EFFECTIVENESS OF ACARICIDES ON THE MITES *TETRANYCHUS TELARIUS* (LINN.) AND *OLIGONYCHUS BICOLOR* (BANKS); GARDEN HOSE SPRAYERS' SPRAY PATTERNS AND FIELD PERFORMANCE ON MITES

By

MAHMOOD ESKAFI

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SPRAY PATTERNS AND FIELD PERFORMANCE ON MITES

Thesis Approved:

R R Walton
Thesis Adviser

James E. Webster

Robert MacVicar
Dean of the Graduate School

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PREFACE

Mites often attack many plant varieties grown for ornamental and practical purposes. The two-spotted mite, Tetranychus telarius (Linn.), is the dominant mite species on greenhouse and home garden plants in Oklahoma. Effective chemical control has become complicated by the development in mites of resistance to certain toxicants that were formerly satisfactory.

An important problem involved in chemical control of arthropods on home plantings is the selection of application equipment. The use of garden hose sprayers has expanded markedly in recent years. Their acceptance was based primarily on their relatively long life and simplicity of operation.

Additional information is needed to guide the home owner in the selection of acaricides and application equipment. The objectives of the studies reported in this paper were as follows: (a) to evaluate standard and experimental acaricides on two strains of the two-spotted mite, (b) to determine the distribution of spray volume and spray toxicant in the spray patterns of two commerical brands of garden hose sprayers, (c) to evaluate the effectiveness of these sprayers as applicators in field tests.

The author wishes to express appreciation to his major adviser, Dr. R. R. Walton, for suggestions and assistance in planning the work and in preparing the report. Sincere thanks are expressed for technical assistance rendered by Dr. H. B. Boudreaux, Louisiana State University, who identified the test mites.

The author is grateful for critical suggestions made during the preparation of this paper by his advisory committee. These were Dr. W. A. Drew, Entomology; Dr. J. E. Webster, Biochemistry; and Dr. D. E. Howell, Head, Department of Entomology.

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I. INTRODUCTION

This thesis consists of two parts; tests of toxicants against spider mites and tests on the performance of two models of garden hose sprayers. These subjects are linked together, in the latter part of the thesis, by applying the toxicants against the spider mites through garden hose sprayers.

In a survey made to determine the more important pest species present in greenhouses in Oklahoma in 1959, the most prevalent group found were mites among which the most commonly found species was the two-spotted spider mite, *Tetranycus telarius* (Linn.) (1).

In testing the toxicants against spider mites, the two-spotted spider mite (*Tetranychus telarius*) was used under greenhouse conditions. A number of chemical toxicants were screened by spray tower application on potted plants infested with mites and their eggs. These tests were conducted from January to September of 1961. The *T. telarius* used in tests were of two separate strains of high and low resistance. Some toxicants showed distinctly more effectiveness against one strain than the other.

Toxicants against spider mites have always been in demand for the use in greenhouses, orchards, and gardens. The need for new and effective toxicants increases whenever mites develop resistance to materials already in use.

Hose sprayers are becoming increasingly popular to amateur operators for the use in yards and gardens. Their advantages over other kinds of sprayers, when used in yard and garden for a small area, are that they last longer and are cheaper.

Testing hose sprayers, as reported in this paper, was conducted to determine the rate of discharge of concentrate per given volume of water at different water pressures. Testing was also done to determine the volume of discharge and the concentration of toxicant in such discharge in different parts of the spray pattern. The results of the tests revealed considerable difference between the two models tested.

The toxicants and the sprayers tested in the laboratory were also compared in field tests. Field results followed closely those obtained in the greenhouse.

II. TESTS OF ACARICIDAL TOXICANTS

Review of the Literature

The two-spotted spider mite belongs to the order Acarina, family Tetranychidae, and genus Tetranychus (2).

The adult female is an eight-legged pale yellow or greenish mite, and about 1/60 inch in length; the male is approximately 1/80 inch. Two dark spots, composed of the food contents, show through the transparent body wall. After mating, the female mites begin laying 2 to 6 eggs a day, a total of 70 or more in a mite's lifetime. The eggs are attached to the lower surface of the leaves and hatch to nymphs in 4 to 5 days at greenhouse temperatures of 80-90°F. A complete generation is produced in every 10 to 40 days, depending on the temperature, and overlaps with other generations (3).

Temperature has a direct effect on population increase; female mites lay more eggs at 75°F. than at 55°F. The life cycle may require as little as 8 days at 75°F. while 36 days may be necessary at 55°F. High humidity is generally unfavorable to mites (4).

There are very few plants grown in greenhouses which are not subject to injury by the two-spotted spider mites. Among plants sustaining severe injury are cucumbers, tomatoes, carnations, chrysanthemums, melons, sweet peas, snapdragons, violets, roses, asparagus, and fuchsia. Those lightly infested have pale blotches or spots showing through the leaf. In heavy infestations the entire leaf becomes light in color and dries up after turning reddish brown in blotches or around the edge. Plants usually lose their vigor and die. If slightly infested, the leaves will have silken threads spun across them. In heavy infestations these threads may form a web, over the entire plant, on which mites crawl and to which they fasten their eggs.

The most common method of dissemination of the two-spotted spider mite in the greenhouse is by direct contact of infested plants with non-infested stock. Experiments proved that the rate of dissemination is considerably greater in direction of the prevailing wind than against it. It has also been demonstrated that heavy populations may cause leaf drop and kill plants without the mites making an attempt to migrate (5).

For nearly ten years it has been known that two-spotted spider mites rapidly develop resistance to organic phosphorus acaricides (6). The resistance to a specific compound generally is effective against most of the members of the group (7).

Where mites are susceptible organic phosphate chemicals still are in use. Where resistance exists most of the growers either apply organic phosphates more often and in larger amounts than formerly with a higher concentrate, or use chlorinated hydrocarbon acaricides.

Recently, however, the first case of multi-resistance was reported where a spider mite population of a rose house, developed resistance to both Kelthane and Chlorobenzilate. This resistance developed in two years after not more than ten applications. The population was also resistant to organic phosphate compounds (8). The failure of Kelthane to control Tetranychus mites in apple orchards in the State of Washington was also reported. One strain showed 200-fold increase in the Ld-50 over a susceptible strain (9). The author has not found a report of definite resistance to tetradiafon, a chlorinated hydrocarbon sulphone. In one case, however, eggs did not show nonviability normally caused by previous exposure of females to tetradiafon (10).

Little has been reported on the use of different applicators for treating mites despite the great attention given to toxicants. The general trend seems to favor the aerosol and small droplet sprays for greenhouse use. In comparing the low and high gallonage sprays outdoors with the constant dosages of systemic insecticide per acre basis, the results showed no differences (11).

The ovicidal action of toxicants has been studied on both resistant and susceptible strains of spider mites. The possibility of differences in the incubation period, rate of development of immature mites, and the rate of oviposition between resistant and susceptible strains of the two-spotted spider mites have been studied and shown to be of no significance (12). But it has been shown that female mites previously exposed to tetradiafon for a number of generations developed resistance to the extent that most eggs are viable (10).

Methods and Materials

Two strains of two-spotted spider mite, obtained from different cources, were used in tests under greenhouse conditions. Strain "A" was collected from American bittersweet in a greenhouse. These mites were transferred to potted chrysanthemum plants and allowed to increase. Strain "B" mites were collected from holyhock plants growing outdoors. These mites were reared on bean plants.

Procedure. Mites of all stages (egg, larva, nymph, and adult) were raised on Indiana White chrysanthemum and Baby Fordhook lima bean plants. Chrysanthemum plants were potted in individual pots, approximately 12 weeks before being infested. Chrysanthemum plants were especially suited for the study because of the large number of leaves per plant. They were replaced by bean plants during the summer months because the former developed flowers and seed-stalks under summer conditions. Seedling plants could be rapidly grown for test purposes and did not present important fruiting problems. Bean plants were seeded in 3.5 x 2.5-inch tin cans about three weeks before being infested. In order to infest the test plants, one or more leaves of the infested stock were placed on each plant.

Specimens of resistant and susceptible strains used in greenhouse tests were identified by Dr. H. B. Boudreaux, Louisiana State University, as *T. telarius* (Linn.). He also identified a mite species infesting burr oaks, that was treated in a later described field test as *Oligonychus bicolor* (Banks).

Mites were counted before and after treatment in all tests. Two leaves were detached from each chrysanthemum plant; one from the upper part and one from the lower part. The terminal leaves and the lowest leaves were avoided. Six plants were used per treatment. The mites on the lower surface of the leaves were counted by means of a binocular microscope. In bean plant tests mites on the lower surface of a single leaf, attached to the plant, were counted. Methods of counting were determined by speed, accuracy, and feasibility. The numerous leaf growth of chrysanthemums permitted the cutting of leaves at each count so that they could be examined easily under the microscope. The small number of leaves on bean plants prevented periodical removal of leaves. The small size of bean plants and their tin containers, however, permitted the plant to be placed on its side on the microscope stage so that mites could be counted on the attached leaves. One hole was punched in each leaf for identification by using a paper punch. If such a leaf was missing, a similar leaf which had been exposed to the treatment was substituted. Four plants were used per treatment. Test plants were kept on a bench arranged in rows by treatments, with a minimum space of six inches between treatments and also between the pots.

Within 24 hours after counting, test plants were sprayed in a spray tower. The spray tower (fig. 1) was kept in the greenhouse in winter, and outdoors in summer. It consisted of two separate pieces; the tower and the air pump. The electric air pump contained a pressure tank capable of holding up to 100 psi, an adjustment valve for lower pressures, and a shut-off valve. An air hose, with a nozzle at it's end, was connected to the tank. This spray nozzle was one from a throat antomizer and was equipped with an air valve and a cartridge to

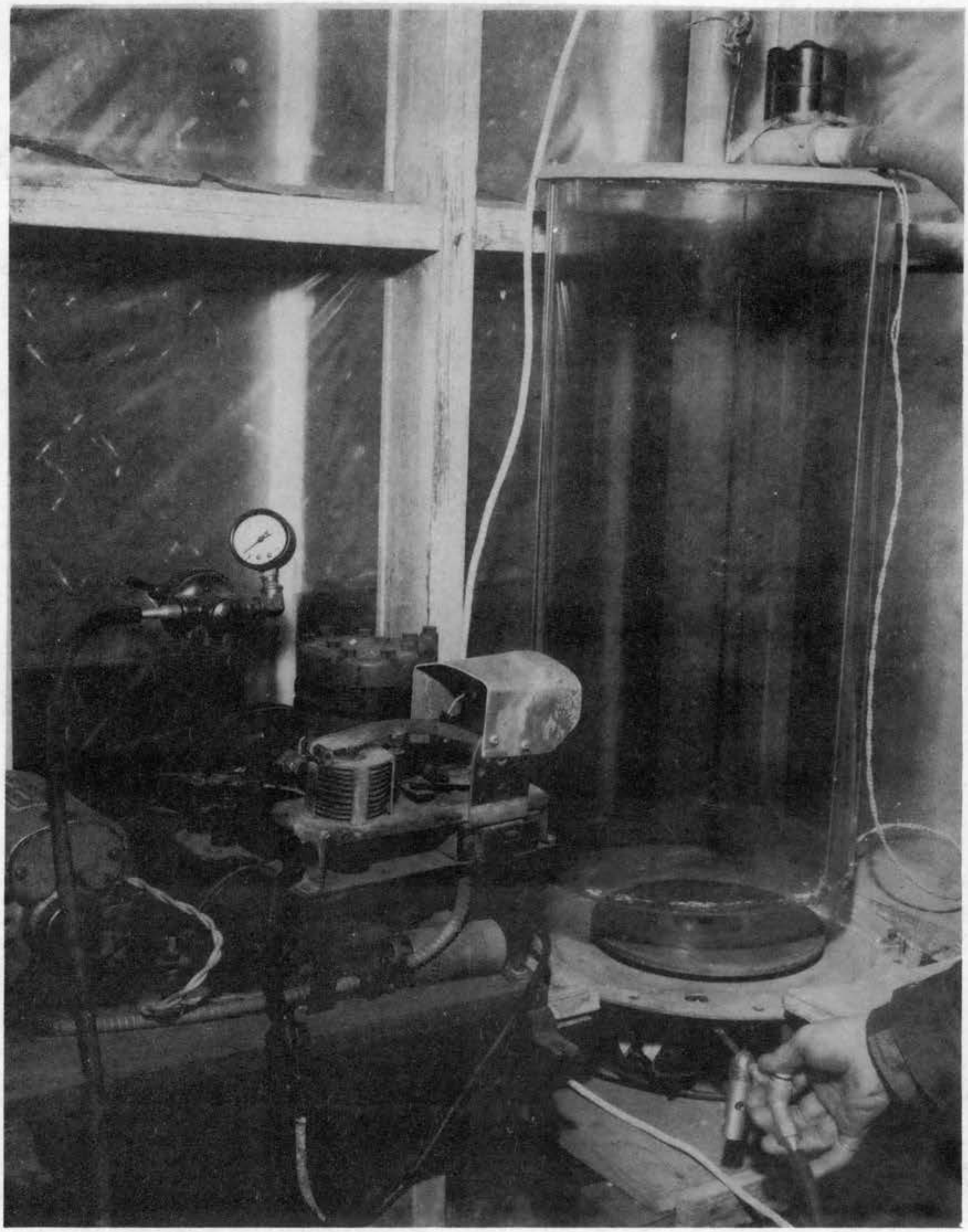

Figure 1. Spray tower and air pump.

hold a 7.50 ml vial of spray (fig. 2).

The spray tower consisted of a glass cylinder, 26 inches high and 13 inches in diameter, closed at the top with a close fitting metal lid and resting on a metal base with a circular rotating platform. The platform, with a variable speed regulator, was adapted from a phonograph and was operated by an electric motor. The tower top was equipped with a small exhaust pump and hose which were used to exhaust fumes from the tower after each application. To accomodate the introduction and removal of potted plants the glass cylinder and top assembly were lifted from or lowered to the tower hose by means of a rope-and-pulley unit attached above the tower to a stationary beam.

The procedure of spraying the test plants began with mixing the spray material for each treatment. One hundred ml. of distilled water was placed in a 4 oz. screw cap bottle. The liquid concentrate toxicant was measured in a pipette and poured in the bottle. The bottle was shaken thoroughly and the spray thus formed was poured in the vial and put in the cartridge of the spray nozzle. A single test plant was placed on the rotating disk and cylinder returned to position. In order to spray the lower surface of the leaves the nozzle was extended into the tower through the lower hole and the line of mist was directed upward and against the rotating plant. The rate of rotation was 30 times per minute. The exhaust pump and hose carried the excess mist and fume outdoors. To avoid contamination of nozzle and the intake tube, distilled water was run through the atomizer, the vial was renewed and the pipette was washed in benzene after each application.

The eggs used in ovicide tests were of the resistant strain which were on cotton plants. A cotton leaf of small size was picked off a

Figure 2. Spray tower nozzle and accessories.

plant and placed lower side up in a petri dish lined with water-saturated cotton. The petiole was cut diagonally with a razor blade and also covered with wet cotton. The adult mites on these leaves were punctured and killed by use of a needle. Four dishes were treated in the spray tower with 3.5 ml spray. Four days after application the unhatched eggs were counted and recorded. The dishes were kept moist and intact for another three days for a second count.

The toxicants used in screening tests are listed below with the number of active pounds per gallon and the formulation used.

1. Bayer 29492; O,O-diethyl O 4-(methyl-thio-m-tolyl) phosphorothioate; 4 EC*
2. Chlorobenzilate; 1,2 ethyl 4, 4'-dichlorobenzilate; 2 EC
3. demeton; 2 and 2.50 EC
4. Dibrom; 1,2-dibromo-2,2-dichloroethyl dimethyl phosphate; 8 EC
5. dimethoate; 4 SC*
6. ethion; 4 EC
7. Genite; 2, 4-dichlorophenyl ester benzene sulfonic acid; 4.50 EC
8. Kelthane; 1, 1-bis(p-chlorophenyl)-2,2, 2-trichloroethanol; 1.50 EC
9. malathion; 5 EC
10. Methyl Trithion; O,O-dimethyl S- (p-chloro-phenylthio) methyl phosphorodithioate; 4 EC
11. parathion; 2 EC
12. phorate; 4 EC

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*EC - Emulsifiable Concentrate
*SC - Soluble concentrate

13. Phostex; bis(dialkoxyphosphinothioyl) disulfides (alkyl ratio 25% isopropyl, 75% ethyl); 8 miscible

14. SD 4294; alka-methylbenzyl 3-(dimethoxyphosphinyloxy)-cis-crotonate; 2 EC

15. SD 3562; 3-(dimethoxyphosphinyloxy)-N, N-dimethylcrotonamide; 8 miscible

16. tetradiafon; 2,4,4',5-tetrachloro-diphenyl sulfone; 1 EC

Results and Discussion

A few preliminary tests were run to determine the amounts of toxicants to apply. Trial rates were influenced by manufacturer's recommendations and by published experimental results. A total of sixteen acaricidal toxicants were tested against two strains of two-spotted spider mites. Totals of 408 test plants and 63,893 mites and eggs were involved in 15 spray tower tests.

Comparison of Toxicants. Tables 1-4 inclusive present data on the control of a resistant strain of two-spotted mites by sprays containing various toxicants. Table 1 shows the results obtained with 10 treatments against resistant mites at intervals after applications. At the rates used in these tests only one toxicant, Kelthane, produced a high level of control. Genite, malathion, and parathion, at higher rates, gave moderate reductions. Only Kelthane exerted control at 20 days.

In a second test (table 2) four of the toxicants were tested at higher rates. Tetradiafon, at the rate of 10 mg was the most effective treatment. The results with this toxicant, in this test and in a later test (table 3), indicate that the maximum control occurs more than two days after application. Parathion at 21 mg gave somewhat better control than the systemics, demeton and phorate at 14 mg.

In a third test (table 3) the order of effectiveness of the various toxicants was about that obtained in the earlier tests. These changes, however, can be noted. Tetradiafon gave a high degree of control up to

20 days. Parathion was the least effective of the eight materials tested.

Table 1. Effectiveness of toxicants against strain "A", resistant, two-spotted spider mites, *T. telarius*, on chrysanthemums in the greenhouse, March 8, 1961.

Toxicant	Mg Toxicant Applied Per Plant	Pretreatment Population[a]	Per Cent Pretreatment Population Days After Application 2	4	20
Untreated	--	309	123	173	202
Kelthane	14	380	4	2	50
Genite	14	234	17	19	256
Malathion	21	264	23	36	353
Parathion	21	175	24	191	203
Phostex	14	187	30	28	276
Phorate	7	238	32	28	--
Demeton	7	170	38	96	--
Ethion	7	180	51	78	257
Dimethoate	21	132	57	57	290
Tetradiafon	7	138	61	100	89
Bayer 29493	14	280	73	110	--

[a]Number living mites on two leaves on each of six plants per treatment.

Table 2. Effectiveness of toxicants against strain "A", resistant, two-spotted spider mite, T. telarius, on chrysanthemums in the greenhouse, March 26, 1961.

Toxicant	Mg Toxicant Applied Per Plant	Pretreatment Population[a/]	Per Cent Pretreatment Population Days After Application			
			2	4	20	30
Untreated	--	430	79	60	94	34
Tetradiafon	10.5	632	18	11	13	31
Parathion	21	514	2	36	94	76
Demeton	14	386	13	15	37	69
Phorate	14	560	19	15	75	74

[a/]Number of living mites on two leaves from each of six plants per treatment.

Table 3. Effectiveness of toxicants against strain "A", resistant, two-spotted spider mite, T. telarius, on chrysanthemums in the greenhouse, April 20, 1961.

Toxicant	Mg Toxicant Applied Per Plant	Pretreatment Population[a/]	Per Cent Pretreatment Population Days After Application		
			2	4	20
Check	--	48	550	570	1358
Tetradiafon	10.5	158	24	1	7
Kelthane	10.5	224	9	3	139
Phostex	21	210	18	8	130
Malathion	21	206	2	19	107
Phorate	21	52	35	20	192
Genite	21	82	20	40	487
Parathion	21	64	56	94	171

[a/]Number of living mites on two leaves from each of six plants per treatment.

Table 4. Effectiveness of toxicants against strain "A", resistant, two-spotted spider mites, *T. telarius*, on chrysanthemums in the greenhouse, April 27, 1961.

Toxicant	Mg Toxicant Applied Per Plant	Pre-treatment Population[a/]	Per Cent Pretreatment Population Days After Application			
			2	4	20	30
Check	--	178	175	225	226	144
Demeton	21	134	14	6	16	61
Ethion	28	314	6	17	20	70
Genite	21	276	6	65	64	190
Phorate	21	256	26	79	52	70

[a/] Number of living mites on two leaves from each of six plants per treatment.

Table 4 shows the results obtained when demeton, phorate, and Genite were compared with ethion at higher rates of 21-28 mg per plant. Demeton and ethion established significantly higher levels of control than the others, during a 20-day period.

Tables 5 and 6 present data on the control of a nonresistant strain of two-spotted spider mites by the toxicants used against resistant mites. The results of these tests made during June are given in table 5. Rates of 10 to 21 mg caused marked reductions in mite populations. Complete control was achieved for four days by demeton, ethion, phorate, Kelthane, tetradiafon, and experimental compound Bayer 29492.

In September the above mentioned compounds, including seven additional toxicants, were tested against nonresistant mites at reduced rates of application (table 6). A majority of these treatments established a high level of control for the 20-day test period. Demeton,

Table 5. Effectiveness of toxicants against strain "B", two-spotted spider mites, *T. telarius*, on bush lima beans in the screened insectary.

Toxicant	Mg Toxicant Applied Per Plant	Pre-treatment Population[a]	Per Cent Pretreatment Population Days After Application 2	4
		Test No. 1. June 3, 1961		
Check	--	102	143	203
Demeton	10.5	204	0	0
Parathion	10.5	142	7	18
		Test No. 2. June 8, 1961		
Check	--	232	88	211
Ethion	10.5	270	0	0
Phorate	10.5	202	0	0
Genite	10.5	325	11	27
		Test No. 3. June 28, 1961		
Check	--	310	79	68
Bayer 29493	21	479	0	0
Kelthane	10	568	0	0
Tetradiafon	14	918	0	0
Phostex	21	734	0	67

[a]Number of living mites on two leaves from each of six plants per treatment.

Table 6. Effectiveness of toxicants against strain "B" two-spotted spider mites, *T. telarius*, on bush lima beans in the greenhouse.

Toxicant	Mg Toxicant Applied Per Plant	Pre-treatment Population[a]	Per Cent Pretreatment Population Days After Treatment 2	4	20
		Test No. 1. September 6, 1961			
Untreated	--	155	316	761	800
Chlorobenzilate	5	345	0	0	0
Dimethoate	10	406	0	0	0
Demeton	2.5	450	1	0	0
Methyl Trithion	5	650	2	0	0
Kelthane	2.5	490	0	0	1
Malathion	5	810	1	0	0
Phostex	20	1120	0	0	7
SD-4294	5	404	0	2	28
Tetradiafon	2.5	1110	0	0	36
Parathion	5	1110	0	0	47
		Test No. 2. October 22, 1961			
Untreated	--	480	31	25	146
SD-3562	10	470	0	0	0
Phorate	5	1120	0	0	0
Ethion	5	664	1	0	1
Bayer 29493	10	650	3	7	0
Genite	10	372	1	11	13
Debrom	20	360	1	22	22

[a] Number of living mites on two leaves from each of six plants per treatment.

Kelthane, and tetradiafon used at the low rate of 2.5 mg were highly effective, but the test indicated the higher rate for tetradiafon was necessary to insure residual effectiveness. Among the toxicants tested for the first time, Chlorobenzilate, dimethoate, Methyl trithion, SD-4244 and SD-3562 performed excellently. Dibrom used at the high rate of 20 mg showed the least promise of all toxicants.

Table 7 contains some information concerning the effects of various toxicants on the eggs of mites. The method of testing toxicants used in these tests have been proven satisfactory (13). The eggs or untreated leaves hatched and the mites were active as long as seven days. In these tests made in late July, three materials, tetradiafon, chlorobenzilate, and parathion showed higher degrees of ovicidal action. Several other toxicants reduced hatchability of eggs compared with the untreated eggs. In the case of these treatments the egg chorion became transparent and the embryos could be definitely recognized as being dead. The highest level of ovicidal effects in these tests occured in Tetradiafon treated eggs. The majority of these eggs developed an opaque and yellowish appearance and never hatched. A few of these nonviable eggs, however, turned transparent with the dead embryo visible inside.

Mite Resistance to Toxicants. The spray tests show a marked difference in reaction to the toxicants between the two strains of mites. The mites of the resistant "A" strain were much more difficult to kill by each of the toxicants. In four tests made on resistant mites (tables 1,2,3,4) the average control for all toxicants at four days after application was 35.1%. This contrasts with a mean control of 93.8% achieved by the same toxicants when applied in five tests to mites of strain "B",

Table 7. Effect of toxicants on eggs of strain "A", resistant, two-spotted spider mite, T. telarius, on cotton leaves in the laboratory at 4 days after treatment.

Toxicant	Mg Toxicant per Application	Number Eggs	Per Cent not Hatched	Unhatched Eggs: Chorion Appearance	Unhatched Eggs: Larvae	Surviving Larvae and Nymphs
			Test 1. July 26, 1961			
Untreated	--	782	15	Normal	?	Normal
Tetradiafon	10	573	67	Transparent or opaque yellow	Dead	None
Kelthane	20	579	35	Transparent	Dead	None
Genite	25	503	33	Transparent	Dead	None
Methyltrithion	25	885	25	Transparent	Dead	None
Dimethoate	35	511	0	Normal	?	None
			Test 2. July 27, 1961			
Untreated	--	211	6	Normal	?	Normal
Chlorobenzilate	15	346	54	Transparent	Dead	None
SD-3562	20	591	1.7	Transparent	Dead	None
Dibrom	40	231	11	Normal	?	Normal
SD-4294	5	573	10	Transparent	Dead	Normal
			Test 3. July 28, 1961			
Untreated	--	207	6	Normal	?	Normal
Parathion	15	239	57	Transparent	Dead	Some
Ethion	25	308	29	Transparent	Dead	Some
Phostex	25	289	29	Transparent	Dead	Normal
Phorate	25	370	24	Transparent	Dead	Normal
Malathion	25	327	12	Normal	?	Normal
Bayer 29493	35	333	11	Normal	?	Normal

(tables 5,6). This discrepancy, however, does not measure the entire difference in reaction to these toxicants, because in the resistant mites' tests the average rate of application was 15.1 mg contrasted with 9.6 mg applied against nonresistant mites. If control levels and application rates are compared, the average resistance to all toxicants by strain "A" was indicated to be approximately four times that of strain "B".

It is interesting to examine comparative kills obtained by certain specific toxicants on the two strains. Parathion tested three times against resistant mites at 21 mg resulted in an average control of 48.7%. The corresponding averages on the nonresistant mites were 7.7 mg and 100%. That the effectiveness of parathion on nonresistant mites was higher than the averages given was indicated by the fact that the 5 mg rate also resulted in 100% kill. Extrapolating from the parathion data (a two-fold increase in mortality by an application rate reduced four fold) a resistance factor of eight is indicated for the reaction of resistant mites to parathion compared with the nonresistant strain.

When the results of two tests with Kelthane against each of the strains, were similarly compared it was found that resistance to Kelthane by strain "A" was less than two times that exhibited in the non-resistant strain "B".

If similar comparisons are made with data from the remaining toxicants, it will be found that the difference in resistance between the two strains of mites is greater for most of the phosphate toxicants (parathion, malathion, Phostex, dimethoate, phorate, demeton) than for non-phosphate compounds such as kelthane, tedion, and ethion. This general condition is not unusual since it is reported by other workers that resistance to organic phosphate miticides is generally higher and encountered more frequently than to non-phosphate acaricides (14).

III. SPRAY PATTERNS OF GARDEN HOSE SPRAYERS

Review of the Literature

A kind of sprayer has been developed and put on the market in recent years that is called the garden hose sprayer. Garden hose sprayers fall in the category of hand equipments used to apply low volume sprays. This category primarily consists of hand atomizers, knapsack sprayers, or modifications of these two types (15). The group also includes the household-intermitent, continuous compressed air, bucket, barrel, and slide sprayers (16). A search of the literature did not disclose experimental work with garden hose sprayers. Only popular literature published by the manufacturers was available on this equipment.

Methods and Materials

Garden hose sprayers usually consist of three principal parts (fig. 3). There is a short straight intake pipe extended as an outlet pipe, with a built-in nozzle, valve, and feeding tube. The starting point of this pipe is threaded to fit a garden hose. A metal dispersing spoon is fastened tightly on the nozzle tip. Finally a bottle made of plastic or glass holds the concentrated toxicant and fits the intake-outlet pipe where the feeding tube is connected. This bottle is hereafter reported as the toxicant bottle. The feeding tube extends to near the bottom of the toxicant bottle.

The mechanism of operation is simple. When water passes through the intake-outlet pipe the pressure in the feeding tube is reduced causing the toxicant concentrate to be fed into the intake-outlet pipe. Water and toxicant thus combined is forced out through the nozzle and is dispersed by the spoon in a spray pattern.

Two brands of sprayers were tested: Gilmour's Hose Master Model 484 and the Hayes 6-gallon Model. The Hose Master Model was tested with both a concave and a flat spoon.

General Procedure. The sprayer discharge rate of water and toxicant were determined by plotting against time, the volume of water collected and the volume of concentrate withdrawn from the toxicant bottle at given pressures in the hose.

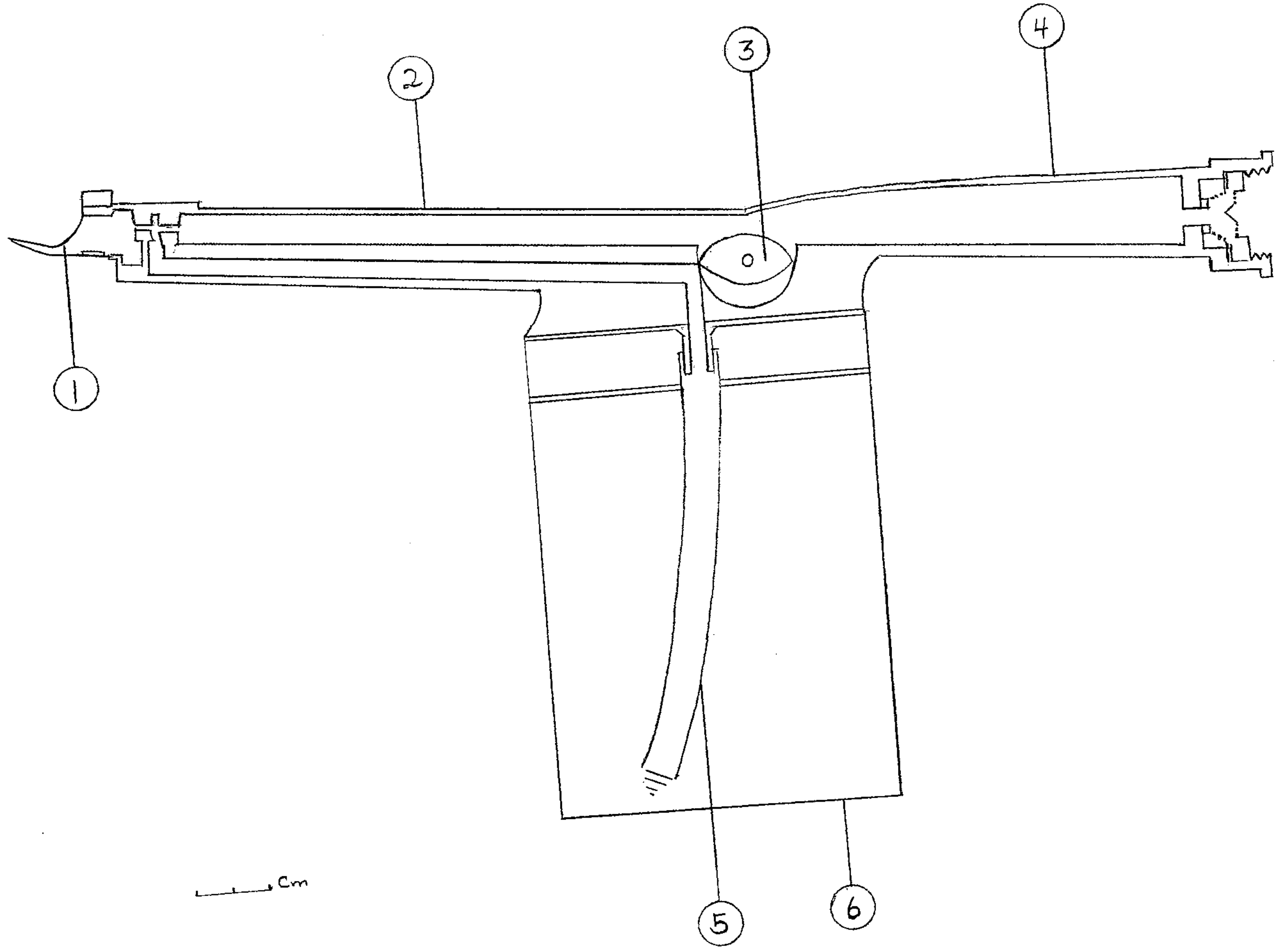


Fig. 3. Longitudinal cross section of Hayes 6-Gallon Sprayer, 1/2 actual size.
1. Spoon. 2. Outlet pipe. 3. Valve. 4. Intake pipe. 5. Feeding tube. 6. Toxicant bottle.

The distribution of water volume in the spray pattern was studied by methods demonstrated in figures 4 and 5. Each sprayer was mounted rigidly at a point above the laboratory floor. This point was between 6-8 feet from the floor although variations of a few inches occurred due to the length of different nozzles. The spray was discharged vertically downward toward a block of empty one-pint glass jars resting on the floor. The blocks of containers which encompassed the entire spray pattern was composed of closely appressed jars held together by a wooden frame (fig. 5). A pressure gage and a pressure regulator were inserted in the hose line for the control of water pressure.

Before each test certain adjustments and measurements were made in the positions of the sprayer, the sprayer spoon, and the container blocks. The sprayer and spoon were adjusted to discharge the center of the spray pattern downward along a line perpendicular to the floor. The block of containers was adjusted so that its center coincided with the center of the spray pattern. The sprayer was operated for periods of one to four minutes and then the volume of spray in each jar was recorded. Five replicate spray intervals were recorded for each test.

To determine the distribution of toxicants in the spray pattern the sprayer was operated in two different positions. In one type of tests the vertical discharge position and pattern, discussed above for for volume distribution tests, was used. In the second series of tests, the sprayer was set to discharge a horizontal spray pattern into five vertically mounted metal troughs, located at five equally spaced points in the spray pattern (fig. 6). Each trough, open at both ends, was 18 inches long, with a three-inch flat bottom and one-inch sides. The lower end of each trough was inserted in a wide-mouth quart jar to

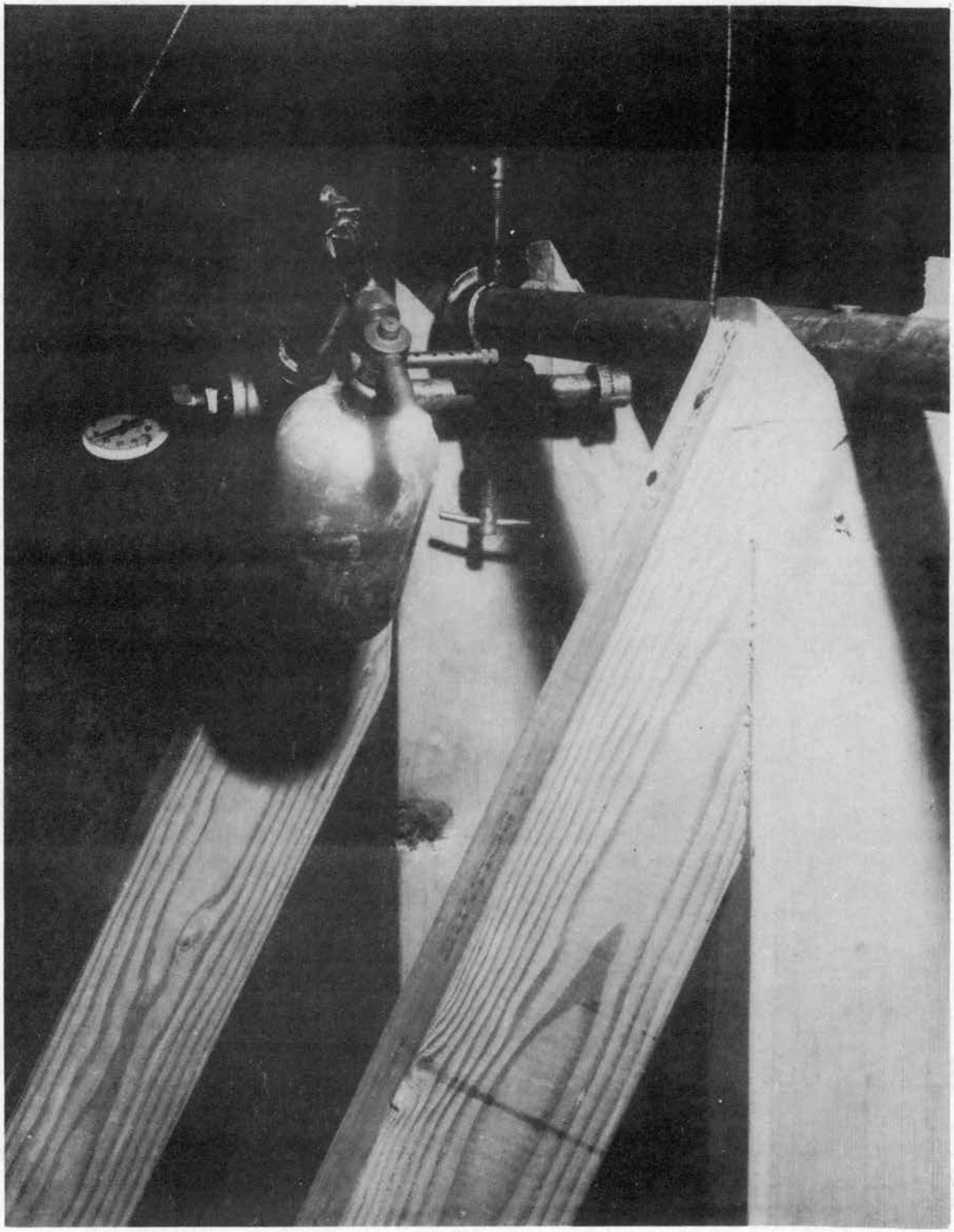


Figure 4. Mounted sprayer for vertical discharge.

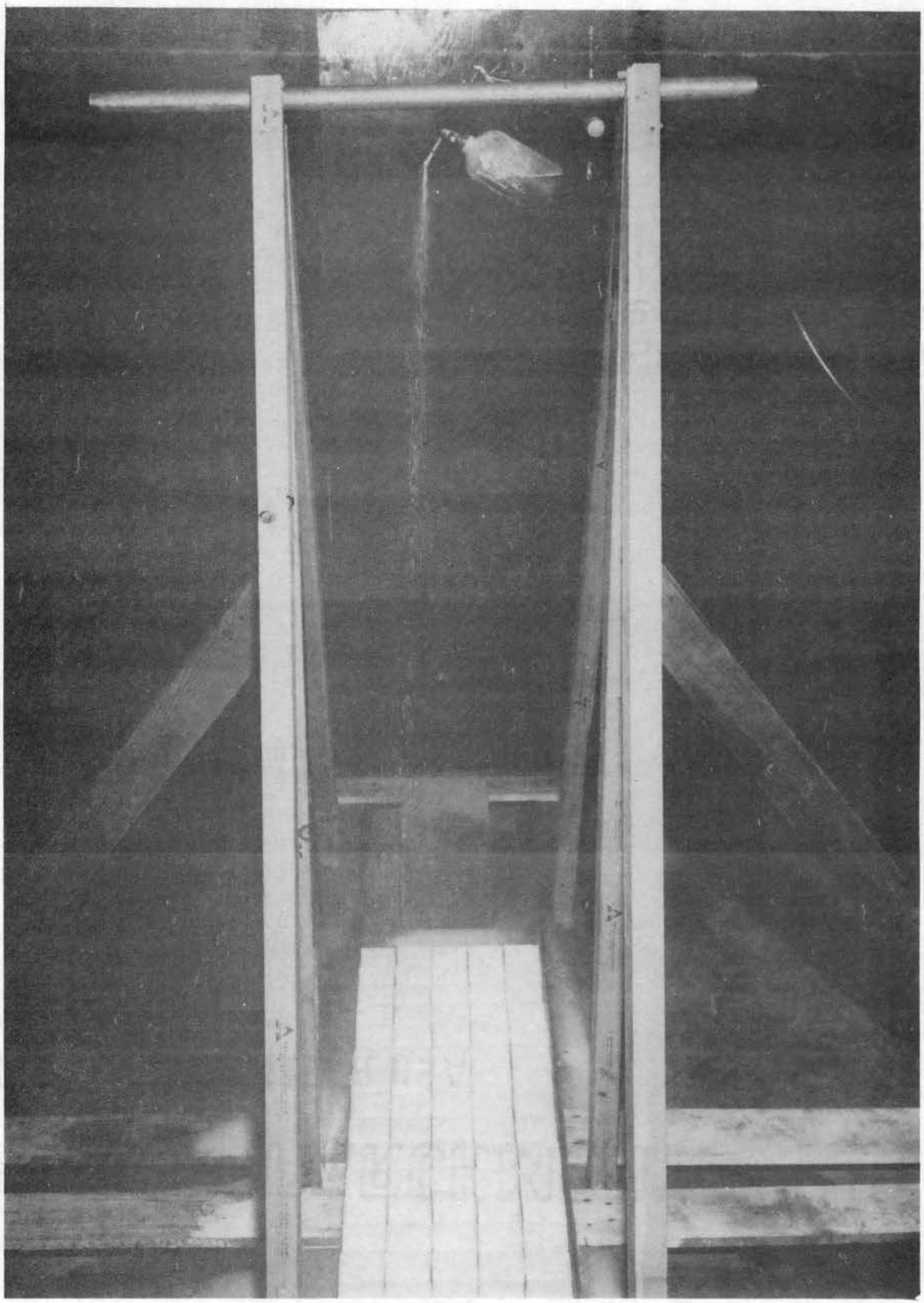


Figure 5. The vertical spray discharge.

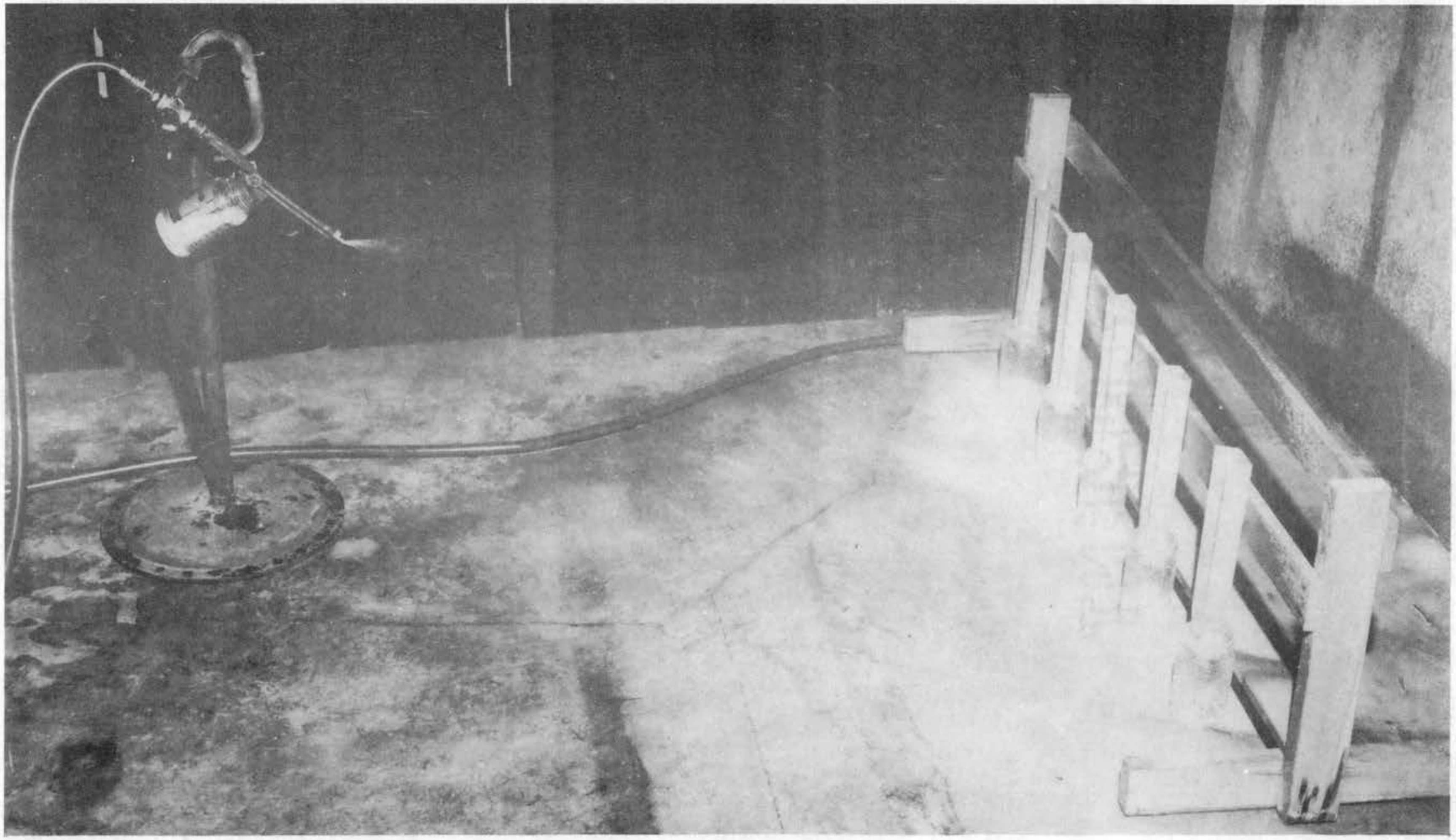


Figure 6. Horizontal spray discharge.

collect the spray intercepted by the trough.

The comparative distribution of toxicant was obtained by determining the distribution of emulsifiable toxicant concentrate in the spray pattern. Fifty ml of spray were taken from each container used in collecting spray from each of vertical and horizontal spray patterns. The emulsion in spray samples was broken and the resultant concentrate recovered was measured and plotted against the sample location in the spray pattern. Five replicate tests were made for each container.

Spray emulsions were treated by adding 50 ml of spray to a Babcock cream test bottle containing 10 g of canning grade sodium chloride. The spray in the collection container was agitated vigorously immediately before the 50 ml sample was withdrawn. The test bottle was shaken vigorously and then centrifuged at 848 rpm for 10 minutes. The concentrate including solvent, emulsifier, and toxicant, was collected as a supernatant liquid above the water in the neck of the bottle. The volume of concentrate recovered in this manner was calculated by using the calibration scale on the neck of the test bottle.

The efficiency and reliability of this method for spray analysis was tested with spray samples prepared in the laboratory by mixing measured amounts of concentrate and water. Ten such samples, analyzed by sodium chloride - centrifuge method, showed a variation of $\pm$ 3.4% and an average recovery of 70.8% of the concentrate (table 8).

The toxicant used in the spray was emulsifiable concentrate DDT containing 2.00 lbs. actual toxicant per gallon.

Attempts were made to check the accuracy of the salt-centrifuge method by measuring the acaricidal effects of spray samples. Samples were prepared in the laboratory by mixing proper amounts of toxicant

Table 8. Performance of a sodium chloride-centrifuge method in measuring the amount of toxicant concentrate in laboratory prepared 50 ml spray samples containing 2.0 ml toxicant concentrate.

Sample Number	Concentrate Recovered	
	Ml	Per Cent
1	1.40	70.0
2	1.45	72.5
3	1.40	70.0
4	1.45	72.0
5	1.35	68.5
6	1.40	70.0
7	1.35	68.5
8	1.45	72.5
9	1.40	70.0
10	1.45	72.5
Mean	1.41	70.8

(Kelthane) and water, to equal the concentration of samples discharged from the sprayer, as indicated by the salt-centrifuge method. Samples were collected from each of the five pattern points previously described in the horizontal spray tests. Sprayer and laboratory samples were applied in the sprayer tower to bean plants infested with two-spotted mites.

Mite mortality varied markedly in the test with the Hose Master sprayer samples (table 9). Both sprayer and laboratory samples with the higher concentrations (points A and E) produced the higher mite mortalities. Kills by samples from the three intermediate points (B,C,D) were not correlated with their concentrations. The data indicated consider-

Table 9. Effect of Kelthane spray samples, from different points of the spray pattern of Hose Master sprayer, on two-spotted spider mites.

Pattern Point Sample	Mg Toxicant/ 100 ml Spray	Per Cent Reduction After 4 Days: Sprayer Sample	Per Cent Reduction After 4 Days: Lab Sample of Same Concentration
A	75	90	87
B	49	72	87
C	46	85	77
D	53	76	83
E	83	97	96
Average	61	84	87
Untreated	--	20	20

[a]/Based on the number of living mites on two leaves from six plants per sample.

able experimental error-either in the mite-plant factor or in the salt-centrifuge method.

In the test with samples from the Hayes Sprayer, mortalities were generally correlated with results of chemical analysis (table 10). As shown in figure 1 and table 10 the concentrations of samples from the five points of the pattern were generally uniform. Mite mortalities of these sprayer samples showed moderate variation but not in excess of that usually encountered in biological screening of toxicants. Mortalities produced by laboratory samples were generally correlated with kills by sprayer samples of the same concentrations. The data indicated that the salt-centrifuge analysis was sufficiently accurate for comparative purposes in this study of garden hose sprayer patterns.

Table 10. Effect of Kelthane spray samples, from different points of the spray pattern of Hays 6-gallon sprayer, on two-spotted spider mites.

Pattern Point Sample	Mg Toxicant/ 100 ml Spray	Per Cent Reduction After 4 Days	
		Sprayer Sample	Lab. Sample of Same Concentration
A	65	98	94
B	63	91	91
C	62	93	88
D	62	95	88
E	62	94	93
Average	63	94	91
Untreated	--	0	0

Results and Discussion

Table 11 shows the output of hose sprayers in terms of spray volume and amount of spray concentrate when operated at the three pressures of 30, 35, and 40 psi. Spray volume was measured in gallons per hour and the volume of concentrate output was calculated from amounts recovered by the salt-centrifuge method. In the case of both sprayers, spray volume increased directly with increase of pressure. At the assending pressures spray volumes from the Hays sprayers were approximately 23, 24, and 25 gallons per hour respectively; the corresponding volumes for the Hose Master were 46, 52, and 56 gph. According to the manufacturers' specifications, both sprayers would put out approximately 59 ml of concentrate per gallon of spray at the various pressures. The amounts of

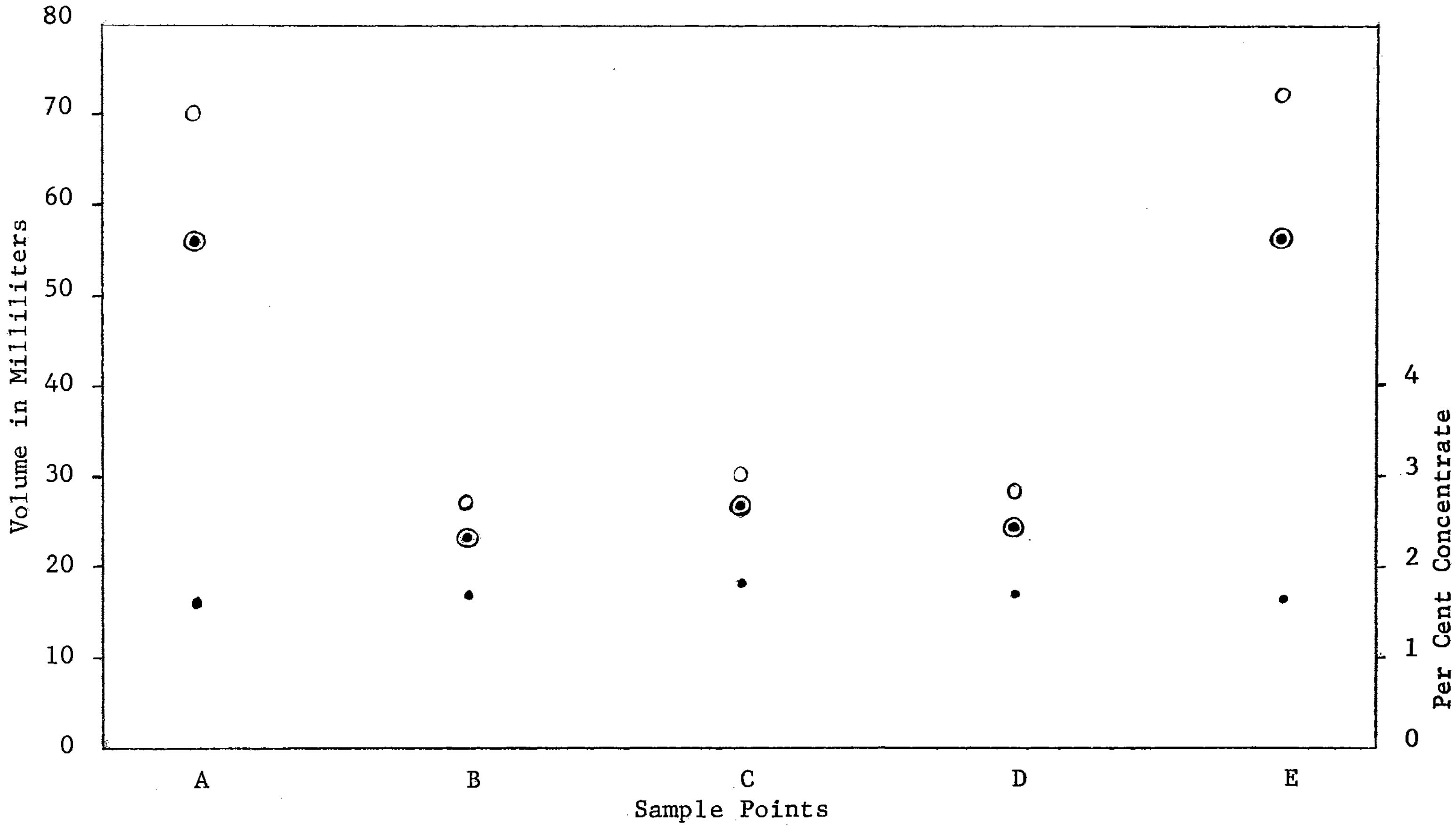
Table 11. Output of spray volume and concentrate by garden hose sprayers at three pressures.

Pressure PSI	Spray GPH	Ml Concentrate Per Gallon Recovered	Expected
	Hays 6-Gallon Sprayer		
30	22.7	88	59
35	24.0	85	59
40	25.5	87	59
	Hose Master Sprayer		
30	46.3	89	59
35	52.3	80	59
40	55.8	68	59

spray concentrate collected and recovered from both sprayers markedly exceeded the amounts expected on the basis of manufacturers' predictions. The output of spray concentrate by the Hayes sprayer was essentially the same at the three pressures. In the case of the Hose Master sprayer, however, concentrate volume varied inversely with pressure.

Figure 7 shows the distribution of spray volume and spray concentrate at five points in horizontal discharge spray pattern of the Hose Master sprayer, with concave spoon, at 40 psi. It should be emphasized that values are known only for the points illustrated; the patterns between these points were not determined.

Distribution of spray volume among the five points varied greatly. Troughs at points A or E, located near the outer margins of the pattern, collected 70-72 ml of spray per minute compared to 28-30 ml caught at



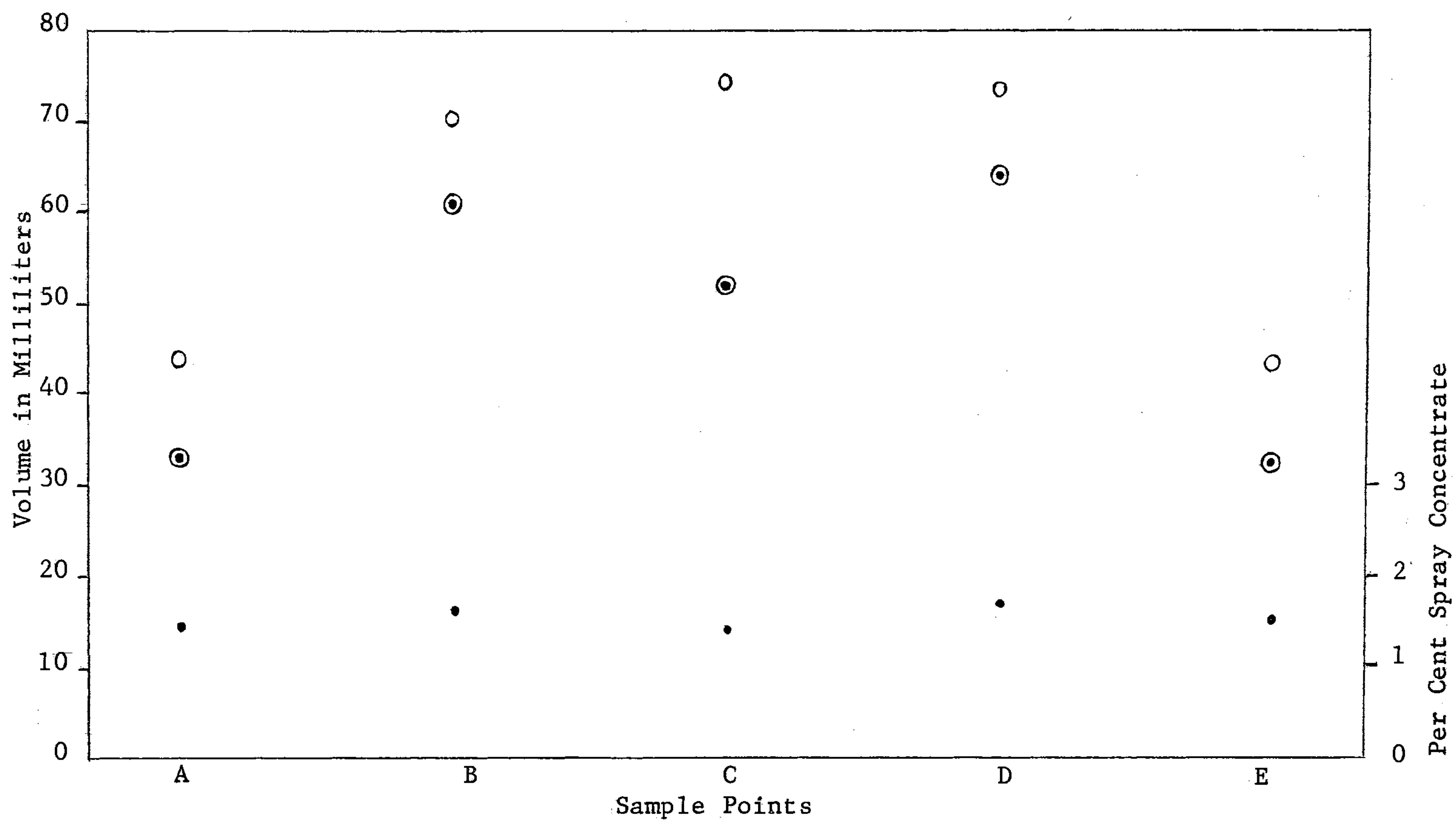
⊙ Concentrate volume collected in 50 minutes
• Per cent concentrate
○ Spray volume per minute

Fig. 7. Distribution of spray volume and concentrate at five points in the horizontally discharged spray pattern of Hose Master Sprayer, with concave spoon attached, at 40 psi.

points B, C, or D. Thus, approximately 62% of the total spray collected was recovered at A and E. The range from 28 to 72 ml represented a variation of 157% among the five points. The volume of concentrate collected in 50 minutes was obtained by integrating spray volume and concentrate per cent obtained at each point. This distribution of concentrate volume which depicts relative potential insecticidal effectiveness at the five points tends to roughly approximate the distribution of spray volume. Thus, under the conditions of operation described here, extreme variation in insecticidal performance within the spray pattern may occur.

Figure 8 presents the results obtained when the Hose Master sprayer was tested a second time by the method described above except that a flat spoon, supplied by the manufacturer, replaced the concave spoon.

Spray volume varied greatly again, but the range from 42-44 ml at A or E to 74 ml at C represented a variation of 76%, considerably lower than that obtained with the concave spoon. Volumes obtained at the five points were inverted in interpoint relations compared to the first test; in the former maximum volumes were at A and E, in the latter at C and to a less extent at B and D. The per cent concentration in spray ranged from approximately 1.4 to 1.7%, to a variation of 21%, with the minimum occurring at point C. The relative distribution of concentrate volume at the five points tended to correlate with the spray volumes except that a significant decrease occurred at the center of the pattern (C). Although much variation existed among the five points, the distribution, both as to degree of variability and to location of maximum concentrate volume, made for greater potential insecticidal effectiveness than that of the concave spoon.



◉ Concentrate volume collected in 50 minutes.

• Spray concentrate

○ Spray volume per minute

Fig. 8. Distribution of spray volume and concentrate at five points of the horizontally discharged spray pattern of the Hose Master sprayer, with flat spoon, at 40 psi.

Figure 9 illustrates the performance of the Hays garden hose sprayer obtained by the same methods. Spray volume distribution among the five points ranged from 10.5 to 29 ml per minute with 78% of total volume being collected at points B, C, and D. The per cent of concentration in spray ranged from 1.5 at C to 1.7 at A and E, a variation of only 13%. Maximum variation within B-C-D (the commonly utilized central segment of the pattern), however, was only 15% compared to 23% for the same points in the Hose Master flat spoon test. On this basis the expected insecticidal effectiveness of the central segment of the Hayes pattern would be higher than that of the same segment in the pattern obtained with Hose Master sprayer with either types of spoon.

Further tests were conducted by a different method to obtain more specific information on patterns of these two sprayers. In these tests the sprayers were positioned to discharge the center of the spray pattern vertically downward. The main area of the pattern was determined by measuring the volume and per cent concentration of spray collected in contiguously located wide-mouth pint fruit jars placed on the floor.

Data for the Hose Master sprayer with concave spoon are given in figures 10 and 11. Volume distribution was variable, with the greatest concentration occurring in two small areas near the lateral margins of the pattern (fig 10), where 27 to 67 ml of spray were collected in sample jars. Between these two areas in the three central rows, volume ranged from 7 to 15 ml per jar. In the remainder of the pattern sampled, volume generally decreased progressively toward the upper and lower margins of the pattern.

Little correlation occurred between volume distribution (fig 10) and concentration distribution (fig 11) in the pattern. The per cent concentrate varied from 1.2 to 2.2, with greatest concentrations occurr-

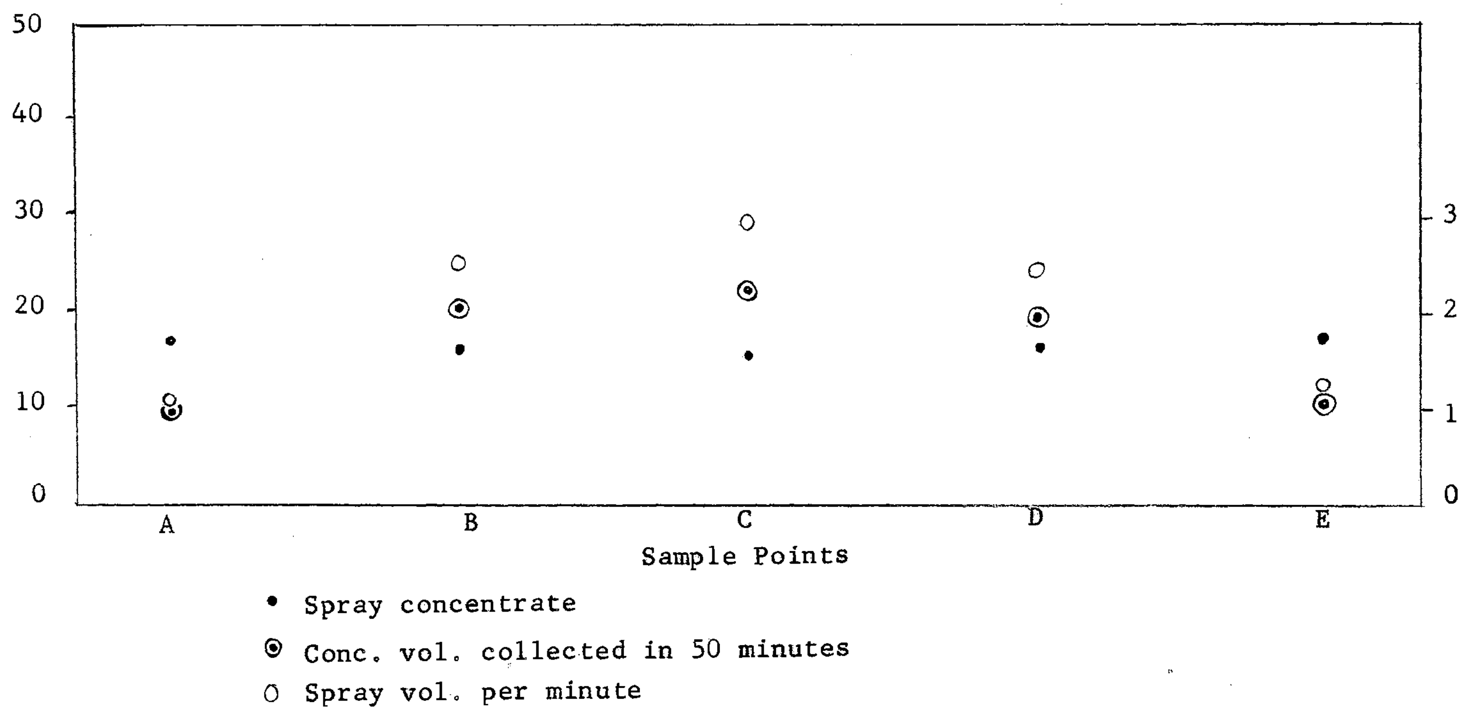


Fig. 9. Distribution of spray volume and concentrate at five points in the horizontal discharge spray pattern of the Hayes 6-gallon garden hose sprayer at 40 psi.

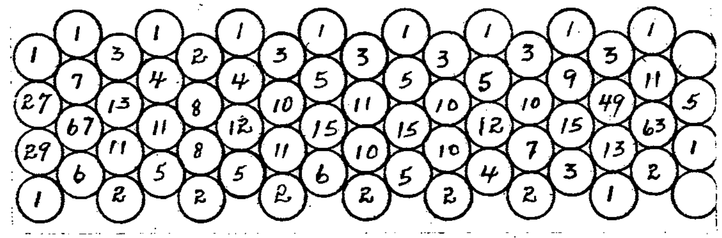


Fig. 10. Distrubution of spray volume in spray pattern of Hose Master sprayer with concave spoon when discharged vertically downward at 40 psi (ml per pint jar in 20 seconds).

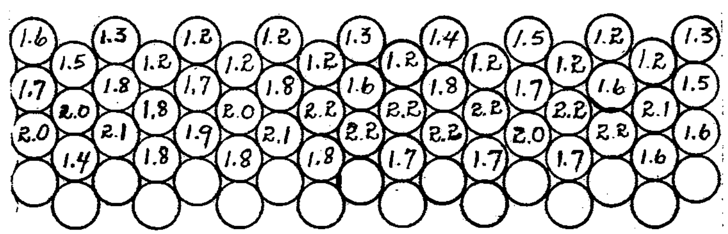


Fig. 11. Distribution of concentrate in spray pattern of Hose Master sprayer, with concave spoon, when discharged vertically downward at 40 psi (per cent concentrate in spray).

ing in rows two and three (from bottom of pattern) where it was 1.8 to 2.2.

The results given in figures 10 and 11 show that variation in volume in this vertical discharge test was considerably less than that for the horizontally discharged test (fig. 7). A portion of the discrepancy between these two tests may be due to the relatively small segments that were sampled in the horizontal test.

The Hose Master sprayer was tested for volume distribution when the flat spoon was used (fig 12). The pattern obtained was much wider than that of the concave spoon (fig 10). Variation was great but was less than that with the concave spoon.

The higher volume readings in this test were obtained in approximately the central one-third segment of the pattern, where the majority ranged from 20 to 30 ml with a maximum of 34 ml. Because of a greater volume concentration and uniformity in the central segment, greater insecticidal effectiveness may be expected from the flat spoon than with the concave type.

Results obtained with the Hayes 6-gallon sprayer in vertical discharge tests are presented in figures 13 and 14. The volume distribution although considerably varied, was the most uniform obtained with hose sprayers. In approximately the central three-fourths segment of the pattern, volume per jar varied from 17 to 33 ml with 64% of the readings with the range of 20-29 ml. The per cent of concentrate within the spray pattern varied from 1.4 to 2.0 with an average of 1.7. General distribution was distorted somewhat with a tendency of higher concentrations to occur near pattern margins.

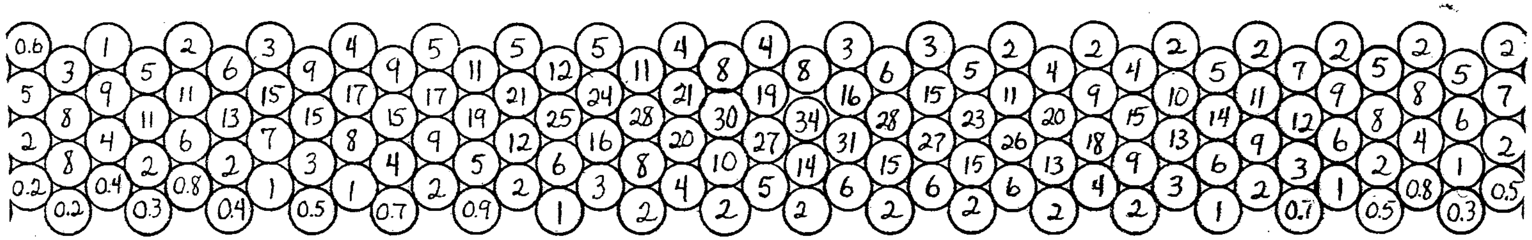


Fig. 12. Distribution of spray volume in spray pattern of Hose Master garden hose sprayer with flat spoon, when discharged vertically downward at 35 psi (ml per pint jar in 24 seconds).

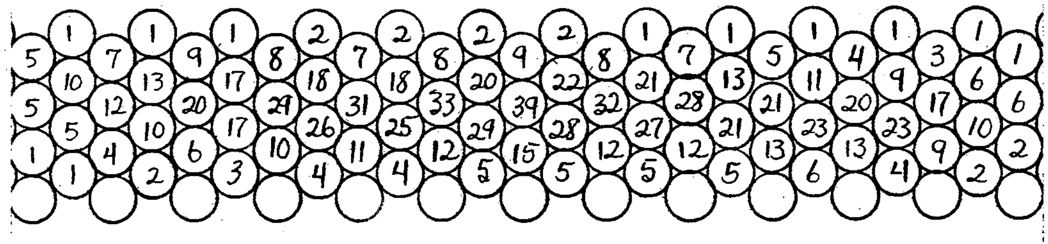


Fig. 13. Distribution of spray volume in spray pattern of Hayes 6-gallon garden hose sprayer when discharged vertically downward at 45 psi (ml volume per pint jar in 36 seconds).

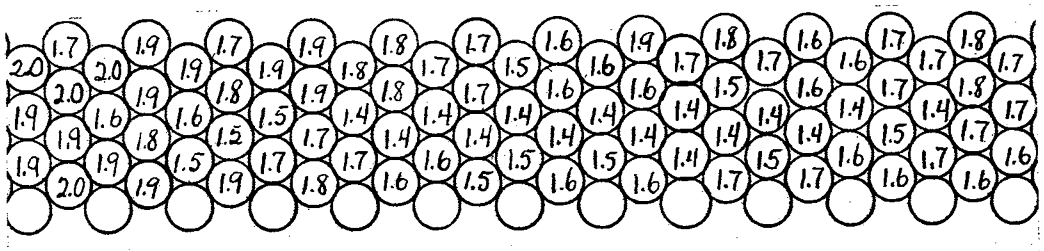


Fig. 14. Distribution of concentrate in spray pattern of Hayes 6-gallon garden hose sprayer when discharged vertically downward at 45 psi (per cent concentrate in spray).

Considering all tests the Hayes 6-gallon sprayer would be expected to give the best performance of the sprayers tested.

IV. FIELD TESTS WITH TOXICANTS AND HOSE SPRAYERS

Review of The Literature

Laboratory tests of toxicants, under controlled conditions, may prove a toxicant worthy of trial in the field and also are a milestone towards the recommended dosage. The adverse conditions in the field and lack of precision instruments for bulk application reduce the optimum effects of toxicants. The study of effects under natural conditions, however, is necessary in any screening test of toxicants.

The garden hose sprayers, although tested mechanically in the laboratory, need to perform in the field from the standpoint of actual effects on pests. The fact that there has been no literature available on testing of garden hose sprayers makes these tests more important and challenging.

Along with the field tests, which have a tendency to show the actual effect of a toxicant, goes biological testing, which in turn, shows the actual kill by a toxicant. This kind of testing is especially useful when adequate methods for chemical analysis are not available, or as a supplementary method of analysis (17). To further prove the validity of bioassay method it is desirable to analyze field treated samples by both bioassay and a standard chemical method (17).

According to most authors biological testing is done in two broad areas; residue on substrata, and the residue in plant and animal material

(17,18). The technique of spraying is not popular due to lack of accurate measuring technique for the amount deposited on the organism or ingested by the organism. The principal of bioassy, however, is applicable if the object is to prove that effectiveness of a sample of known quality and unknown quantity is equal to another sample of the same quality and known quantity (19).

Methods and Materials

The toxicants used in the laboratory, against the spider mites, were later used in the field. These were applied by the Hayes 6-gallon garden hose sprayer against the mite <u>Oligonychus</u> <u>bicolor</u> (Banks) on burr oak trees. The concentrations of the toxicants were adapted and modified from laboratory tests and recommendations from other sources.

Badly infested trees were selected on the Oklahoma State University campus in the month of July. The trees were tagged. Four trees were used for each toxicant and counts were made on eight leaves of each tree. The leaves were picked from different parts of the tree, following a pattern covering the whole tree. The adult mites were concentrated on the midrib region on the upper surface of the leaves. Along this midrib, a spot most covered with mites was focused on under the binocular microscope and the total number of mites of that area was recorded. The number of eggs, larvae, and nymphs was also recorded.

The pressure and the water for Hayes 6-gallon sprayer was supplied by a John Bean 50-gallon sprayer tank set at 50 psi. The toxicants were mixed in the field in the spray jar. The concentrations of toxicants were adapted from the laboratory tests. The height of the trees ranged from 10 to 20 feet with a majority being about 12 feet tall. The trees were sprayed continuously for 45 to 120 seconds depending on the height and width. The top branches of the trees were sprayed with no spoon attached to the nozzle.

The two garden hose sprayers were compared with a high pressure, high volume spray gun against O. bicolor on burr oak trees. All sprayers were supplied with water or spray by a John Bean power sprayer. The high pressure gun, supplied by spray from the tank, was operated at 300 psi with a number 7 nozzle disk; hose sprayers were operated at 50 psi. Approximately equal amounts of toxicant concentrate was applied by each sprayer by regulating the amount of time each sprayer was operated. Kelthane served as the acaricide. The methods of spraying and counting were the same as in the field test of toxicants.

Results and Discussion

The relative effectiveness of eleven toxicants against *O. bicolor*, when applied with the Hayes 6-gallon sprayer on burr oaks, is summarized in table 12. The results are generally similar to those obtained in laboratory tests on *T. telarius*.

All of the toxicants, except Genite, showed promise against *O. bicolor*. Tetradiafon, ethion and Kelthane, the leading toxicants against the two-spotted mite, were highly effective on the oak-infesting species. The performance of demeton was also in this class, with phorate following closely. The contact phosphates (malathion, Bayer 29493, methyl trithion, parathion, and Phostex) produced markedly lower mortalities, as they did in tests against resistant *T. telarius*.

The single application of tetradiafon, ethion, demeton or Kelthane gave excellent control of mites during the 45-day test period. Control from phorate was high at 15 days but was only 45 per cent at the end of the test period.

Table 13 gives results obtained when three sprayers were compared against *O. bicolor* at the time toxicants were screened. The Hayes 6-gallon sprayer gave the best and most consistent effects. The per cent control was 92, 100, and 80 on 4, 15, and 45 days after application. The Hose Master sprayer gave significantly lower control. The high pressure high volume spray gun, operated off of the John Bean sprayer, was inferior to both garden hose sprayers.

Table 12. Effectiveness of toxicants applied with the Hayes 6-gallon sprayer[a] against the mite *Oligonychus bicolor* (Banks) on burr oak trees, July 8, 1961.

			Days After Treatment: 4	15				45			
Toxicant	Pounds Toxicant/ 100-Gallon Spray	Pretreat Population[b]	Per Cent Pretreat Population[c]	Forms Present: Egg	Nymph	Adult	Per Cent Pretreat Population	Forms Present: Egg	Nymph	Adult	treat Popula-tion
Check	--	152	214	Yes	Yes	Yes	178	Yes	Yes	Yes	114
Tedion	0.33	148	9	No	No	No	0	No	No	No	0
Ethion	0.50	156	3	No	No	No	0	No	No	No	1
Demeton	0.33	158	12	No	No	No	0*	No	No	No	1*
Kelthane	0.50	283	8	No	No	No	0	No	Yes	Yes	20
Phorate	0.33	179	2	No	No	Yes	5	Yes	Yes	Yes	152
Malathion	0.67	186	11	Yes	Yes	Yes	23	No	Yes	Yes	45
Bayer 29493	0.50	131	43	No	Yes	Yes	12	Yes	Yes	Yes	47*
Methyl Trithion	0.33	149	30	No	No	No	2*	Yes	Yes	Yes	56*
Parathion	0.50	251	28	Yes	Yes	Yes	34	Yes	Yes	Yes	65
Phostex	0.50	270	51	Yes	Yes	Yes	43	Yes	Yes	Yes	83
Genite	0.50	134	97	Yes	Yes	Yes	58	Yes	Yes	Yes	283

[a] 50 psi.
[b] Total number of mites on certain areas of 8 liaves from each of the 4 trees (total of 32 leaves).
[c] Nymphs and adults, not including eggs.
*Phytotoxicity.

Table 13. Effectiveness of Kelthane[a/], applied by three types of sprayers, against the mite Oligonychus bicolor (Banks) on burr oak trees, July 8, 1961.

Sprayer	psi	Pre-treat Population	Days After Treatment: 4 — Per Cent Pretreat Population	15 — Forms Present: Eggs	15 — Forms Present: Nymph	15 — Forms Present: Adult	15 — Per Cent Pretreat Population	45 — Forms Present: Eggs	45 — Forms Present: Nymph	45 — Forms Present: Adult	45 — Per Cent Pretreat Population
Check	--	152	214	Yes	Yes	Yes	178	Yes	Yes	Yes	114
Hayes	50	283	8	No	No	No	0	No	Yes	Yes	20
Hose Master	50	228	24	No	Yes	Yes	4	Yes	Yes	Yes	66
John Bean	300	259	21	No	No	Yes	10	Yes	Yes	Yes	105

[a/] 0.50 lb. per 100 gallons of water.

The following factors appear to be contributors in the order of ranking of the sprayers in this test. The quantity of spray applied per tree was measured by the periods of spray application in seconds. Previous tests with the Hose Master sprayer have shown that majorities of toxicants and water volume were concentrated in the outer portions of the patterns. At times it was feasible to apply only the central portion of the pattern to the trees; under these conditions the majority of the toxicant was wasted. Since less of the toxicant in the Hayes sprayer was located in the pattern extremities, a greater proportion and amount of toxicant were applied to the tree.

In the case of the high pressure gun, the greatest losses in effectiveness were probably related to particle size and failure to obtain complete coverage of all foliar portions of the tree. The small particles in the mist-like spray pattern did not appear to deposit on and wet foliage to the extents obtained with the larger particles of the hose sprayers. High temperatures (95-98^{o}F.) and low relative humidities (20-25%) probably reduced the deposition rate for the mist pattern.

This test shows that small trees can be effectively treated with garden hose sprayers. The danger to the operator, however, may be considerably greater than from the use of conventional high-pressure guns. In the above test the operator was clothed in raincoat, rainhat, rubber goloshes, and rubber gloves. The operator, when on the ground, was forced to stand under the tree in order for the spray to reach the upper half of the tree. In this position he was struck by considerable amounts of spray drift and fall. It was conservatively estimated, that, in the absence of protective clothing, the operator would have become drenched with spray in an hour of continuous spraying.

Much of this exposure to spray wetting could be avoided if devices such as spray decks, ladders, or extension sprayer handles could be used to eliminate or reduce the necessity for the operator to stand under the tree. The use of a toxicant of low mammalian toxicity or limiting spray treatment to only a few trees would, also, make garden hose sprayers practicable and safe tools for tree spraying.

V. SUMMARY AND CONCLUSIONS

Sixteen toxicants were compared on a "resistant" and a "susceptible" strain of *Tetranychus telarius* (Linn.), in 12 greenhouse tests, including 408 potted plants and 63,893 mites, during March to October, 1961.

Two garden hose sprayers were studied in 12 laboratory and field tests in relation to spray patterns and to effectiveness, practicability, and safety in applying acaricides to trees infested with a mite, *Oligonychus bicolor* (Banks).

Nearly all toxicants, including contact organophosphorous compounds gave fair to excellent control of a susceptible strain of *T. telarius*. Against resistant strains of this species, tetradiafon, Kelthane and ethion were highly effective and much superior to other toxicants.

The spray patterns of garden hose sprayers were studied primarily to determine distribution of spray volume and of the toxicant; spray samples from 3-inch intervals over the cross-section of the pattern were analyzed. The concentration of toxicants in samples was measured by breaking emulsion by addition of sodium chloride and centrifuging. The supernatant liquid in each sample was measured and compared with supernatant volumes obtained when samples of known concentrations were prepared in the laboratory and processed by the sodium chloride-centrifuge method.

The amounts of spray concentrate recovered from both sprayers markedly exceeded the amounts expected on the basis of manufacturers' predictions. The curvature of the antomizing and spreading spoon attached to the sprayer outlet had a pronounced effect on the distribution of spray volume and toxicant in the spray pattern. A concave spoon supplied with the sprayer by the manufacturer produced a pattern which contained very disproportional amounts of spray and toxicant in two relatively small areas near the sides of the pattern. The pattern from a flat spoon had much better distribution of toxicant and spray.

Ten of eleven toxicants tested against *O. bicolor* produced a reduction in population. Tetradifafon, ethion, demeton, Kelthane and phorate were highly effective.

Hose sprayers were more effective in applying an acaricide for control of mites on small trees than a high pressure, high volume spray gun.

Spraying trees by hose sprayers with highly toxic chemicals pose serious poison hazards to the operator, resulting from spray drip and drift.

LITERATURE CITED

1. Boudreaux, H. B. 1956. Revision of the two-spotted spider mite (Acarina Tetranychidae) complex, Tetranychus telarius (Linn.) Ann. Ent. Soc. Am. 49(1): 43-48.

2. Boyle, W. Wayne. 1956. On the mode of dissemination of the two-spotted spider mite, Tetranychus telarisu (Linn.) (Acarina: Tetranychidae). Proc. Hawaiian Ent. Soc. 16(2): 261-268.

3. Dillion, L. S. 1958. Reproductive isolation among certain spider mites of Tetranychus telarius complex, with preliminary systematic notes. Ann. Ent. Soc. Am. 51(5): 441-448.

4. Ebeling, W. and R. J. Pence. Pesticide formulation: influence of formulation on effectiveness. Jour. Agri. Food Chem. 1(15): 386-397.

5. Helle, W. 1960. The occurance of resistance to organic phosphate compounds in the spotted spider mite at Aalsmeer. Planteziekten 65(3): 107-115.

6. Helle, W. and W. Oudshoorn. 1961. Multiresistance in the two-spotted spider mite at Aalsmeer. Plantezikten 67(1): 28-31. Illus.

7. Henneberry, T. J., E. A. Taylor and A. L. Boswell. 1961. The effect of Tedion on eggs and larvae of the three strains of the two-spotted spider mite, Tetranychus telarius. Jour. Econ. Ent. 54(1): 168-169.

8. Hoyt, S. C. and F. H. Harries. 1961. Laboratory and field studies on orchard mite resistant to Kelthane. Jour. Econ. Ent. 54(1): 12-16.

9. Lehr, R. and F. Smith. 1957. Reproductive capacity of three strains of the two-spotted spider mite complex. Jour. Econ. Ent. 50(5): 634-636.

10. Metcalf, C. A. W. D. Flint and R. L. Metcalf. 1951. Destructive and useful insects, their habits and control. 4th Ed. McGraw-Hill. New York.

11. Nagasawa, S. 1959. Biological assay of insecticide residue. Ann. Rev. Ent. 4: 319-392.

12. Pfadt, R. E. 1961. Fundamentals of applied entomology. McMillan Company. New York. p. 192.

13. Potts, S. F. 1958. Application of concentrated spray with hand equipment. E-824. USDA, Bur. Ent. and Pl. Quaran.

14. Price, R. G. 1959. A survey of arthropod pests in Oklahoma greenhouses in fall, winter, and spring. Thesis. Okla. State Univ. Stillwater, Oklahoma.

15. Shepard, H. H. 1960. Methods of testing chemicals against insects. Burgess Pub. Co. Minneapolis. Vol. II: 319-338.

16. Smith, F. E. 1957. A resume of spider mite control in greenhouses. Florists Exchange. 128(18): 10, 36-40.

17. Sun, Y. P. and J. Y. T. Sun. 1952. Microbioassay of insecticides with special reference to aldrin and dieldrin. Jour. Econ. Ent. 45(1): 26-37.

18. Sun, J. Y. T. and Y. P. Sun. 1953. Microbioassay of insecticides in milk by a feeding method. Jour. Econ. Ent. 46(6): 927-930.

19. Sun, Y. P. 1957. Bioassay of pesticide residues. Adv. Pest Cont. Res. Vol. I: 449-496.

20. Thompson, H. E. 1961. Controlling two-spotted mites in greenhouse. Report. Dept. Ent. Kan. State Univ., Manhattan, Kansas.

21. Wilcox, J. and A. F. Hawland. 1957. Systemic insecticides applied in high and low gallonage sprays on strawberry, lima beans, and Swiss chard. Jour. Econ. Ent. 50(6): 800-801.

VITA

MAHMOOD ESKAFI

Candidate for the Degree of

Master of Science

Thesis: EFFECTIVENESS OF ACARICIDES ON THE MITES TETRANYCHUS TELARIUS (LINN.) AND OLIGONYCHUS BICOLOR (BANKS); GARDEN HOSE SPRAYERS' SPRAY PATTERNS AND FIELD PERFORMANCE ON MITES

Major Field: Entomology

Biographical:

Personal Data: Born at Tehran, Iran May 13, 1934

Education: Did undergraduate study at Oklahoma State University beginning in 1955 and received B. S. degree in entomology summer of 1962.

Experiences: Finished high school in Tehran, Iran and entered the United States as a student in 1955. Held part-time jobs and summer jobs while at school; U. S. Forest Service 1956 as field man, Clearwater Ranger Station, Idaho. Pest Control Operator, Dead Shot Chemical Company, Oklahoma City Oklahoma 1958. Oklahoma Foundation Seed Stocks 1960, 1961, 1962, Stillwater, Oklahoma. Part-time Research Assistant, Department of Entomology, Oklahoma State University, 1961. Farm Advisor, Agricultural Extension Service, University of California, Riverside, California, 1963.

Typist: Mrs. Glenn Duckwall