.80
R-11	12.13	R-874	13.38	R-11	15.95
Nilodor	12.44	D-41927	13.50	D-463	16.13
R-1357	12.46	D-460	14.00	Odor Sorb 202 & Oil	16.23
R-874	12.75	Lethane 384	14.50	R-874	16.27
Lethane 384	13.44	MGK-933	14.56	D-42516	16.35
Pyrethrins	13.63	Piperonyl Butoxide	14.69	Triton X-155	16.38
MGK-933	13.73	D-462	15.13	Gulf Livestock Oil	16.41
Emcol	14.06	Nilodor	15.19	Triton X-131	16.48
Piperonyl Butoxide	14.44	D-463	15.80	Isopropyl Alcohol	16.51
Amsco	14.69	R-326	15.88	D-458	16.69
D-462	14.74	Odor Sorb 201 & Water	15.97	D-461	16.75
Volpa-3	14.87	Amsco	15.98	Gulf Fly Spray Oil	16.77
Odor Sorb Emulsifier	14.87	D-41994	16.01	Piperonyl Butoxide	16.80
MGK-264	14.90	Gulf Livestock Oil	16.05	D-460	16.81
Isopropyl Alcohol	14.94	Triton X-700	16.09	Pyrethrins	16.83
Triton X-131	15.00	D-42516	16.13	R-326	16.85
D-41928	15.06	Volpa-3	16.25	D-462	16.88
Methylene Chloride	15.19	Gulf Fly Spray Oil	16.25	Triton X-131 & Toximul-P	16.90
D-41968	15.21	Isopropyl Alcohol	16.31	Odor Sorb 201 & Water	16.94
Gulf Livestock Oil	15.30	Triton X-131	16.35	Igepal	17.00
Triton X-700	15.35	D-41928	16.35	Apco 140	17.04
Toximul-P & Water	15.37	Triton B-1956	16.37	D-464	17.06
Triton X-155	15.50	Odor Sorb 202 & Oil	16.44	D-41928	17.06
D-463	15.56	D-464	16.46	MGK-933	17.08
Apco 140	15.69	Emcol	16.50	D-465	17.13

TABLE 7. (continued)

Mean Number of Cockroaches at Designated Periods After Treatment					
7 Days		21 Days		42 Days	
Atlox 1045A	15.75	Odor Sorb Emulsifier	16.63	D-41925	17.13
D-878	15.77	Pyrethrins	16.69	Perfume 19	17.25
D-41925	15.81	D-461	16.96	Igepal & Espesol-5	17.26
Triton X-131 & Toximul-P	15.81	D-465	17.00	Trichloroethylene	17.29
Igepal & Espesol-5	15.88	D-41925	17.01	Methylene Chloride	17.31
D-41994	16.01	D-41968	17.13	D-42516	17.34
D-42516	16.06	D-878	17.25	Espesol-5 & Water	17.38
Triton B-1956	16.13	D-458	17.27	Atlox 1045A	17.38
Odor Sorb 201 & Water	16.19	Apco 140	17.31	D-41927	17.40
Trichloroethylene	16.25	Triton X-155	17.36	Toximul-P & Water	17.44
Gulf Fly Spray Oil	16.29	Atlox 1045A	17.38	Odor Sorb Emulsifier	17.50
Triton X-100	16.50	Perfume 19	17.44	Triton X-800 & Water	17.53
D-458	16.59	Triton X-100	17.60	Volpa-3	17.53
R-326	17.06	MGK-264	17.69	Nilodor	17.69
D-465	17.13	Triton X-131 & Toximul-P	17.75	Triton X-700	17.75
Igepal	17.31	Methylene Chloride	17.82	MGK-264	17.80
Odor Sorb 202 & Oil	17.50	Toximul-P & Water	17.94	D-41994	17.88
D-464	17.63	Igepal	17.96	Amsco	17.94
D-461	17.69	Espesol-5 & Water	18.14	Emcol	18.00
Triton X-800 & Water	18.06	Igepal & Espesol-5	18.25	Triton B-1956	18.02
Perfume 19	18.69	Triton X-800 & Water	18.41	Triton X-100	18.31
Espesol-5 & Water	18.88	Trichloroethylene	18.82	D-878	18.63

*Treatments ranked from the most repellent to least repellent material for each test period.
**Average number of cockroaches appearing on one panel after 16 observations.

TABLE 8. Analysis of variance for the response of *P. americana* to surfaces treated with either pyrethrins or piperonyl butoxide.

Source	d.f.	M.S.	F
Chemicals (A)	1	15.04	4.41*
Concentrations (B)	2	5.16	1.51
Chemicals x Concentrations	2	7.49	2.20
Days (D)	3	134.05	39.31***
Days x Chemicals	3	5.88	1.72
Days x Concentrations	6	6.72	1.97
Days x Conc. x Chemicals	6	7.02	2.06
Error (Panels in A, B, D)	72	3.41	

*Significant at the .05 level of probability.
**Significant at the .01 level of probability.
***Significant at the .005 level of probability.

TABLE 9. Analysis of variance for the response of *B. germanica* to surfaces treated with either pyrethrins or piperonyl butoxide.

Source	d.f.	M.S.	F
Chemicals (A)	1	5.85	1.60
Concentrations (B)	2	24.97	6.82***
Chemicals x Concentrations	2	3.68	1.01
Days (D)	3	201.72	55.12***
Days x Chemicals	3	6.36	1.74
Days x Concentrations	6	5.54	1.51
Days x Conc. x Chemicals	6	2.90	.79
Error (Panels in A, B, D)	72	3.66	

TABLE 10. Analysis of variance for the response of *P. americana* to surfaces treated with either MGK-264 or Lethane 384.

Source	d.f.	M.S.	F
Chemicals (A)	1	4.71	1.71
Concentrations (B)	2	3.86	1.40
Chemicals x Concentrations	2	11.96	4.35*
Days (D)	3	103.57	37.66***
Days x Chemicals	3	2.22	.81
Days x Concentrations	6	7.48	2.72*
Days x Conc. x Chemicals	6	9.41	3.42***
Error (Panels in A, B, D)	72	2.75	

TABLE 11. Analysis of variance for the response of *B. germanica* to surfaces treated with either MGK-264 or Lethane 384.

Source	d.f.	M.S.	F
Chemicals (A)	1	.32	.10
Concentrations (B)	2	8.36	2.65
Chemicals x Concentrations	2	12.26	3.89*
Days (D)	3	130.91	41.56***
Days x Chemicals	3	.78	.25
Days x Concentrations	6	8.52	2.71*
Days x Conc. x Chemicals	6	11.88	3.77***
Error (Panels in A, B, D)	72	3.15	

TABLE 12. Analysis of variance for the response of *P. americana* to surfaces treated with surfactants.

Source	d.f.	M.S.	F
Chemicals (A)	1	11.52	4.45*
Concentrations (B)	2	.36	.14
Chemicals x Concentrations	2	18.67	7.21***
Days (D)	3	117.31	45.29***
Days x Chemicals	3	4.59	1.77
Days x Concentrations	6	3.96	1.53
Days x Conc. x Chemicals	6	3.42	1.32
Error (Panels in A, B, D)	72	2.59	

TABLE 13. Analysis of variance for the response of *B. germanica* to surfaces treated with surfactants.

Source	d.f.	M.S.	F
Chemicals (A)	1	16.25	8.01**
Concentrations (B)	2	8.93	4.40*
Chemicals x Concentrations	2	12.04	5.93***
Days (D)	3	36.67	18.06***
Days x Chemicals	3	4.25	2.09
Days x Concentrations	6	5.33	2.63*
Days x Conc. x Chemicals	6	9.61	4.73***
Error (Panels in A, B, D)	72	2.03	

TABLE 14. Analysis of variance for the response of P. americana to surfaces treated with chemical deodorants.

Source	d.f.	M.S.	F
Chemicals (A)	1	5.16	2.43
Concentrations (B)	2	8.85	4.17*
Chemicals x Concentrations	2	16.14	7.61***
Days (D)	3	166.23	78.41***
Days x Chemicals	3	4.66	2.20
Days x Concentrations	6	5.14	2.43*
Days x Conc. x Chemicals	6	5.42	2.56*
Error (Panels in A, B, D)	72	2.12	

TABLE 15. Analysis of variance for the response of B. germanica to surfaces treated with chemical deodorants.

Source	d.f.	M.S.	F
Chemicals (A)	1	.07	.002
Concentrations (B)	2	89.03	25.43***
Chemicals x Concentrations	2	.46	.13
Days (D)	3	97.98	27.99***
Days x Chemicals	3	13.78	3.94*
Days x Concentrations	6	12.79	3.65***
Days x Conc. x Chemicals	6	15.46	4.42***
Error (Panels in A, B, D)	72	3.50	

TABLE 16. Analysis of variance for the response of *P. americana* to surfaces treated with Diazinon plus selected spray additives.

Source	d.f.	M.S.	F
Total	2,304		
Replication in Days	4		
Chemical-Concentration Combinations	17		
Chemicals	8		
Diazinon vs Other Chemicals	1	22.04	3.44
Other Chemicals	7		
Types in Other Chemicals	3	89.69	3.99*
Additives in Types in Other Chemicals			
Atlox 1045A vs Toximul-P	1	.01	.00
D-41927 vs D-460	1	2.42	.38
Pyrethrins vs Piperonyl Butoxide	1	2.51	.39
MGK-264 vs Lethane 384	1	.32	.05
Concentrations	1	1.41	.22
Concentrations x Chemicals	8	10.15	1.58
Days	3	358.91	55.99***
Days x Chemical-Concentration Combinations	51		
Days x Chemicals	24		
Days x Diazinon vs Other Chemicals	3	14.51	2.26
Days x Other Chemicals	21		
Days x Types in Other Chemicals	9	23.32	3.64***
Days x Additives in Types in Other Chemicals	12	6.50	1.02
Days x Concentrations	3	3.70	.58
Days x Concentrations x Chemicals	24	6.11	.95
Error (Replication x Chemical-Concentration Combination in Days)	68	6.41	
Panels in Replication, Chemical-Concentration Combination, Days	432		
Counts in Panels	1,728		

TABLE 17. Analysis of variance for the response of *B. germanica* to surfaces treated with Diazinon plus selected spray additives.

Source	d.f.	M.S.	F
Total	2,304		
Replication in Days	4		
Chemical-Concentration Combinations	17		
Chemicals	8		
Diazinon vs Other Chemicals	1	216.88	14.19***
Other Chemicals	7		
Types in Other Chemicals	3	567.07	37.11***
Additives in Types in Other Chemicals			
Atlox 1045A vs Toximul-P	1	44.54	2.92
D-41927 vs D-460	1	16.59	1.09
Pyrethrins vs Piperonyl Butoxide	1	.00	.00
MGK-264 vs Lethane 384	1	.82	.05
Concentrations	1	10.43	.68
Concentrations x Chemicals	8	13.67	.89
Days	3	2,680.21	175.41***
Days x Chemical-Concentration Combinations	51		
Days x Chemicals	24		
Days x Diazinon vs Other Chemicals	3	39.99	2.62
Days x Other Chemicals	21		
Days x Types in Other Chemicals	9	58.92	3.86***
Days x Additives in Types in Other Chemicals	12	21.97	1.44
Days x Concentrations	3	9.83	.64
Days x Concentrations x Chemicals	24	12.63	.83
Error (Replication x Chemical-Concentration Combination in Days)	68	15.28	
Panels in Replication, Chemical-Concentration Combination, Days	432		
Counts in Panels	1,728		

TABLE 18. Toxicity of spray additives plus 1.0% Diazinon to P. americana.

Treatments*	Per Cent Mortality at Designated Periods After Application							
	1 Day		7 Days		21 Days		42 Days	
	12-Hour Exposure	24-Hour Exposure	12-Hour Exposure	24-Hour Exposure	12-Hour Exposure	24-Hour Exposure	12-Hour Exposure	24-Hour Exposure
MGK-264 1.0%	96	100	82	92	18	70	22	40
MGK-264 0.01%	94	100	78	94	18	62	20	34
Lethane 384 1.0%	91	100	76	91	16	54	34	60
Lethane 384 0.01%	94	100	65	95	18	62	24	32
Toximul-P 1.0%	94	100	73	92	24	80	40	66
Toximul-P 0.01%	96	100	79	96	16	56	38	76
Atlox 1045A 1.0%	97	100	95	98	32	88	20	32
Atlox 1045A 0.01%	93	100	80	94	50	86	36	62
D-41927 1.0%	90	100	80	94	18	52	16	32
D-41927 0.01%	96	100	72	86	25	74	28	44
D-460 1.0%	93	100	62	83	14	42	24	44
D-460 0.01%	92	100	86	98	12	70	18	36
Pyrethrins 1.0%	96	100	76	90	26	80	28	58
Pyrethrins 0.01%	93	100	68	90	16	62	18	38
Piperonyl Butoxide 1.0%	93	100	87	100	72	100	18	34
Piperonyl Butoxide 0.01%	94	100	63	96	24	58	16	32
Diazinon 1.0%	94	100	85	96	42	92	40	58
Diazinon 0.01%	18	25	9	10	4	10	8	11

*All treatments contained 1.0% Diazinon except the 0.01% Diazinon treatment.

TABLE 19. Toxicity of spray additives plus 1.0% Diazinon to B. germanica.

Treatments*	Per Cent Mortality at Designated Periods After Application							
	1 Day		7 Days		21 Days		42 Days	
	12-Hour Exposure	24-Hour Exposure	12-Hour Exposure	24-Hour Exposure	12-Hour Exposure	24-Hour Exposure	12-Hour Exposure	24-Hour Exposure
MGK-264 1.0%	90	100	90	98	30	84	2	31
MGK-264 0.01%	90	100	95	100	24	64	5	35
Lethane 384 1.0%	85	100	90	99	30	76	5	36
Lethane 384 0.01%	89	100	90	98	31	73	10	37
Toximul-P 1.0%	89	98	90	99	31	85	10	47
Toximul-P 0.01%	92	100	95	100	37	95	4	34
Atlox 1045A 1.0%	79	96	94	100	43	95	9	29
Atlox 1045A 0.01%	92	98	90	100	33	89	2	32
D-41927 1.0%	75	97	87	98	27	80	4	37
D-41927 0.01%	75	98	83	97	24	80	5	34
D-460 1.0%	86	100	83	97	27	67	1	36
D-460 0.01%	84	100	80	93	20	50	2	31
Pyrethrins 1.0%	70	95	75	93	35	85	4	26
Pyrethrins 0.01%	87	100	76	99	26	75	9	33
Piperonyl Butoxide 1.0%	89	98	82	96	36	87	11	34
Piperonyl Butoxide 0.01%	88	100	82	98	26	84	4	34
Diazinon 1.0%	92	100	96	100	35	95	4	26
Diazinon 0.01%	84	96	87	100	26	53	9	11

*All treatments contained 1.0% Diazinon except the 0.01% Diazinon treatment.

TABLE 20. Centimeters of spread on chromatographic paper by solvents and solvents plus 1.0% surfactant.

Solvents Used	Solvent Plus Surfactant						
	Solvent Alone	Atlox 1045A	*T X-100	T X-700	T X-131	Odor Sorb	Volpa-3
Amsco	2.710	2.650	2.240	2.140	2.346	2.188	2.203
Apco 125	2.400	2.522	2.142	2.220	2.230	2.240	2.225
Apco 140	2.900	2.771	2.443	2.450	2.446	2.380	2.433
Apco 467	3.283	3.262	2.693	2.852	2.880	2.737	2.978
AR-50	3.735	3.311	3.245	3.445	2.995	2.943	3.042
AR-50G	3.663	3.376	2.996	3.162	2.900	2.920	3.073
AR-55	3.583	3.004	2.710	2.893	2.695	2.793	2.833
Base Oil No. 1	2.560	2.641	2.234	2.315	2.216	2.115	2.344
Base Oil No. 2	3.503	3.435	2.684	2.902	3.022	2.679	3.130
Benzene	1.860	1.612	1.444	1.498	1.475	1.503	1.528
Cottonseed Oil	3.820	4.500	-	-	-	-	-
Diesel	3.403	3.325	3.063	3.264	3.133	3.125	3.179
Espesol-5	2.200	2.343	1.963	1.979	1.896	1.798	1.922
Gulf Fly Spray Oil	3.410	3.236	2.532	2.786	2.820	2.785	2.726
Gulf Livestock Oil	3.570	3.461	3.096	3.176	3.322	3.102	3.367
Isopropyl Alcohol	1.530	1.615	1.481	1.441	1.467	1.452	1.482
Kerosene	3.100	2.901	2.768	2.750	2.739	2.530	2.685
Methylene Chloride	1.400	1.350	1.355	1.287	1.287	1.302	1.310
Normal Hydrocarbon Blend	2.870	2.832	2.578	2.601	2.593	2.532	2.597
Soltrol 130	2.550	2.480	2.286	2.296	2.272	2.096	2.254
Soltrol 170	3.120	3.010	2.503	2.848	2.741	2.726	2.765
Soltrol 200	3.286	3.206	2.934	3.081	3.124	2.914	3.168
Trichloroethylene	1.500	1.510	1.573	1.573	1.548	1.609	1.581
Xylene	2.040	2.190	1.937	1.873	1.876	1.850	1.894

*T=Triton

TABLE 21. Centimeters of spread on chromatographic paper by solvents plus 1.0% Diazinon and solvents plus 1.0% Diazinon and 1.0% surfactant.

Solvents Used	Solvent & Diaz.	Solvent Plus Diazinon and Surfactant					
		Atlox 1045A	*T X-100	T X-700	T X-131	Odor Sorb	Volpa-3
Amsco	2.657	2.403	2.270	2.316	2.288	2.265	2.240
Apco 125	2.381	2.393	2.157	2.194	2.226	2.260	2.180
Apco 140	2.385	2.522	2.219	2.284	2.337	2.385	2.375
Apco 467	3.006	2.890	2.870	2.755	2.751	2.707	2.730
AR-50	3.205	3.093	3.170	3.159	2.949	2.922	2.995
AR-50G	3.015	3.105	3.160	3.038	3.118	2.828	2.835
AR-55	2.904	2.891	2.906	2.870	3.066	2.650	2.860
Base Oil No. 1	2.345	2.195	2.265	2.332	2.353	2.280	2.210
Base Oil No. 2	3.078	2.915	2.756	2.934	3.035	2.760	2.775
Benzene	1.520	1.532	1.581	1.466	1.532	1.520	1.517
Diesel	3.426	3.250	3.254	3.106	3.079	3.095	3.120
Espesol-5	2.015	1.910	2.055	1.956	1.912	1.900	1.895
Gulf Fly Spray Oil	2.893	2.735	2.718	2.691	2.803	2.510	2.579
Gulf Livestock Oil	3.405	3.061	3.255	3.179	3.129	3.073	3.055
Isopropyl Alcohol	1.515	1.503	1.500	1.543	1.508	1.491	1.500
Kerosene	2.657	2.490	2.627	2.653	2.683	2.495	2.455
Methylene Chloride	1.352	1.372	1.530	1.400	1.459	1.372	1.390
Normal Hydrocarbon Blend	2.591	2.600	2.410	2.449	2.365	2.423	2.385
Soltrol 130	2.165	2.181	2.252	2.195	2.250	2.160	2.190
Soltrol 170	2.910	2.622	2.725	2.630	2.678	2.660	2.635
Soltrol 200	3.049	3.283	3.175	2.985	2.920	2.763	2.905
Trichloroethylene	1.470	1.663	1.635	1.675	1.673	1.625	1.660
Xylene	2.085	1.940	1.895	1.859	2.054	1.860	1.890

*T=Triton

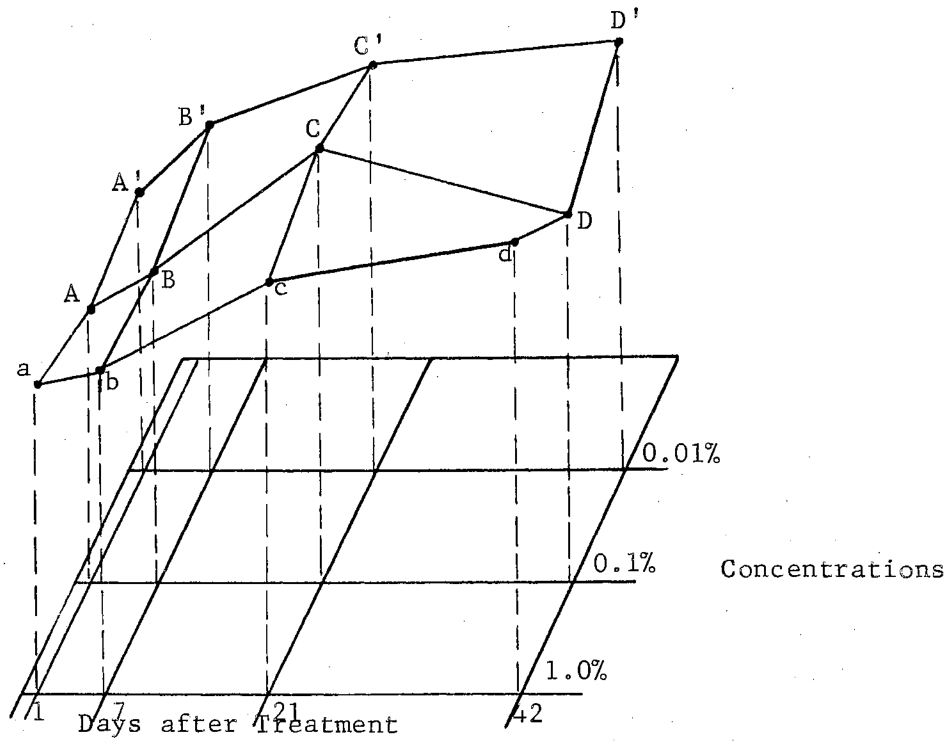

FIG. 1. Response based on the mean number of P. americana appearing on a surface treated with pyrethrins.

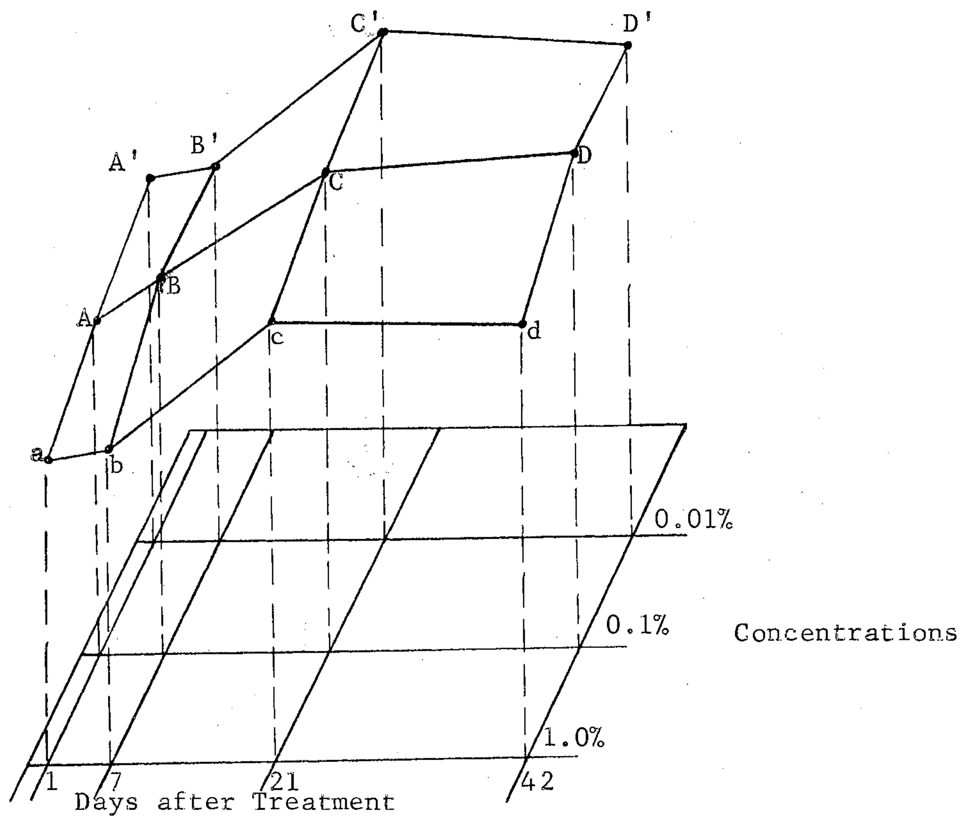

FIG. 2. Response based on the mean number of B. germanica appearing on a surface treated with pyrethrins.

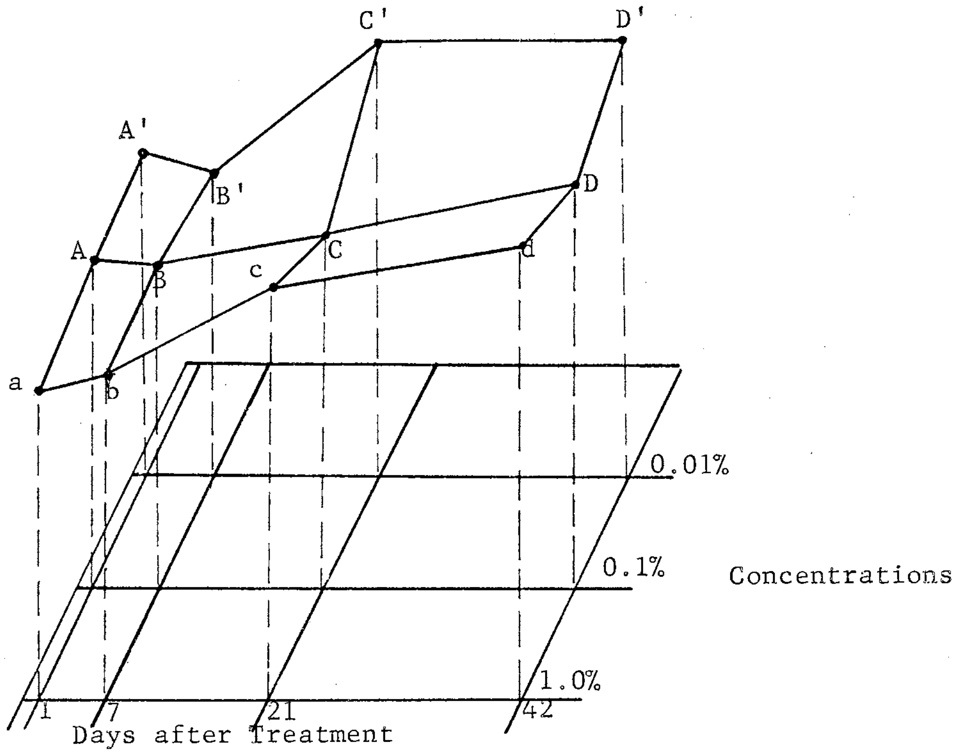

FIG. 3. Response based on the mean number of P. americana appearing on a surface treated with piperonyl butoxide.

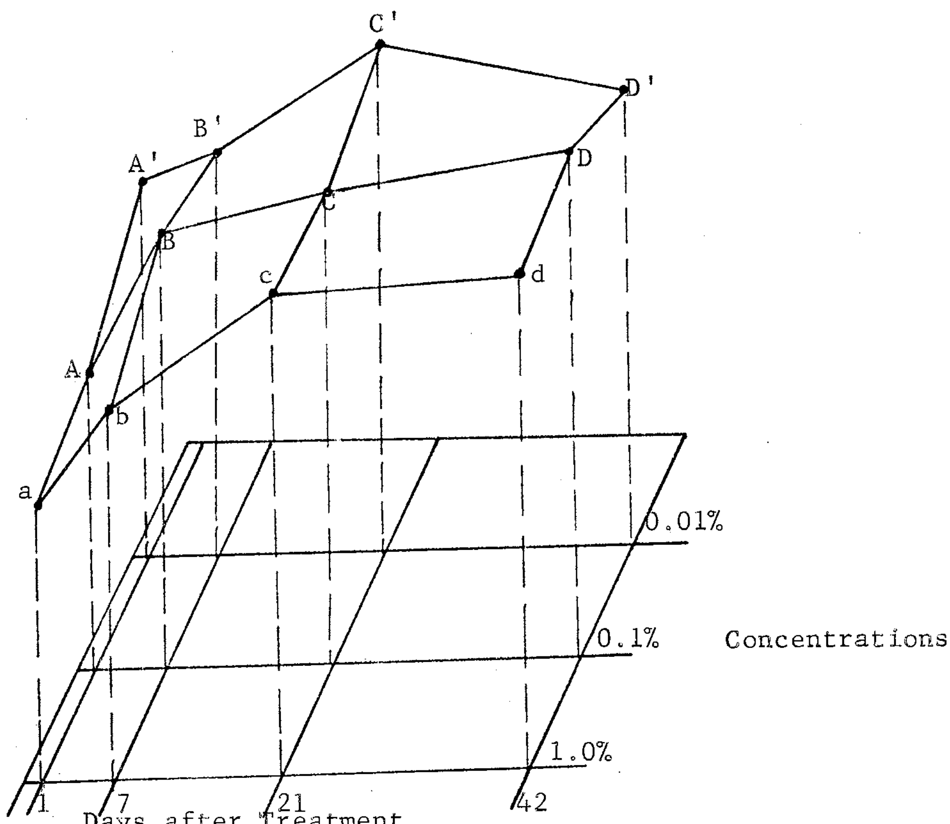

FIG. 4. Response based on the mean number of B. germanica appearing on a surface treated with piperonyl butoxide.

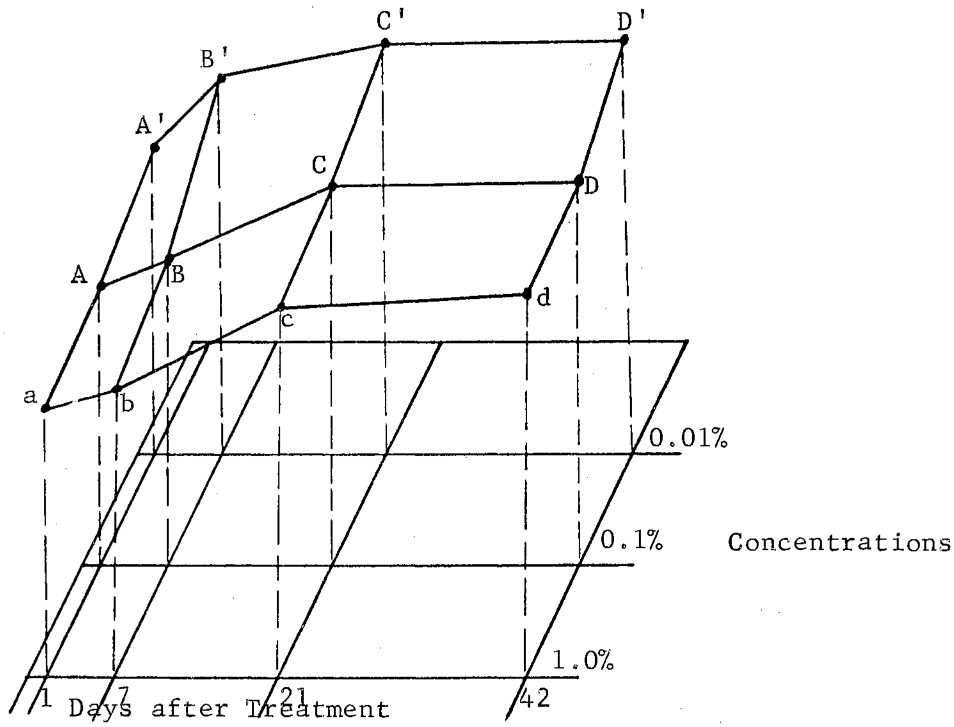

FIG. 5. Response based on the mean number of P. americana appearing on a surface treated with MGK-264.

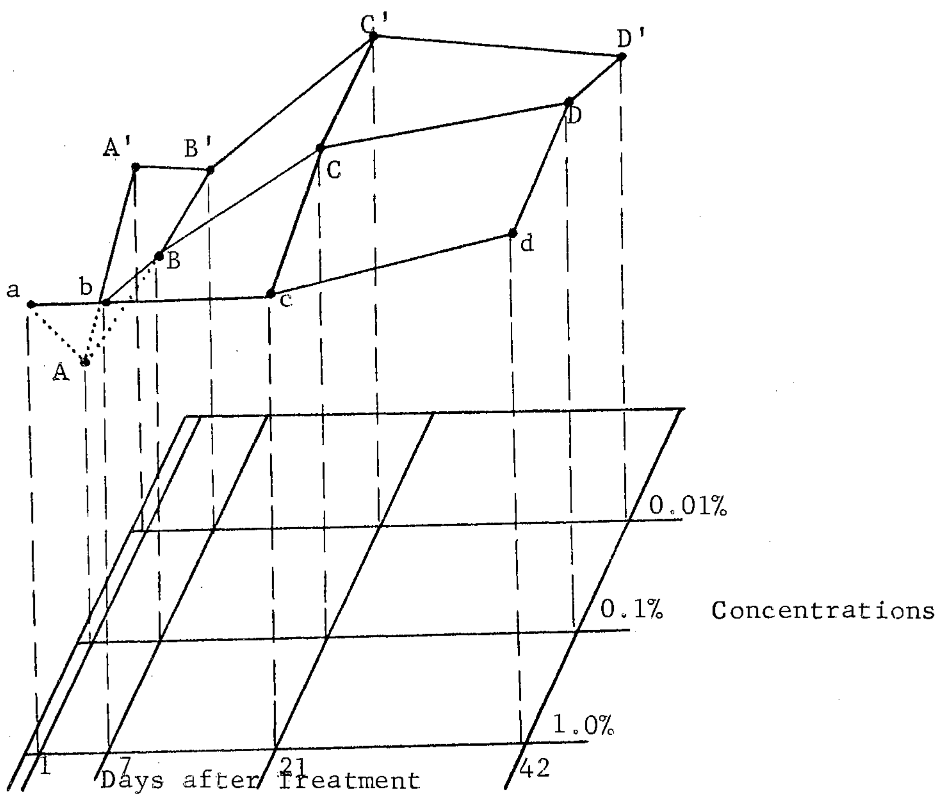

FIG. 6. Response based on the mean number of B. germanica appearing on a surface treated with MGK-264.

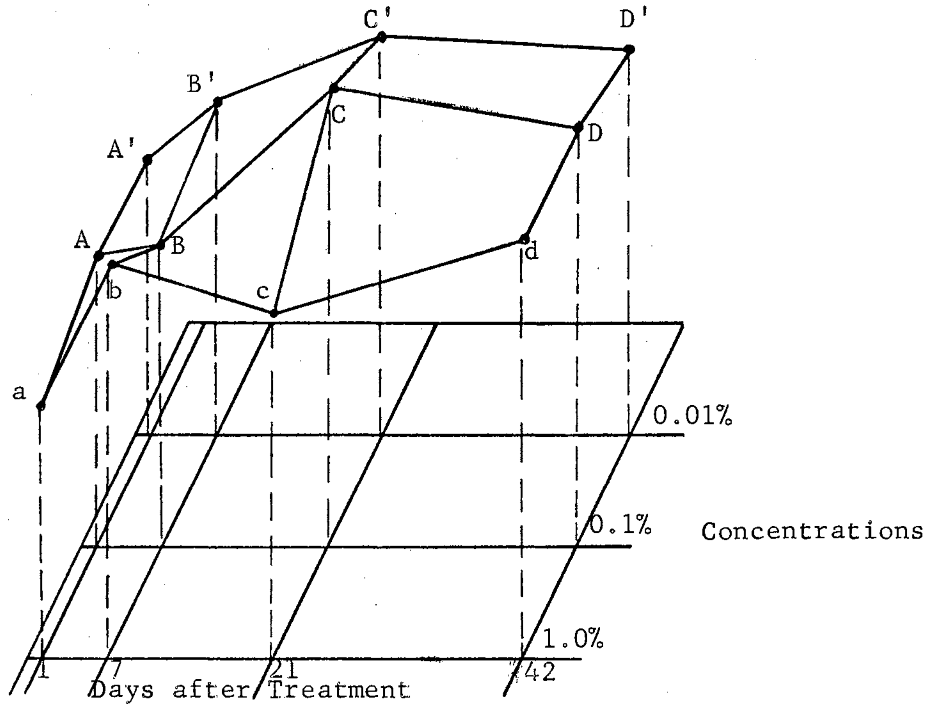

FIG. 7. Response based on the mean number of P. *americana* appearing on a surface treated with Lethane 384.

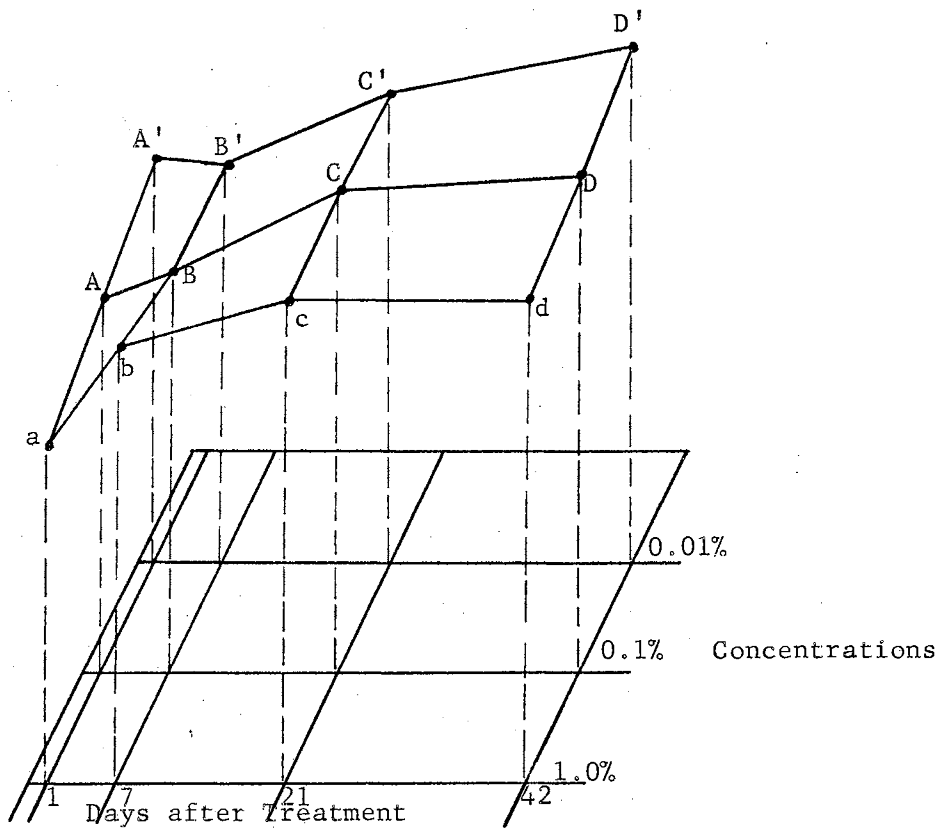

FIG. 8. Response based on the mean number of B. *germanica* appearing on a surface treated with Lethane 384.

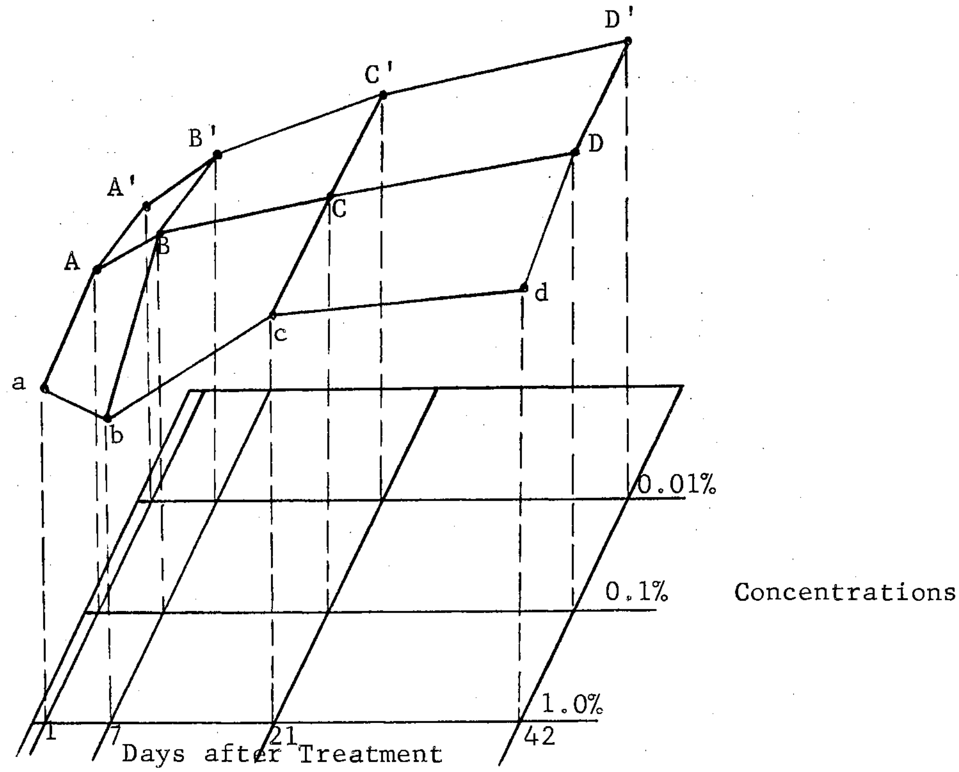

FIG. 9. Response based on the mean number of P. americana appearing on a surface treated with Toximul-P.

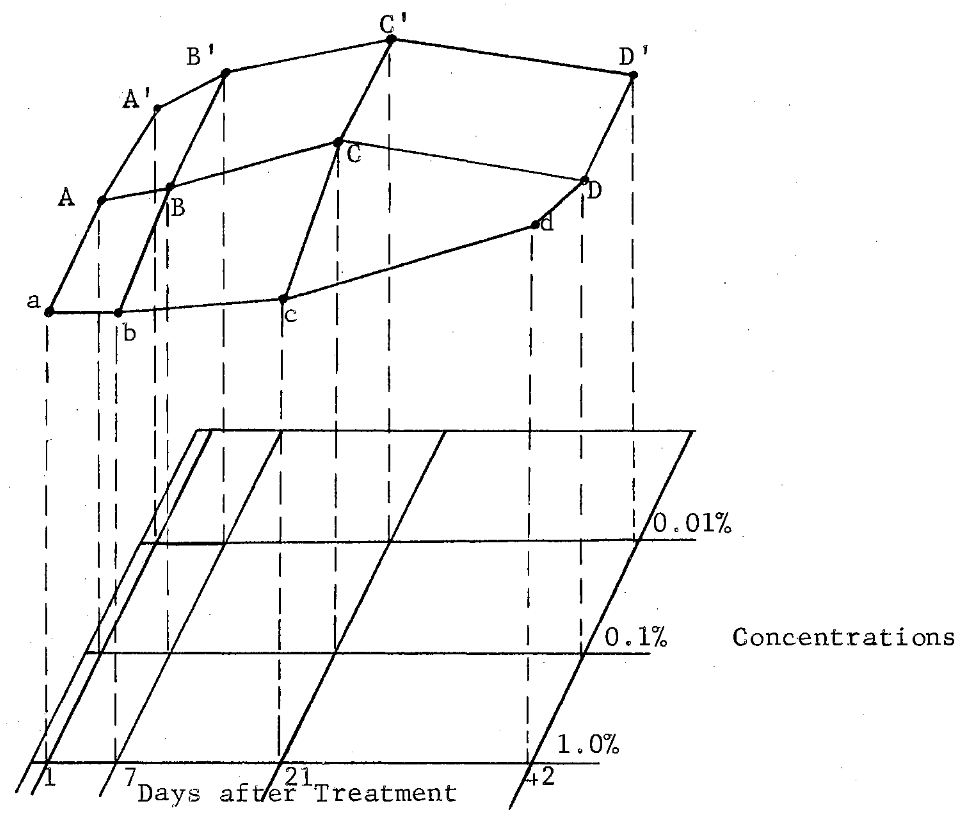

FIG. 10. Response based on the mean number of B. germanica appearing on a surface treated with Toximul-P.

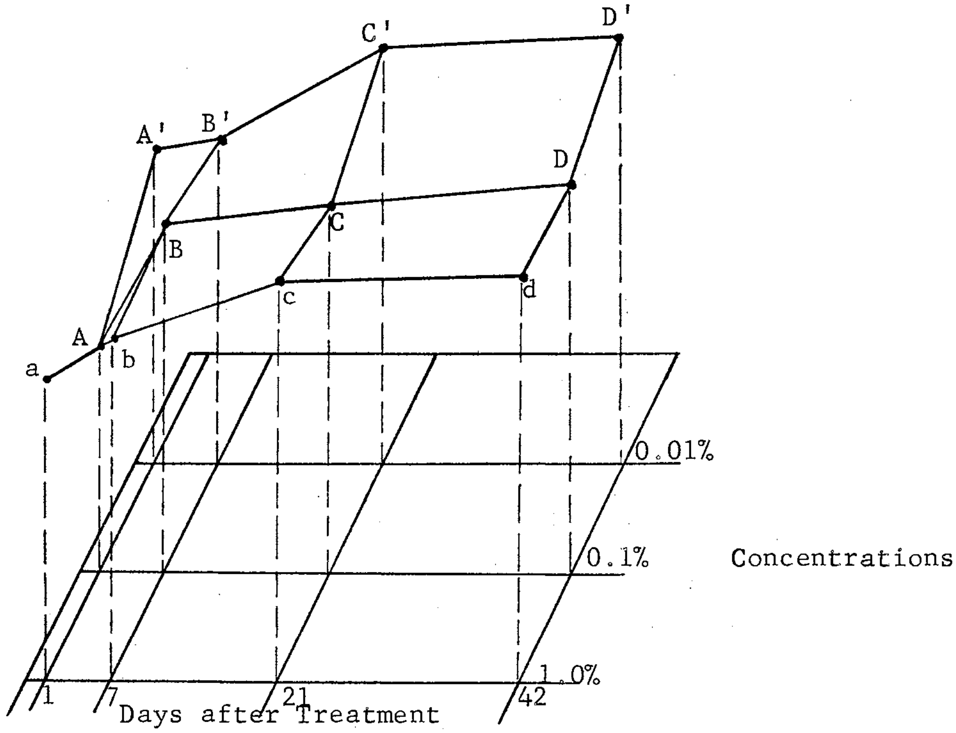

FIG. 11. Response based on the mean number of P. americana appearing on a surface treated with Atlox 1045A.

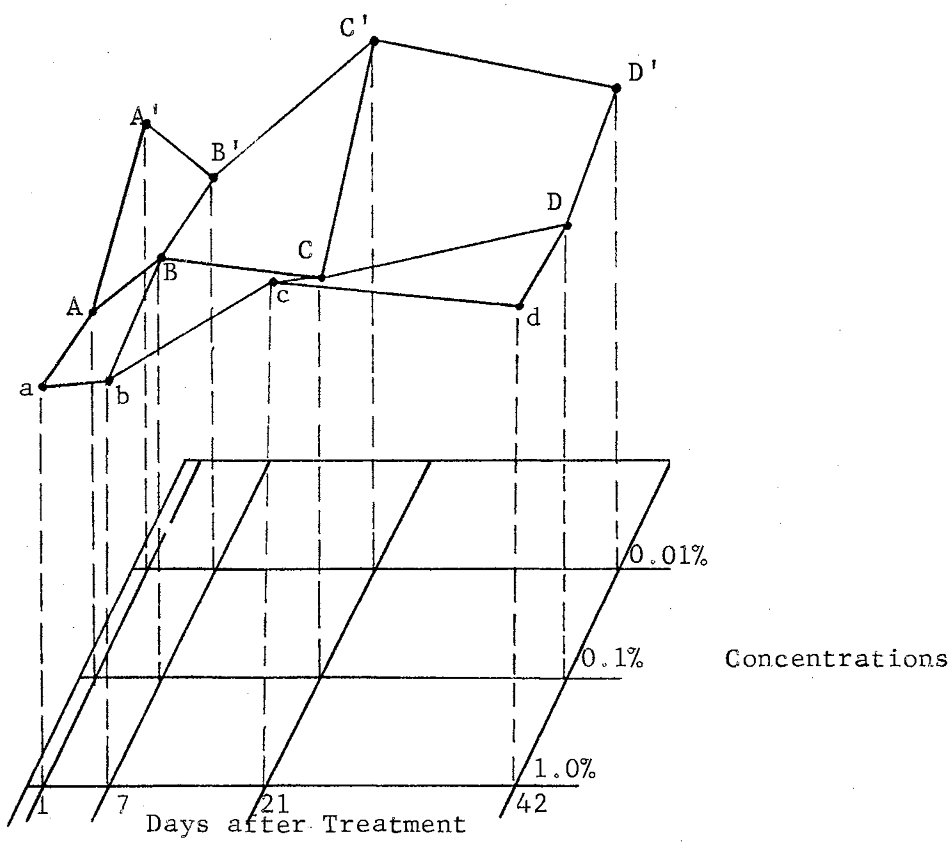

FIG. 12. Response based on the mean number of B. germanica appearing on a surface treated with Atlox 1045A.

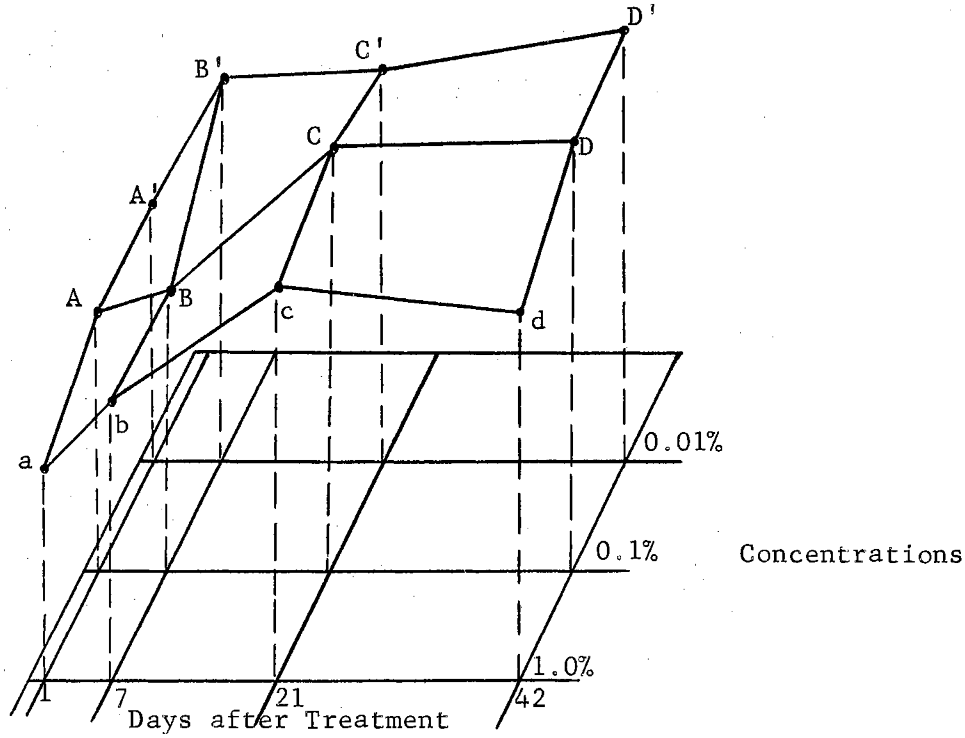

FIG. 13. Response based on the mean number of P. *americana* appearing on a surface treated with D-41927.

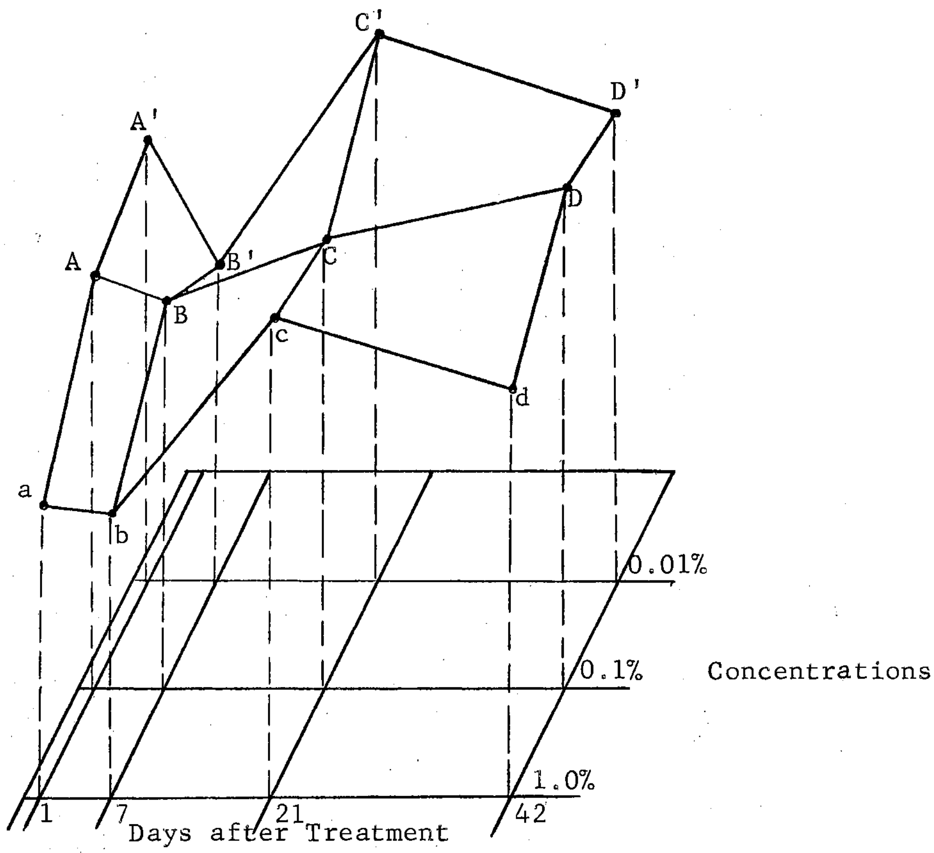

FIG. 14. Response based on the mean number of B. *germanica* appearing on a surface treated with D-41927.

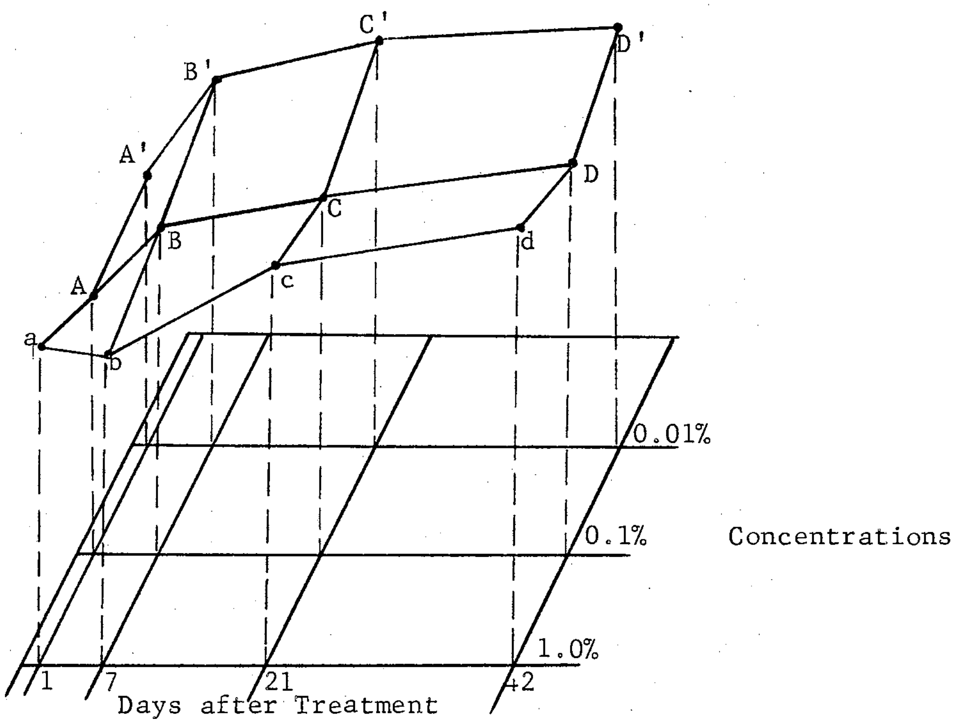

FIG. 15. Response based on the mean number of P. americana appearing on a surface treated with D-460.

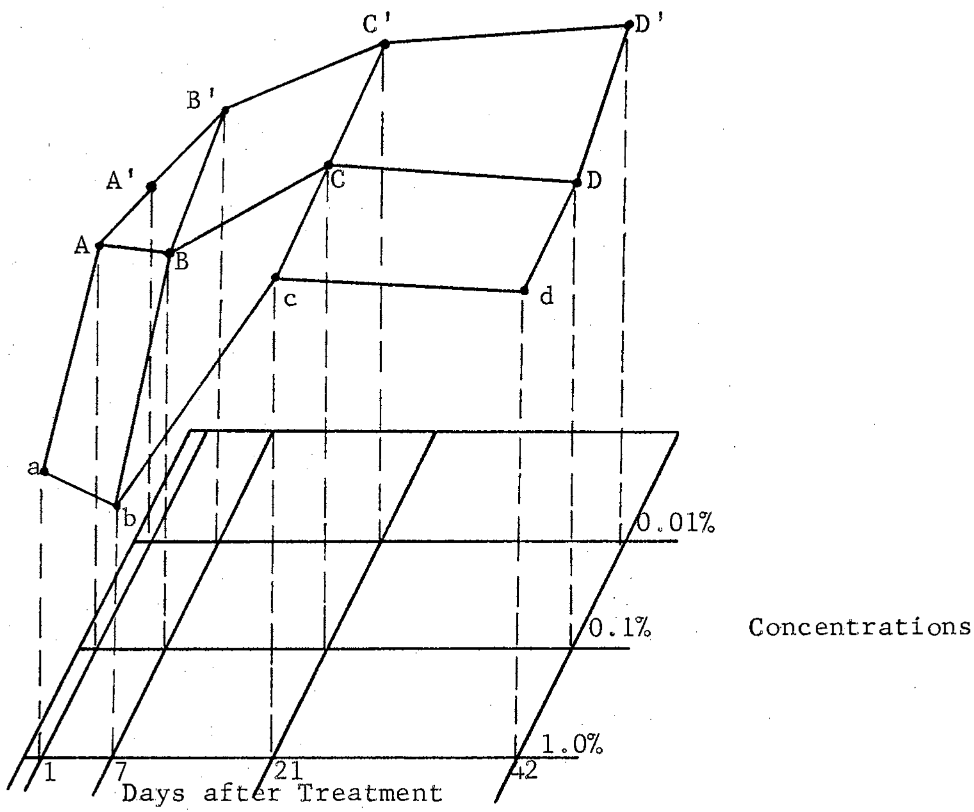

FIG. 16. Response based on the mean number of B. germanica appearing on a surface treated with D-460.

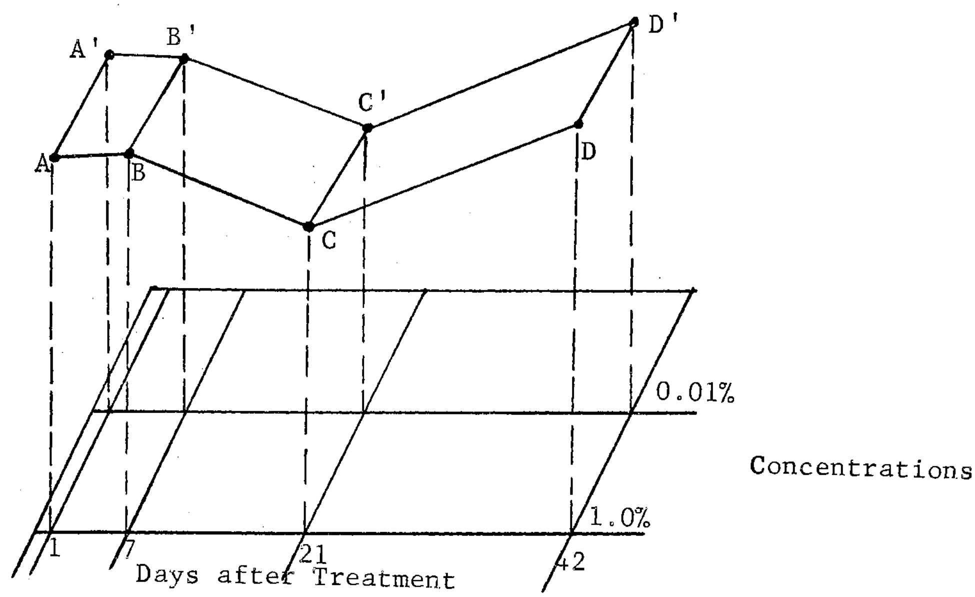

FIG. 17. Response based on the mean number of P. americana appearing on a surface treated with 1.0% Diazinon plus pyrethrins.

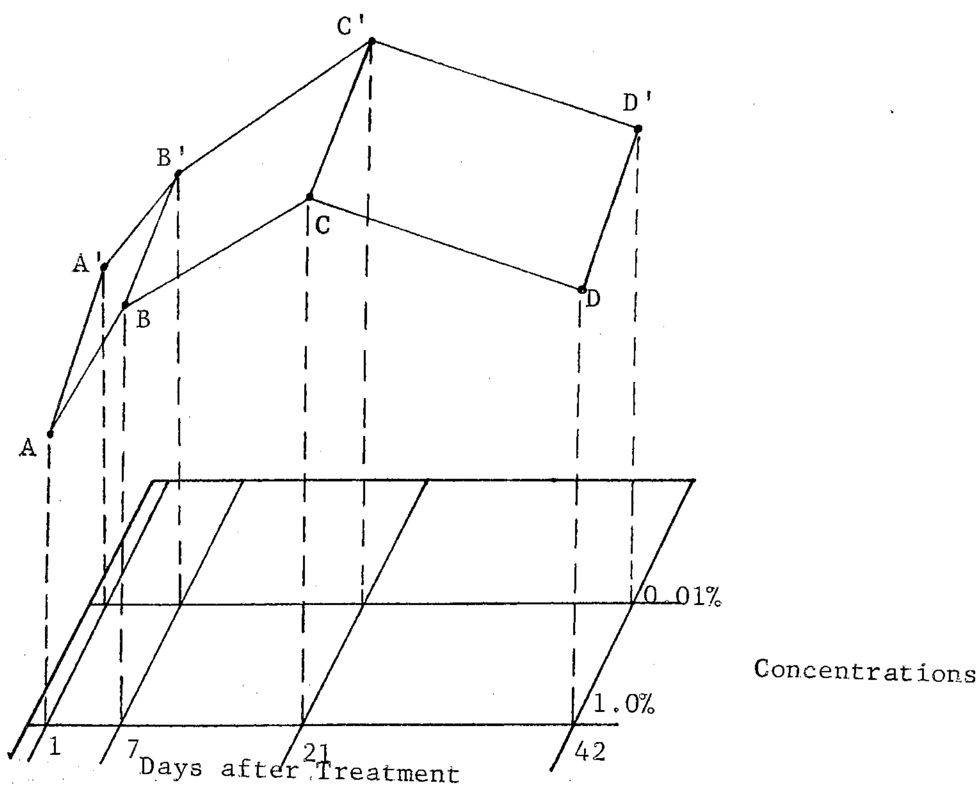

FIG. 18. Response based on the mean number of B. germanica appearing on a surface treated with 1.0% Diazinon plus pyrethrins.

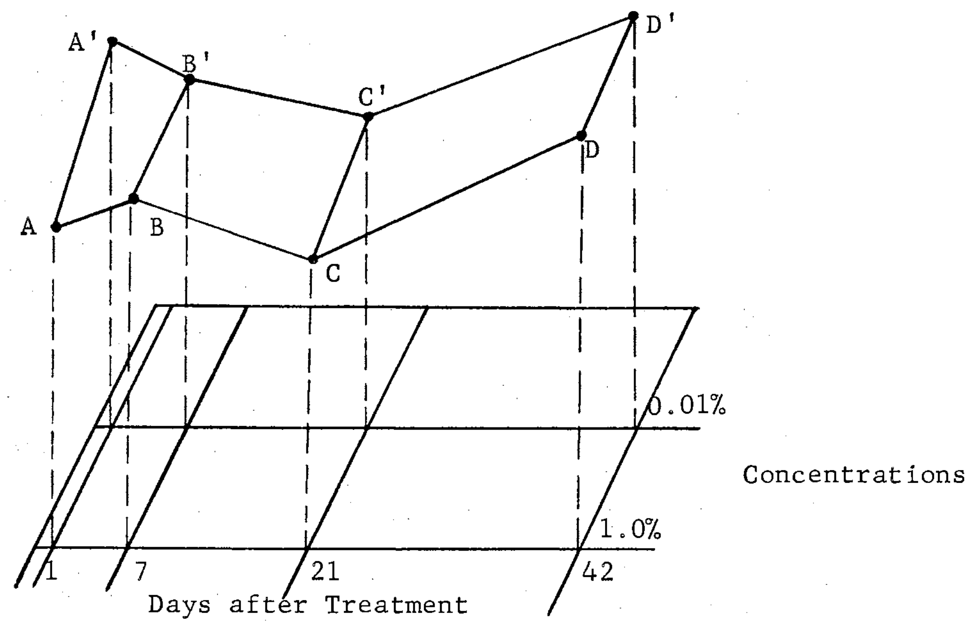

FIG. 19. Response based on the mean number of P. americana appearing on a surface treated with 1.0% Diazinon plus piperonyl butoxide.

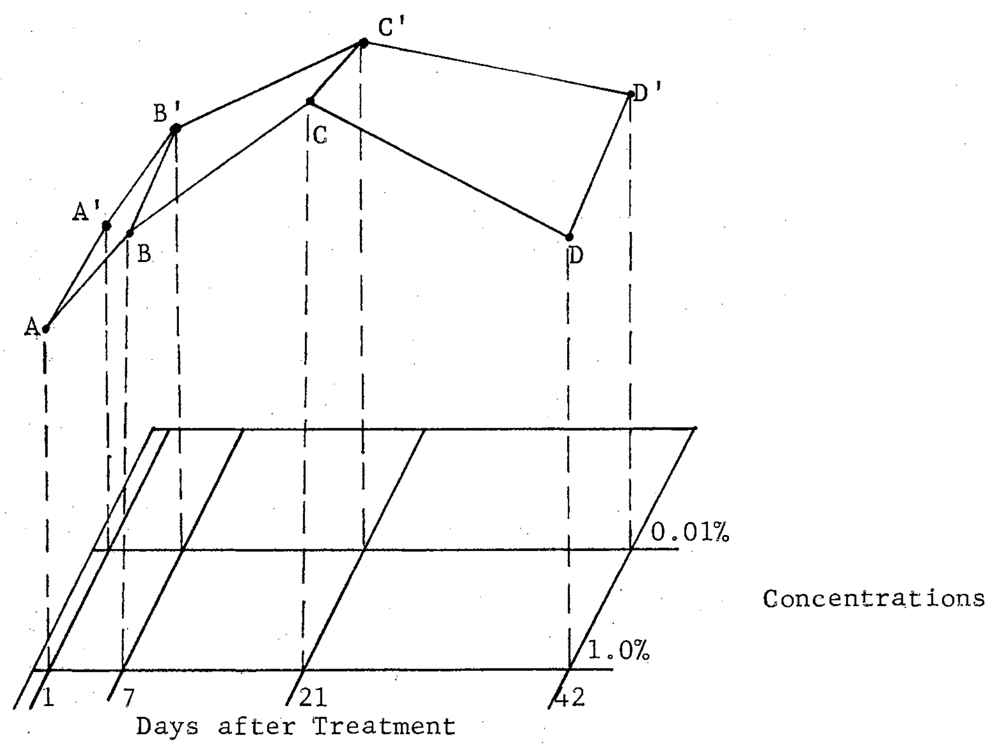

FIG. 20. Response based on the mean number of B. germanica appearing on a surface treated with 1.0% Diazinon plus piperonyl butoxide.

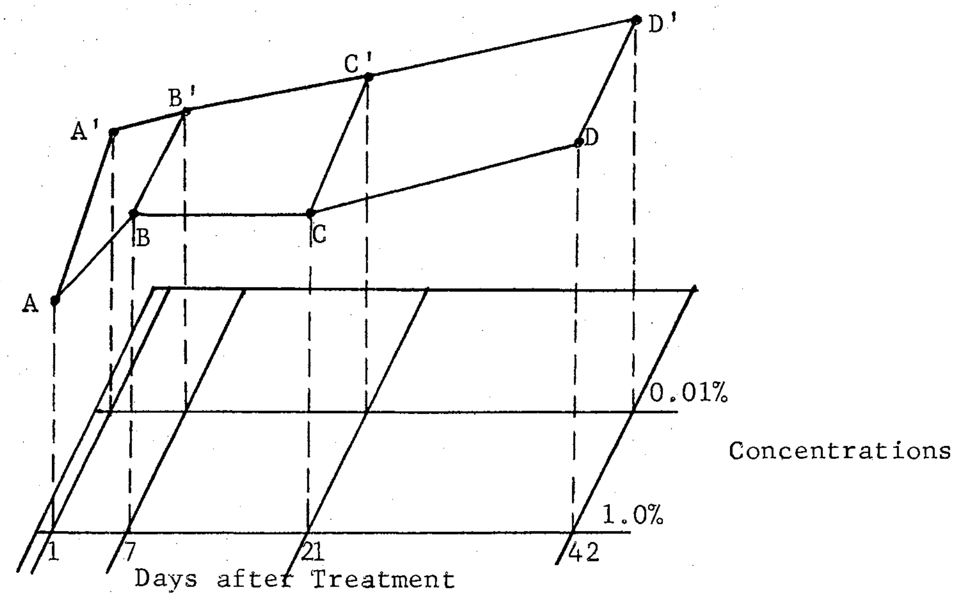

FIG. 21. Response based on the mean number of P. americana appearing on a surface treated with 1.0% Diazinon plus D-41927.

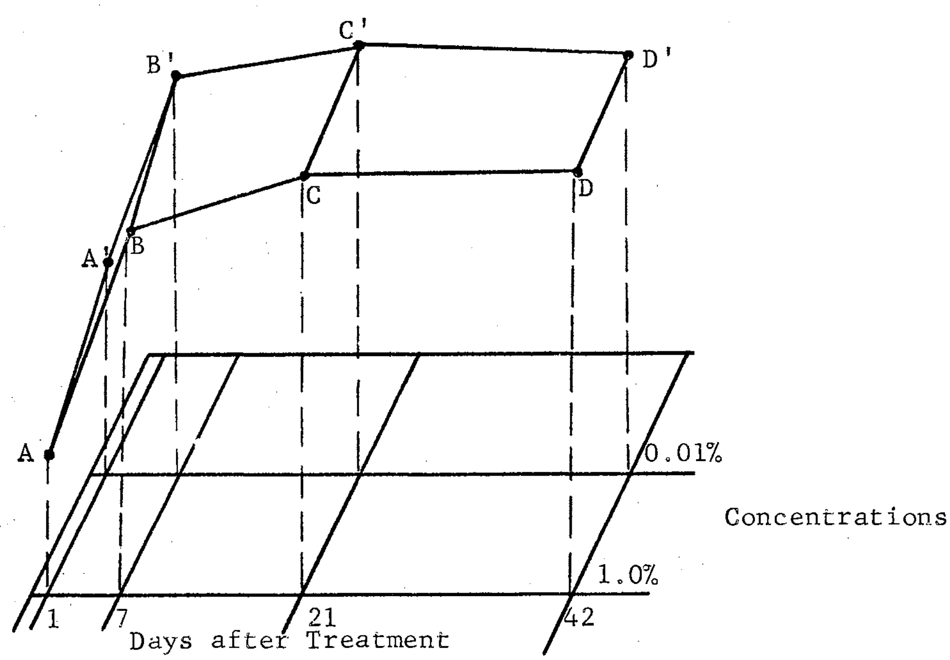

FIG. 22. Response based on the mean number of B. germanica appearing on a surface treated with 1.0% Diazinon plus D-41927.

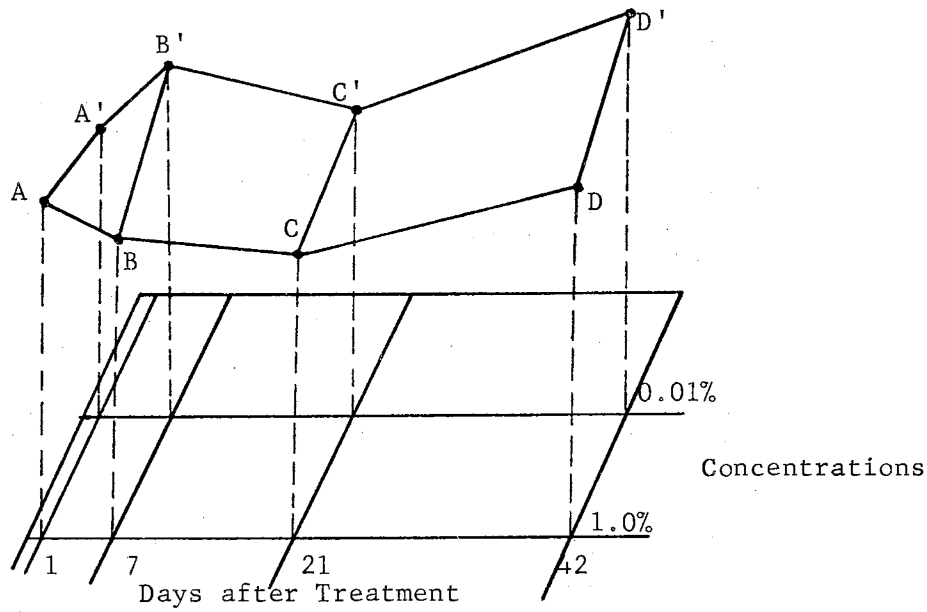

FIG. 23. Response based on the mean number of P. americana apperaring on a surface treated with 1.0% Diazinon plus D-460.

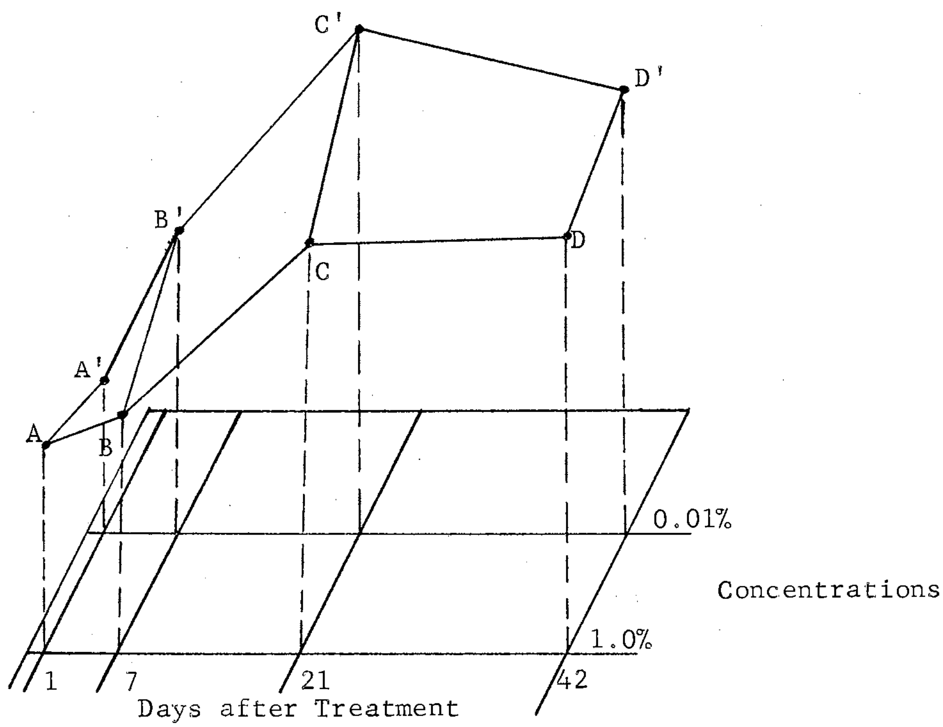

FIG. 24. Response based on the mean number of B. germanica appearing on a surface treated with 1.0% Diazinon plus D-460.

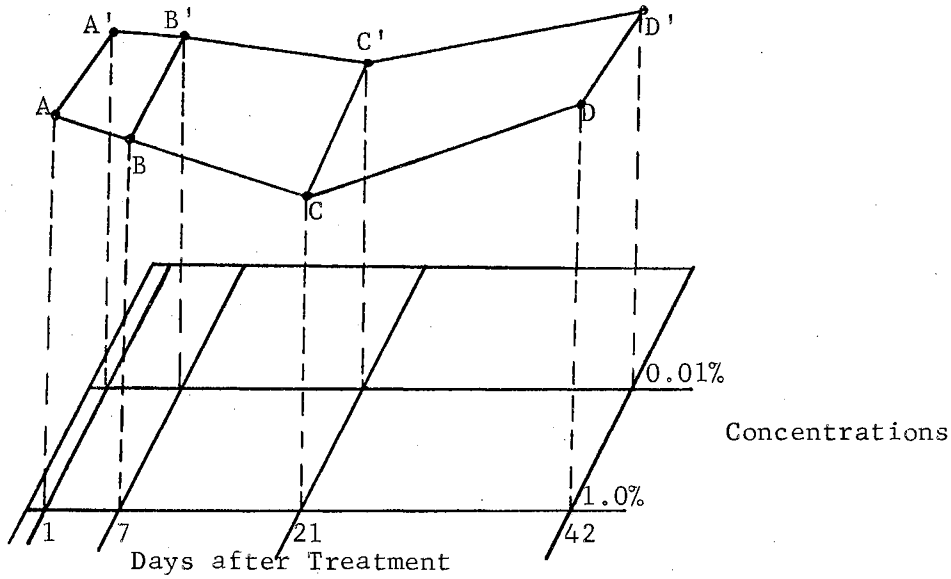

FIG. 25. Response based on the mean number of P. americana appearing on a surface treated with 1.0% Diazinon plus MGK-264.

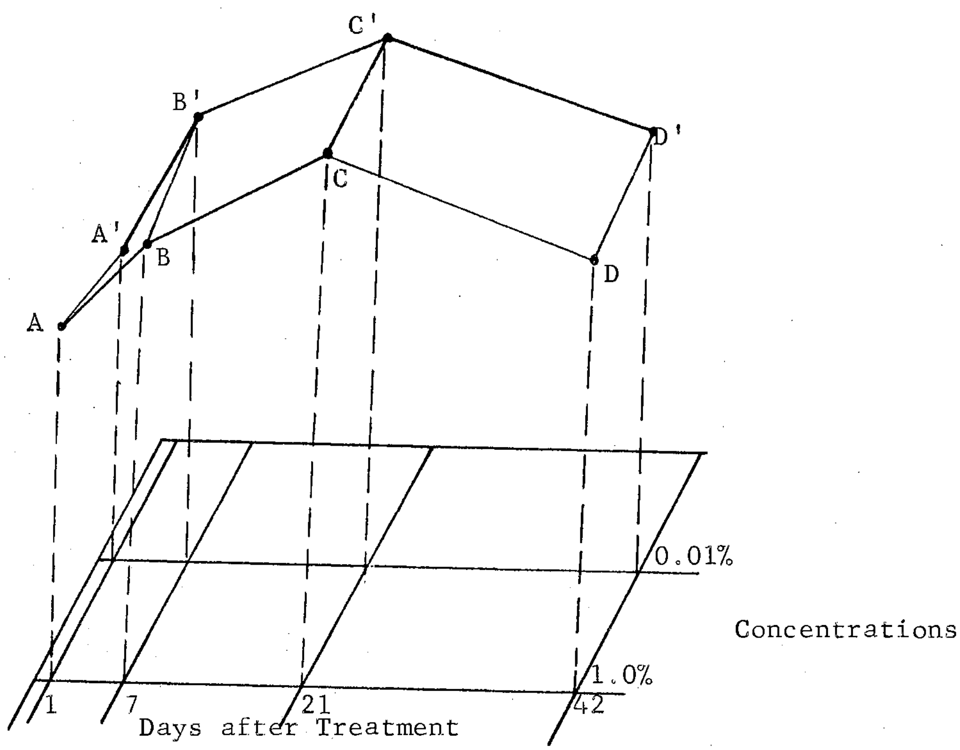

FIG. 26. Response based on the mean number of B. germanica appearing on a surface treated with 1.0% Diazinon plus MGK-264.

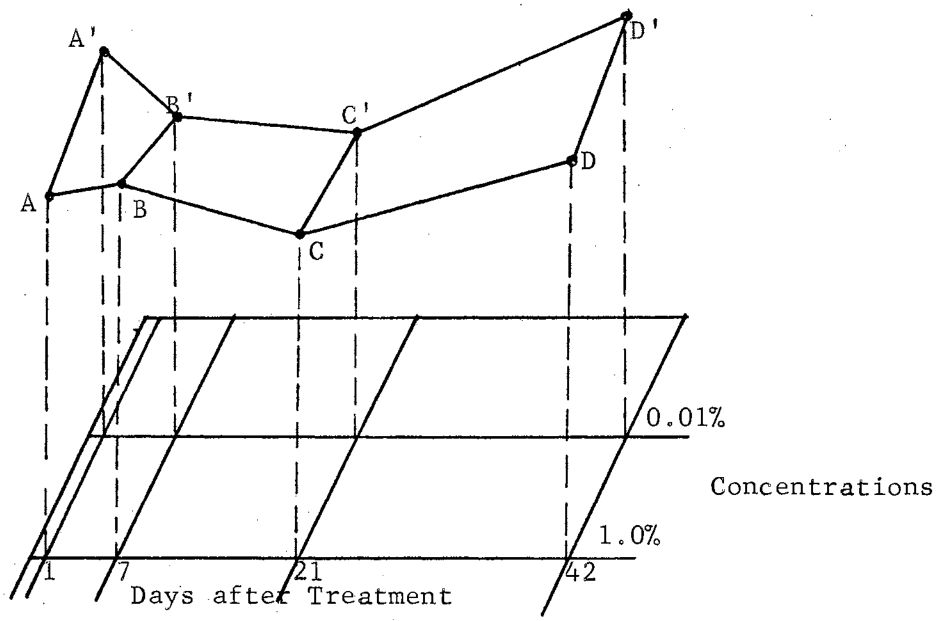

FIG. 27. Response based on the mean number of P. americana appearing on a surface treated with 1.0% Diazinon plus Lethane 384.

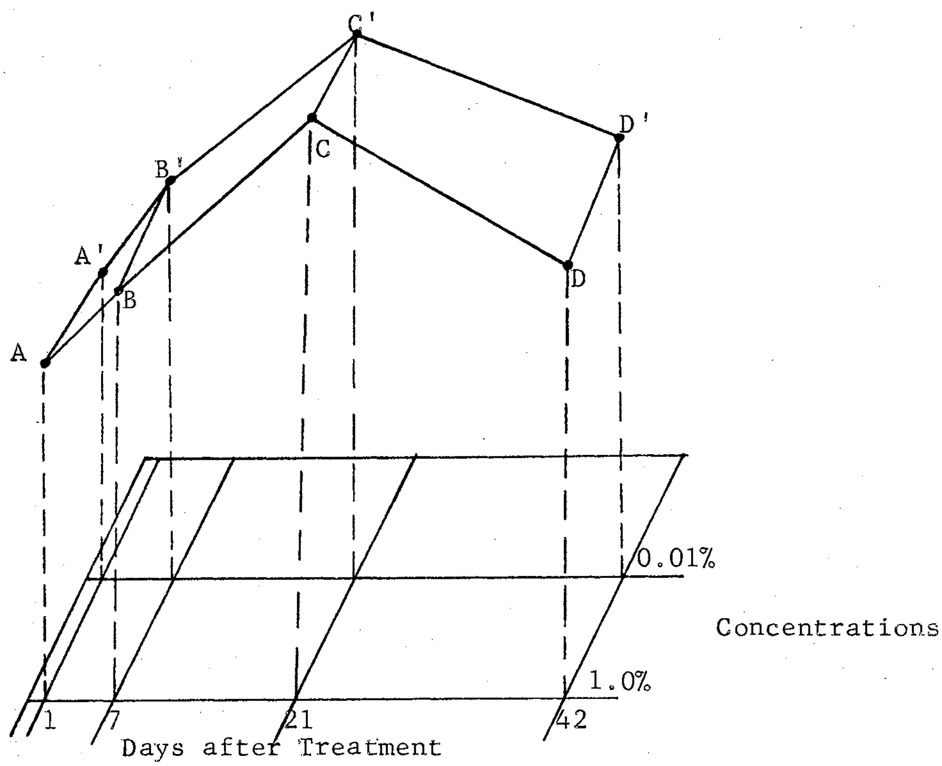

FIG. 28. Response based on the mean number of B. germanica appearing on a surface treated with 1.0% Diazinon plus Lethane 384.

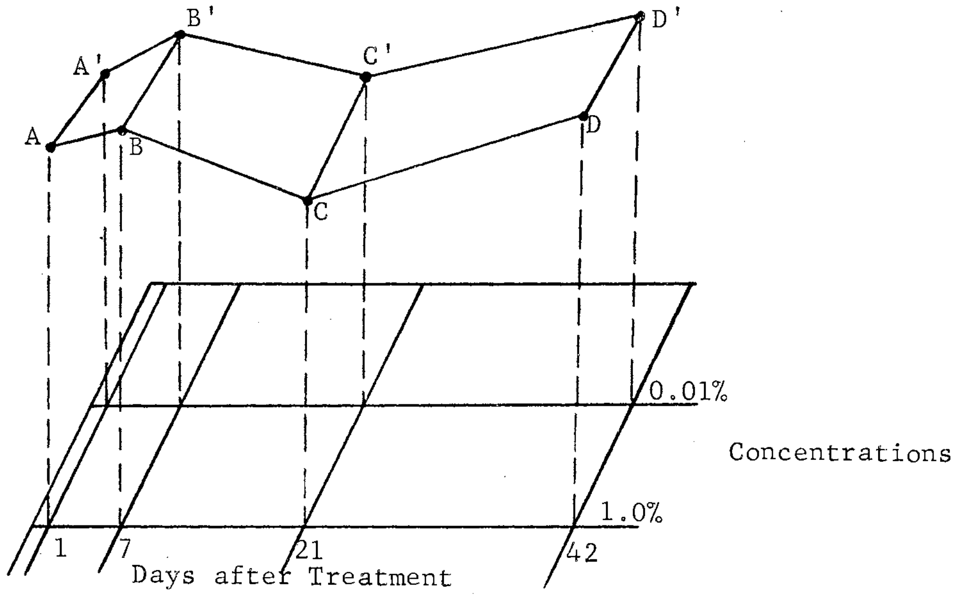

FIG. 29. Response based on the mean number of P. americana appearing on a surface treated with 1.0% Diazinon plus Toximul-P.

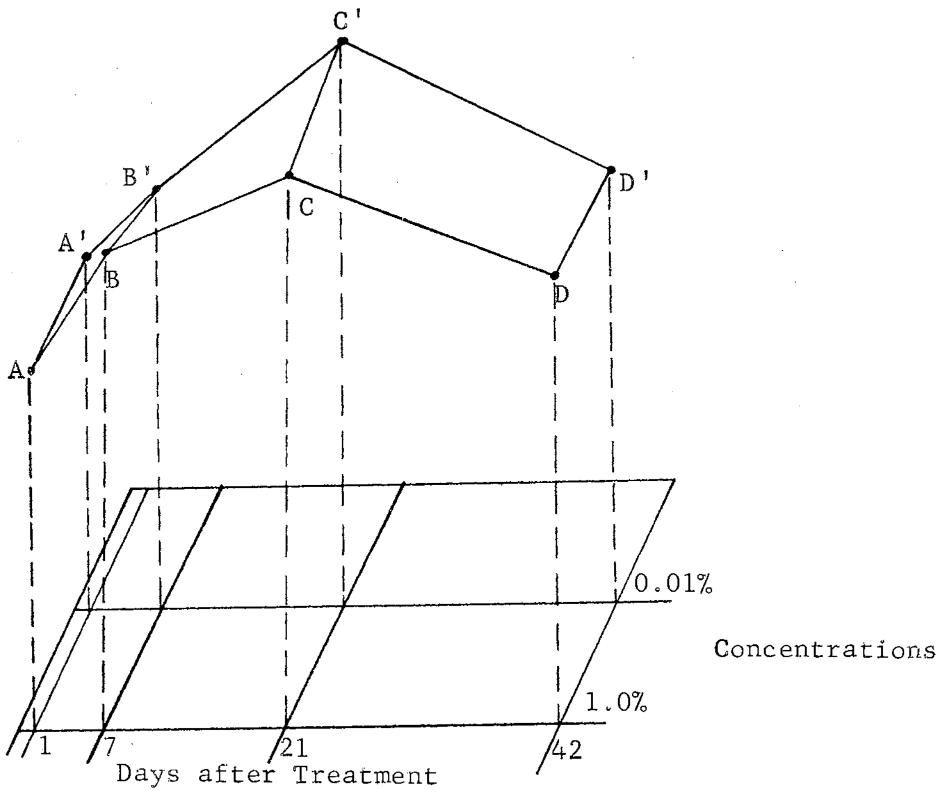

FIG. 30. Response based on the mean number of B. germanica appearing on a surface treated with 1.0% Diazinon plus Toximul-P.

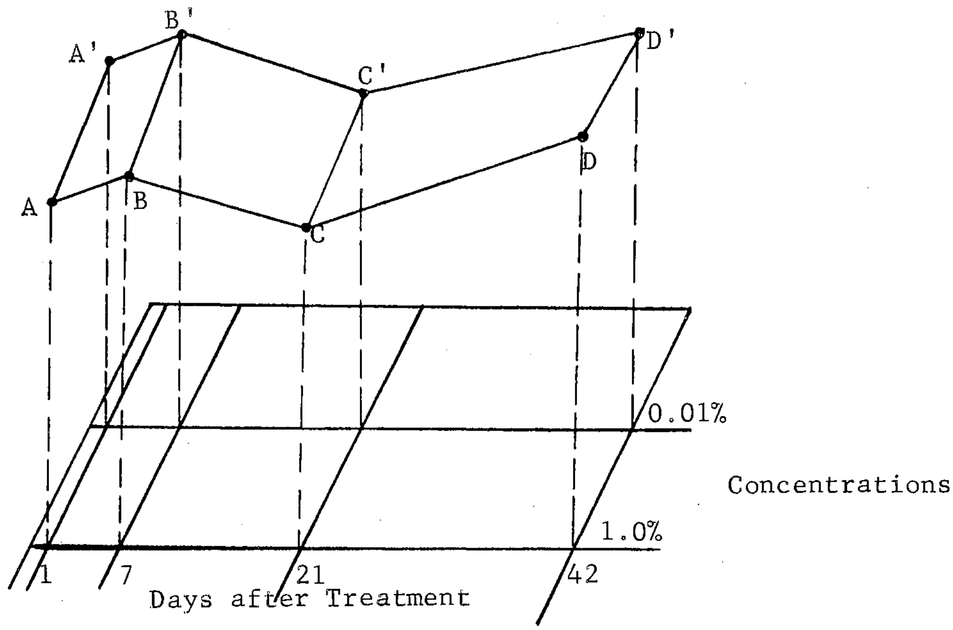

FIG. 31. Response based on the mean number of P. americana appearing on a surface treated with 1.0% Diazinon plus Atlox 1045A.

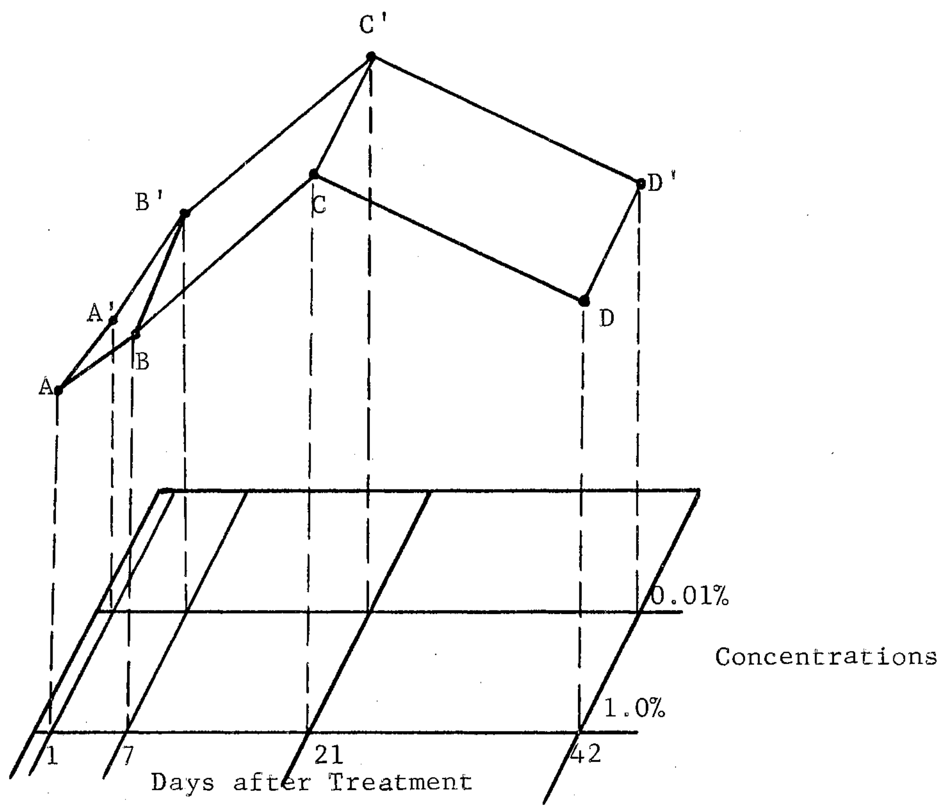

FIG. 32. Response based on the mean number of B. germanica appearing on a surface treated with 1.0% Diazinon plus Atlox 1045A.

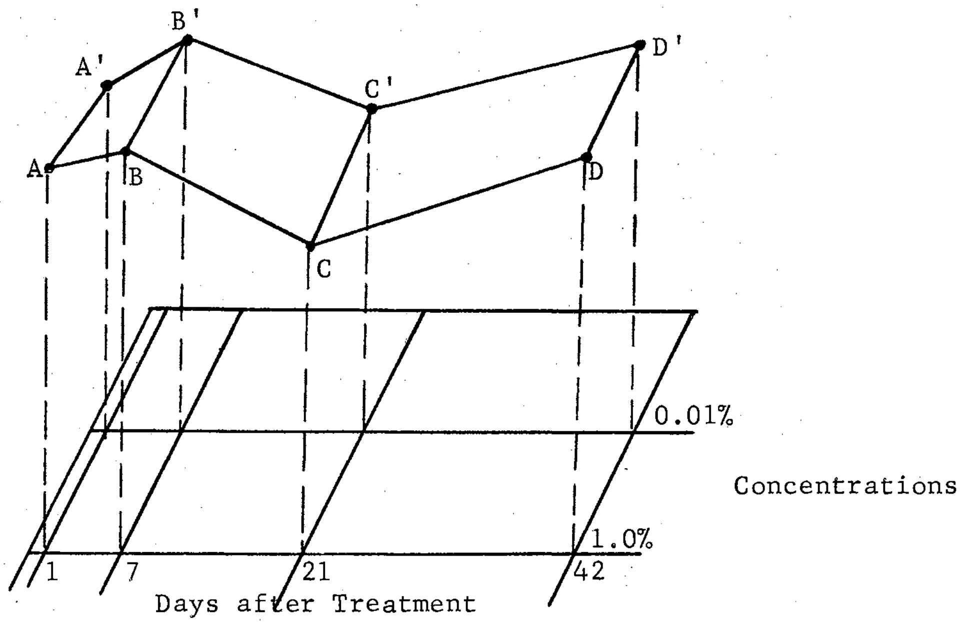

FIG. 33. Response based on the mean number of P. *americana* appearing on a surface treated with Diazinon.

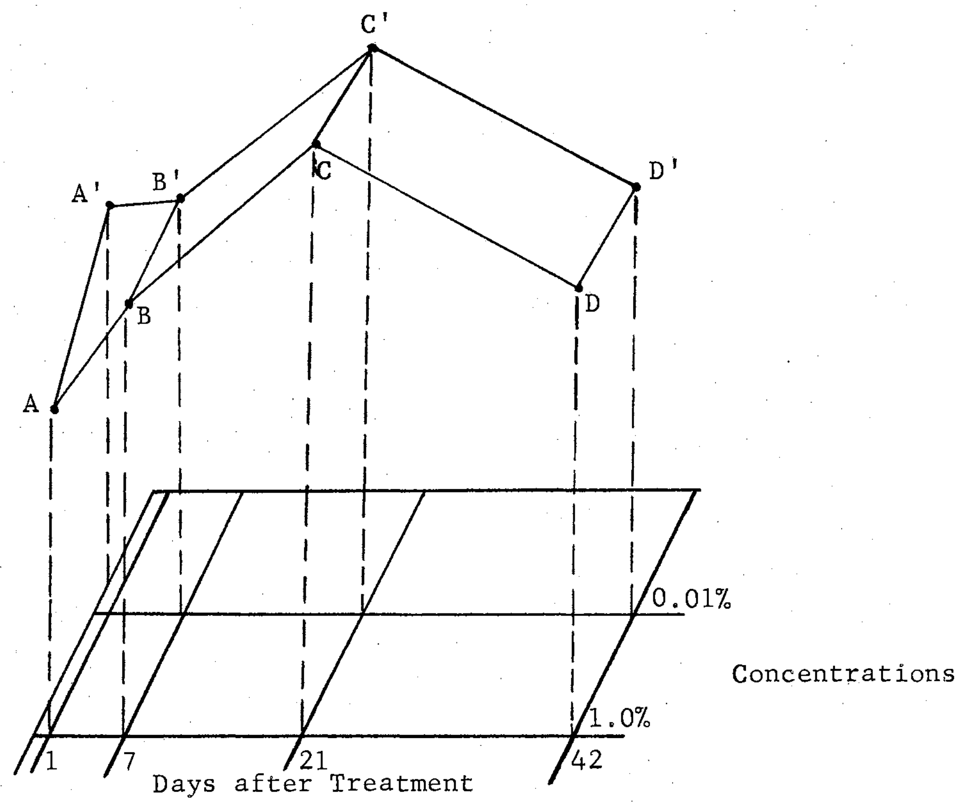

FIG. 34. Response based on the mean number of B. *germanica* appearing on a surface treated with Diazinon.

VITA

PAUL DAVID STERLING, JR.

Candidate for the Degree of

Doctor of Philosophy

Thesis: THE BIOLOGICAL EVALUATION OF SPRAY ADDITIVES AND SOLVENTS WITH BLATTELLA GERMANICA (LINN.) AND PERIPLANETA AMERICANA (LINN.)

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Professional Experience: General and dairy farming, previous to 1959 and summers of 1960 and 1961; Dead Shot Chemical Company, Oklahoma City, Oklahoma, 1962-63; Research Assistant, Department of Entomology, Oklahoma State University, summer and fall, 1963; Research Grant, National Pest Control Association, February, 1964-present.

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