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FURTHER STUDIES ON THE TOXICITY OF INSECTICIDES AND ACARICIDES TO THE PAPAYA

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FURTHER STUDIES ON THE TOXICITY OF INSECTICIDES AND ACARICIDES TO THE PAPAYA*

Martin Sherman and Fernando F. Sanchez

INTRODUCTION

With the discovery of DDT and the subsequent development of synthetic organic insecticides, there has developed, concurrently, interest in the toxic effects to plants of these materials. Phytotoxicity of insecticidally active chemicals precludes their use on agricultural crops and thus reduces the usefulness of the insecticides.

The great majority of pesticides used in Hawaii are formulated in the continental United States and tested for phytotoxicity on the crops that are grown there. Most of the information obtained, therefore, is not directly applicable to Hawaii, which has plants characteristic of tropical or subtropical areas. Shortly after World War II, the Department of Entomology of the University of Hawaii established a number of projects to study the phytotoxicity of insecticides (Tanada, *et al.*, 1947, 1951; Holdaway, *et al.*, 1948; Sherman and Mitchell, 1953; Sherman and Tamashiro, 1959; Nakata and Tanada, 1961).

Because of the increasing importance of the papaya (*Carica papaya* L.), its widespread distribution throughout the tropical and subtropical world, its availability, and its sensitivity to some widely used insecticides and acaricides, this plant was selected as one of the test organisms to determine whether commercial pesticides formulated in the continental United States have detrimental effects when applied under the more tropical conditions existing in Hawaii.

Sherman and Tamashiro (1959) published an intensive study on the toxicity to the Solo papaya of 22 formulations of 14 insecticidal and acaricidal materials. In their study, they reported the history of the papaya, its importance, and a detailed discussion of its pests. For purposes of clarity and continuity, a brief discussion of these aspects of study follows.

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*This material was presented in part by the senior author at the 18th International Symposium on Crop Protection held at the Rijksfaculteit der Landbouwwetenschappen in Ghent, Belgium, on May 3, 1966.

The papaya apparently is a plant of West Indian or Central American origin (de Candolle, 1864) that is now grown throughout most of the tropical and subtropical countries of the world. It was introduced to Hawaii from the Marquesas Islands between 1800 and 1823 (Storey, 1941) and has since become the most popular breakfast fruit in Hawaii.

Although the papaya is relatively free of pests, a few species of mites and insects can become very destructive to it if control measures are not instituted promptly. Among the mites are the broad mite, *Polyphagotarsonemus latus* (Banks), which is found primarily on the lower surface of the younger leaves and in extremely heavy infestations has been known to kill plants; the carmine spider mite, *Tetranychus telarius* (L.), found on the lower surface of the older leaves; the Texas citrus mite, *Eutetranychus banksi* (McGregor), found on the upper surface of the older leaves; and the red and black flat mite, *Brevipalpus phoenicis* (Geijskes), found not on the leaves but on the upper trunk, petioles, and, more importantly, on the fruit, where it causes a scarification appearing as brown, scaly, sunken areas.

Insects are of relatively minor importance as pests of papaya. The three important species of fruit flies in Hawaii, the oriental fruit fly, *Dacus dorsalis* Hendel; the melon fly, *Dacus cucurbitae* Coquillett; and the Mediterranean fruit fly, *Ceratitis capitata* Wiedemann; can become injurious when the fruit are allowed to ripen on the tree, but since fruits are usually removed mature-green, they are not attractive to the ovipositing female flies. The aphids, *Myzus persicae* Sulzer, *Macrosiphum euphorbiae* (Thomas), *Aphis gossypii* Glover, *A. craccivora* Koch, and *A. fabae* Scopoli, can become damaging and several have been implicated in the transmission of a formerly serious virus disease, papaya ringspot. The onion thrips, *Thrips tabaci* Lind, may also cause injury.

EXPERIMENTAL METHODS

In general, the procedures used in this study were similar to those described by Sherman and Tamashiro (1959).

Seedlings used throughout the experimental work were of the Solo variety of papaya grown in No. 2½ cans. Treatments were initiated when the plants were between 6 and 13 cm. tall. Prior to the initial spray treatment the potted plants were assigned random treatment and replication numbers and the heights of the seedlings were measured. The height taken was the distance from a point on the trunk at the same level as the top of the container to the base of the terminal growing point of the plant.

The plants were treated four at a time on a turntable in a specially designed spray chamber. Two adjustable spray booms, each fitted with one spray nozzle, were arrayed to direct the spray from below and above the passing plant. A Teejet spray nozzle ¼ T3 (Spraying Systems Co., Bellwood, Ill.) which delivered a hollow cone spray was used. At 60 p.s.i.

pressure, this nozzle delivered 488 ml. per minute. A volume of 800 ml. of each emulsion or suspension concentration to be tested was prepared and used since this volume insured sufficient material to give thorough coverage of the plants.

Materials Tested and Procedures

Each of the formulations was diluted to four concentrations equivalent to 2 pounds, 1 pound, ½ pound, and ¼ pound of actual material per 100 gallons of spray. These concentrations were equivalent to 0.25, 0.125, 0.062, and 0.031 percent active ingredients and encompassed the usual field recommendations for insect and mite control. Each concentration was applied to four plants at weekly intervals for three weeks. A commercial sticker (Triton B-1956) composed of modified phthalic glycerol alkyd resins was added at the rate of 1:2,000 to all treatments including controls. After treatment, the plants were allowed to dry before they were placed outdoors on tables in a randomized block arrangement.

Phytotoxicity was determined in two ways: (1) measurements indicating effect on growth and (2) gross leaf pathology, which included observations on defoliation, chlorosis, necrosis, curling, and other apparent abnormalities.

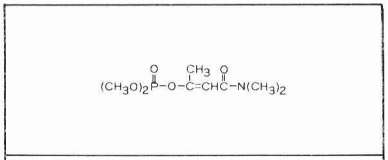
Final measurements of the height of the seedlings were ordinarily taken five weeks after the initial treatment, although in some instances additional observations were made six weeks after the third treatment. The growth of the treated plants were compared with that of the control plants using analysis of covariance (Snedecor, 1946).

Using these testing procedures, the phytotoxicity to seedling papayas of 72 formulations of 50 insecticidal and acaricidal compounds was determined. The majority of the compounds used are classified as organophosphates. These as well as the carbamates, carbonates, chlorinated aryl hydrocarbons, acaricides, and an insect repellant are discussed in separate classes in the appropriate section of Experimental Results.

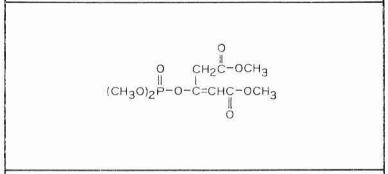
EXPERIMENTAL RESULTS

THE PHOSPHATES

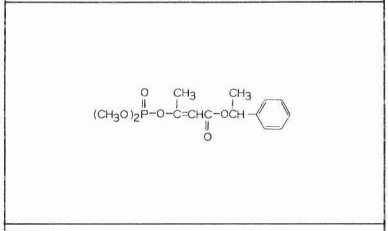
The effects of the following phosphate formulations were studied:



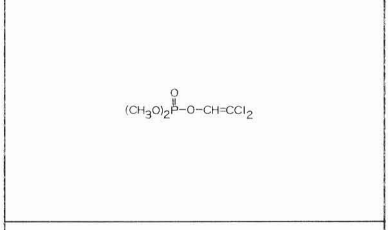
(1) Bidrin®, 3-hydroxy-N,N-dimethyl-*cis*-crotonamide dimethyl phosphate, a technical grade formulation containing 7.9 pounds of technical Bidrin per gallon;



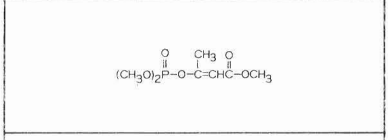
(2) Bomyl®, dimethyl 3-hydroxyglutaconate dimethyl phosphate, a 25 percent wettable powder and an emulsifiable concentrate containing 4 pounds of technical Bomyl per gallon;



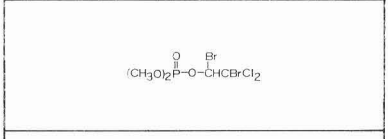
(3) Ciodrin®, *alpha*-methylbenzyl 3-hydroxycrotonate dimethyl phosphate, a technical grade formulation containing 8.6 pounds of technical Ciodrin per gallon and an emulsifiable concentrate containing 4 pounds of technical Ciodrin per gallon;



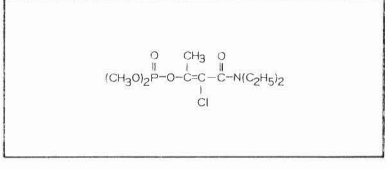
(4) dichlorvos, 2,2-dichlorovinyl dimethyl phosphate, a technical grade formulation containing 11.6 pounds of technical dichlorvos per gallon and an emulsifiable concentrate containing 4 pounds of technical dichlorvos per gallon;



(5) mevinphos, methyl 3-hydroxy-*alpha* crotonate dimethyl phosphate, an emulsifiable concentrate containing 2 pounds of technical mevinphos per gallon;



(6) naled, 1,2-dibromo-2,2-dichloroethyl dimethyl phosphate, an emulsifiable concentrate containing 8 pounds of technical naled per gallon;



(7) phosphamidon, 2-chloro-2-diethylcarbamoyl-1-methylvinyl dimethyl phosphate, a liquid formulation containing 4 pounds of technical phosphamidon per gallon.

Table 1 summarizes the effect of treatment with various formulations of the phosphates on the growth of the papaya.

Bidrin. Concentrations as low as 0.062 percent technical grade Bidrin caused significant retardation of growth (Fig. 1). Serious foliar damage was evident after the first spray application. The edges of the leaves were burned. The young leaves and growing tips were particularly susceptible to damage. There was also a development of very small leaves. Beginning just prior to the third spray and continuing through the final observation period two weeks after treatment, the same symptons were evident. The older leaves were less affected than the younger. The leaves were not only burnt but fern-like in shape, narrowed, and thickened, and had conspicuous veins (Fig. 2) resembling typical broad mite damage. The terminal tips were killed by the 0.25 percent concentration.

Bomyl. All treatments with emulsifiable concentrates and wettable powders caused significant retardation of growth (Fig. 3). Serious foliar damage was evident after the first spray application, particularly at the 0.25 and 0.125 percent concentrations of both the emulsifiable concentrates and wettable powders. There was tip burning and moderate reduction of terminal growth. Two weeks after the third spray, it was evident that treatment with the wettable powder formulation resulted in more serious damage than equivalent concentrations of the emulsifiable formulation. The leaves of all plants were small with rounded edges and tips (Fig. 4) except those treated with 0.031 percent emulsifiable concentrate, the leaves of which were normal except for being chlorotic. The plants were observed for an additional four weeks (Fig. 5). At this time, six weeks after the final treatment, all of the plants treated with emulsions had recovered but were stunted when compared with the untreated plants. Of the wettable powder-treated plants, three of the four treated with the 0.25 percent concentration had died, leaving but one small survivor, while all of the plants treated with the lower concentrations had recovered but were still stunted.

Ciodrin. All treatments except 0.062 percent of the technical grade material caused significant reduction in growth (Fig. 6). One week after the first spray application, plants treated with 0.25 and 0.125 percent of the technical grade material showed severe tip burn, necrosis, and a mosaic-chlorosis. The older leaves had a blunted or rounded appearance. The plants treated with the emulsifiable concentrate exhibited more severe injury than plants treated with equivalent concentrations of the technical material. Even 0.031 percent of the emulsifiable material caused tip burn.

A week after the second spray, plants treated with 0.25 percent of the emulsifiable concentrate were completely defoliated and their terminals were dead. The plants treated with 0.25 percent of the technical material

Table 1. Effect of phosphates on the growth of the Solo papaya

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Bidrin®		
Technical grade (7.9 lb. act./gal.)	2	0.25	10.1	5.2**
	1	0.125	10.0	9.1**
	0.5	0.062	12.1	12.3**
	0.25	0.031	12.3	16.0
Control	—	—	10.2	22.7
			L.S.D. (1%): 6.1	
		Bomyl®		
E.C. (4 lb. act./gal.)	2	0.25	6.0	2.9**
	1	0.125	6.3	5.7**
	0.5	0.062	5.9	7.8**
	0.25	0.031	5.6	9.7**
25% W.P.	2	0.25	6.4	2.2**d
	1	0.125	5.9	6.0**
	0.5	0.062	6.1	6.3**
	0.25	0.031	6.2	8.7**
Control	—	—	6.4	12.7
			L.S.D. (1%): 2.0	
		Ciodrin®		
Technical grade (8.6 lb. act./gal.)	2	0.25	10.3	1.3**
	1	0.125	10.9	6.1**
	0.5	0.062	9.6	9.0
	0.25	0.031	8.9	8.5**
E.C. (4 lb. act./gal.)	2	0.25	9.5	d
	1	0.125	9.5	2.6**
	0.5	0.062	9.4	6.6**
	0.25	0.031	9.7	5.5**
		Dichlorvos		
Technical grade (11.6 lb. act./gal.)	2	0.25	9.4	9.8
	1	0.125	8.5	10.0
	0.5	0.062	10.0	9.5
	0.25	0.031	9.7	9.8
E.C. (4 lb. act./gal.)	2	0.25	9.3	9.7
	1	0.125	9.4	9.1
	0.5	0.062	9.5	10.8
	0.25	0.031	8.4	9.5
Control	—	—	8.8	10.6
			L.S.D. (1%): 1.8	

Table 1 (continued)

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Mevinphos		
E.C.	2	0.25	11.1	10.2
(2 lb. act./gal.)	1	0.125	11.9	12.1
	0.5	0.062	11.0	12.8
	0.25	0.031	12.2	15.7
		Naled		
8 E.C.	2	0.25	12.6	16.0
(8 lb. act./gal.)	1	0.125	12.5	16.7
	0.5	0.062	12.1	13.8
	0.25	0.031	14.5	16.0
Control	—	—	12.0	13.5
				L.S.D. (1%): 4.5
		Phosphamidon		
4 Spray	2	0.25	10.6	8.0**
(4 lb. act./gal.)	1	0.125	11.0	11.4
	0.5	0.062	10.5	12.3
	0.25	0.031	10.1	14.9
Control	—	—	11.4	12.8
				L.S.D. (1%): 3.4

[a] W.P. = wettable powder; E.C. = emulsifiable concentrate. Sprays were applied as follows: mevinphos and naled, July 12, 19, and 26, 1962; Bomyl, August 10, 17, and 24, 1962; Bidrin, May 27, June 3, and June 10, 1963; Ciodrin and dichlorvos, January 16, 23, and 30, 1964; and phosphamidon, March 12, 19, and 26, 1964. Triton B-1956 was added to all sprays at 1:2,000.

[b] Measurements were taken one day before 1st spray application except for Bidrin-treated plants which were measured five days before treatment.

[c] Final measurements were taken on August 3, 1962, for mevinphos and naled; August 31, 1962, for Bomyl; June 24, 1963, for Bidrin; February 13, 1964, for Ciodrin and dichlorvos; and April 9, 1964, for phosphamidon.

[d] Terminal tips killed after some growth or little or no growth.

** Growth significantly inferior to that of control plants.

showed severe foliar damage; all of the younger leaves and all but two or three of the older leaves had dropped but the terminals were still alive. Lower concentrations of both formulations were also destructive; the 0.031 percent concentrations caused severe burning on the older leaves while the younger leaves were fern-like, thickened, had conspicuous veins (similar to broad mite damage), and were very chlorotic.

Two weeks after the third spray (Fig. 6), plants treated with 0.25 percent of the emulsifiable formulation were dead. Those treated with 0.25 percent of the technical material were almost completely defoliated with dead terminal growing tips, but their stems were still green and had

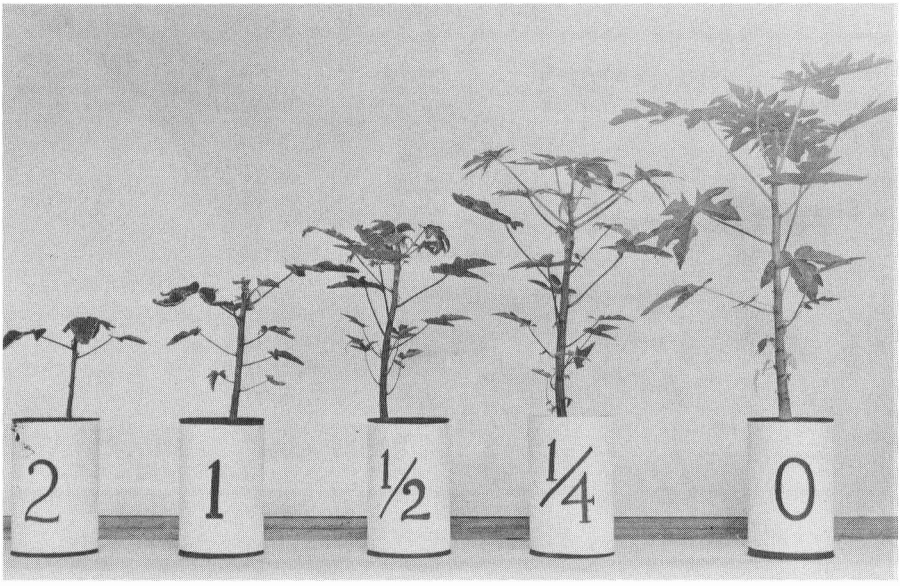


Fig. 1. Effect of three weekly applications of Bidrin on the growth and foliage of papaya. Numbers are equivalent to pounds of technical material per 100 gallons of spray.

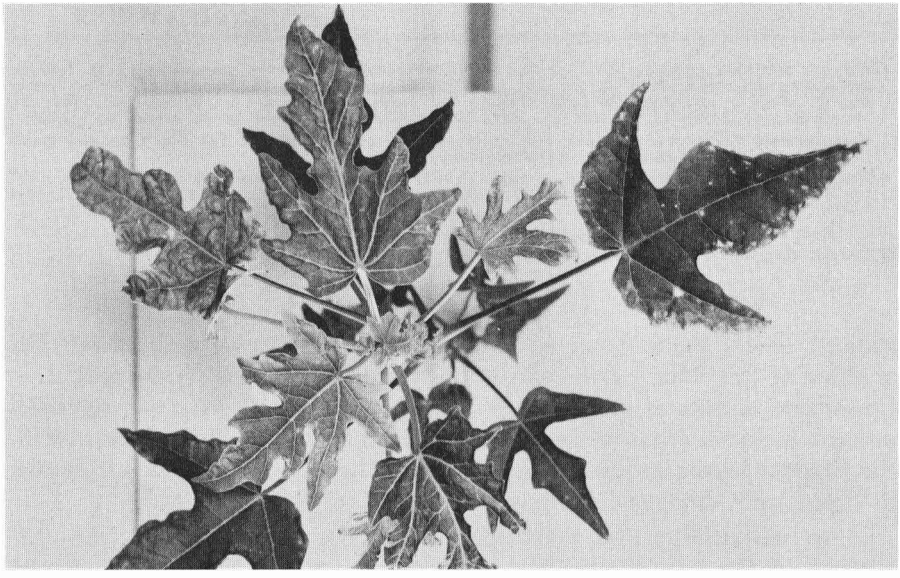


Fig. 2. Treatment with equivalent of ½ pound actual Bidrin per 100 gallons of spray. Note thickened veins on younger papaya leaves resembling broad mite damage.

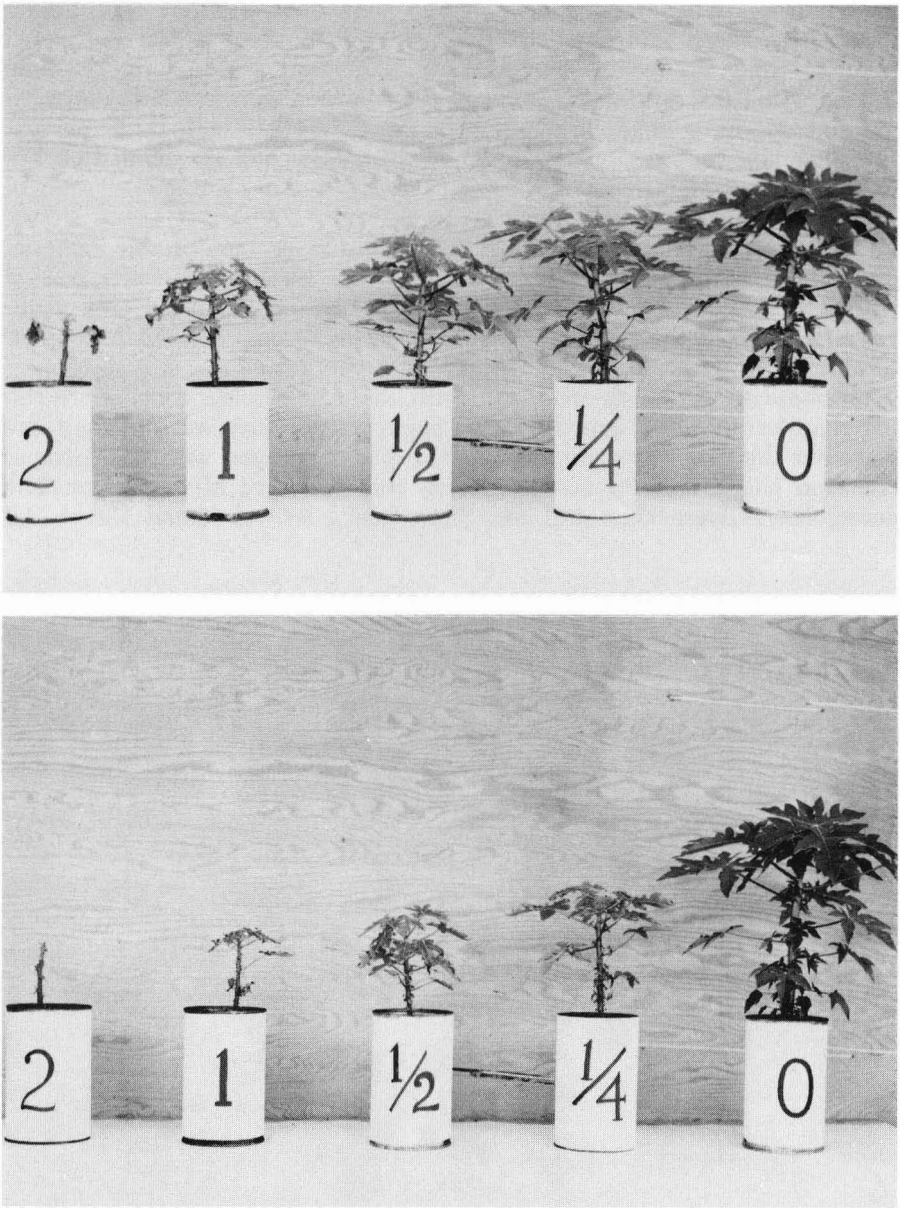


Fig. 3. Comparison of effects of three weekly applications of Bomyl emulsifiable concentrate (top) and wettable powder (bottom) on growth and foliage of papaya two weeks after third application. Note relatively greater effect of wettable powder than emulsion at equivalent concentrations.

some active lateral buds. Plants treated with 0.125 percent emulsifiable formulation were severely defoliated; two of the four plants had dead terminals and the young leaves were malformed and chlorotic. Those treated with 0.062 and 0.031 percent of the emulsion were similarly damaged but did not have dead terminals. The plants treated with 0.125 percent and lower concentrations of the technical material had no defoliation but the young leaves resembled those treated with the emulsion.

Dichlorvos. Treatments with technical grade or emulsifiable material did not affect growth. No foliar damage was evident in plants treated with the technical grade formulation and the emulsion caused only negligible tip burn at the two higher concentrations of 0.25 and 0.125 percent.

Mevinphos. Although treatment with the emulsifiable concentrate did not significantly affect growth of the plant, foliar injury was apparent one day after the first spray application. The plants sprayed with 0.25 percent emulsion had severe tip burn, necrosis, and distortion of the leaves. The young leaves were chlorotic, and there was a loss of lateral leaves. All

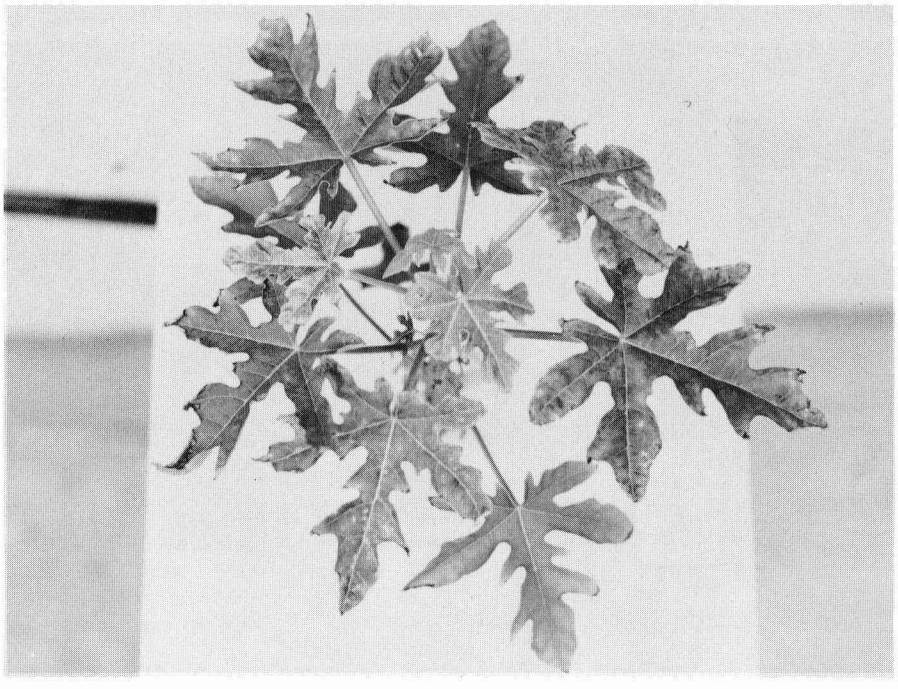


Fig. 4. Foliar injury caused by treating papaya with ¼ pound Bomyl wettable powder per 100 gallons of spray.

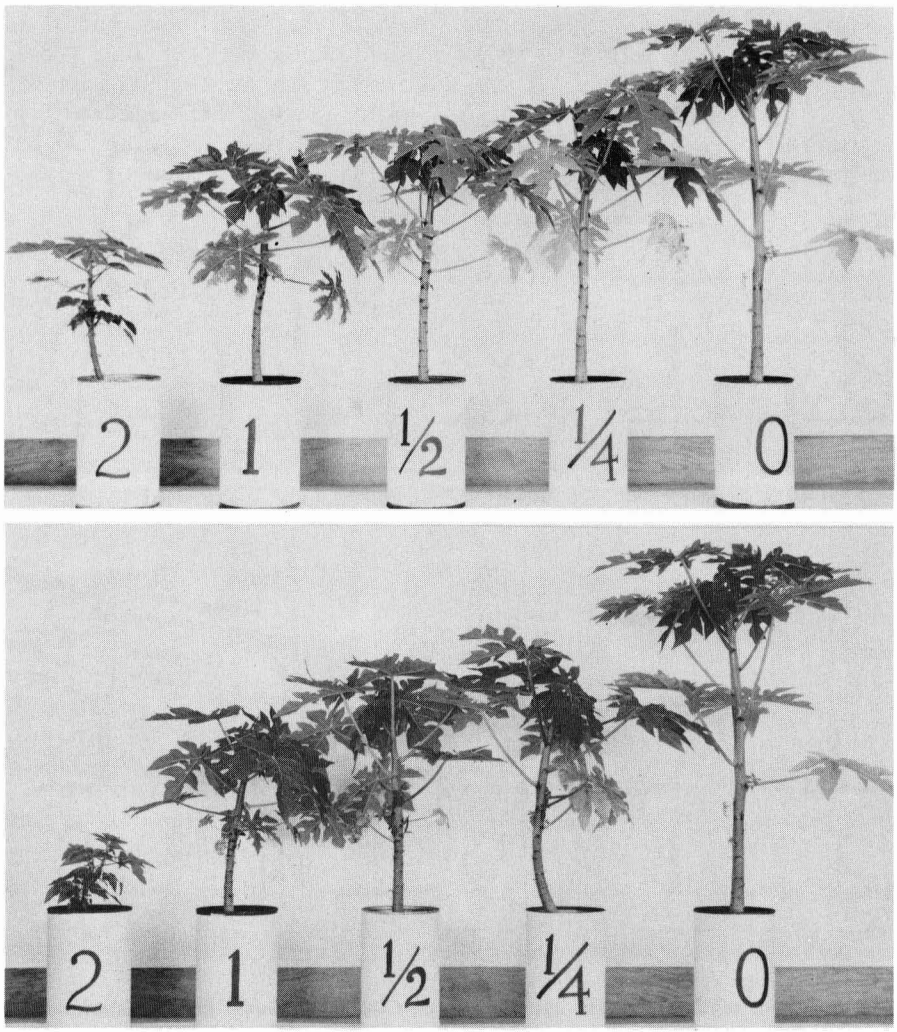


Fig. 5. Recovery in papaya seedlings, six weeks after three weekly treatments with Bomyl emulsion (top) and wettable powder (bottom).

other concentrations caused slight chlorosis. Two weeks after the third spray, the leaves were chlorotic and necrotic; the edges were dead and blunted; the younger leaves were more susceptible than the older (Fig. 7).

Naled. Treatment with the emulsifiable concentrate had no effect on growth nor caused foliar damage.

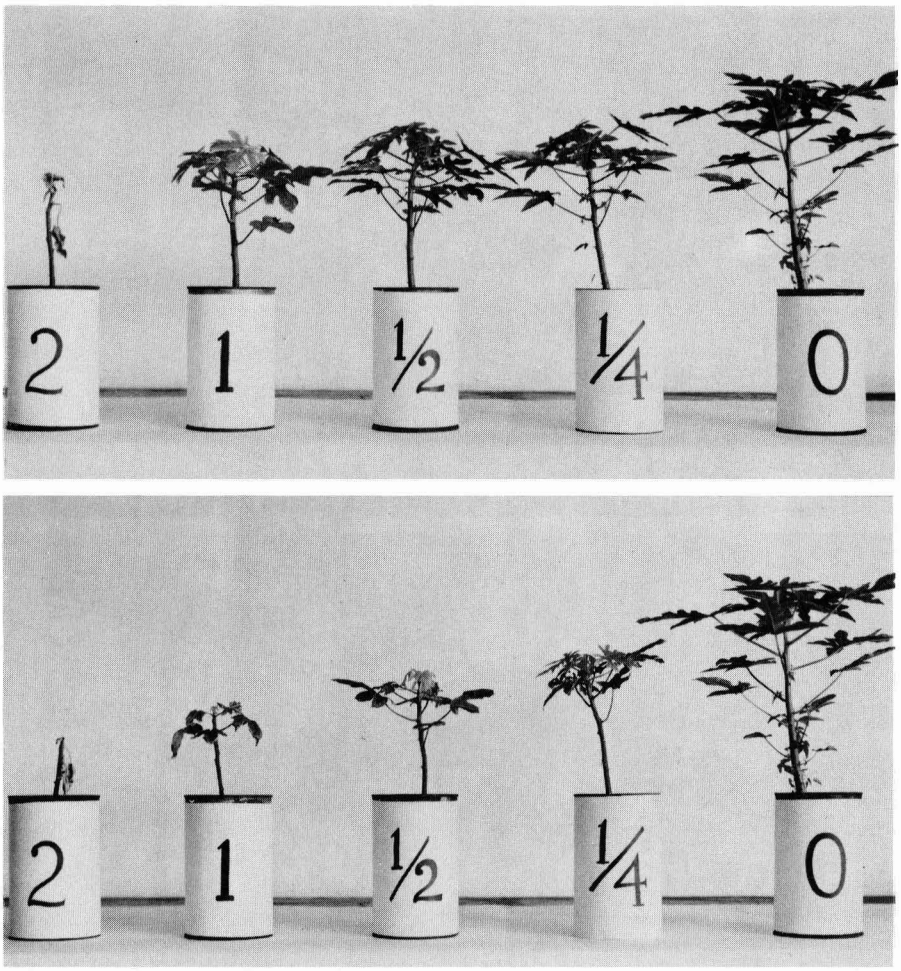


Fig. 6. Effect of three weekly applications of Ciodrin technical grade material (top) and emulsifiable concentrate (bottom) on growth and foliage of papaya.

Phosphamidon. Treatment of the plants with 0.25 percent of the liquid formulation retarded growth. Injury consisted of a rounding, wrinkling, and chlorosis of the leaves; older leaves showed a browning on the upper surface. Two weeks after the third spray application, the plants treated with the 0.25 percent concentration had leaves that were stubby, chlorotic with vein clearing, and formed a bunchy top (Fig. 8). Lower concentrations caused less injury but all treatments caused the leaves to be narrower than normal.

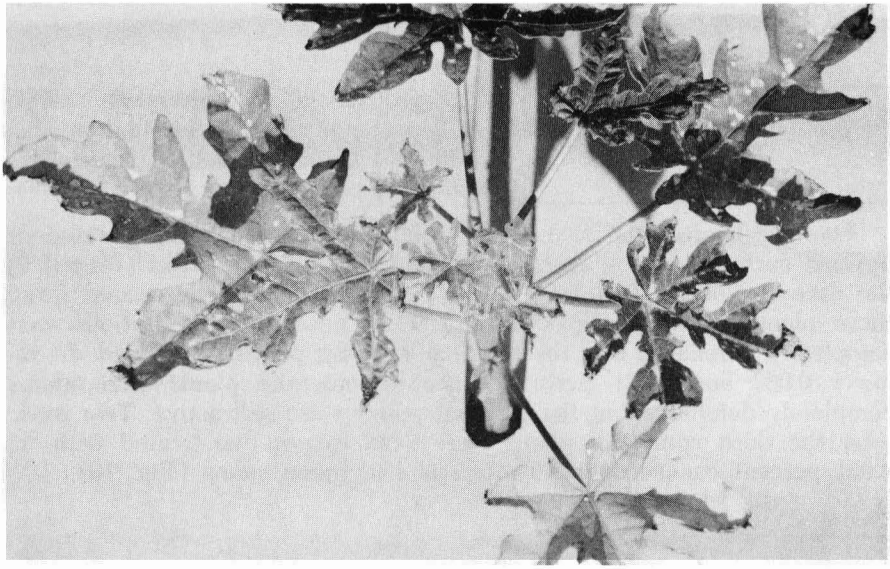


Fig. 7. Foliar damage to papaya caused by 0.25 percent spray of mevinphos emulsion.

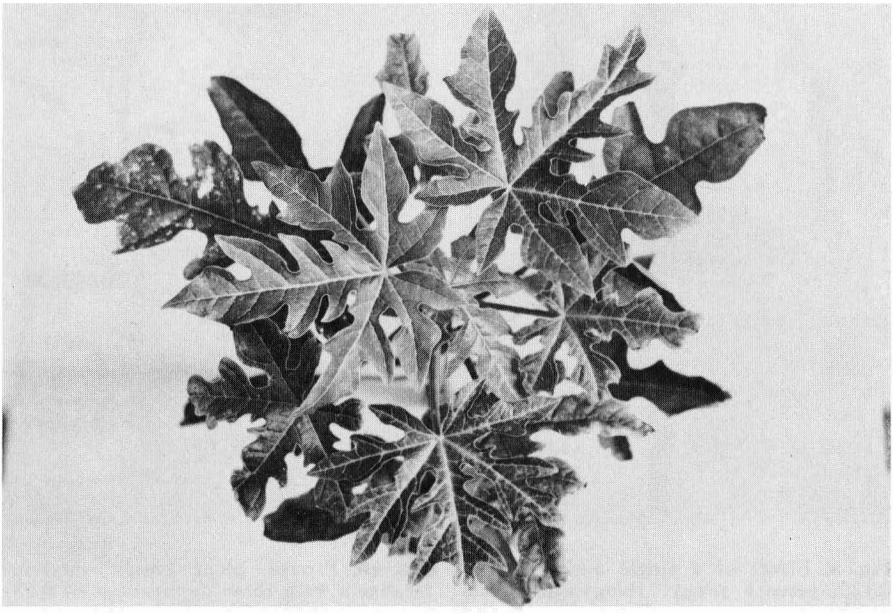
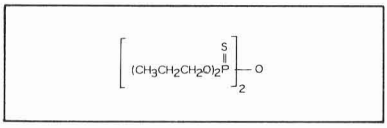


Fig. 8. Typical papaya foliar damage caused by 0.25 percent phosphamidon liquid formulation.

PYROPHOSPHATE

The effects of one pyrophosphate were studied:



(1) propyl thiophyrophosphate (ASP-51), an emulsifiable formulation containing 4 pounds of actual material per gallon of concentrate.

One week after the first spray application all treatments caused an upward curling and rolling of leaves and an "umbrella-effect" caused by the drooping of the petioles (Fig. 9). One week after the second spray, those plants sprayed with 0.25 and 0.125 percent concentrations were completely defoliated and the terminal growing points were dead. At the lower 0.062 and 0.031 percent concentrations, the plants were almost completely defoliated but the growing points were still active. Two weeks after the third spray, all plants were dead except two treated with the 0.031 percent concentration. These still had green stems (Fig. 10).

Fig. 9. Effect of a single application of 0.125 percent propyl thiopyrophosphate emulsion on papaya. Note the upward curling and rolling of the leaves and the "umbrella-effect" caused by the drooping of the petioles.

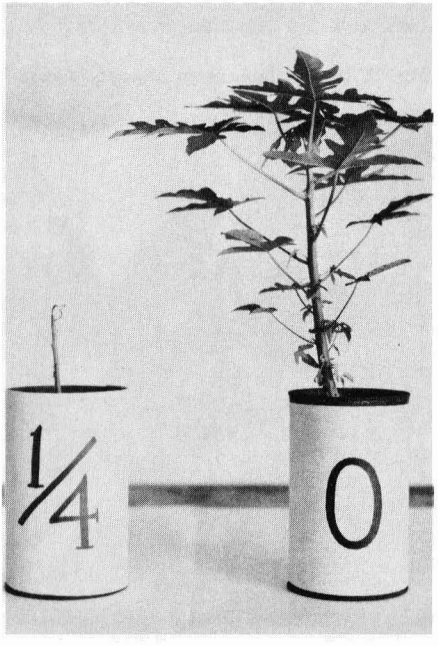
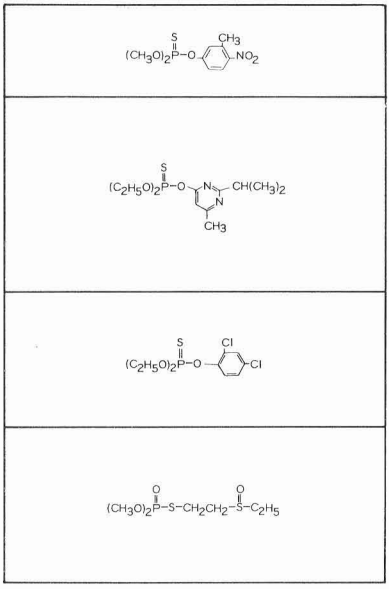


Fig. 10. Papaya plant barely surviving treatment with three applications of 0.031 percent propyl thiopyrophosphate emulsion (left). All leaves have dropped but meristematic tissue still living. Plant on right is a control plant.

PHOSPHOROTHIOATES

The effects of the following phosphorothioate formulations were studied:



(1) Bay 41831, *O, O*-dimethyl *O*-4-nitro-*m*-tolyl phosphorothioate, a 75 percent emulsifiable concentrate;

(2) diazinon, *O, O*-diethyl *O*-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate, a 25 percent wettable powder and two emulsifiable concentrates containing 2 pounds and 4 pounds of technical diazinon per gallon;

(3) Nemacide®, *O*-(2,4-dichlorophenyl) *O, O*-diethyl phosphorothioate, an emulsifiable concentrate containing 7.9 pounds of technical Nemacide per gallon;

(4) oxydemetonmethyl, *O,O*-dimethyl S-[2-(ethylsulfinyl)ethyl] phosphorothioate, an emulsifiable concentrate containing 2 pounds of technical oxydemeton-methyl per gallon.

Table 2 summarizes the effect of treatment with various formulations of the phosphorothioates on the growth of the papaya.

Bay 41831. Only 0.25 percent of the solubilized formulation had a detrimental effect on growth. The emulsifiable concentrate caused only minor foliar damage at 0.25 percent as evidenced by slight tip burn and minor chlorosis. The wettable powder at 0.25 percent caused necrosis, particularly along the edge and at the tips of the leaves. The solubilized formulation was much more destructive to the leaves than the others; at concentrations of 0.25 and 0.125 percent, the leaves were necrotic and had blunted edges, particularly the older leaves, on which burning had occurred.

Diazinon. All concentrations of the 50 percent emulsifiable concentrate and 0.25 and 0.125 percent of both the 25 percent emulsifiable concentrate and the wettable powder formulations caused a retardation in growth (Fig. 11).

One day after the first spray application, plants treated with 0.25 percent of the emulsifiable concentrates showed severe burning along the edges of the leaves. One week after the first spray, the leaves were chlorotic and narrow with the edges of the leaves rolled upward. Just prior to the third spray, the plants treated with the 0.25 percent emulsion had

Table 2. Effect of phosphorothioates on the growth of the Solo papaya

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Bay 41831		
75 E.C. (0.94 gm. act./ml.)	2	0.25	10.2	16.7
	1	0.125	10.6	20.6
	0.5	0.062	11.4	20.3
	0.25	0.031	12.6	20.5
Control	—	—	10.2	22.7
			L.S.D. (1%): 6.1	
S.C. (4 lb. act./gal.)	2	0.25	8.2	8.6**
	1	0.125	9.7	13.0
	0.5	0.062	9.2	15.1
	0.25	0.031	10.1	15.0
25 W.P.	2	0.25	9.7	12.1
	1	0.125	10.4	13.6
	0.5	0.062	9.9	14.5
	0.25	0.031	10.0	15.7
Control	—	—	11.4	12.8
			L.S.D. (1%): 3.4	
		Diazinon		
50 E.C. (4 lb. act./gal.)	2	0.25	9.5	2.8**
	1	0.125	9.2	4.8**
	0.5	0.062	9.3	6.0**
	0.25	0.031	9.6	8.5**
Control	—	—	11.4	12.8
			L.S.D. (1%): 3.4	
25 E.C. (2 lb. act./gal.)	2	0.25	12.5	5.3**
	1	0.125	12.3	7.1**
	0.25	0.031	11.9	12.8
25 W.P.	2	0.25	13.1	6.0**
	1	0.125	14.2	7.2**
	0.5	0.062	12.5	11.5
	0.25	0.031	12.8	11.0
Control	—	—	12.0	13.5
			L.S.D. (1%): 4.5	
		Nemacide®		
E.C. (7.9 lb. act./gal.)	2	0.25	10.3	7.0**
	1	0.125	11.1	11.2
	0.5	0.062	11.4	14.0
	0.25	0.031	10.4	14.2
Control	—	—	11.4	12.8
			L.S.D. (1%): 3.4	

Table 2 (continued)

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Oxydemetonmethyl		
E.C.	2	0.25	12.1	5.6
(2 lb. act./gal.)	1	0.125	12.6	6.0
	0.5	0.062	12.6	6.2
	0.25	0.031	11.2	6.9
Control	—	—	13.0	6.9
				N.S.D.

[a] W.P. = wettable powder; S.C. = solubilized concentrate; E.C. = emulsifiable concentrate. Sprays were applied as follows: diazinon 25 E.C. and 25 W.P., July 12, 19, and 26, 1962; oxydemetonmethyl, October 12, 19, and 26, 1962; Bay 41831, 75 E.C., May 27, June 3, and 10, 1963; and diazinon 50 E.C., Bay 41831 S.C. and W.P., and Nemacide, March 12, 19, and 26, 1964. Triton B-1956 was added to all sprays at 1:2,000.

[b] Measurements were taken one day before first spray application except for the plants treated with the 75 E.C. and S.C. formulations of Bay 41831 which were measured five days before treatment.

[c] Final measurements were taken on August 3, 1962, for diazinon 25 E.C. and W.P.; November 9, 1962, for oxydemetonmethyl; June 24, 1963, for Bay 41831 E.C.; and April 9, 1964, for diazinon 50 E.C., Bay 41831 S.C. and W.P., and Nemacide.

** Growth significantly inferior to that of control plants.

lost their older leaves and the young leaves still attached were fern-like and distorted. Plants treated with lower concentrations had less damage. The wettable powder sprays caused similar damage. Two weeks after the third spray application all formulations caused similar symptoms. At 0.25 percent concentrations there was complete defoliation except for young lateral leaflets. At 0.125 percent there were still terminal leaflets, but they were fern-like and rolled and lateral growth had begun. The plants treated with the lower concentrations had more leaves but they were chlorotic, small, and rolled-up.

Nemacide. Treatment with 0.25 percent emulsion caused significant retardation in growth. Foliar symptoms were chlorosis and burning just prior to the second spray on plants treated with 0.25 and 0.125 percent concentrations. Just prior to the third spray, the older leaves were drooping while the younger leaves were erect. Two weeks after the third application plants treated with the higher concentrations exhibited a stippled chlorosis. The leaves were narrow, rolled upwards; the old lateral leaves had dropped off but new lateral growth was starting.

Oxydemetonmethyl. No retardation of growth occurred after treatment with the emulsifiable concentrate. The only foliar abnormalities detectable were chlorosis, especially along the edges of the older leaves, together with some tip burn and moderate necrosis.

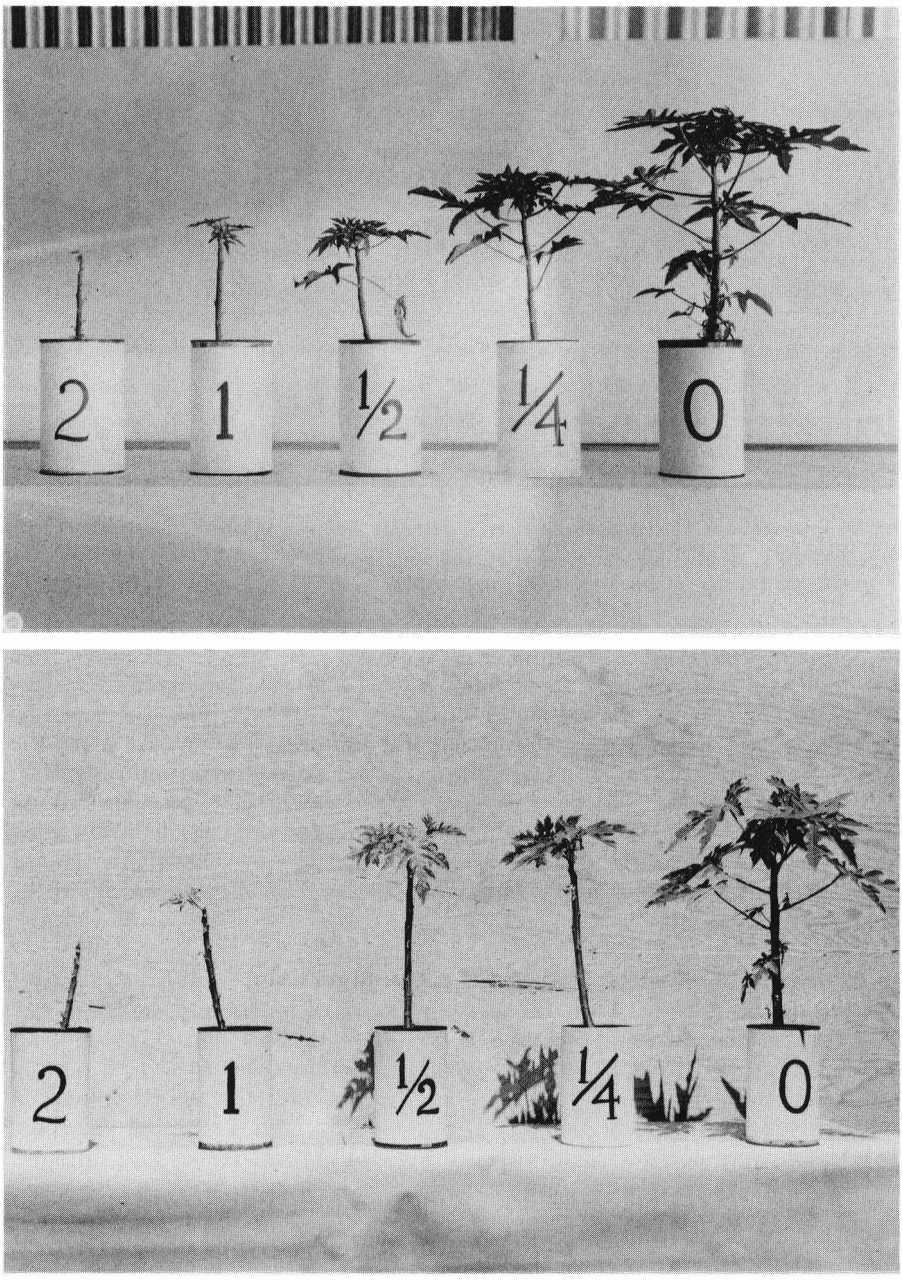
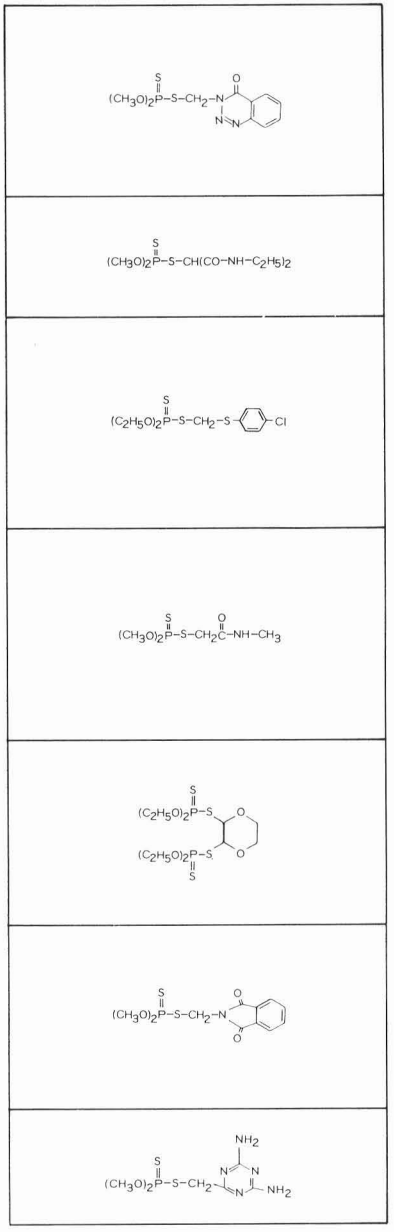


Fig. 11. Damage to papaya plants, two weeks after treatment with three applications of 50 percent (top) and 25 percent (bottom) emulsifiable concentrates of diazinon.

PHOSPHORODITHIOATES

The effects of the following phosphorodithioate formulations were studied:



(1) azinphosmethyl, *O,O*-dimethyl phosphorodithioate S-ester with 3-(mercaptomethyl)-1,2,3-benzotriazin-4(3H)-one, a 25 percent wettable powder and an emulsifiable concentrate containing 2 pounds of technical azinphosmethyl per gallon;

(2) Bayer 47185, *O,O*-dimethyl-S-(*N,N'*-diethyl malonicamide) phosphorodithioate, an 80 percent wettable powder;

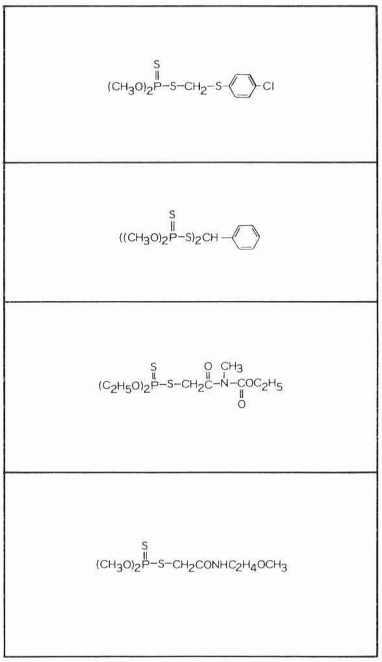
(3) carbophenothion, S-[(p-chlorophenylthio) methyl] *O,O*-diethyl phosphorodithioate, a 25 percent wettable powder and an emulsifiable concentrate containing 2 pounds of technical dimethoate per gallon;

(4) dimethoate, *O,O*-dimethyl S-(*N*-methylcarbamoylmethyl) phosphorodithioate, a 25 percent wettable powder formulation and an emulsifiable concentrate containing 2 pounds of technical dimethoate per gallon;

(5) dioxathion, *p*-dioxane-2,3-diyl ethyl phosphorodithioate, a 25 percent wettable powder and an emulsifiable concentrate containing 4 pounds of technical dioxathion per gallon;

(6) Imidan®, *O,O*-dimethyl S-phthalimidomethyl phosphorodithioate, a 50 percent wettable powder and an emulsifiable concentrate containing 3 pounds of technical Imidan per gallon;

(7) menazon, S-[(4,6-diamino-*s*-triazin-2-yl) methyl] *O,O*-dimethyl phosphorodithioate, a 70 percent wettable powder;



(8) Methyl Trithion®, *S*-(*p*-chlorophenylthio) methyl *O*,*O*-dimethyl phosphorodithioate, an emulsifiable concentrate containing 4 pounds of technical Methyl Trithion per gallon;

(9) SD 7438, *S*,*S*'-benzylidene bis-(*O*,*O*-dimethyl phosphorodithioate), an emulsifiable concentrate containing 1.6 pounds of technical SD 7438 per gallon;

(10) TD-72, *S*-(*N*-ethoxy-carbomyl-*N*-methylcarbamoyl-methyl) diethyl phosphorodithioate, an emulsifiable concentrate containing 6.7 pounds of technical TD-72 per gallon;

(11) Thiocron®, *O*,*O*-dimethyl-*S*-(2-methoxethylcarbamoyl-methyl) phosphorodithioate, a 50 percent wettable powder and an emulsifiable concentrate containing 2.58 pounds of technical Thiocron per gallon.

Table 3 summarizes the effect of treatment with various formulations of the phosphorodithioates on the growth of the papaya.

Azinphosmethyl. The wettable powder formulation had no detrimental effect on growth but concentrations as low as 0.125 percent of the emulsion did retard growth significantly (Fig. 12). The wettable powder formulation also had no detrimental effect on the foliage but the two higher concentrations of the emulsion within one week after the first spray application, caused severe foliar burning and large necrotic areas were found on the leaves. Two weeks after the third spray, the plants receiving 0.25 percent of the emulsion had undersized leaves, as well as burning.

Bayer 47185. No effect on growth or foliage was noted after treatment with the wettable powder.

Carbophenothion. All concentrations of both emulsifiable and wettable powder formulations significantly retarded growth.

Just prior to the second spray all plants were chlorotic and were showing the "umbrella-effect." The wettable powder formulation was more detrimental to the plants than was the emulsion.

Two weeks after the third application (Fig. 16, top) plants sprayed with 0.25 and 0.125 percent of the emulsion had lost all their leaves and

the growing tips were burned. Those treated with 0.062 percent emulsion had lost most of their leaves; the remaining older leaves were burned, while the younger leaves were narrow and fern-like. Those sprayed with 0.031 percent emulsion had retained their leaves, but they were drooping, giving a ball-like appearance when viewed from the side. There was also a highly chlorotic, yellow stippling present.

The wettable powder concentrations gave similar but more severe indications of phytotoxicity (Fig. 16, bottom).

Table 3. Effect of phosphorodithioates on the growth of the Solo papaya

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Azinphosmethyl		
E.C.	2	0.25	8.4	4.8**
(2 lb. act./gal.)	1	0.125	8.5	6.9**
	0.5	0.062	8.2	10.6
	0.25	0.031	9.0	11.1
25 W.P.	2	0.25	9.5	11.1
	1	0.125	8.6	11.3
	0.5	0.062	8.8	11.3
	0.25	0.031	8.0	10.0
Control	—	—	8.8	10.6
			L.S.D. (1%):	1.8
		Bayer 47185		
80 W.P.	2	0.25	9.6	23.5
	1	0.125	10.8	19.8
	0.5	0.062	11.6	21.0
	0.25	0.031	10.8	19.8
Control	—	—	10.2	22.7
				N.S.D.
		Carbophenothion		
E.C.	2	0.25	6.3	d
(4 lb. act./gal.)	1	0.125	6.8	2.5**
	0.5	0.062	6.9	3.0**
	0.25	0.031	6.8	4.4**
25 W.P.	2	0.25	6.6	0.9**
	1	0.125	6.6	1.8**
	0.5	0.062	6.7	3.4**
	0.25	0.031	7.0	3.6**
Control	—	—	6.4	12.7
			L.S.D. (1%):	2.0

Table 3 (continued)

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Dimethoate		
2 E.C.	2	0.25	9.1	5.8**
(2 lb. act./gal.)	1	0.125	8.8	8.1**
	0.5	0.062	8.8	9.5
	0.25	0.031	8.8	10.5
25 W.P.	2	0.25	9.2	7.2**
	1	0.125	9.0	10.0
	0.5	0.062	9.4	10.2
	0.25	0.031	9.8	9.5
		Dioxathion		
E.C.	2	0.25	8.4	death of plants
(4 lb. act./gal.)	1	0.125	8.9	death of plants
	0.5	0.062	8.8	d
	0.25	0.031	8.6	d
25 W.P.	2	0.25	8.2	d
	1	0.125	8.9	d
	0.5	0.062	8.6	3.2**
	0.25	0.031	9.2	3.9**
Control	—	—	8.8	10.6
			L.S.D. (1%):	1.8
		Imidan®		
3 E.C.	2	0.25	5.9	10.6**
(3 lb. act./gal.)	1	0.125	5.9	11.2
	0.5	0.062	5.8	11.4
	0.25	0.031	6.8	11.7
50 W.P.	2	0.25	5.9	13.5
	1	0.125	6.0	11.5
	0.5	0.062	7.0	11.7
	0.25	0.031	6.6	12.0
Control	—	—	6.4	12.7
			L.S.D. (1%):	2.0
		Menazon		
70 W.P.	2	0.25	11.8	16.5
	1	0.125	13.8	14.2
	0.5	0.062	12.4	15.0
	0.25	0.031	11.2	14.2
Control	—	—	11.4	12.8
			L.S.D. (1%):	3.4

Table 3 (continued)

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Methyl Trithion®		
4 E.C.	2	0.25	11.1	6.4
(4 lb. act./gal.)	1	0.125	11.2	7.1
	0.5	0.062	10.2	6.1
	0.25	0.031	10.9	7.8
Control	—	—	13.0	6.9
				N.S.D.
		SD 7438		
E.C.	2	0.25	10.0	17.9
(1.6 lb. act./gal.)	1	0.125	11.7	19.8
	0.5	0.062	11.3	23.3
	0.25	0.031	10.8	22.2
Control	—	—	10.2	22.7
				N.S.D.
		TD-72		
E.C.	2	0.25	10.0	5.0**
(6.7 lb. act./gal.)	1	0.125	10.2	4.6**
	0.5	0.062	10.4	5.6**
	0.25	0.031	10.2	7.0**
		Thiocron®		
30 E.C.	2	0.25	10.9	12.9
(2.58 lb. act./gal.)	1	0.125	9.3	13.1
	0.5	0.062	9.8	14.8
	0.25	0.031	10.8	14.6
50 W.P.	2	0.25	10.6	13.0
	1	0.125	10.7	13.8
	0.5	0.062	10.6	14.3
	0.25	0.031	10.0	16.0
Control	—	—	11.4	12.8
				L.S.D. (1%): 3.4

[a] W.P. = wettable powder; E.C. = emulsifiable concentrate. Sprays were applied as follows: carbophenothion and Imidan, August 10, 17, and 24, 1962; Methyl Trithion, October 12, 19, and 26, 1962; Bayer 47185 and SD 7438, May 27, June 3, and 10, 1963; azinphosmethyl, dimethoate, and dioxathion, January 16, 23, and 30, 1964; menazon, TD-72, and Thiocron, March 12, 19, and 26, 1964. Triton B-1956 was added to all sprays at 1:2,000.

[b] Measurements were taken one day before first spray application except for Bayer 47185- and SD 7438-treated plants, which were measured five days before treatment.

[c] Final measurements were taken on August 31, 1962, for carbophenothion and Imidan; November 9, 1962, for Methyl Trithion; June 24, 1963, for Bayer 47185 and SD 7438; February 13, 1964, for azinphosmethyl, dimethoate, and dioxathion; and April 9, 1964, for menazon, TD-72, and Thiocron.

[d] Terminal tips killed; little or no growth.

** Growth significantly inferior to that of control plants.

Fig. 12. Damage to papaya two weeks after three weekly applications of azinphos-methyl emulsion.

Fig. 17 shows the plants as they appeared six weeks after the last spray. In the emulsion treatments, all plants sprayed with 0.25 percent concentrations had died. Only one plant had survived treatment with 0.125 percent emulsion and it was stunted. All plants survived treatment with the lower concentrations. In the wettable powder treatments, one plant survived application of the 0.25 percent concentrations, two plants survived treatment with the 0.125 percent concentrations, and all plants treated with the lower concentrations recovered but were badly stunted.

Dimethoate. Application of 0.125 percent of the emulsion and 0.25 percent of the wettable powder formulations significantly retarded growth.

Two weeks after the third application, the leaves of plants sprayed with 0.25 percent of the emulsion had rounded edges and some necrosis and were very chlorotic along the edges. Those sprayed with 0.125 percent of the emulsion had less rounding of the leaves but there was some chlorosis along the leaf edge. The two lower concentrations were less affected. In fact, the 0.031 percent emulsion caused little or no abnormalities. The wettable powder formulation caused similar damage but less than that caused by equivalent concentrations of the emulsion spray (Fig. 13).

Dioxathion. This material affected the plants very seriously. All concentrations of both emulsifiable and wettable formulations either killed the entire plant or the terminals or barely allowed growth.

Fig. 13. Effect of treatment with equivalent concentrations (0.25 percent) of emulsifiable concentrate (left) and wettable powder (center) of dimethoate on growth and foliar damage of papaya.

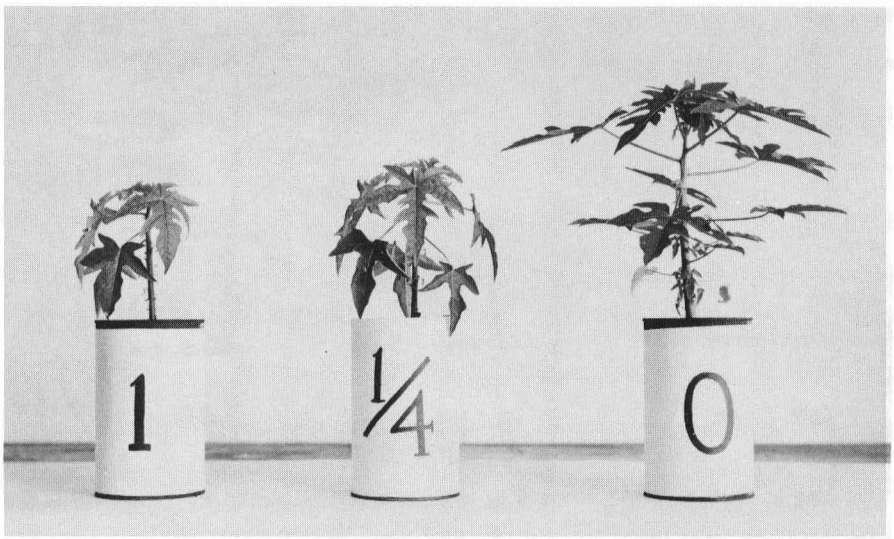


Fig. 14. Papaya one week after treatment with one application of 0.125 and 0.031 percent dioxathion emulsion. Note upward curling of leaves and drooping of the petioles in the treated plants. Untreated control plant on right.

Just prior to the second spray application, the plants treated with the emulsion showed the "umbrella-effect" at all concentrations. There was an upward curling of the leaves and a drooping of the petioles (Fig. 14). The wettable powder formulations showed a similar effect but to a lesser extent.

One week later, just prior to the third spray application, the plants treated with 0.25 and 0.125 percent concentrations were completely defoliated and the growing tips were dead. Those treated with the two lower concentrations of 0.062 and 0.031 percent had severely damaged leaves still adhering to the stems and the growing tips were still alive. The phytotoxic effect of the wettable powders was considerably less than that of the emulsion. The damage caused by 0.25 percent wettable powder was equivalent to that caused by the 0.031 percent emulsion. The lower concentrations of wettable powder caused the plants to exhibit the "umbrella-effect."

Two weeks after the third spray application all concentrations of the emulsion had caused complete defoliation, death of the terminals or of the entire plant. The wettable powders at 0.25 and 0.125 percent had caused complete defoliation and death of the terminal growing point, although some lateral buds were actively growing but were distorted. The plants receiving the two lower concentrations were completely defoliated,

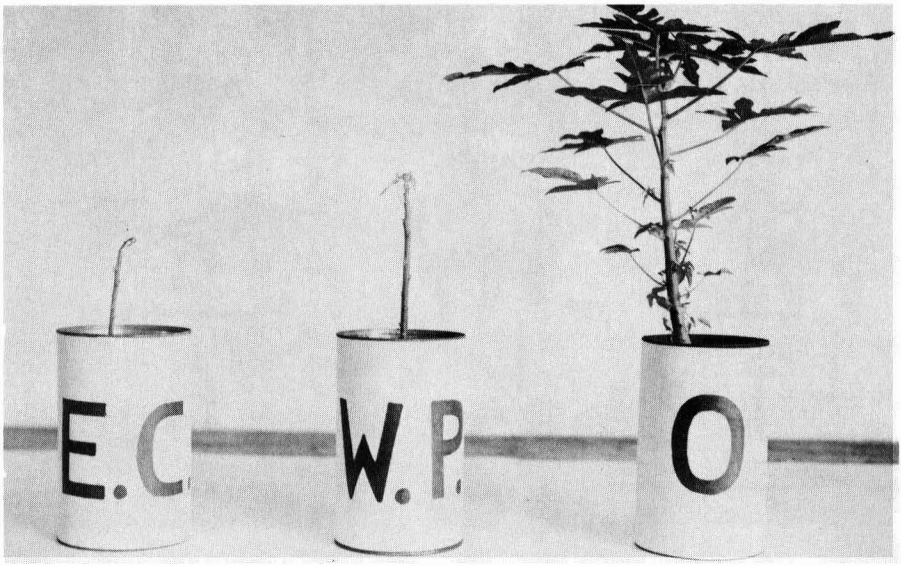


Fig. 15. Plants two weeks after the third application of 0.031 percent dioxathion emulsion (left) and wettable powder (center).

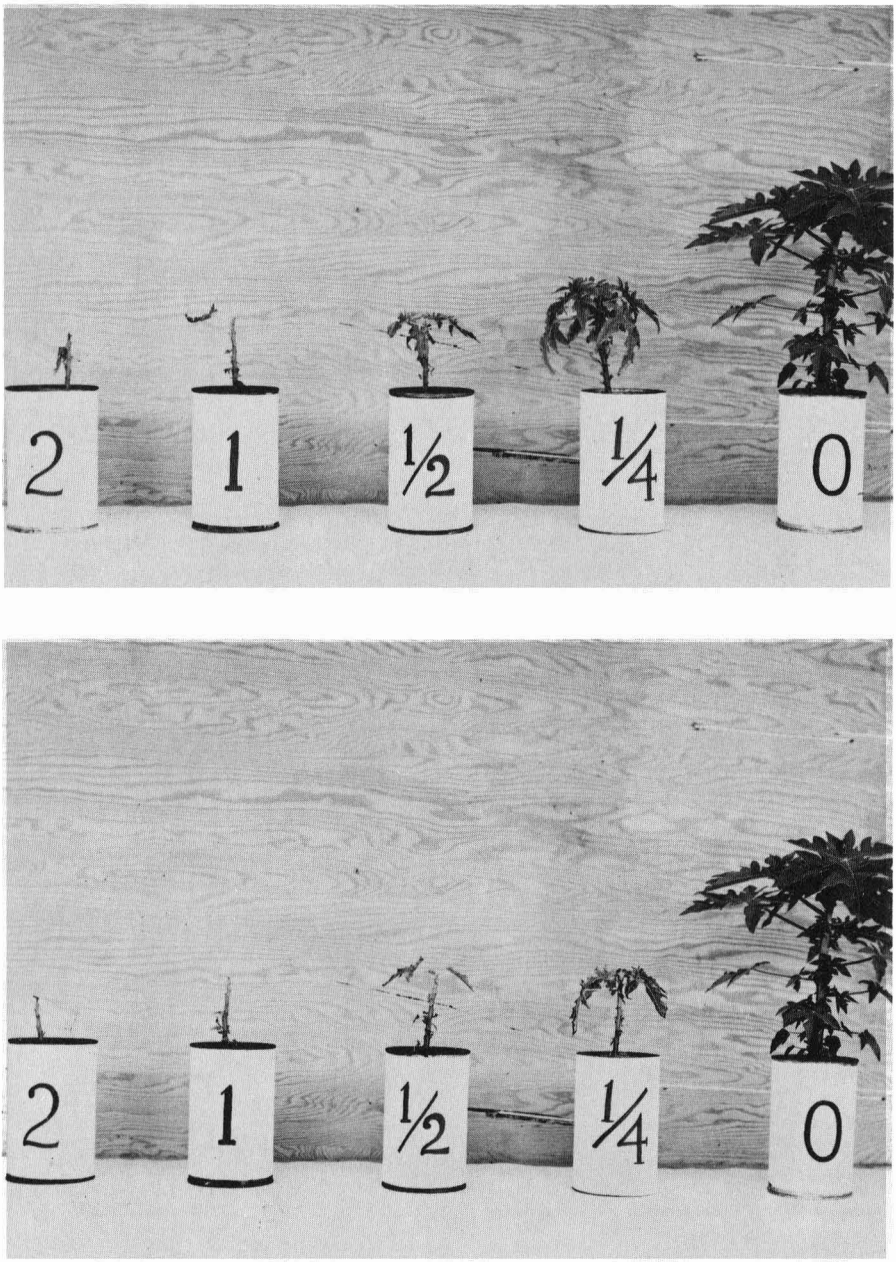


Fig. 16. Effect of three weekly treatments with carbophenothion emulsifiable concentrate (top) and wettable powder (bottom) on the growth and foliage of papaya.

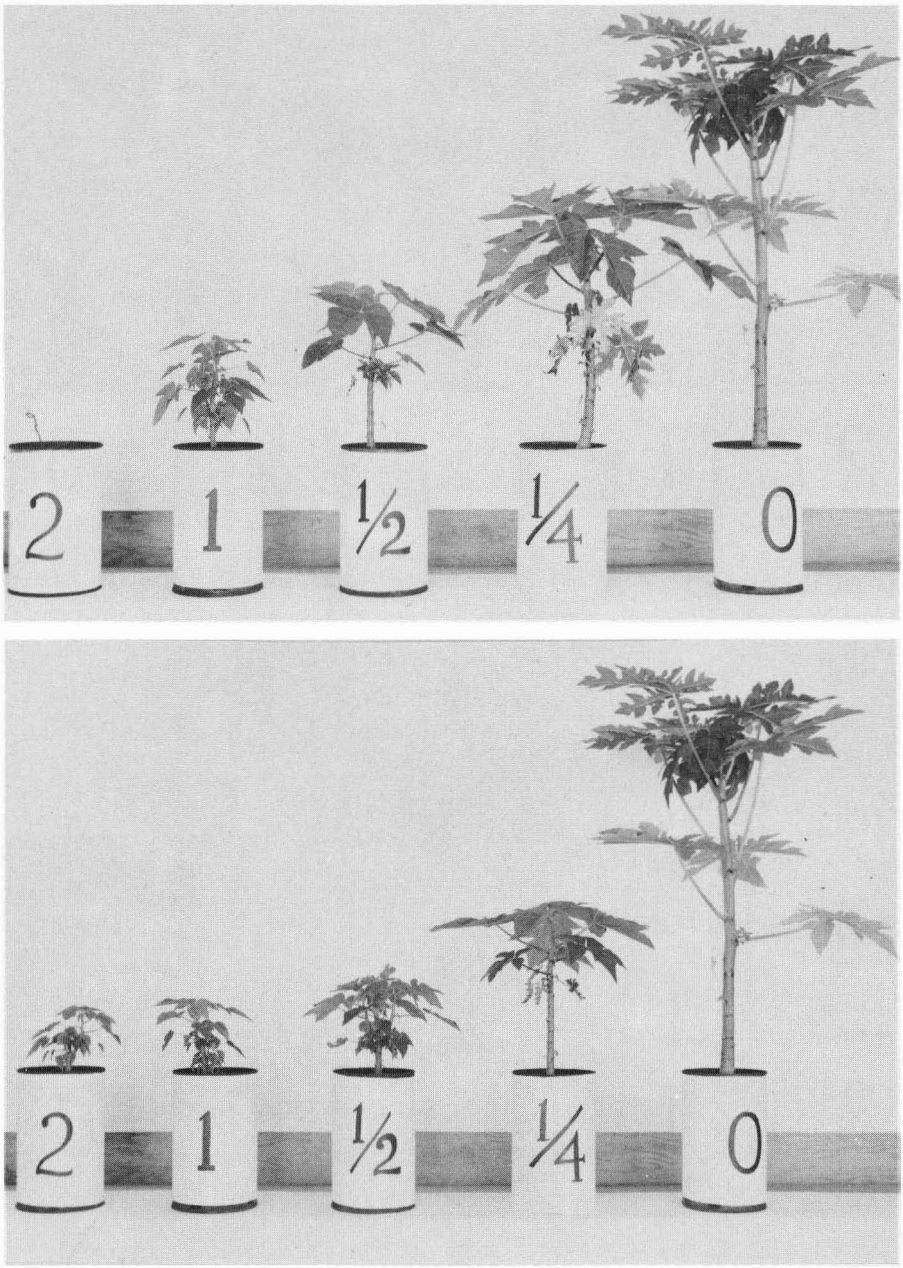


Fig. 17. Recovery in papaya seedlings, six weeks after three weekly applications of carbophenothion emulsion (top) and wettable powder (bottom).

and although the terminal growing tips were active the young leaves were distorted (Fig. 15).

Imidan. Only treatment with 0.25 percent of the emulsion caused significant retardation in growth. The only foliar effect with this concentration was minor tip chlorosis. Treatments with the lower emulsion concentrations and all wettable powder concentrations had no detrimental effect on the plants.

Menazon. No effect on growth or foliage was noted after treatment with a wettable powder formulation.

Methyl Trithion. No effect on growth was noted after treatment with the emulsifiable formulation. The only abnormal effect was a slight chlorosis and necrosis of the tips of leaves treated with the highest concentration of 0.25 percent. It is interesting to note that carbophenothion, the ethyl analog of this compound, was so much more drastic in its effects on the papaya (see discussion above).

SD 7438. No effect on growth was noted after treatment with the emulsion. Foliar injury was somewhat delayed. All plants appeared normal prior to the second spray application, but one week later tip burn occurred in plants treated with the 0.25 percent emulsion. Two weeks after the third spray, these same plants still showed tip burn and some of the older leaves had dropped. Leaf drop also occurred in plants treated with 0.125 percent emulsion. Plants treated with 0.062 and 0.031 percent emulsion were normal.

TD-72. All levels of the emulsifiable formulation caused significant retardation of growth (Fig. 18). One week after the first spray application and just prior to the second, foliar evidence of phytotoxicity consisted of an upward curl of the leaf edges and a resulting fern-like appearance. A chlorosis with a distinct pattern of yellow lines, the severity of which was greater with the higher concentrations, was also present. Foliar symptoms became more severe with additional treatment (Fig. 19), but two weeks after treatment new foliage was present.

Thiocron. No effect on growth by treatment with either the wettable powder or emulsifiable formulation was noted. Equivalent concentrations of both formulations caused the same degree of foliar injury. One week after the first spray application, leaves of plants treated with the 0.25 percent emulsion or suspension showed tip burn. The edges of the younger leaves were rounded and wrinkled. Less damage was caused by the lower concentrations. Two weeks after the third spray application, the leaves of plants treated with the 0.25 percent emulsion or suspension were chlorotic with rounded edges. The older leaves in particular were badly distorted. The symptoms decreased with decreasing concentration; plants treated with 0.031 percent Thiocron showed no foliar injury.

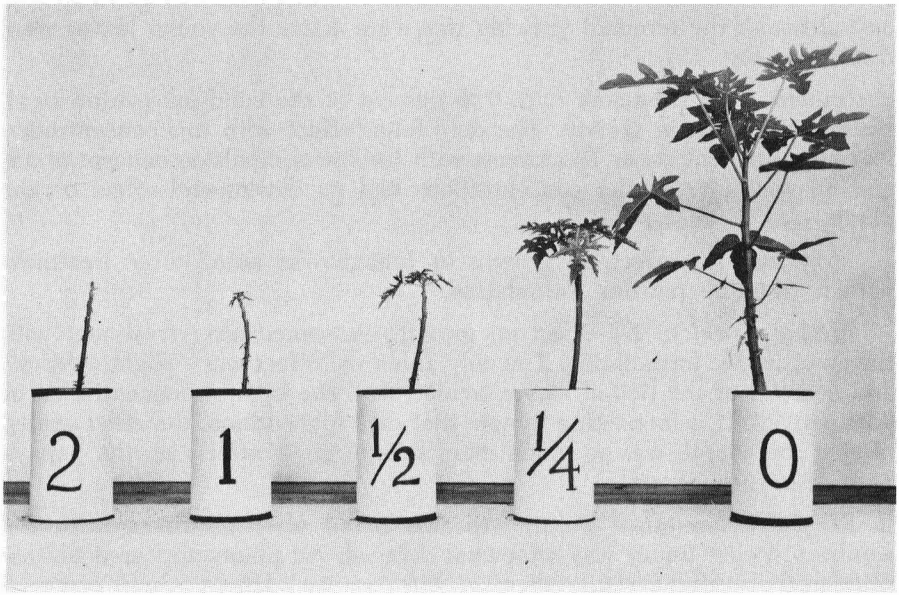


Fig. 18. Effect on growth and foliar damage two weeks after three applications of TD-72 emulsions.

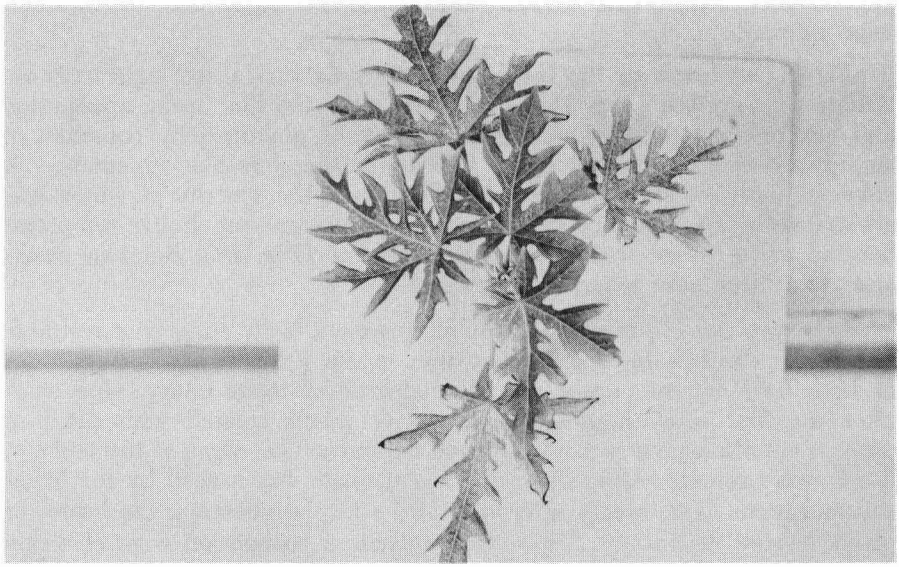
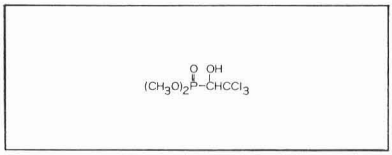


Fig. 19. Close-up of foliar symptoms caused by three applications of 0.031 percent TD-72 emulsion.

PHOSPHONATE

The effects of one phosphonate were studied:



(1) trichlorfon, dimethyl (2,2,2-trichlo=ro-1-hydroxyethyl) phosphonate, in the form of a 50 percent wettable powder and a solution containing 4 pounds of technical trichlorfon per gallon.

Table 4 summarizes the effect of trichlorfon on the growth of the papaya.

Although treatment with the liquid formulation had no effect on growth, 0.25 percent wettable powder significantly restricted growth. The effect of the wettable powder on the foliage was also greater than that of the liquid solution but the damage was not very serious. Only treatment with the 0.25 percent concentrations resulted in slight burning along the leaf edge and tips and some chlorosis.

Table 4. Effect of a phosphonate on the growth of the Solo papaya

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Trichlorfon		
S	2	0.25	8.3	9.6
(4 lb. act./gal.)	1	0.125	8.3	10.8
	0.5	0.062	9.9	10.9
	0.25	0.031	9.5	10.6
50 W.P.	2	0.25	9.5	8.8**
	1	0.125	9.5	9.8
	0.5	0.062	9.0	10.6
	0.25	0.031	8.4	10.4
Control	—	—	8.8	10.6
				L.S.D. (1%): 1.8

[a] W.P. = wettable powder; S = solution. Sprays were applied January 16, 23, and 30, 1964. Triton B-1956 was added to all sprays at 1:2,000.

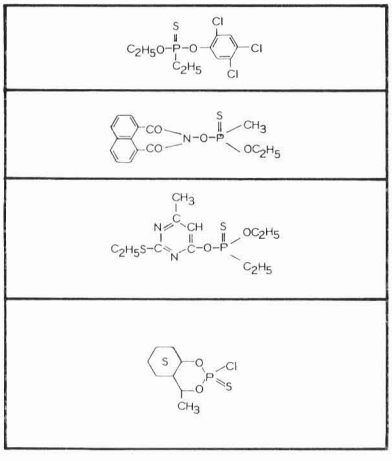
[b] Measurements were taken one day before first spray application.

[c] Final measurements were taken on February 13, 1964.

** Growth significantly inferior to that of control plants.

PHOSPHONOTHIOATES

The effects of the following phosphonothioate formulations were studied:



(1) Bayer 37289, *O*-ethyl *O*-2,4,5-trichlorophenyl ethylphosphonothioate, a 50 percent emulsifiable concentrate;
(2) Bayer 39197, *O*-ethyl-*O*-(naphthyloxime)-methylphosphonothioate, an 80 percent wettable powder;
(3) Bayer 46676, *O,O*-diethyl-*O*-(2-oxy-4-methyl-6 ethyl-pyrimidinyl) phosphonothioate, a 50 percent emulsifiable concentrate;
(4) UC 8305, *P*-chloro-2,4-dioxa-5-methyl-*P*-thiono-3-phospha-bicyclo (4·4·0) decane, a 50 percent wettable powder and an emulsifiable concentrate containing 4 pounds of technical UC 8305 per gallon.

Table 5 summarizes the effects of these phosphonothioates on the growth of the papaya.

Bayer 37289. No effect on growth was noted after treatment with an emulsifiable formulation. Foliar damage was negligible. Application of 0.25 and 0.125 percent concentrations resulted in a slight chlorosis and distortion of the leaf.

Bayer 39197. Treatment with 0.25 percent of a wettable powder formulation resulted in significant reduction in growth. Some foliar damage was apparent in all treated plants, as evidenced by tip burn and chlorosis, particularly on the older leaves. Intensity of damage decreased with a decrease in concentration.

Bayer 46676. All concentrations of an emulsifiable formulation caused a significant reduction in growth. Foliar damage occurred at all concentrations. Just prior to the second spray application, the plants treated with 0.25 percent emulsion showed severe burning and extensive loss of the older leaves. Lower concentrations caused less damage. At the last observation two weeks after the third spray application, the older leaves had dropped (Fig. 20) in all plants treated with the higher concentrations.

UC 8305. No effect on growth was noted after treatment with either emulsifiable or wettable powder formulations. The effect of the wettable powder formulation on foliage was slightly greater than the effect of the emulsion. Treatment with 0.25 percent of the emulsion and 0.25 and 0.125 percent of the wettable powder caused white, necrotic spots in the center and along the edges of the leaves. However, this damage was not very serious. All other treatments had no effect on foliage.

Table 5. Effect of phosphonothioates on the growth of the Solo papaya

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Bayer 37289		
50 E.C.	2	0.25	10.0	19.4
(0.55 g. act./ml.)	1	0.125	10.2	22.1
	0.5	0.062	12.7	22.9
	0.25	0.031	11.7	24.8
		Bayer 39197		
80 W.P.	2	0.25	10.7	12.3**
	1	0.125	10.4	17.7
	0.5	0.062	9.8	16.2
	0.25	0.031	10.8	18.6
		Bayer 46676		
50 E.C.	2	0.25	11.8	5.4**
(0.54 g. act./ml.)	1	0.125	11.3	7.4**
	0.5	0.062	11.2	9.7**
	0.25	0.031	12.0	13.1**
Control	—	—	10.2	22.7
				L.S.D. (1%): 6.1
		UC 8305		
4 E.C.	2	0.25	12.3	7.2[d]
	1	0.125	11.6	6.6[d]
	0.5	0.062	10.5	6.4
	0.25	0.031	11.5	6.1
50 W.P.	2	0.25	11.4	6.1
	1	0.125	11.2	6.6
	0.5	0.062	12.5	6.4
	0.25	0.031	12.6	7.1
Control	—	—	13.0	6.9
				N.S.D.

[a] W.P. = wettable powder; E.C. = emulsifiable concentrate. Sprays were applied as follows: UC 8305, October 12, 19, and 26, 1962; Bayer 37289, Bayer 39197, and Bayer 46676, May 27, June 3 and 10, 1963. Triton B-1956 was added to all sprays at 1:2,000.

[b] Measurements were taken one day before first spray application.

[c] Final measurements were taken on November 9, 1962, for UC 8305 and June 24, 1963, for Bayer 37289, Bayer 39197, and Bayer 46676.

[d] One to two plants were infected with pythium. Data are mean of healthy plants and were not included in the statistical analysis.

** Growth significantly inferior to that of control plants.

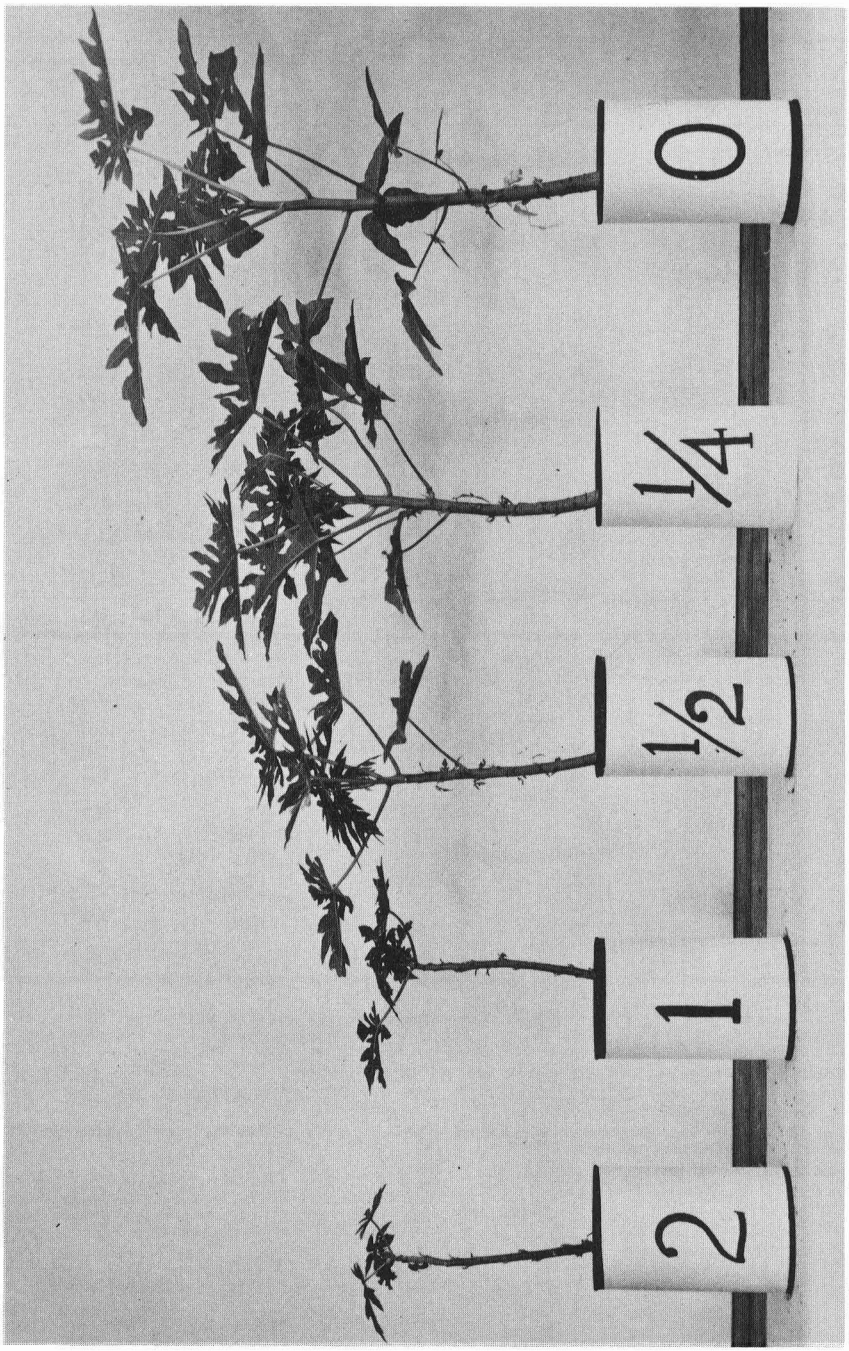
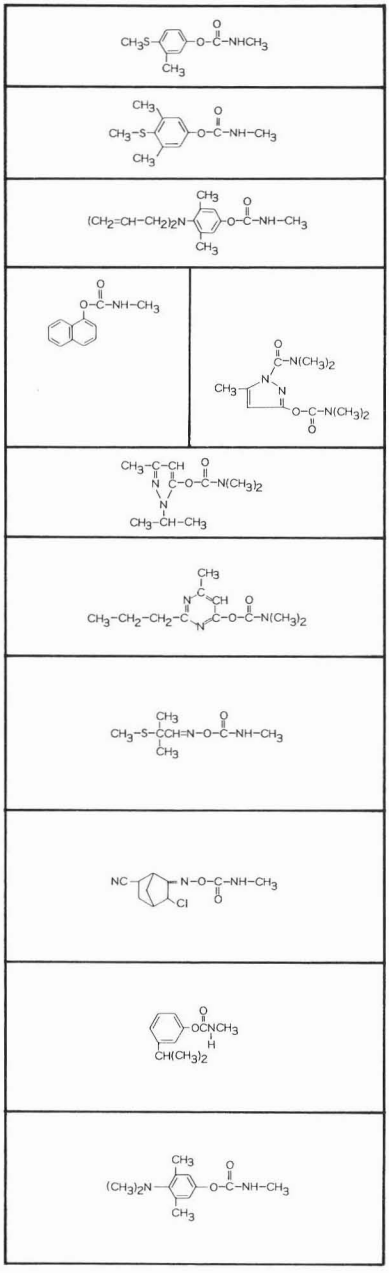


Fig. 20. Papaya two weeks after the third application of Bayer 46676 emulsions.

CARBAMATES

The effects of the following carbamate formulations were studied:



(1) Bayer 32651, 4-methylthio-(3-methylphenyl)-*N*-methylcarbamate, a 25 percent emulsifiable concentrate;

(2) Bayer 37344, 4-(methylthio)-3,5-xylyl methylcarbamate, a 50 percent wettable powder;

(3) Bayer 50282, 3,5-dimethyl-4-diallylamino-phenyl-*N*-methylcarbamate, a 50 percent wettable powder;

(4) carbaryl, 1-naphthyl *N*-methylcarbamate, a 50 percent wettable powder;

(5) dimetilan, 1-dimethyl-carbamoyl-5-methyl 3-pyrazolyl dimethylcarbamate, a 25 percent wettable powder and a 25 percent emulsifiable concentrate;

(6) Isolan®, 1-isopropyl-3-methyl-5-pyrazolyl dimethylcarbamate, a 25 percent emulsifiable concentrate;

(7) Pyramat®, 6-methyl-2-propyl-4-pyrimidinyl dimethylcarbamate, a 25 percent wettable powder and a 25 percent emulsifiable concentrate;

(8) Temik®, 2-methyl-2-(methylthio)-propionaldehyde *O*-(methylcarbamoyl)-oxime, an emulsifiable concentrate containing 1 pound of technical Temik per gallon.

(9) Tranid®, 5-chloro-6-oxo-2-norbornanecarbonitrile *O*-(methylcarbamoyl)-oxime, an emulsifiable concentrate containing 2 pounds of technical Tranid per gallon;

(10) UC 10854, 3-isopropylphenyl-*N*-methyl carbamate, a 75 percent wettable powder and an emulsifiable concentrate containing 1 pound of technical UC 10854 per gallon;

(11) Zectran®, 4-dimethylamino-3,5-xylyl methylcarbamate, a 25 percent wettable powder and an emulsifiable concentrate containing 2 pounds of technical Zectran per gallon;

Table 6 summarizes the effects of these carbamates on the growth of the papaya.

Bayer 32651. Treatment with 0.25 percent of an emulsifiable formulation significantly reduced growth. Foliar damage consisting of tip burn was caused by treatment with 0.25 percent and to a lesser extent with 0.125 percent concentrations.

Bayer 37344. No effect on growth or foliage was noted after treatment with a wettable powder formulation.

Bayer 50282. No effect on growth was evidenced after treatment with a wettable powder, and the only foliar damage was some chlorosis and burning caused by application of the 0.25 percent concentration.

Carbaryl. No effect on growth was noticed but some chlorosis was noticed in all treatments with the wettable powder. Two weeks after the third application, however, complete recovery had occurred.

Dimetilan. This material not only affected growth at all concentrations of both the emulsifiable and wettable powder formulations but actually killed the plants. Foliar symptoms became evident rather quickly. One week after the first spray application all concentrations of both formulations caused burning along the edges and tips of the leaves, a reduction of terminal growth, and stunting of the young leaves (Fig. 21). Two weeks after the third spray, plants treated with 0.25 percent emulsion could not be measured since the growing tips were dead and there were no leaves. Plants treated with 0.125 percent emulsion were also severely damaged; terminals were dead but lateral leaves were growing although they were badly burned. Some of the older leaves were still attached to the plants but were very necrotic. Even the plants treated with 0.062 and 0.031 percent emulsion were seriously damaged. Plants treated with the wettable powder were more damaged than those treated with equivalent concentrations of the emulsion. All plants sprayed with 0.25, 0.125 and 0.062 percent wettable powder were dead two weeks after treatment (Fig. 22).

Six weeks after the third treatment, the plants were once more observed (Fig. 23). Plants treated with 0.25 and 0.125 percent emulsion had died, those treated with 0.062 and 0.031 percent emulsion were recovering but were stunted. All plants treated with the wettable powder formulations had died except for one leafless survivor of treatment with 0.031 percent concentration.

Isolan. Emulsion concentrations as low as 0.062 percent significantly reduced growth. Considerable foliar damage occurred by application of 0.25 and 0.125 percent of the emulsion. After one application, most of the older leaves dropped and those remaining were chlorotic and burned along the edges. After the second spray all of the leaves and particularly the

terminals were severely burned. Two weeks after the third application the same symptoms were still evident. The 0.062 and 0.031 percent concentrations caused the leaves to be chlorotic.

Pyramat. The effect of pyramat closely resembled that of dimetilan. Growth was greatly affected by treatment with all concentrations of the emulsion and wettable powder formulations. One week after the first spray all treatments caused foliar burning and the young leaves were stunted.

Two weeks after the third spray application, treatment with 0.25 percent concentrations caused death of the plants. The other treatment levels caused necrosis and chlorosis. Plants treated with the wettable powder formulations were more damaged than those treated with emulsions.

Six weeks after the third application another observation was made. There were no survivors of treatment with 0.25 percent concentrations of both formulations. Treatment with 0.125 percent emulsion killed two plants; the survivors had leaves present but they were chlorotic. The plants treated with 0.062 and 0.031 percent emulsion had recovered, and the leaves were actively growing but with a mosaic-chlorosis. The plants treated with 0.062 and 0.031 percent wettable powder were small, chlorotic, and more damaged than those treated with equivalent concentrations of emulsion.

Table 6. Effect of carbamates on the growth of the Solo papaya

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Bayer 32651		
25 E.C.	2	0.25	10.5	8.4**
(0.27 g. act./ml.)	1	0.125	10.6	19.1
	0.5	0.062	9.7	17.8
	0.25	0.031	10.2	23.1
		Bayer 37344		
50 W.P.	2	0.25	11.3	19.6
	1	0.125	11.0	19.0
	0.5	0.062	9.8	17.7
	0.25	0.031	10.0	20.2
Control	—	—	10.2	22.7
			L.S.D. (1%):	6.1
		Bayer 50282		
50 W.P.	2	0.25	11.0	16.4
	1	0.125	10.0	14.2
	0.5	0.062	9.7	15.8
	0.25	0.031	10.2	16.6
Control	—	—	11.4	12.8
			L.S.D. (1%):	3.4

Table 6 (continued)

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Carbaryl		
50 W.P.	2	0.25	11.1	13.8
	1	0.125	11.3	13.5
	0.5	0.062	9.7	17.2
	0.25	0.031	11.4	13.1
Control	—	—	12.0	13.5
				N.S.D.
		Dimetilan		
25 E.C.	2	0.25	6.1	d
(0.27 gm. act./ml.)	1	0.125	7.1	3.2**
	0.5	0.062	6.6	5.8**
	0.25	0.031	6.1	6.6**
25 W.P.	2	0.25	5.9	d
	1	0.125	6.2	d
	0.5	0.062	6.1	d
	0.25	0.031	6.0	4.8**
Control	—	—	6.4	12.7
			L.S.D. (1%):	2.0
		Isolan®		
25 E.C.	2	0.25	12.1	9.5**
(0.25 gm. act./ml.)	1	0.125	11.3	13.4**
	0.5	0.062	10.6	14.9**
	0.25	0.031	10.0	19.9
Control	—	—	10.2	22.7
			L.S.D. (1%):	6.1
		Pyramat®		
25 E.C.	2	0.25	6.6	d
(0.27 gm. act./ml.)	1	0.125	7.0	3.1**
	0.5	0.062	6.4	5.3**
	0.25	0.031	6.6	5.8**
25 W.P.	2	0.25	7.0	d
	1	0.125	7.1	1.6**
	0.5	0.062	6.6	4.4**
	0.25	0.031	7.0	5.4**
Control	—	—	6.4	12.7
			L.S.D. (1%):	2.0

Table 6 (continued)

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		UC 10854		
1 E.C.	1	0.125	15.4	6.0
(1 lb. act./gal.)	0.5	0.062	12.7	6.4
	0.25	0.031	11.6	5.9
75 W.P.	2	0.25	13.4	5.2
	1	0.125	13.1	6.8
	0.5	0.062	11.5	6.8
	0.25	0.031	11.4	6.3
Control	—	—	13.0	6.9
				N.S.D.
		Temik®		
1 E.C.	2	0.25	12.5	15.3
(1 lb. act./gal.)	1	0.125	11.5	14.8
	0.5	0.062	12.2	15.0
	0.25	0.031	11.9	13.1
		Tranid®		
2 E.C.	2	0.25	12.5	12.0
(2 lb. act./gal.)	1	0.125	13.2	15.6
	0.5	0.062	12.9	14.8
	0.25	0.031	10.9	14.7
Control	—	—	11.4	12.8
				L.S.D. (1%): 3.4
		Zectran®		
E.C.	2	0.25	13.4	12.4
(2 lb. act./gal.)	0.5	0.062	12.7	13.9
	0.25	0.031	11.7	15.7
25 W.P.	2	0.25	10.9	13.6
	1	0.125	11.7	15.6
	0.25	0.031	10.5	13.1
Control	—	—	12.0	13.5
				N.S.D.

[a] W.P. = wettable powder; E.C. = emulsifiable concentrate. Sprays were applied as follows: carbaryl and Zectran, July 12, 19, and 26, 1962; dimetilan and Pyramat, August 10, 17, and 24, 1962; UC 10854, October 12, 19, and 26, 1962; Bayer 32651, Bayer 37344, and Isolan, May 27, June 3 and 10, 1963; and Bayer 50282, Tranid, and Temik, March 12, 19, and 26, 1964. Triton B-1956 was added to all sprays at 1:2,000.

[b] Measurements were taken one day before first spray application except for Bayer 32651-, Bayer 37344-, and Isolan-treated plants which were measured five days before treatment.

[c] Final measurements were taken on August 3, 1962, for carbaryl and Zectran; August 31, 1962, for dimetilan and Pyramat; November 9, 1962, for UC 10854; June 24, 1963, for Bayer 32651, Bayer 37344 and Isolan; and April 9, 1964, for Bayer 50282, Tranid, and Temik.

[d] Terminal tips killed; little or no growth.

** Growth significantly inferior to that of control plants.

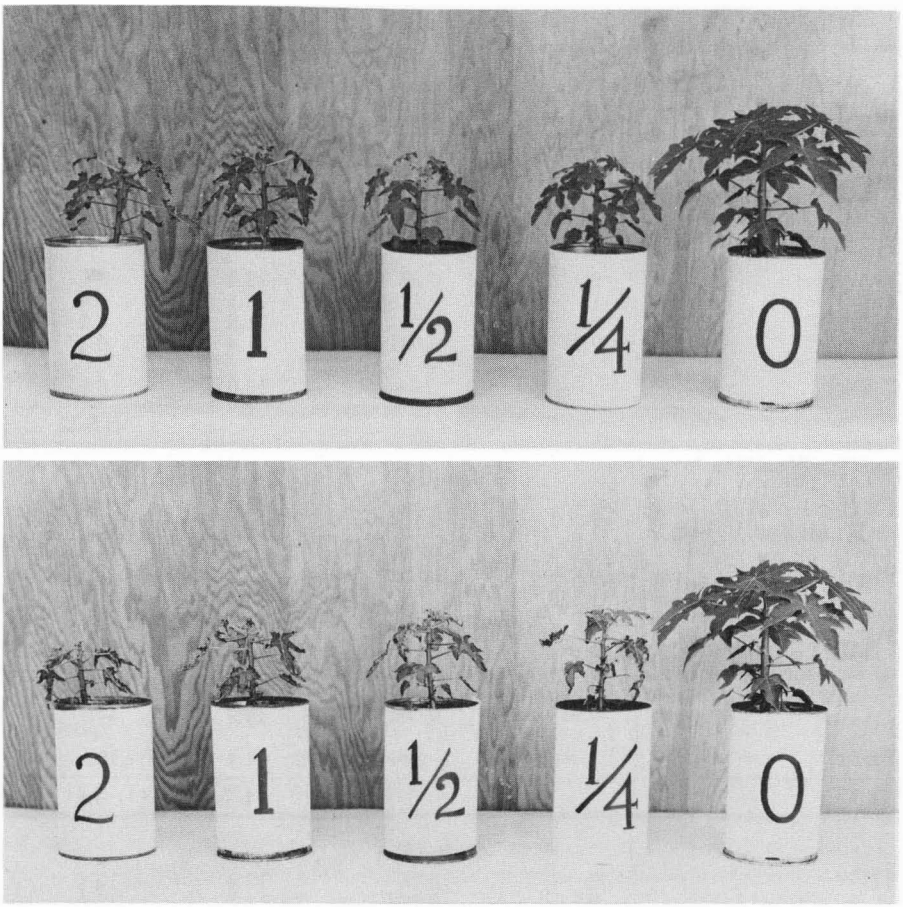


Fig. 21. Papaya, one week after a single application of dimetilan emulsion (top) and wettable powder (bottom) concentrations.

Temik. Treatment with this emulsifiable material had no effect on growth or foliage.

Tranid. No retardation of growth was caused by the emulsion. Foliar damage consisting of chlorosis and crinkling was caused by application of 0.25 percent of the emulsion and to a lesser degree by the 0.125 percent concentration.

UC 10854. No effect on growth was noted after treatment with either the emulsifiable or the wettable powder formulations. Foliar damage was negligible.

Zectran. No effect on growth was noticed in treatments with either emulsifiable or wettable powder formulations. Two weeks after the third application some necrosis on the edges of the leaves was noted in plants treated with 0.25 and 0.125 percent of the emulsion and 0.25 percent of the wettable powder. The damage caused by the wettable powder was less than that caused by the emulsion. Some of the treatments were dropped from the experiment due to excess infection of the plants with pythium.

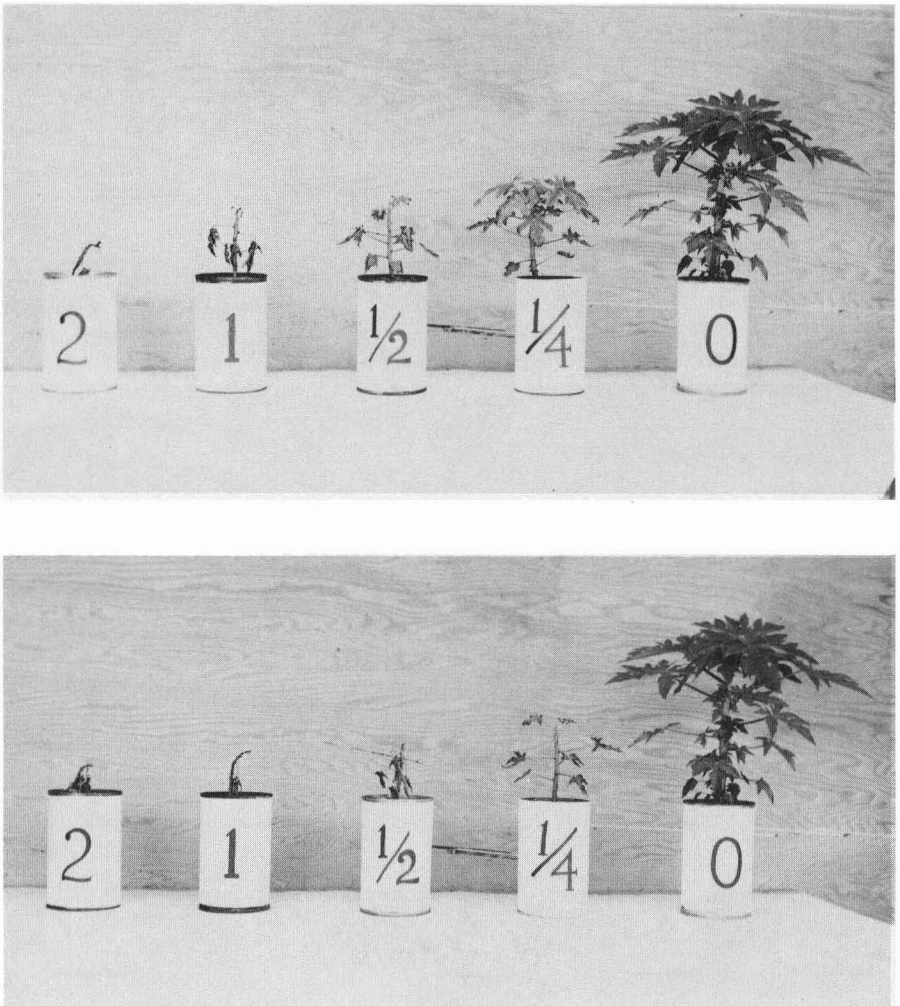


Fig. 22. Papaya, two weeks after the third application of dimetilan emulsion (top) and wettable powder (bottom) concentrations.

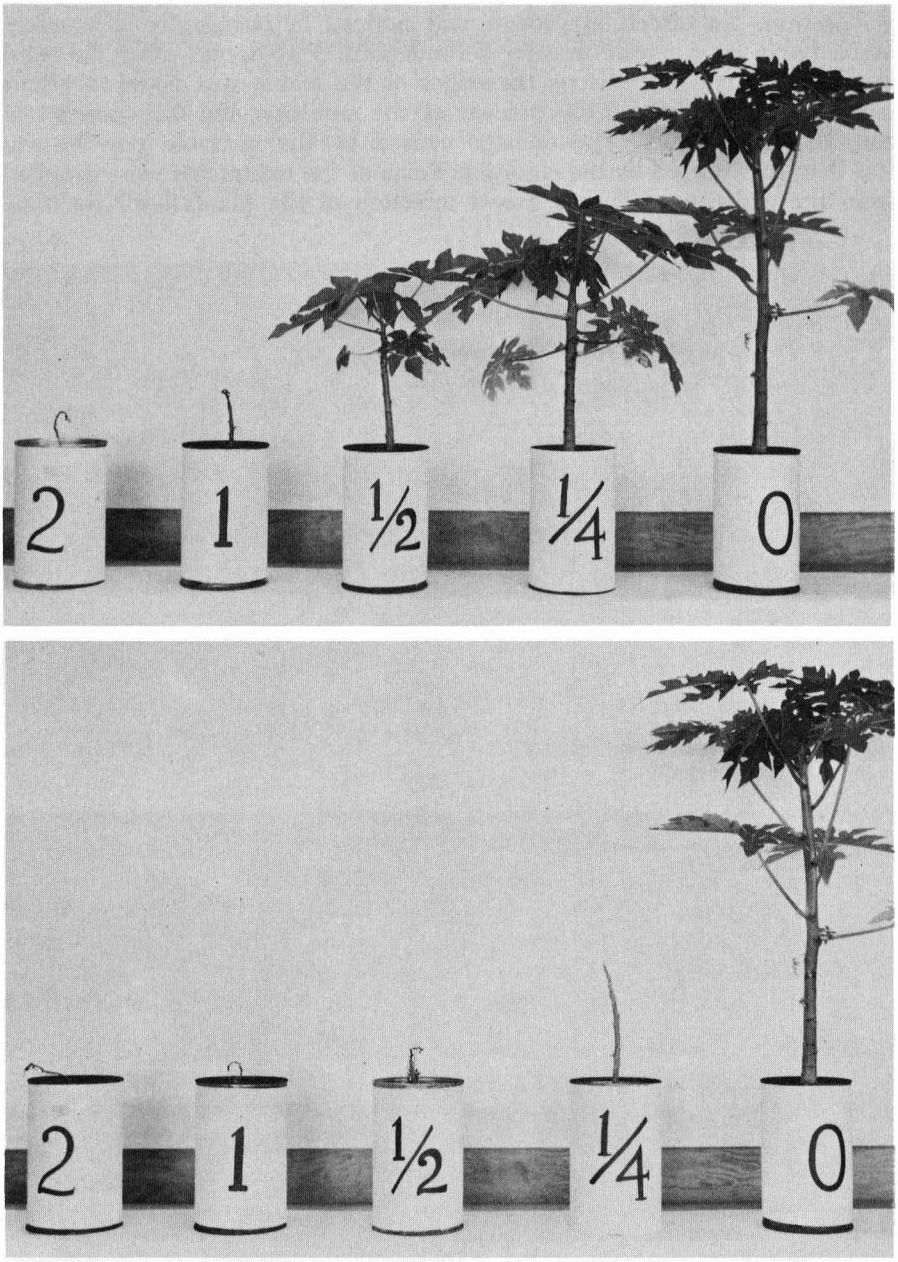
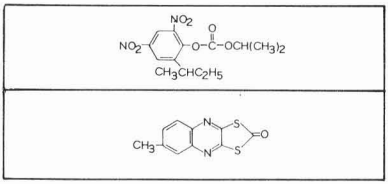


Fig. 23. Papaya, six weeks after treatment with three weekly applications of dimetilan emulsion (top) and wettable powder (bottom) concentrations.

CARBONATES

The effects of the following two compounds were investigated:



(1) Dessin®, 2-*sec* butyl 4, 6-dinitrophenol isopropyl carbonate, a 50 percent wettable powder;
(2) Morestan®, 6-methyl-2,3-quinoxalinedithiol cyclic *S,S*-dithiocarbonate, a 25 percent wettable powder.

Table 7 summarizes the effects of the carbonates on the growth of the papaya.

Dessin. Treatment with 0.25 percent wettable powder significantly affected growth. One week after the first spray application leaves treated with 0.25 and 0.125 percent concentrations were necrotic, particularly at the tips and along the edges. The lower concentrations of 0.062 and 0.031 percent caused no foliar abnormalities. By the second week, the areas of the leaves previously necrotic had torn off. These symptoms were present throughout the period of observation.

Morestan. The wettable powder formulation had no effect on the growth of the papaya. Foliar injury was evident one week after the first spray application. Plants treated with 0.25 percent of the wettable powder were severely burned; white, necrotic areas appeared on the upper surface

Table 7. Effect of carbonates on the growth of the Solo papaya

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Dessin®		
50 W.P.	2	0.25	12.7	8.7**
	1	0.125	11.8	10.4
	0.5	0.062	11.8	10.8
	0.25	0.031	12.2	11.9
		Morestan®		
25 W.P.	2	0.25	9.9	10.6
	1	0.125	10.7	13.1
	0.5	0.062	10.1	12.4
	0.25	0.031	12.1	14.4
Control	—	—	11.4	12.8
				L.S.D. (1%): 3.4

[a] W.P. = wettable powder. Sprays were applied March 12, 19, and 26, 1964. Triton B-1956 was added to all sprays at 1:2,000.
[b] Measurements were taken one day before first spray application.
[c] Final measurements were taken on April 9, 1964.
** Growth significantly inferior to that of control plants.

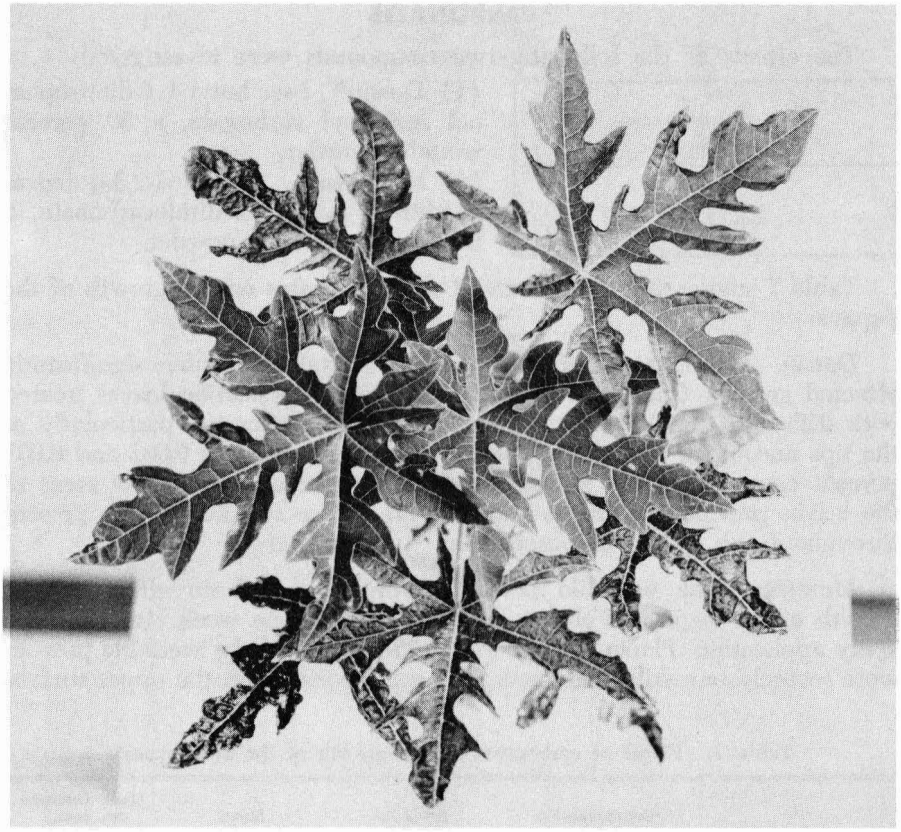


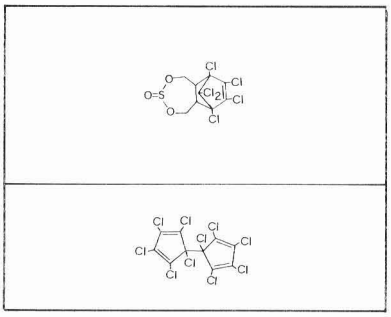
Fig. 24. Close-up of foliar damage in papaya, two weeks after three applications of 0.25 percent Morestan wettable powder. Note normal leaves and badly damaged older leaves.

of the older leaves and the younger leaves appeared crinkled and distorted. Plants treated with 0.125 percent wettable powder showed less of the same kind of damage. Treatment with the lower concentrations had no detrimental effect.

Two weeks after the third spray application the older leaves of the plants treated with 0.25 percent of the wettable powder were crinkled and distorted while the newer leaves were normal (Fig. 24). Damage decreased with decreasing concentration.

CHLORINATED ARYL HYDROCARBONS

The effects of the following two compounds were studied:



(1) endosulfan, 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin 3-oxide, a 25 percent wettable powder and a miscible concentrate containing 2 pounds of technical endosulfan per gallon;

(2) Pentac®, bis (pentachloro-2,4-cyclopentadien-1-yl), a 50 percent wettable powder and an emulsifiable concentrate containing 1.5 pounds per gallon.

Table 8. Effect of chlorinated hydrocarbons on the growth of the Solo papaya

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Endosulfan		
Miscible (2 lb. act./gal.)	2	0.25	14.3	12.7
	1	0.125	13.4	12.8
	0.5	0.062	12.0	15.8
	0.25	0.031	12.1	14.4
25 W.P.	2	0.25	13.5	12.7
	1	0.125	12.3	15.1
	0.5	0.062	12.3	16.5
	0.25	0.031	12.1	14.7
Control	—	—	12.0	13.5
				N.S.D.
		Pentac®		
E.C. (1.5 lb. act./gal.)	2	0.25	11.2	7.2**
	1	0.125	10.6	8.0**
	0.5	0.062	10.8	11.6
	0.25	0.031	9.0	11.9
50 W.P.	2	0.25	9.2	14.9
	1	0.125	9.4	13.8
	0.5	0.062	9.9	14.6
	0.25	0.031	9.9	13.4
Control	—	—	11.4	12.8
				L.S.D. (1%): 3.4

[a] W.P. = wettable powder; E.C. = emulsifiable concentrate. Sprays were applied as follows: endosulfan, July 12, 19, and 26, 1962; Pentac, March 12, 19, and 26, 1964. Triton B-1956 was added to all sprays at 1:2,000.

[b] Measurements were taken one day before first spray application.

[c] Final measurements were taken on August 3, 1962, for endosulfan and April 9, 1964, for Pentac.

** Growth significantly inferior to that of control plants.

Table 8 summarizes the effect of the chlorinated hydrocarbons on the growth of the papaya.

Endosulfan. No effect on growth or foliage was noted after treatment with either the miscible liquid or wettable powder formulation.

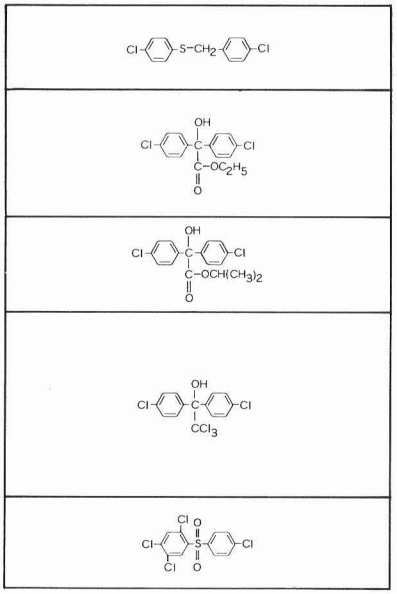
Pentac. Treatment with 0.25 and 0.125 percent of the emulsifiable formulation significantly affected growth but the wettable powder had no effect on growth.

One week after the first spray application, plants treated with 0.25 and 0.125 percent emulsion showed severe foliar symptoms; younger leaves were thickened, distorted, and spidery while the older leaves showed slight tip-burn and chlorosis. At the lower 0.062 and 0.031 percent concentrations, the emulsion caused only slight injury, particularly chlorosis in the younger leaves. Treatment with 0.25 and 0.125 percent of the wettable powder caused less damage than half the concentration of the emulsion but the younger leaves were thicker than normal and chlorotic, and exhibited necrotic spots along the veins.

Two weeks after the third spray, all plants treated with the emulsion had leaves that were distorted and thick. The wettable powder treatments affected the foliage far less. Damage caused by the 0.25 percent wettable powder was equivalent to that caused by the 0.062 percent emulsion.

ACARICIDES

The effects of the following acaricidal formulations were studied:



(1) chlorbenside, *p*-chlorobenzyl *p*-chlorophenyl sulfide, a 40 percent wettable powder;

(2) chlorobenzilate, ethyl 4,4'dichlorobenzilate, an emulsifiable concentrate containing 4 pounds of technical chlorobenzilate per gallon;

(3) Chloropropylate®, 2,3-isopropyl 4,4'-dichlorobenzilate, a 25 percent emulsifiable concentrate;

(4) dicofol, 4,4'-dichloro-*alpha*-(trichloromethyl)benzhydrol, a 25 percent wettable powder; an emulsifiable concentrate and a miscible formulation, both containing 2 pounds of technical dicofol per gallon;

(5) tetradifon, *p*-chlorophenyl 2,4,5-trichlorophenyl sulfone, a 25 percent wettable powder;

(6) Volck Supreme Oil Spray, 98 percent petroleum oils, unsulfonated residue 92 percent, 6.94 pounds per gallon.

Table 9 summarizes the effect of these acaricides on the growth of the papaya.

Chlorbenside. No effect on growth was noted after treatment with the wettable powder formulation. The only foliar symptoms noted were on the leaves of plants treated with the 0.25 percent suspension, a slight mosaic and browning of the upper surface of the older leaves.

Chlorobenzilate. Treatment with 0.25 and 0.125 percent emulsion caused significant growth retardation. These treatments also caused severe burning along the edges and the middle of the leaves, particularly of the older leaves. Two weeks after the third spray, plants receiving the two higher concentrations were defoliated and the edges of the remaining leaves were necrotic. The older leaves of plants treated with 0.062 percent emulsion were less burned and the lowest concentration of 0.031 percent had no detrimental effect on the plants.

Chloropropylate. Concentrations as low as 0.062 percent of the emulsion significantly affected the growth of the papaya. The major foliar effects were chlorosis of the leaves and necrosis along the leaf edges.

Dicofol. The wettable powder formulation had no effect on growth but 0.25 percent of the emulsifiable formulation, and 0.125 percent of the miscible formulation significantly affected growth.

No foliar damage was caused at any time by treatment with the wettable powder formulation. Of the two liquid formulations, miscible formulation was more damaging. Two weeks after the third spray application, the 0.25 percent miscible formulation caused severe defoliation. The 0.125 percent concentration caused less severe defoliation but tip burn was very obvious. The 0.062 percent concentration caused only slight tip burn and necrosis, while the 0.031 percent caused only minor injury.

Tetradifon. No effect on growth or foliage was noted after treatment with the wettable powder.

Volck Supreme Oil Spray. No effect on growth was noted. Some of the older leaves on plants treated with 0.25 and 0.125 percent concentrations had edges rolling in an upward position (Fig. 25). With this exception, all plants were unaffected.

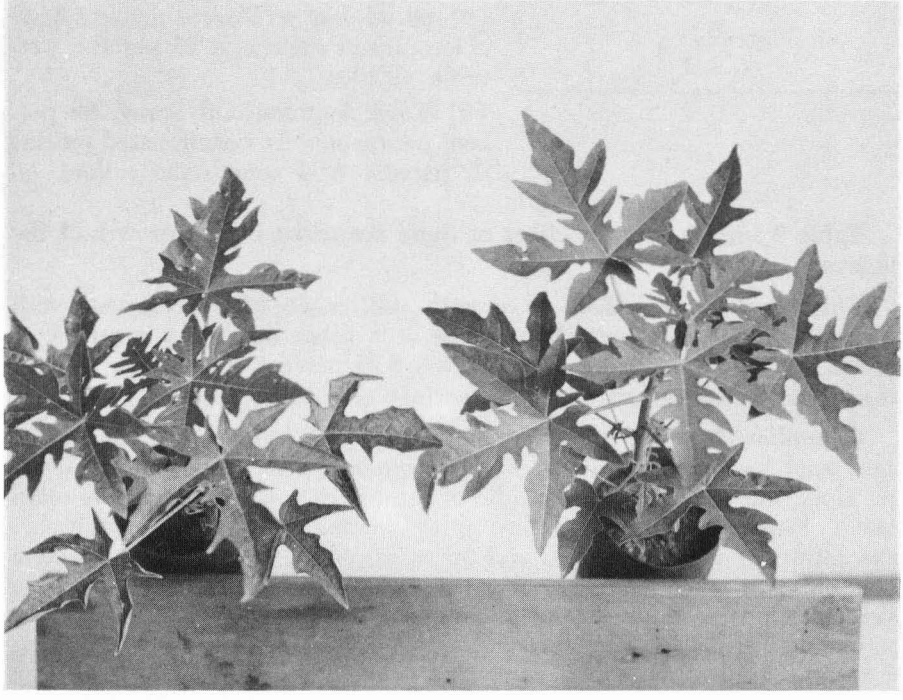


Fig. 25. Upward rolling of leaves of papaya treated with 0.25 percent Volck Supreme Oil Spray (left). Normal plant on right.

Table 9. Effect of acaricides on the growth of the Solo papaya

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Chlorbenside		
40 W.P.	2	0.25	13.2	11.7
	1	0.125	11.0	14.6
	0.5	0.062	12.0	13.7
	0.25	0.031	10.5	12.8
Control	—	—	11.4	12.8
				N.S.D.
		Chlorobenzilate		
50 E.C.	2	0.25	10.0	6.2**
(4 lb. act./gal.)	1	0.125	9.0	10.6**
	0.5	0.062	9.0	20.2
	0.25	0.031	11.4	17.2
		Chloropropylate®		
25 E.C.	2	0.25	11.4	6.8**
(0.64 gm. act./ml.)	1	0.125	10.4	10.4**
	0.5	0.062	11.5	13.5**
	0.25	0.031	11.2	23.0
		Dicofol		
25 W.P.	2	0.25	11.2	16.6
	1	0.125	11.0	20.6
	0.5	0.062	11.5	19.6
	0.25	0.031	10.0	21.3
E.C.	2	0.25	11.4	6.8**
(2 lb. act./gal.)	1	0.125	10.4	20.1
	0.5	0.062	10.9	21.0
	0.25	0.031	10.9	23.6
M.F.	2	0.25	10.8	5.2**
(2 lb. act./gal.)	1	0.125	10.2	11.9**
	0.5	0.062	11.0	22.4
	0.25	0.031	11.0	19.4
Control	—	—	10.2	22.7
				L.S.D. (1%): 6.1
		Tetradifon		
25 W.P.	2	0.25	5.6	12.6
	1	0.125	6.1	14.4
	0.5	0.062	6.0	12.5
	0.25	0.031	6.9	13.4
Control	—	—	6.4	12.7
				N.S.D.

Table 9 (continued)

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		Petroleum Oil		
Volck Supreme Oil Spray (6.94 lb./gal.)	2	0.25	8.7	10.6
	1	0.125	9.4	10.9
	0.5	0.062	8.8	12.3
	0.25	0.031	9.0	11.0
Control	—	—	8.8	10.6
				N.S.D.

[a] W.P. = wettable powder; E.C. = emulsifiable concentrate; M.F. = miscible formulation. Sprays were applied as follows: tetradifon, August 10, 17, and 24, 1962; chlorobenzilate, Chloropropylate and dicofol, May 27, June 3 and 10, 1963; Volck Supreme Oil Spray, January 16, 23, and 30, 1964; and chlorbenside, March 12, 19, and 26, 1964. Triton B-1956 was added to all sprays at 1:2,000.

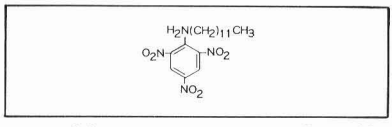
[b] Measurements were taken one day before first spray application except for chlorobenzilate-, Chloropropylate- and dicofol-treated plants which were measured five days before treatment.

[c] Final measurements were taken on August 31, 1962, for tetradifon; June 24, 1963, for chlorobenzilate,· Chloropropylate, and dicofol; February 13, 1964, for Volck Supreme Oil Spray; and April 9, 1964, for chlorbenside.

** Growth significantly inferior to that of control plants.

INSECT REPELLANT

The phytotoxic effects of an experimental chemical were studied:



(1) TD-211, dodecylamine picrate, a 50 percent wettable powder formulation exhibiting repellant properties to a number of insect species.

Table 10 summarizes the effect on the growth of the papaya of applying TD-211. No effect on growth was noted. Only minor foliar tip burn and a slight chlorosis was evident in those plants treated twice with the highest concentration. All plants were normal two weeks after the third application.

Table 10. Effect of dodecylamine picrate on the growth of the Solo papaya

Formulation[a]	Concentration actual lb./100 gal.	Percent actual insecticide	Mean ht. (cm.) pre-spray[b]	Mean increase ht. (cm.) 2 weeks after 3rd spray[c]
		TD-211		
50 W.P.	2	0.25	9.9	18.9
	1	0.125	10.1	18.1
	0.5	0.062	11.0	20.0
	0.25	0.031	10.6	20.8
Control	—	—	11.4	12.8
				N.S.D.

[a] W.P. = wettable powder. Sprays were applied March 12, 19, and 26, 1964. Triton B-1956 was added to all sprays at 1:2,000.

[b] Measurements were taken one day before first spray application.

[c] Final measurements were taken on April 9, 1964.

DISCUSSION

In an earlier study on the phytotoxicity of insecticidal and acaricidal formulations to the papaya, Sherman and Tamashiro (1959) gave the effects of six organophosphates, three synthetic acaricides, four chlorinated hydrocarbon insecticides, sulfur, and a triethanolamine salt of dinitro-o-sec butylphenol. All of the organophosphates except malathion caused retardation of growth and foliar injury after application. The emulsifiable formulations caused more severe reactions than did equivalent concentrations of the wettable powders.

In the present study, a greater number and variety of compounds were investigated. Many of the organophosphorus insecticides studied were non-toxic to the papaya seedlings. Although in general the emulsifiable form of a particular pesticide was more toxic than the suspension, in a number of instances the wettable powder formulation was more toxic to the plant than equivalent concentrations of the emulsifiable formulation. These did not belong to any particular group of compounds but were distributed among several, e.g., Bomyl, a phosphate; carbophenothion, a phosphorodithioate; and two carbamates, Dimetilan and Pyramat. Ordinarily, one would expect the smaller particle size and the greater solubility of a toxicant in the emulsion form to increase foliar penetration and possibly cause increased phytotoxicity. There is no doubt that the inherent toxicity of the solvents and surfactants used in the preparation of both types of formulation plays a very important role in phytotoxicity. Gast and Early (1956), among others, reported that much of the phytotoxicity caused by agricultural sprays was due to the surfactant rather than to the solvent or the pesticide. Nakata and Tanada (1961) found that lychee leaves were susceptible to both ionic and non-ionic surfactants. In the present study, since all of the preparations were proprietary or commercial formulations, it can be safely assumed that surfactants played a particularly important role in the determination of phytotoxicity.

Four compounds in particular were extremely damaging to the papaya in that they actually killed the plant—propyl thiopyrophosphate, dioxathion, Dimetilan, and Pyramat. In the previous study it was almost impossible to kill the papaya seedling. Despite retardation of growth, loss of leaves, and the exhibition of other phytopathological symptoms, actual mortality due to chemical action of an insecticide or acaricide did not occur previously. These four materials, however, at the concentration levels used in this study, were sufficiently toxic to cause death of the plants.

The syndrome exhibited by plants treated with chlorobenzilate in the present study was quite different from the one exhibited by plants in the previous study (Sherman and Tamashiro, 1959). Earlier, all plants treated with chlorobenzilate as either a 25 percent wettable powder or a 25 percent emulsifiable concentrate had a mosaic type of chlorosis which increased with concentration. No such syndrome was caused by the 50 percent emulsifiable concentrate used in the present study.

SUMMARY

The phytotoxicity to papaya of 72 commercial formulations of 50 insecticidal and acaricidal pesticide chemicals was determined. Phytotoxicity was determined by measuring the effect on seedling growth and by gross foliar pathology. Table 11 summarizes the effects of applying these pesticides. Although generally the wettable powders were less phytotoxic than equivalent concentrations of the emulsifiable formulations, Bomyl, carbophenothion, trichlorfon, UC 8305, Dimetilan, and Pyramat were more toxic as wettable powders.

Table 11. Summary of the effects of pesticides on the Solo papaya

Pesticide formulation	Concentration actual lb./100 gal.	Retardation of growth[1]	Foliar injury[2]
Azinphosmethyl Emulsifiable Conc.	2.0	+	+++
	1.0	+	++
	0.5	0	+
	0.25	0	0
Azinphosmethyl Wettable Powder	2.0	0	0
	1.0	0	0
	0.5	0	0
	0.25	0	0
Bayer 32651 Emulsifiable Conc.	2.0	+	++
	1.0	0	+
	0.5	0	0
	0.25	0	0
Bayer 37289 Emulsifiable Conc.	2.0	0	+
	1.0	0	+
	0.5	0	0
	0.25	0	0
Bayer 37344 Wettable Powder	2.0	0	0
	1.0	0	0
	0.5	0	0
	0.25	0	0
Bayer 39197 Wettable Powder	2.0	+	++
	1.0	0	+
	0.5	0	+
	0.25	0	+
Bay 41831 Emulsifiable Conc.	2.0	0	+
	1.0	0	0
	0.5	0	0
	0.25	0	0
Bay 41831 Solubilized Conc.	2.0	+	++
	1.0	0	+
	0.5	0	0
	0.25	0	0
Bay 41831 Wettable Powder	2.0	0	+
	1.0	0	+
	0.5	0	0
	0.25	0	0

Table 11.—continued (2)

Pesticide formulation	Concentration actual lb./100 gal.	Retardation of growth[1]	Foliar injury[2]
Bayer 46676 Emulsifiable Conc.	2.0	+	+++
	1.0	+	+++
	0.5	+	++
	0.25	+	++
Bayer 47185 Wettable Powder	2.0	0	+
	1.0	0	0
	0.5	0	0
	0.25	0	0
Bayer 50282 Wettable Powder	2.0	0	+
	1.0	0	0
	0.5	0	0
	0.25	0	0
Bidrin® Technical Grade	2.0	+	+++
	1.0	+	+++
	0.5	+	+++
	0.25	0	++
Bomyl® Emulsifiable Conc.	2.0	+	+++
	1.0	+	++
	0.5	+	++
	0.25	+	+
Bomyl® Wettable Powder	2.0	++	+++
	1.0	+	+++
	0.5	+	++
	0.25	+	++
Carbaryl Wettable Powder	2.0	0	+
	1.0	0	0
	0.5	0	0
	0.25	0	0
Carbophenothion Emulsifiable Conc.	2.0	++	+++
	1.0	+	+++
	0.5	+	++
	0.25	+	++
Carbophenothion Wettable Powder	2.0	+	+++
	1.0	+	+++
	0.5	+	++
	0.25	+	++
Chlorbenside Wettable Powder	2.0	0	+
	1.0	0	0
	0.5	0	0
	0.25	0	0
Chlorobenzilate Emulsifiable Conc.	2.0	+	+++
	1.0	+	+++
	0.5	0	++
	0.25	0	0

Table 11.—continued (5)

Pesticide formulation	Concentration actual lb./100 gal.	Retardation of growth[1]	Foliar injury[2]
Chloropropylate®	2.0	+	+++
Emulsifiable Conc.	1.0	+	++
	0.5	+	+
	0.25	0	0
Ciodrin®	2.0	++	+++
Technical Grade	1.0	+	++
	0.5	0	++
	0.25	+	++
Ciodrin®	2.0	++	+++
Emulsifiable Conc.	1.0	+	++
	0.5	+	++
	0.25	+	++
Dessin®	2.0	+	+
Wettable Powder	1.0	0	+
	0.5	0	0
	0.25	0	0
Diazinon	2.0	+	+++
50 Emulsifiable Conc.	1.0	+	+++
	0.5	+	++
	0.25	+	++
Diazinon	2.0	+	++
25 Emulsifiable Conc.	1.0	+	+
	0.25	0	+
Diazinon	2.0	+	++
Wettable Powder	1.0	+	+
	0.5	0	+
	0.25	0	+
Dichlorvos	2.0	0	0
Technical Grade	1.0	0	0
	0.5	0	0
	0.25	0	0
Dichlorvos	2.0	0	0
Emulsifiable Conc.	1.0	0	0
	0.5	0	0
	0.25	0	0
Dicofol	2.0	+	+++
Emulsifiable Conc.	1.0	0	+
	0.5	0	0
	0.25	0	0
Dicofol	2.0	+	+++
Miscible Formulation	1.0	+	++
	0.5	0	+
	0.25	0	+

Table 11.—continued (8)

Pesticide formulation	Concentration actual lb./100 gal.	Retardation of growth[1]	Foliar injury[2]
Dicofol Wettable Powder	2.0	0	0
	1.0	0	0
	0.5	0	0
	0.25	0	0
Dimethoate Emulsifiable Conc.	2.0	+	++
	1.0	+	+
	0.5	0	+
	0.25	0	0
Dimethoate Wettable Powder	2.0	+	+
	1.0	0	+
	0.5	0	0
	0.25	0	0
Dimetilan Emulsifiable Conc.	2.0	++	+++
	1.0	+	+++
	0.5	+	+++
	0.25	+	+++
Dimetilan Wettable Powder	2.0	all plants killed	
	1.0	all plants killed	
	0.5	all plants killed	
	0.25	all plants killed	
Dioxathion Emulsifiable Conc.	2.0	all plants killed	
	1.0	all plants killed	
	0.5	++	+++
	0.25	++	+++
Dioxathion Wettable Powder	2.0	++	+++
	1.0	++	+++
	0.5	+	+++
	0.25	+	+++
Endosulfan Miscible	2.0	0	0
	1.0	0	0
	0.5	0	0
	0.25	0	0
Endosulfan Wettable Powder	2.0	0	0
	1.0	0	0
	0.5	0	0
	0.25	0	0
Imidan® Emulsifiable Conc.	2.0	+	+
	1.0	0	+
	0.5	0	0
	0.25	0	0
Imidan® Wettable Powder	2.0	0	0
	1.0	0	0
	0.5	0	0
	0.25	0	0

Table 11.—continued (10)

Pesticide formulation	Concentration actual lb./100 gal.	Retardation of growth[1]	Foliar injury[2]
Isolan®	2.0	+	+++
Emulsifiable Conc.	1.0	+	++
	0.5	+	+
	0.25	0	+
Menazon	2.0	0	0
Wettable Powder	1.0	0	0
	0.5	0	0
	0.25	0	0
Methyl Trithion®	2.0	0	+
Emulsifiable Conc.	1.0	0	+
	0.5	0	0
	0.25	0	0
Mevinphos	2.0	0	++
Emulsifiable Conc.	1.0	0	++
	0.5	0	++
	0.25	0	++
Morestan®	2.0	0	++
Wettable Powder	1.0	0	++
	0.5	0	+
	0.25	0	0
Naled	2.0	0	0
Emulsifiable Conc.	1.0	0	0
	0.5	0	0
	0.25	0	0
Nemacide®	2.0	+	++
Emulsifiable Conc.	1.0	0	++
	0.5	0	+
	0.25	0	+
Oxydemetonmethyl	2.0	0	++
Emulsifiable Conc.	1.0	0	+
	0.5	0	+
	0.25	0	0
Pentac®	2.0	+	++
Emulsifiable Conc.	1.0	+	++
	0.5	0	++
	0.25	0	+
Pentac®	2.0	0	+
Wettable Powder	1.0	0	+
	0.5	0	0
	0.25	0	0
Phosphamidon	2.0	+	++
Emulsifiable Conc.	1.0	0	+
	0.5	0	+
	0.25	0	+

Table 11.—continued (12)

Pesticide formulation	Concentration actual lb./100 gal.	Retardation of growth[1]	Foliar injury[2]
Propyl Thiopyrophosphate Emulsifiable Conc.	2.0	all plants killed	
	1.0	all plants killed	
	0.5	all plants killed	
	0.25	all plants killed	
Pyramat® Emulsifiable Conc.	2.0	all plants killed	
	1.0	+	+++
	0.5	+	+++
	0.25	+	++
Pyramat® Wettable Powder	2.0	all plants killed	
	1.0	+	+++
	0.5	+	+++
	0.25	+	+++
SD 7438 Emulsifiable Conc.	2.0	0	++
	1.0	0	+
	0.5	0	0
	0.25	0	0
TD-72 Emulsifiable Conc.	2.0	+	+++
	1.0	+	++
	0.5	+	++
	0.25	+	++
TD-211 Wettable Powder	2.0	0	0
	1.0	0	0
	0.5	0	0
	0.25	0	0
Temik® Emulsifiable Conc.	2.0	0	0
	1.0	0	0
	0.5	0	0
	0.25	0	0
Tetradifon Wettable Powder	2.0	0	0
	1.0	0	0
	0.5	0	0
	0.25	0	0
Thiocron® Emulsifiable Conc.	2.0	0	+
	1.0	0	+
	0.5	0	+
	0.25	0	0
Thiocron® Wettable Powder	2.0	0	+
	1.0	0	+
	0.5	0	+
	0.25	0	0
Tranid® Emulsifiable Conc.	2.0	0	+
	1.0	0	+
	0.5	0	0
	0.25	0	0

Table 11.—continued (13)

Pesticide formulation	Concentration actual lb./100 gal.	Retardation of growth[1]	Foliar injury[2]
Trichlorfon	2.0	0	+
Liquid Solution	1.0	0	+
	0.5	0	+
	0.25	0	+
Trichlorfon	2.0	+	+
Wettable Powder	1.0	0	0
	0.5	0	0
	0.25	0	0
UC 8305	2.0	0	+
Emulsifiable Conc.	1.0	0	0
	0.5	0	0
	0.25	0	0
UC 8305	2.0	0	+
Wettable Powder	1.0	0	+
	0.5	0	0
	0.25	0	0
UC 10854	1.0	0	0
Emulsifiable Conc.	0.5	0	0
	0.25	0	0
UC 10854	2.0	0	0
Wettable Powder	1.0	0	0
	0.5	0	0
	0.25	0	0
Volck Supreme Oil Spray	2.0	0	0
Emulsifiable Conc.	1.0	0	0
	0.5	0	0
	0.25	0	0
Zectran®	2.0	0	+
Emulsifiable Conc.	1.0	0	+
	0.5	0	0
	0.25	0	0
Zectran®	2.0	0	+
Wettable Powder	1.0	0	0
	0.5	0	0
	0.25	0	0

[1] ++ Terminal growing tips killed.
+ Significant retardation of growth.
0 No retardation of growth.

[2] +++ Severe injury: defoliation.
++ Moderate injury: necrosis, chlorosis, tip-burn.
+ Slight injury: necrosis, chlorosis, tip-burn.
0 Insignificant to no injury, normal leaves, some spotting.

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