STUDIES OF THE INFLUENCE OF PESTICIDES ON GROWTH AND YIELDS OF VEGETABLES

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ABSTRACT

STUDIES OF THE INFLUENCE OF PESTICIDES
ON GROWTH AND YIELDS OF VEGETABLES

By

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Two years results indicated that pesticides may influence growth and yield of vegetable crops in ways other than by pest control. Several agricultural chemicals were shown to increase early yields of muskmelons (*Cucumis melo* L. cv. Burpee Hybrid) and tomatoes (*Lycopersicon esculentum* L. cv. Jet Star) in 1972. Disulfoton (*O,O*-diethyl *S*-(2-[ethylthio] ethyl) phosphorodithioate) at 1.12 kg/ha was especially effective for increasing early melon yield. Agricultural chemicals were more effective in altering plant growth under less desirable growing conditions of 1972, than in 1971. Total melon weights in 1972 were increased significantly by bensulide (*S*-(*O,O*-diisopropyl phosphorodithioate ester of *N*-(2-mercaptoethyl) benzenesulfonamide), naptalam (*N*-1-napthylphthalamic acid), trifluralin (*α,α,α*-trifluoro-2,6-dinitro-N, *N*-dipropyl-*p*-toluidine), and disulfoton with the lowest concentrations generally resulting in largest increase in yield. Largest yield for each chemical occurred at 3.4 kg/ha of dinoseb (2,4-dinitro-6-*sec*-butylphenol) 3.4 kg/ha of bensulide, 2.2 kg/ha of naptalan and 1.1 or 2.2 kg/ha of disulfoton.

Dennis Edward Deyton

Flowering of tomato plants was modified by application of dinoseb, naptalam, and disulfoton. These chemicals were observed to increase fasciated flowers, and polychotomous branching of clusters. Naptalam significantly increased the occurrence of seedlessness.

Yield of beans (*Phaselous vulgaris* L. cv. Próvider) was increased by all chemicals, except naptalam. Trifluralin and disulfoton resulted in the largest increases in yield. The increased yield corresponded to increased stand with each chemical except naptalam. Lowest concentrations gave greater increases of yield or stand. than the control.

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By

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TABLE OF CONTENTS

LIST OF TABLES

TABLE Page

LIST OF FIGURES

FIGURE Page

INTRODUCTION

Pesticides are valued for their control of undesirable pests. Their value is generally determined by their ability to control a pest without excessive damage to the crop. Thus, pesticide research has often centered upon what chemicals will provide adequate control of a pest with minimum acceptable damage to the crop.

Although the importance of research emphasis on pest control is self-evident, perhaps more emphasis should be placed on the direct effect of the chemicals on crop growth. The gaining of "a better understanding of the existing herbicides might be more productive than the continued research and development of new pesticides" (63). It has often been difficult to determine what might have been direct effects on crop growth. There have been numerous reports of yield increases associated with pesticide use. Difficulty lies in determining if the increase was due to elimination of the pest or if some increase may have been contributed to a direct stimulation of crop growth. It is especially interesting to observe the activity of herbicides, which may retard growth of some plants, not effect the growth of others, and may even stimulate growth in some plants.

Devlin (11) defines plant growth regulators as organic compounds which in small amounts promote, inhibit, or otherwise modify any physiological processes in plants. Thus many of our organic herbicides, which are often used in very small quantities may meet the criteria of this definition. Even sublethal concentrations of pesticides that would not control pests can modify the growth of plants (58).

The purpose of this study was to determine the influence of pesticides on the growth of vegetable plants. Special emphasis will be placed on determining promotion of plant growth.

REVIEW OF LITERATURE

Pesticides may influence plant growth in various ways. More obvious additional influences of a pesticide may be in supplying of some nutrient to plants. For example, Klingman (27) recommended the use of ammonium nitrate solution as a directed contact herbicide for corn. The spray solution served the dual benefit of controlling weed growth and supplying nitrogen to corn.

The metal based fungicides supply trace nutrients to plants. Application of zineb (zinc ethylenebisdithiocarbamate), a fungicide, has resulted in a ten-fold increase in zinc accumulation in strawberries (10). This is an obvious benefit where zinc is deficient. Increased yields of grapes treated with zineb were reported by Baldacci and Bonola (6); and Webster et al. (56) reported that another fungicide, maneb (manganese ethylene-1,2-bisdithiocarbamate) stimulated growth of lima bean plants.

Many other pesticides have been reported to cause an increase in growth or development by some manner more complex than just supplying a deficient nutrient. Hughes (22) reported that the insecticide, dieldrin (1,2,3,4,10,10-hexachloro-exo-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-exo-5,8-dimethanonaphthalene), stimulated an increase in mean fresh weight of harvested cabbage that could not be attributed to insect control. Maclagan (32) reported that dieldrin and BHC (benzene hexachloride) stimulated growth and development of a larger percentage of longer roots in parsnip seedlings. Allen and Casida (4) found that BHC stimulated bean stem growth and Gould (16) found that it affected floral growth of tomatoes, with aerial applications to blossoms resulting in a marked increase in tomato yield. Another insecticide, aldrin (1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4-endo-exo-5,8-dimethano-naphthalene), has been reported by Jones (23) to stimulate an increase in the yield of carrots, which could not be attributed to insect control.

Long et al. (29) reported that during the first 11 weeks of growth under greenhouse conditions, chlorodane (octachloro-4,7-methanotetrahydro-indane) enhanced sugar cane growth by 58%, while insects were responsible for reductions in plant weight ranging from 21 to 30%. They observed that, "It seems likely that the stimulating effects of chlorodane on growth may be at least as important as the control of any anthropod pest."

Several researchers have found that DDT (dichloro diphenyl trichloro-ethane) may have a regulatory effect on plant growth. Chapman and Allen (9) found that higher concentrations of DDT restricted plant growth, yet lower concentrations stimulated growth in some plants. Aerial applications stimulated maximum vegetative growth of squash and cucumber at 0.0005 percent, tomato at 0.008 percent, and carrot and potato at 0.512 percent. They suggested that the effects of DDT "closely resemble that of some plant hormones." Allen and Casida (4) noted DDT stimulated bean stem growth when auxin was absent in nutrient solution. A possible relationship was suggested between DDT and auxin.

Besides affecting vegetative growth, DDT at low rates has been observed to affect floral development. Chapman and Allen (9) observed in cucumbers that as DDT stimulated vegetative growth, the number of blossoms also increased proportionally. Rao (44) reported that spraying tomato vines with DDT resulted in 4.8 fruit weighing 95 grams compared to 0.38 fruit per vine weighing 6.2 grams on unsprayed plants, which was apparently due to stimulation as there was no insect infestion problem.

Brown et al. (7) cited an increase in cotton boll production and yield when DDT was applied at weekly intervals beginning with the appearance of the first squares and flowers. This increase occurred without effecting leaf number or dry weight. Hacskalyo and Scales (18) observed that DDT in combination with dieldrin retarded flower formation, boll set, and plant growth. They also noted that the systemic insecticide Guthion (O,O-dimethyl S-(4-oxo-1,2,3-benzotrianzin-3(4H)-lymethyl) phosphorodithioate) at 0.25 lb/A increased the number of flowers on cotton plants.

Herbicides also function as growth regulators. Taylor and Arnst (53) reported that trifluralin (α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine) at 1 lb/A preplant incorporated resulted in a 40% pea yield increase. As the experiment was designed to examine weed control, the question remains whether the increased yield was due only to weed control or partially to growth stimulation.

Kesner and Ries (26), examining the effect of low concentrations of diphenamid (N,N-dimethyl-2,2-diphenylacetamide) on tomato plants in pots found low concentrations enhanced vine growth. Diphenamid was observed to increase the growth of two fungi whose filtrate stimulated growth.

Researchers have tried to determine how herbicides may affect plant growth. Many have noted an effect on ion uptake or accumulation in the plant. For example, Ries et al. (46), reported that peach trees treated with a mixture of simazine (2-chloro-4,6-bis(ethyl amino)-s-triazine), amitrole (3-amino-1,2,4-triazole), and amitrole-T (amitrole plus ammonium thiocyanate) contained higher leaf nitrogen and produced longer terminal growth than trees where weeds were controlled by hand. The concentration of other ions has been found to be influenced by the concentration of the triazines. Millikan et al. (35) found that simazine concentration of 0.5, 1, and 2 ppm resulted in an increase in phosphorus and zinc concentrations in the first true leaves of soybeans. Other ions observed to increase were K, Mn, and Si while Ca, Mg, B, Sr, Mo, Co, and Ba were reduced by more than 50% as compared to high phosphorus treatments. Ruiz (49) found that 1/8 lb/A of simazine applied on peas resulted in an increase in K and Ca accumulation.

Researchers have reported various results for the phenol herbicides. Wojtasek (60) conducted a test to determine how DNBP (4,6-dinitro-o-sec-butylphenol) inhibited accumulation of P^{32} and the incorporation of ADP into ATP. Ruiz (49) found that DNBP caused a 25% increase in accumulation of phosphorus and reduced sodium accumulation by 65% in peas and that combinations involving DNBP resulted in over a 25% increase in Cu and Zn accumulation. Nwachuka (40) indicated that DNP reduced potassium uptake of castor bean plants grown in water culture, but sodium absorption was increased.

Nashed and Ilnicki (38) observed an increase absorption of calcium and sulfate from nutrient solution by juvenile corn, soybeans, and large crabgrass when treated by linuron (3-[3,4-dichlorophenyl]-1-methoxy-1-methylurea). Houge (21) conducted a test noting the effects of both letha

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lethal and sublethal concentrations of linuron on tomatoes and parsnips. The foliar application of both sublethal (1/2 lb/A) and lethal concentration (2 lb/A) stimulated the uptake of P^{32} from a nutrient culture solution. Also, there was stimulation of P^{32} translocation to the leaves. The increased P^{32} seemed to be associated with the inorganic phosphate fraction. Contrary to Nashed and Ilnicki's report of increased Ca absorption in several crops, Houge (21) reported that linuron inhibited absorption and translocation of Ca^{45} in tomatoes and parsnips.

There have been reports of growth regulating properties associated with the chlorophenoxy herbicides. Diem and Davis (13) reported that 2,4-D (2,4-dichlorophenoxyacetic acid) at low concentrations of 10^{-10} to 10^{-7}M resulted in increased absorption of water and Ca^{45} with higher concentrations reducing absorption. Wort (61) observed that a 0.1% concentration of 2,4-D at 12 lb/A gave an 11 to 13% increase in growth and 23 to 40% increase in yield of green beans. Rathore and Wort (45) applied sprays containing 1 ppm of 2,4-D with or without the micronutrients Fe, Mg, Ca, Zn and B at 5×10^{-4} M. Largest increases in growth of bean plants resulted from the combination of 2,4-D plus micronutrients. The combination resulted in an increase of green pod weight of 27%. The 2,4-D may in some manner have aided in the absorption of the micronutrients, although an analysis was not reported of the concentrations in the plant.

Some chlorophenoxy type compounds have been shown to influence the flowering of plants. Para-chlorophenoxyacetic acid and 4-chlorophenoxyacetic acid have been effective inducers of seedlessness in tomato fruit (28,19). Marth and Webster (31) reported that the herbicide

2,4,5-T applied on lima beans resulted in "apparent overall stimulation in plant growth manifested by moderate increase in size of the plant."

Pesticides probably influence plant growth in many ways. Nashed and Ilnicki (38) stated that "changes in ion uptake in herbicide treated plants may be symptomatic of basic changes in metabolism or of changes in the permeability characteristic of plant membranes." Herbicides such as chlorophenoxy type may upset the hormonal balance in the plant. Weintraub (57) reported that 2,4-D treatments lowered the auxin content of beans and Henderson _et al_. (20) showed that 2,4-D increased the rate of destruction of IAA in sections of pea stems. Houge (21) suggested that linuron may possess kinin type activity since it was observed to delay senescence of tomato leaf disks.

Nashed and Ilnicki (38) suggested that linuron possibly changed the permeability characteristics of cell membranes of soybeans because of observed loss of Mg. Price (42) indicated that some relationship existed between dichlobenil and calcium in maintaining plant membrane integrity in beet roots.

Another herbicide has been observed to possibly retard the rate of breakdown of protein or its loss from the plant. Agbakda and Goodin (3) reported paraquat (1,1'-dimethyl-4,4'-dipyridylium cation) treated costal bermuda grass contained more nitrogen than control plants, apparently due to retarding the rate of loss of nitrogen.

In conclusion, numerous researchers have reported some rather pronounced variations in growth and development with pesticide treatment. It is often difficult to determine if increased yields are due to elimination of pests or to a direct effect on the plant. There is evidence that the pesticides affect the physiological functions of the plant, such as membrane integrity and perhaps the hormonal balance of the plant.

MATERIALS AND METHODS

Horticulture Farm, 1971

Field studies were undertaken during the summer of 1971 at the Horticultural Research Center to determine the effects of pesticides on selected vegetable crops. One experiment involved muskmelon (Cucumis melo L. cv. Burpee Hybrid Melon) plants transplanted on June 17, five 2 plant pots to a plot, 1.53 meters apart in rows 1.83 meters apart. In another experiment, 6 tomato (Lycopersicon esculentum L. cv. Campbell 721) plants were similarly transplanted .92 meters apart in rows 1.53 meters apart. One-fourth liter of 10-52-8 (1.36 kg/189 liter) was applied to each plant. The starter solution also contained the systemic insecticide diazinon 218 grams/189 liter, ai. In a third experiment, 17 green bean (Phaselous vulgaris L. cv. Provider) seeds were planted per 1.22 meter plot on July 2.

Each experiment consisted of 16 treatments in a randomized block design with two replicates. The treatments consisted of seven chemicals applied at two concentrations plus two controls (Table 1A).

All treatments were applied the morning of June 17 before transplanting tomato and melon plants. The chemicals were sprayed on to 9.15 X 0.92 meter plots using a CO_2 sprayer.

All crops were sprayed, cultivated, and hand hoed as required during the season. Melons were harvested and yield data recorded from August 26 through October 1, tomatoes from September 13 through October 7, and beans on August 25, September 1, and September 7.

Abnormal growth and development as influenced by the chemical treatments was noted. Leaves were analyzed to determine if nutrient concentration was influenced by treatment. On September 4 leaf samples were taken from melon and tomato plants and oven dried at 150°F. Nitrogen was determined by the Kjeldahl method, potassium with a flame photometer, and P, Na, Ca, Mg, Fe, Cu, B, Zn, and Al by spectrophotometer.

Zucchini squash (Cucurbita pepo) were transplanted June 25, 0.92 meters apart in rows 1.22 meters apart and 2.75 meters long. Squash were also seeded June 28 in a separate plot at similar spacings. Plots received treatments of either 2.24 kg/ha of dinoseb, 0.84 kg/ha of trifuralin, 0.28 kg/ha of simazine, or no chemicals. Treatments were applied June 5 over foliage and irrigated afterwards.

Aurelius Farm, 1972

Field studies were conducted at the Aurelius farm during 1972. Peat pot grown Burpee Hybrid muskmelons were planted June 5, 5 per plot 1.22 meters apart in rows 1.68 meters apart. Peat pot grown Jet Star tomatoes were planted in the field on June 5, 6 per plot spaced 0.92 meters apart in rows 1.68 meters apart. Each transplant received starter solutions.

Each experiment consisted of 16 treatments with three replicates. Treatments consisted of 5 chemicals applied at three concentrations plus the control (Table 1B).

The chemicals were applied to a 5.49 X 0.92 meter plot for tomatoes and 6.10 X 0.92 plot for muskmelons. Bensulide was sprayed over the plants using a CO_2 sprayer and immediately attempted to wash it off. Trifluralin and disulfoton were applied in granular form with effort taken to avoid crop foliage. The treatments of dinoseb were added to a large volume of water (6778 l/ha) and sprinkled onto the plots with a sprinkling can. Naptalam applied on June 20 was applied in spray form while that applied June 27 was sprinkled onto the plots. After the application on June 27, the chemicals were incorporated by raking the soil.

Provider green beans were seeded June 12 into 4.88 X .92 meter plots. Applied chemicals covered the entire plot. Treatment plots were 1.83 meters apart with a guard row between. Only the center 3.05 meters of each treatment plot was harvested for record. Treatments for beans were similar to those used on muskmelons and tomatoes, except intermediate concentrations of dinoseb and disulfoton were deleted (Table 1C).

The treatments for each experiment were in a randomized block design with three replicates. All experiments were on a sandy loam soil that had been previously fertilized with 448 kg/ha of 10-20-20 and later side-dressed with 168 kg/ha of ammonium nitrate. The soil had been treated in late April with 2.2 kg/ha of Amitrole T. Weed competition was minimized by hand and tractor cultivation.

Observations of bean growth and of melon vine growth were made through the season. Beans were harvested from August 5 through August 21. After the final harvest, bean vines were counted, cut off at ground level and the vines weighed. Melons were harvested September 5 through

Table 1. Treatment applications for 1971 and 1972.

1A. Treatment applications to muskmelons (cv. Burpee Hybrid) and tomatoes (cv. Campbell 721), 1971.

chemical		kg/ha, ai (low trt rate)	kg/ha, ai (high trt rate)
Captan	50% WP	4.48	13.45
Carbaryl	50% WP	4.48	13.45
Alar	85% WP	4.48	13.45
Diazinon	84% WP	3.36	10.09
Bensulide	4EC	3.36	10.09
Simazine	80% WP	0.14	0.42
Solan	4EC	3.36	10.09
Control	--		

1B. Treatment applications to muskmelons (cv. Burpee Hybrid) and tomatoes (cv. Jet Star), 1972.

chemical	kg/ha, ai (low trt rate)	kg/ha, ai (interm trt rate)	kg/ha, ai (high trt rate)	Date App.
Bensulide 4EC	3.36	6.73	13.45	6/20
Trifluralin 5% G	0.56	1.12	1.68	6/27
Dinoseb 5EC	3.36	6.73	13.45	6/27
Disulfoton 15% G	1.12	2.24	4.48	6/27
Naptalam 2EC	2.24*	4.48	8.97	6/27
Control	--	--	--	

1C. Treatment applications to green beans (cv. Provider), 1972.

chemical	kg/ha (low trt rate)	kg/ha (interm trt rate)	kg/ha (high trt rate)	Date App.
Bensulide 4EC	3.36	6.73	13.45	6/20
Trifluralin 5% G	0.56	1.12	1.68	6/27
Dinoseb 5EC	3.36	--	13.45	6/27
Disulfoton 15% G	1.12	--	4.48	6/27
Naptalam 2EC	2.24*	4.48	8.97	6/27
Control	--	--	--	

*Low rate of naptalam applied on 6/20.

Table 2. Common and scientific names of chemicals used in 1971 and 1972.

Common name	Scientific name
Alar	Succinic acid 2,2-dimethyl hydrazide
Bensulide	S-(O,O-Diisopropyl phosphorodithioate ester of N-(2-mercaptoethyl benezesulfonamide
Captan	Cis-N-([Trichloromethyl]thio)-4-cyclohexene-1,2-dicarboximide
Carbaryl	1-Naphthyl-N-methylcarbamate
Diazinon	O,O-Diethyl-O-(2-isopropyl-6-methyl-4-pyrimidinyl)phosphorothioate
Dinoseb	2,4,O-Dinitro-6-sec-butylphenol
Disulfoton	O,O-Diethyl-5-(2[ethylsulfinyl]ethyl) phosphorodithioate
Simazine	2-Chloro-4,6-bis(ethyl amino)-s-triazine
Solan	Chloro-2-methyl-p-valerotoluidide
Trifluralin	α,α,α-Trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine

September 25 and the number and weight of marketable and unmarketable fruit recorded.

Pesticide effects on tomato growth were observed during the growing season. Because of observed differences in flowering, one plant from each plot of dinoseb, disulfoton, naptalam, and control treatments was removed on August 10 for careful examination. Data on the number of flowers showing yellow and the number of small and large fruits were recorded. Later, a second plant was removed from each plot in the first replication and counts made of cluster number, flower number, fruit number, and fruit and vine weight. Tomatoes were harvested from August 5 through September 6 and records kept of number and weight of marketable and unmarketable fruit. By early September the plants appeared to have been striken by mosiac virus. Thus in order to attain an estimate of later yield, all fruits .8 centimeter or larger were removed, counted, and weighed on September 10.

The data were submitted to analysis of variance and Duncan's Multiple Range Test was used to determine the difference between means.

RESULTS

Pesticide Effects on Vegetable Plants in 1971

Melons

A statistical analysis of melon yield data indicated that none of the chemicals significantly affected either early or total yield. Although no treatment altered early yield significantly, all treatments markedly reduced the number of melons harvested early in the season with simazine causing the greatest reduction (Table 3).

The chemicals had no significant effect on the total number of marketable melons, although there was a trend of all chemicals except Alar to decrease the number of melons. Also, there was a trend for chemicals to reduce the weight of marketable melons, though not significantly.

None of the treatments caused significant differences in the total yield of marketable and unmarketable fruit. All treatments except diazinon caused reductions in the number of melons harvested (Table 3).

Tomatoes

Although the applied chemicals had no significant effect on the yield of tomatoes, there was a trend for diazinon, captan, carbaryl, alar, bensulide, and solan to increase early marketable number and weight slightly. Simazine tended to reduce both early and total yield; other treatments tended to increase total yield slightly (Table 4).

Table 3. Effect of agricultural chemicals on melon (cv. Burpee Hybrid) yield, 1971.[1,5]

Chemical	Number of Fruit $\times 10^3$/ha			Weight of Fruit q/ha		
	Early Marketable[2]	Total Marketable[3]	Total[4]	Early Marketable[2]	Total Marketable[3]	Total[4]
Control	24.0	37.7	49.3	356	512	609
Alar	23.7	38.7	49.2	343	510	631
Diazinon	21.0	35.0	50.4	333	496	620
Solan	19.8	37.0	48.7	302	502	611
Bensulide	19.6	33.8	46.2	312	472	605
Carbaryl	19.1	32.8	48.4	298	455	575
Captan	17.6	35.2	48.2	304	513	625
Simazine	14.7	31.8	39.6	231	437	503

[1]Mean of four plots.

[2]Early marketable = Harvest August 26-September 14.

[3]Total marketable = Harvest August 26-October 1.

[4]Total = Marketable and non-marketable fruit - Harvest August 26-October 1.

[5]All means are nonsignificant at the .05 level using Duncan's Multiple Range Test.

Table 4. Effect of agricultural chemicals on tomato (cv. Campbell 721)[1,4] yield, 1971.

Chemical	Number of Fruit x 10^3/ha		Weight of Fruit q/ha	
	Marketable[2]	Marketable and Mature Green[3]	Marketable[2]	Marketable and Mature Green[3]
Diazinon	309	493	562	824
Captan	308	539	532	857
Carbaryl	299	494	539	854
Alar	295	500	518	817
Bensulide	278	486	512	823
Solan	274	507	502	855
Control	264	537	473	755
Simazine	206	393	385	593

[1]Mean of four plots.

[2]September 13-October 6.

[3]September 13-October 7.

[4]All means are nonsignificant at the 0.05 level using Duncan's Multiple Range Test.

Beans

Solan, carbaryl, bensulide, simazine, alar and diazinon did not significantly influence green bean yield although they tended to reduce it slightly (Table 5).

Zucchini squash

Dinoseb application increased vine weight by 24%, number of squash by 29%, and weight of squash by 32%, but the increases were not significant. Trifluralin and simazine reduced vine weight by 15% and 33%. Each reduced the fruit weight by 24%. Neither greatly influenced the number of fruit harvested (Table 6).

Effect on composition of tomato and melon leaves

Nutrient analysis of tomato and melon leaves indicated relatively little influence of these chemicals on concentration of P, K, Na, Ca, Mg, Fe, B, Zn, and Al. Simazine increased the nitrogen and copper concentration insignificantly in tomato leaves and significantly increased nitrogen and copper concentration in melon leaves (Table 7). The increased concentration seemed to be associated with reduced vigor and size of plants.

Pesticide Effects on Vegetable Plants in 1972

The effects of four herbicides and one systemic insecticide on growth of beans, tomatoes, and muskmelons under field conditions were examined during the summer of 1972. There were significant differences in yield related to the treatments.

Table 5. Effect of agricultural chemicals on green bean (cv. Provider) yield, 1971.[1,2]

Chemical	Kg/1.22 m. Rows
Captan	4.52
Control	4.42
Solan	4.20
Carbaryl	3.76
Bensulide	3.72
Simazine	3.67
Diazinon	3.53
Alar	3.25

[1]Mean of four plots.

[2]All means are nonsignificant at the 0.05 level using Duncan's Multiple Range Test.

Table 6. The effect of dinoseb, trifluralin, and simazine on Zucchini squash, 1971.[1,2]

Chemical	Number of squash	Weight of squash	Vine weight
	(No x 10^3/ha)	(Kg/ha)	(Kg/ha)
Dinoseb	100.1a	856a	493a
Control	78.0a	647a	397ab
Simazine	77.0a	502a	266 b
Trifluralin	74.8a	501a	399ab

[1]Means of two plots.

[2]Those means followed by the same letter are not significant at the 0.05 level by Duncan's Multiple Range Test.

Table 7. Effects of agricultural chemicals on mineral concentration in tomato and melon leaves, 1971.[1,2]

Chemical	Tomato		Melon	
	% N	ppm Cu	% N	ppm Cu
Captan	3.71a	5.94a	3.55bc	3.81b
Simazine	3.53a	7.70a	4.21a	9.82a
Control	3.46a	4.17a	3.57bc	4.86b
Alar	3.45a	4.52a	3.45bc	5.91ab
Carbaryl	3.43a	6.67a	3.29c	5.22b
Bensulide	3.40a	4.19a	3.39bc	6.46ab
Solan	3.40a	6.31a	3.73b	2.42b
Diazinon	3.34a	4.17a	3.55bc	3.63b

[1]Mean of four plots.

[2]Means followed by the same letter are not significant at the 0.05 level by Duncan's Multiple Range Test.

TREATMENT EFFECTS ON MUSKMELON

Early yield of melons

Observations of vine growth on June 30 indicated occasional small necrotic spots on leaves of muskmelon plants treated with dinoseb. Later observations on July 9 indicated that necrotic spots were prevalent on plants treated with higher levels of dinoseb. A slight stunting of vine growth was also observed. Naptalam was associated with slight marginal chlorosis of leaves. Observations on July 17 indicated little difference in vine growth for any of the treatments.

The data in Table 8 indicated that all chemicals, on averages of the three rates, tended to increase both marketable and total yield of melons that were harvested before September 13. Both number and weight of early marketable melons were increased significantly by more than two-fold by the application of the systemic insecticide disulfoton. The other treatments tended to increase yield although not significantly at the 0.05 level. Dinoseb was associated with 65% increase in number of melons and 62% increase in weight. Trifluralin treatment was related to 40% increase number of melons and 36% increase of weight. Average weights of fruit among the three treatments were not significantly different.

The herbicide naptalam was associated with increased number and weight of early marketable melons by 56 and 57%, respectively. Bensulide was associated to a 48% increase of fruit number and 57% increase of weight, or an increase of 120 grams per melon (Table 8A).

The chemicals had similar effects on the total production of early fruit, including marketable and nonmarketable (Table 8B). Again, only

Table 8. The effect of pesticides on early yield of melon (cv. Burpee Hybrid), 1972.[1,2]

Chemical	Number		Weight		Average melon wt
	(No x 10^3/ha)	(% of control)	(q/ha)	(% of control)	(Kg/melon)
		A. Early marketable melon yield (September 5-12).			
Disulfoton	11.09a	227	146.1a	217	1.32 b
Dinoseb	8.05ab	165	108.8ab	162	1.35 b
Naptalam	7.61 b	156	105.3ab	157	1.39ab
Bensulide	7.18 b	148	105.8ab	157	1.49a
Trifluralin	6.85 b	140	91.3 b	136	1.32 b
Control	4.89 b	100	67.2 b	100	1.37ab
		B. Early total yields[3] (September 5-12).			
Disulfoton	13.9a	267	173.7a	247	1.25 b
Trifluralin	10.2a	196	124.3ab	177	1.21 b
Dinoseb	9.6 b	185	122.8ab	175	1.28 b
Naptalam	9.1 bc	175	121.3ab	173	1.33ab
Bensulide	8.8 bc	169	126.1ab	186	1.39a
Control	5.2 c	100	70.2 b	100	1.35ab

[1]Average of 3 levels of the chemical.

[2]Means followed by same letter are not significantly different at 0.05 level by Duncan's Multiple Range Test

[3]Includes marketable and non-marketable melons.

disulfoton significantly increased number and weight of melons. Disulfoton increased number of melons produced by 167% and weight by 147%. Application of trifluralin resulted in a significant 96% increase in number and insignificant 77% increase in weight. Other treatments tended to increase early yield although not significantly. Naptalam treatment was associated to a 75% of number of fruit and 73% increase of weight. Treatment with bensulide resulted in 69% in number of fruit and 86% increase in early total weight. Thus, bensulide is again related to a slight increase in average size of melon (Table 8B).

Table 9A indicates the effects of the three rates of each chemical on number of early marketable fruit. It is of interest to note that for each chemical, except trifluralin, the highest yield occurred at the lowest concentration. The lowest level of disulfoton (1.12 kg/ha) resulted in the most early melons. The various levels of trifluralin that were applied had similar effects on number of melons.

Results in Table 9B show how the different levels of each chemical affected early total yield. There seemed to exist a trend similar to the trend expressed for early marketable melons. The largest yield for each chemical, except trifluralin, occurred at the lowest concentration. Again, the largest yield was associated with the lowest concentration of disulfoton. Trifluralin resulted in greatest increase in melon number at highest rate.

Total yield of melons

The chemicals affected both seasonal yield of marketable melons and total yield of marketable and nonmarketable melons (Table 10).

Table 9. The effect of three rates of five chemicals on early yield of melons (cv. Burpee Hybrid), 1972.[1,2]

Chemical	Rates	Number of melons		
		Low Rate	Interm. Rate	High Rate
	(kg/ha)	(No x 10^3/ha)	(No. x 10^3/ha)	(No x 10^3/ha)
	A. Early marketable yield (September 5-12).			
Bensulide	3.4, 6.7, 13.5	9.45 ab	7.18 ab	4.89 b
Trifluralin	0.6, 1.1, 1.7	6.85 ab	6.85 ab	6.85 ab
Dinoseb	3.4, 6.7, 13.5	10.43 ab	6.85 ab	6.85 ab
Disulfoton	1.1, 2.2, 4.5	12.39 a	11.42 ab	9.46 ab
Naptalam	2.2, 4.5, 9.0	9.13 ab	6.20 ab	7.50 ab
Control			4.89 b	
	B. Early total yield.[3]			
Bensulide	3.4, 6.7, 13.5	10.44 ab	10.11 ab	5.87 b
Trifluralin	0.6, 1.1, 1.7	10.11 ab	9.46 ab	11.09 ab
Dinoseb	3.4, 6.7, 13.5	11.09 ab	8.81 b	8.81 b
Disulfoton	1.1, 2.2, 4.5	16.96 a	12.72 ab	12.07 ab
Naptalam	2.2, 4.5, 9.0	12.07 ab	6.85 b	8.48 b
Control			5.22 b	

[1]Mean of three plots.

[2]Means followed by same letter are not significant at 0.05 level by Duncan's Multiple Range Test.

[3]Includes marketable and unmarketable fruit.

Bensulide significantly increased the number of marketable melons by 45% and weight by 47%. A trend of increased yields seems to exist for the other chemicals. Dinoseb, disulfoton, naptalam, and trifluralin were related to increases of melon number by 34%, 32%, 31%, and 22% and increases in weight by 28%, 31%, 33%, and 23% respectively (Table 10A).

More significant differences were attained for total yield than was for the marketable yield. Disulfoton increased number of melons by 30% and weight by 40%. Bensulide significantly increased number of melons by 27% and to the weight by 32%. Trifluralin and naptalam treatment plots yielded 21% and 19% more fruit and the two treatments significantly increased weight by 28 and 27% (Table 10B).

The results in Table 12 indicate the influence of the different rates of chemicals on the total number of marketable melons produced, Largest increases in number of melons for bensulide, dinoseb, disulfoton, and naptalam treatments again was associated with lower concentrations. The lowest rate of dinoseb was associated with the largest yield attained, but higher rates reduced yield. The highest yield with trifluralin was attained at the intermediate concentration (Table 11A).

The effect of the three different levels of each chemical on total melon yield is indicated in Table 11B. The lower rates of dinoseb, disulfoton, and naptalam were related to greatest increases in yield. As the concentration of each of these increased, the number of melons produced decreased. Slightly greater yields were attained at the medium concentration of bensulide than either lower or higher concentrations. The three levels of trifluralin differed little in their influence on yield.

Table 10. The effect of pesticides on total yield of melon (cv. Burpee Hybrid), 1972.[1,2]

Chemical	Number		Weight		Average melon wt.
	(No x 10^3/ha)	(% of Control)	(q/ha)	(% of Control)	(Kg/melon)
	A. Total marketable yield (September 5-25).				
Bensulide	18.9 a	145	257.2 a	147	1.36 a
Dinoseb	17.5 a	134	223.4 ab	128	1.28 a
Disulfoton	17.3 ab	132	228.4 ab	131	1.31 a
Naptalam	17.1 ab	131	231.4 ab	133	1.35 a
Trifluralin	15.9 ab	122	212.7 ab	123	1.35 a
Control	13.0 b	100	174.5 b	100	1.34 a
	B. Total yield (September 5-25).				
Disulfoton	22.1 a	130	285.9 a	140	1.22 ab
Bensulide	21.5 a	127	268.0 a	132	1.32 a
Trifluralin	20.5 ab	121	262.1 a	128	1.28 ab
Naptalam	20.1 ab	119	260.0 a	127	1.29 ab
Dinoseb	19.7 ab	116	242.2 ab	119	1.22 ab
Control	17.0 b	100	204.3 b	100	1.21 b

[1]Average of three levels of chemical.

[2]Means followed by same letter are not significantly different at 0.05 level by Duncan's Multiple Range Test.

Table 11. Effect of three rates of application of five pesticides on total number of melons (cv. Burpee Hybrid), 1972.[1,2]

Chemical	Rates	Number of Melons		
		Low Rate (No x 10^3/ha)	Interm. Rate (No x 10^3/ha)	High Rate (No x 10^3/ha)
	A. Total marketable number (September 5-25).			
Bensulide	3.4, 6.7, 13.5	19.90 ab	18.59 ab	18.27 ab
Trifluralin	0.6, 1.1, 1.7	16.31 ab	16.96 ab	14.35 ab
Dinoseb	3.4, 6.7, 13.5	21.53 a	17.61 ab	13.37 b
Disulfoton	1.1, 2.2, 4.5	17.61 ab	17.61 ab	16.63 ab
Naptalam	2.2, 4.5, 9.0	20.55 ab	16.31 ab	14.35 ab
Control			13.05 b	
	B. Total number of melons.			
Bensulide	3.4, 6.7, 13.5	22.18 abc	22.83 abc	19.57 abc
Trifluralin	0.6, 1.1, 1.7	19.90 abc	20.88 abc	20.88 abc
Dinoseb	3.4, 6.7, 13.5	23.16 ab	20.22 abc	15.66 c
Disulfoton	1.1, 2.2, 4.5	23.81 ab	21.53 abc	20.88 abc
Naptalam	2.2, 4.5, 9.0	24.14 a	19.57 abc	16.63 bc
Control			16.96 bc	

[1]Average of nine plots.

[2]Means followed by same letter are not significant at 0.05 level using Duncan's Multiple Range Test.

Figure 1 summarizes the results of the 1972 melon experiment. As indicated previously, all chemicals, and especially disulfoton, increased early marketable yield. It is evident from the figure that the chemical also increased the proportion of unmarketable melons. Trifluralin increased the percentage of nonmarketable melons to a much greater extent than the other chemicals.

Disulfoton markedly increased early yield above those of the other treatments although the figure indicates that the chemical did not elevate later yield as much as the control. Bensulide seemed especially effective for increasing both early and later melon yields.

TREATMENT EFFECTS ON TOMATOES

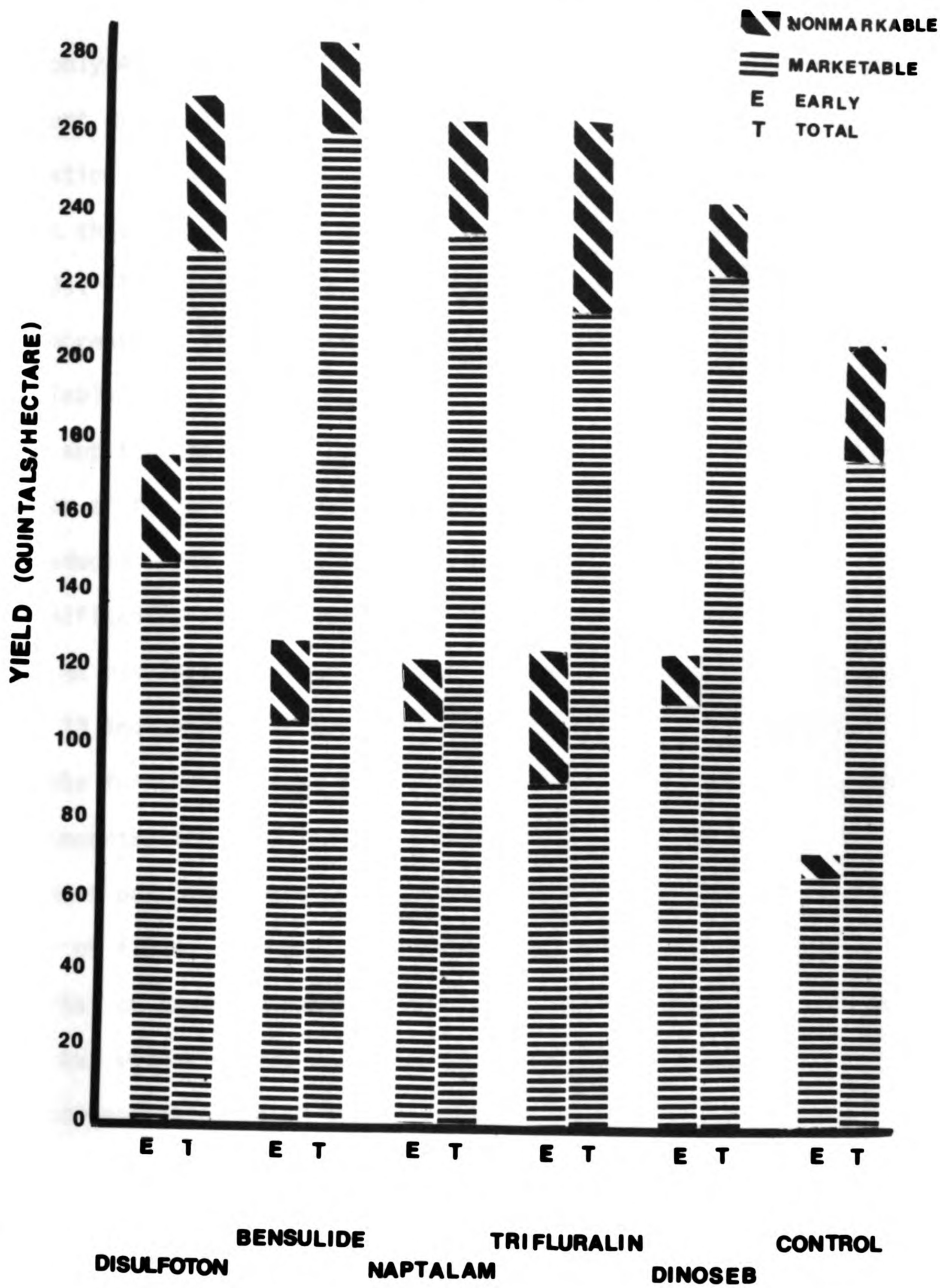
Early growth and floral development

Observations of tomato vine growth on June 30 indicated that all levels of naptalam resulted in epinasty and curling of younger leaves. Observations on July 9 indicated that the epinasty had persisted until that date. Observations at that time also indicated that disulfoton occasionally restricted young leaf growth. Later observations on July 17 indicated that naptalam caused stunting of vine growth and the production of more and larger tomato fruit on the first cluster. These tomatoes were observed to have developed more roughness and cracking on the shoulder of the fruit.

Chemical treatments resulted in variations in the number of flowers produced and in yield of fruit. Measurements collected on August 10 indicated that disulfoton application resulted in a significant increase

Figure 1. The influence of agricultural chemicals on the early and total weight of marketable and nonmarketable melons (*Cucumis melo* L. Burpee Hybrid), 1972.

FIGURE I YIELD OF MELONS (CV. BURPEE HYBRID), 1972



in the number of flowers in the anthesis stage. Total flower and fruit on the plant were increased 23% by disulfoton while vine weight was reduced only 4% (Table 12). Observations on August 10, indicated that development of the largest number of flowers occurred at the highest concentration (4.48 kg/ha) of disulfoton. Flower numbers were increased by 84% at this concentration while vine weight was reduced by only 4% (Table 13). The intermediate level of disulfoton (2.24 kg/ha) resulted in 35% increase in flower number and a five percent increase in vine weight (Table 13).

The application of the herbicide dinoseb only slightly influenced the number of flowers and fruit although vegetative growth was significantly reduced. The results in Table 12 indicated that naptalam treatment significantly reduced vegetative growth and flower and fruit number. An examination of the effects of the various chemical levels in Table 13 indicated that the higher concentrations of naptalam were responsible for the greatest reduction in flower number. Although the lowest concentration (2.24 kg/ha) reduced the vine weight by nearly 50%, more flowers per plant were produced, indicating a very large increase in number of flowers per unit of vine weight. The highest concentration (8.97 kg/ha) of naptalam resulted in a reduction of vine weight of more than 50% but with a corresponding decrease in flower number. The intermediate concentration (4.48 kg/ha) differed from the others since it resulted in slight reduction of flower number and vine weight.

A later flower and fruit count on August 18 again indicated some treatment effect. The previous information had indicated that some

Table 12. The effect of pesticides on growth and flowering of tomato (cv. Jet Star) plants, August 10, 1972.[1,2]

Chemical	Flower number		Number of flower, fruits		Vine wt.	
	(No./ plant)	(% of control)	(No./ plant)	(% of control)	(Kg/ plant)	(% of control)
Disulfoton	245 a	150	310.1 a	123	3.52 a	96
Dinoseb	174 b	106	240.6 b	96	3.30 b	90
Control	164 b	100	251.2 b	100	3.67 a	100
Naptalam	127 b	77	133.4 c	53	2.90 c	79

[1]Average of 3 levels.

[2]Means followed by same letter are not significantly different at the 0.05 level by the Duncan's Multiple Range Test.

Table 13. The effects of three rates of five chemicals on flower number and vine weight of tomato (cv. Jet Star), August 10, 1972.[1,2]

	Rate (kg/ha)	Production of Flowers and Vines at Each Concentration					
		Low		Intermediate		High	
			vine wt.		vine wt.		vine wt.
		(F/plant)	(Kg/plant)	(F/plant)	(Kg/plant)	(F/plant)	(Kg/plant)
Disulfoton	1.1, 2.2, 4.5	212 ab	3.49 b	222 ab	3.87 b	301 a	3.51 b
Dinoseb	3.4, 6.7, 13.5	159 bc	3.31 ab	178 bc	3,49 b	186 abc	2.27 ab
Naptalam	2.2, 4.5, 9.0	179 bc	1.84 ab	130 bc	2.62 ab	71 c	1.29 a
Control				164 bc	3.67 b		

[1]Average of three plots.

[2]Means followed by same letter are not significantly different at the 0.05 level by the Duncan's Multiple Range Test.

chemicals were related to an increased number of flower per plant and that most chemicals were related to increased number of flowers per unit vegetative weight. Thus, a count of number of clusters were included in measurements on August 18. Dinoseb and naptalam treatments resulted in significant reduction of number of flower clusters (Table 14) which seem in general, to be associated with a reduction in vine weight. Although naptalam application was related to a severe reduction of number of flower clusters, it was related to more than a three-fold increase in the number of flowers per cluster at anthesis stage. Observations indicated that many of these flowers were uncharacteristically large and often fasciated with numerous stamens and petals. Numerous small flowers were observed but not counted because they were too small and poorly developed to undergo anthesis. Although naptalam significantly reduced the number of flower clusters, the increased number of flowers per cluster resulted in an increased number of flowers per plants. The total number of flowers and fruit per plant were decreased indicating fewer set fruit on vines.

Dinoseb caused reductions in vine weight and a similar reduction in number of flower clusters. Besides reducing the number of clusters, dinoseb reduced the number of flowers per cluster, resulting in fewer flowers per plant. Dinoseb treatment was also observed to be related to the production of more fasciated flowers, and to more small flowers that failed to develop.

Although causing a very slight reduction in weight of tomato vine and flower clusters, disulfoton application resulted in 66% more flowers

Table 14. The effect of pesticides on number of flowers, fruit, flower cluster, and on vine weight of tomato (cv. Jet Star plants, 1972.[1,2]

Chemicals	Clusters		Flowers				Flower & Fruit		Vine Wt.	
	(No/ plt)	(% of cluster)	(No/ cluster)	(% of control)	(No/ plt)	(% of control)	(No/ plt)	(% of control)	(Kg/plt)	(% of control)
Control	64 a	100	3.22 b	100	206 a	100	305 a	100	3.96 a	100
Disulfoton	56 ab	88	5.36 b	166	294 a	143	398 a	130	3.78 a	95
Dinoseb	52 b	81	2.53 b	79	131 a	64	214 a	70	2.84 b	79
Naptalam	28 c	44	10.08 a	313	287 a	139	294 a	96	2.03 b	52

[1]Average of three rates.

[2]Means followed by same letter are not significantly different at 0.05 level by Duncan's Multiple Range Test.

per cluster and 43% more per plant. Disulfoton application was also observed to be associated with occurrence of more fasicated flowers.

Observation indicated that besides resulting in more fasicated flowers, dinoseb and naptalam seem to cause more fasicated flower stems. Flower clusters were often observed to be large with a fasicated pedical arising from the cluster. Also, the infloresences were large and more polychotomous (Figure 2A). These three chemicals were also associated with occurrence of more seedless fruit on the first two clusters (Figure 2B).

Fruit yield

The treatments also affected fruit yield. All treatments were related to an increased number and weight of early marketable tomatoes. Naptalam increased the number of fruit by 26% and significantly increased the fruit weight by 78%, thus causing large early fruit (Table 15A). It was previously shown that this was associated with a reduction in vine growth. Results in Table 16A indicate that weight was significantly increased at the intermediate rate (4.48 kg/ha) of naptalam and severely reduced in yield at the high level (8.97 kg/ha).

Treatment effects of total marketable, varied more widely than early yield. Naptalam significantly reduced the number and weight of fruit harvested (Table 15B). Results indicate the greatest reduction occurred at the highest concentration (Table 16B).

Bensulide, dinoseb, and trifluralin very slightly increased the number or weight of total marketable fruit (Table 15B). Largest yield

Figure 2. The effect of agricultural chemicals on flowering and fruiting of tomatoes (*Lycopersicon esculentum* L. cv. Jet Star), 1972.

A. Fasciated flowers of plants treated with 2.2 kg/ha of naptalam.

B. Seedless fruit of plants treated with disulfoton (below) and seeded fruit (above) of control plants.

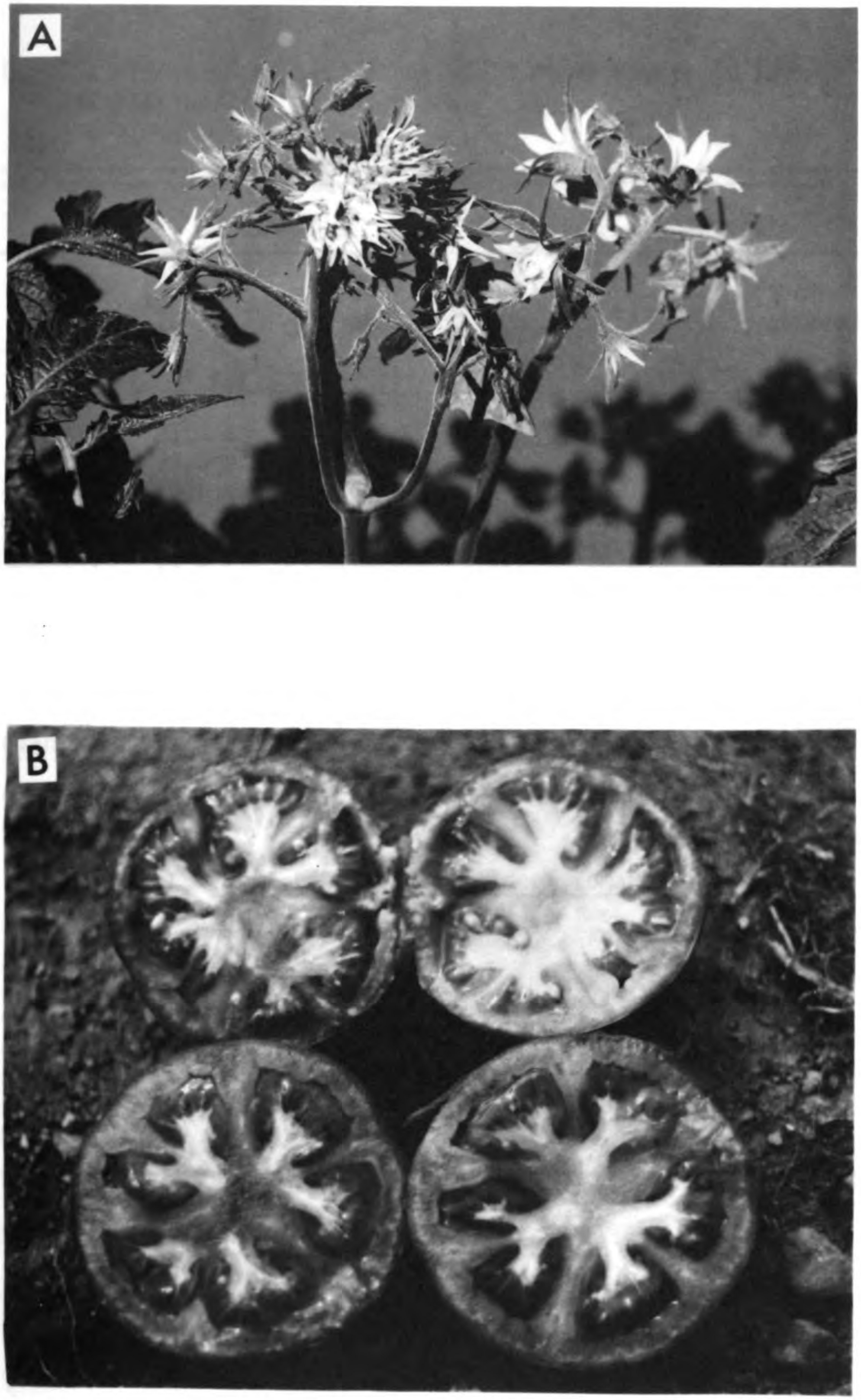


FIGURE 2

Table 15. The effect of pesticides on yield of tomato fruit (cv. Jet Star), 1972.[1,2]

Chemical	Number		Weight	
	(No. x 10^3/ha)	(% of control)	(q/ha)	(% of control)
A. Yield of early marketable tomatoes (August 5-23, 1972).				
Dinoseb	21.4 a	151	28.3 ab	144
Disulfoton	20.8 ab	147	27.3 ab	139
Bensulide	20.5 ab	145	26.7 ab	136
Naptalam	17.9 ab	126	35.0 a	178
Trifluralin	17.5 ab	124	22.8 b	116
Control	14.1 b	100	19.6 b	100
B. Yield of total marketable fruit (August 5-September 6, 1972).				
Bensulide	100.5 a	105	173.2 a	96
Dinoseb	98.5 a	103	182.9 a	101
Trifluralin	97.9 a	102	171.2 a	95
Control	95.7 a	-	180.5 a	100
Disulfoton	83.6 a	87	150.5 a	83
Naptalam	21.3 b	22	45.8 b	25

C. Total biological yield of tomatoes.

Chemical	Kg/ha	% of Control
Control	912 a	100
Disulfoton	874 ab	96
Bensulide	854 a	94
Trifluralin	844 a	93
Dinoseb	788 a	86
Naptalam	254 b	27

[1]Average of nine plots.

[2]Means followed by same letter are not significantly different at 0.05 level by Duncan's Multiple Range Test.

Table 16. The effect of three rates of five chemicals on yield of tomatoes (cv. Jet Star), 1972.[1,2]

Chemical	Rate	Low Rate	Interm. Rate	High Rate
	(kg/ha)	(q/ha)	(q/ha)	(q/ha)
	A. Early marketable yield.			
Naptalam	2.2, 4.5, 9.0	32.4 b	59.7 a	12.9 c
Disulfoton	1.1, 2.2, 4.5	31.0 b	33.2 b	17.7 bc
Dinoseb	3.4, 6.7, 13.5	31.2 b	31.6 b	22.1 bc
Bensulide	3.4, 6.7, 13.5	24.5 bc	30.5 bc	25.2 bc
Trifluralin	0.6, 1.1, 1.7	20.6 bc	24.2 bc	23.7 bc
Control		19.6 bc		
	B. Total marketable yield.			
Dinoseb	3.4, 6.7, 13.5	204.7 a	241.7 a	102.7 a
Disulfoton	1.1, 2.2, 4.5	153.1 a	191.5 a	106.9 a
Trifluralin	0.6, 1.1, 1.8	179.0 a	170.5 a	164.2 a
Bensulide	3.4, 6.7, 13.5	173.3 a	177.2 a	171.0 a
Control		180.5 a		
Naptalam	2.2, 4.5, 9.0	36.0 b	86.8 ab	14.6 b
	C. Biological yield.			
Trifluralin	0.6, 1.1, 1.8	820 a	944 a	769 a
Disulfoton	1.1, 2.2, 4.5	784 a	942 a	895 a
Bensulide	3.4, 6.7, 13.5	869 a	901 a	792 a
Dinoseb	3.4, 6.7, 13.5	809 a	850 a	706 a
Naptalam	2.2, 4.5, 9.0	410 a	234 a	119 a
Control		912 a		

[1]Average of nine plots

[2]Means followed by same letter are not significantly different at 0.05 level by Duncan's Multiple Range Test.

did occur at the intermediate (4.48 kg/ha) and lowest rate (2.24 kg/ha) of dinoseb. Disulfoton reduced weight by 17% with the greatest reduction occurring at the highest level (4.48 kg/ha). The intermediate level (2.24 kg/ha) of the treatment yielded nearly 80% more fruit than the highest level (Table 16B).

All other treatments tended to reduce the yield; naptalam significantly reduced the biological yield of tomatoes (Table 15C). The intermediate concentration of each chemical except naptalam resulted in the greatest yield for each chemical. The intermediate level of trifluralin (1.12 kg/ha) and disulfoton (2.24 kg/ha) resulted in yields slightly greater than the control. Figure 3 summarizes the marketable yield results of the 1972 tomato experiment. It illustrates that all treatments were associated with slightly increased early yields. Naptalam especially increased early yield and decreased later yield.

CHEMICAL TREATMENT ON BEANS

Bean leaves of plants treated with dinoseb were observed on June 30, 1972 to have necrotic spots. Naptalam was associated with epinasty of leaves. Later observation on July 9 associated naptalam with the occurrence of uncharacteristic salvoid-type leaves. These symptoms persisted through observations on July 17. Naptalam treated plants were also growing more slowly.

Differences in final stand and yield were associated with treatment. Final stand was increased 50% by trifluralin and increased significantly 84% by disulfoton (Table 17A). These two chemicals were applied two weeks after seeding germination had occurred.

Figure 3. The influence of agricultural chemicals on early and total weight of marketable tomatoes (*Lycopersicon esculentum* L. Jet Star), 1972.

Table 17. Effect of two rates of five pesticides on green beans (cv. Provider), 1972.[1]

Chemical	Rate	Low Rate	High Rate	Average
		A. Plant Number (x 10^3)/ha.		
Disulfoton	1.1, 2.2, 414	124 a	160 a	142 a
Trifluralin	0.6, 1.1, 1.7	121 a	111 a	116 ab
Naptalam	2.2, 4.5, 9.0	106 a	103 a	105 bc
Bensulide	3.4, 6.7, 13.5	102 a	87 a	95 bc
Dinoseb	3.4, 6.7, 13.5	102 a	81 a	92 bc
Control		77 a		77 c
		B. Yield (q/ha).		
Trifluralin	0.6, 1.1, 1.7	205.1 a	167.1 a	186.1 a
Disulfoton	1.1, 2.2, 4.5	193.1 a	172.0 a	182.5 ab
Bensulide	3.4, 6.7, 13.5	195.8 a	130.2 a	163.0 ab
Dinoseb	3.4, 6.7, 13.5	182.7 a	129.7 a	155.7 ab
Control		147.2a		147.2 b
Naptalam	2.2, 4.5, 9.0	79.2 a	85.2 a	82.2 c
		C. Vine Weight (q/ha).		
Bensulide	3.4, 6.7, 13.5	97.1 a	90.1 a	93.6 a
Disulfoton	1.1, 2.2, 4.5	98.2 a	87.9 a	93.0 a
Trifluralin	0.6, 1.1, 1.7	96.6 a	89.0 a	92.8 a
Naptalam	2.2, 4.5, 9.0	102.5 a	78.1 a	90.3 a
Control		89.5 a		89.5 ab
Dinoseb	3.4, 6.7, 13.5	91.7 a	64.5 a	78.1 a

[1]Average of nine plots.

[2]Means followed by the same letter are not significantly different at the 0.05 level by Duncan's Multiple Range Test.

Naptalam, bensulide, and dinoseb applications slightly increased stand of plants at both concentrations. The lower level of all treatments except disulfoton resulted in higher plant stand.

Naptalam significantly reduced the bean yields. Trifluralin significantly increased yield and disulfoton increased yield by over 20%. Bensulide and dinoseb treatments were related to insignificant increases in yield. All chemicals except for naptalam, were associated with greater increased yield at the lower level at which each was applied. This trend of greatest yield at lowest concentration seemed to correspond to the final stand of plants, with exception of disulfoton (Table 17B).

Only dinoseb caused significant reduction in vine weight, which was apparently due to toxicity at the higher concentration. The other treatments only slightly influenced vine weight. The slight effect on total vine weight and the increase in plant number associated with disulfoton, trifluralin, bensulide, and naptalam, indicates these plants were smaller in size than the control. For each chemical treatment, the greater plant weight occurred at the lower concentration, and in each case this weight was slightly more than the control.

Thus, the insecticide disulfoton and the herbicide trifluralin seem to be effective for promoting plant stand and increased yield.

GENERAL DISCUSSION

The use of herbicides in these experiments influence crop growth in ways other than elimination of competitive weeds. The chemical treatments of 1971 did not cause significant differences in yield. All chemicals in 1971, with the exception of captan, resulted in a reduced early marketable and slight increase in total yield of melons. The reduced early yield of simazine was contributed to observed vine damage to both melons and tomatoes. Many of the chemicals seem to have shifted the harvest peak of tomatoes to earlier in the season. All chemicals, with the exception of simazine, resulted in increased yield of tomatoes and later a slight reduction in total marketable and mature green yield.

The trend toward induced earliness existed in 1972. All of the chemicals that were applied (disulfoton, dinoseb, naptalam, bensulide, and trifluralin) increased the early yield of melons, disulfoton doing so significantly. All treatments also increased the early marketable yield of tomatoes, dinoseb increasing number of fruit significantly and naptalam increasing weight significantly.

The yield trend of 1972 differed from that of 1971 since the treatments in 1972 generally produced more early fruit and continued to outproduce the control, resulting in greater total yields. Disulfoton, bensulide, trifluralin, and naptalam significantly increased total melon weight. Bensulide seems to be especially beneficial to increase both size and number of melons.

The total marketable yield and total yield of tomatoes in 1972 was not greatly influenced by chemical, except for a severe reduction by naptalam. All treatments were associated with higher early yields than the control. This agrees with a report by Rogers (48) that other herbicides, solan at 4 lbs/A and simazine at 1 lb/A on heavy clay soil caused more early tomato fruit than other herbicides or hoed check.

The trend of increased early yields can be especially important to those who strive to produce crops before the market supply peaks. Produce prices are usually higher when the supply of fruit is limited. Disulfoton appears to be especially effective for this purpose on melons, although not labeled for that crop.

As stated before, all chemicals used in 1972 resulted in increased total melon yield, while this was not true in 1971. This is again important to the producer. The early part of the growing season in 1972 was cool and not desirable for melon growth. Average Michigan melon yields fell from 75 Cwt/A in 1971 to 65 Cwt/A in 1972 with prices, increasing from $7.92 in 1971 to $10.30 Cwt in 1972 (18). Producers can be especially benefited by higher yields during stress growing seasons. Herbicides treatments may be of more value in influencing crop growth during suboptimal than optimum growing conditions. Bensulide, a herbicide that is labeled for use on melon, was used both years and appeared more beneficial in 1972.

This study did not ascertain the factors influencing the difference in yields between the two years or why more significant results occurred in 1972. The differences may be associated with timing of application. The 1971 treatments were applied the same day as transplanting, while the 1972 treatments were applied two or three weeks after transplanting. The difference in stage of development may have influenced the activity of the pesticide. For example, the roots of the transplants may have been better established at the time of treatment application in 1972 than in 1971. This would influence the plant's ability to absorb and transport the chemical. Thus, stage of physiological development at time of application may have influenced the activities.

A second possible explanation is that a chemical interaction may have existed in 1972 and not in 1971. Amitrole T had been applied to soil at 2.24 kg/ha in late April of 1972. Thomson (55) describes the chemical as having an average persistance of two to four weeks in soil. The spring and early summer were cool, therefore, the chemical may have persisted longer. Yet, transplanting did not occur until about six weeks after Amitrole T application and treatments were applied two months later. Amitrole T injury symptoms were not observed on any plants. It is, therefore, unlikely that the Amitrole T persisted long enough in soil for an interaction with the treatments to occur.

A third possible explanation for the variation between years may be due to environmental factors. There are many that may be considered, but one evident difference is the variation in the temperature pattern of the early growing season. Early yields were increased both years, but more significantly in 1972. Plantings were established earlier in 1972 and experienced cooler growing conditions. Figure 4 indicates that June of 1972 averaged 9°F cooler than June 1971, and nearly 6°F cooler than the 30 year average. The chemicals may have exerted more influence under cooler conditions.

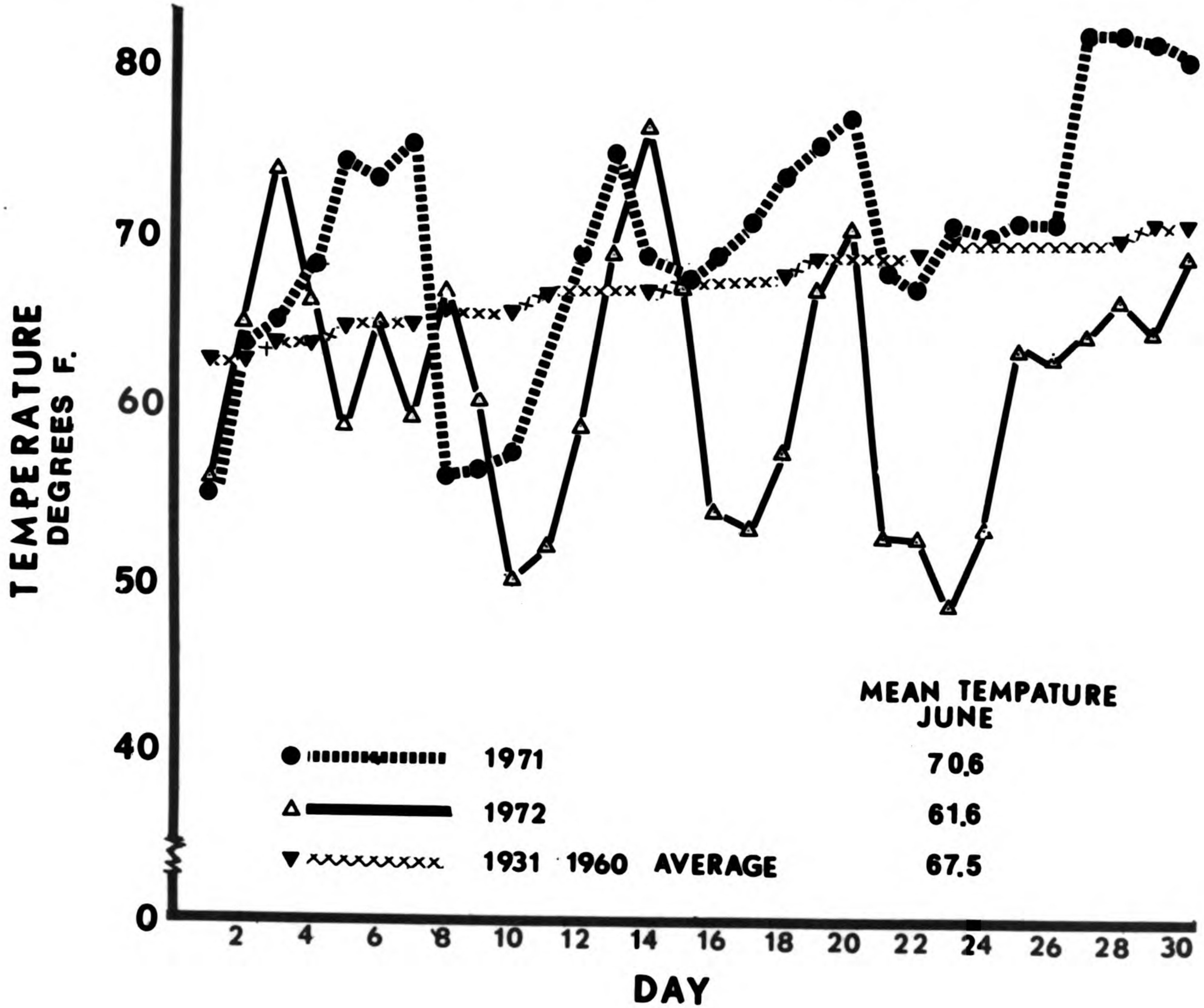
The length of growing season probably influenced the pesticides' effect on total yield. As indicated before, chemicals increased early melon yield in 1972 although not in 1971. This was probably related to growing conditions and length of growing season. The harvest period of 1971 was longer than that of 1972, and about twice the number of melons were harvested. The control plants in the 1971 experiment tended to begin producing later than the chemical treatments, although eventually surpassing most treatments. The following year, all treatments were associated with increase, early yield, and with increased total yields. Perhaps when harvest periods are shorter and yields lower, the earliness trends continue through the season causing increased total yield. The insecticide disulfoton had caused the greatest early melon production, yet the control out-produces it during the latter part of the harvest. Because of the elevated early production, disulfoton resulted in greater overall yield than the control. If the season had been longer, the control may have out-yielded the disulfoton treatment.

The results indicated significant yield increases were attained from dinoseb treatment of zucchini squash in 1971 and from several treatments on muskmelons, tomatoes, and beans in 1972. The observed differences indicate that the chemicals were influencing plant growth in some manner.

Figure 4. Comparison of the mean daily temperature and also the mean monthly temperature for the month of June for 1971, 1972, and a 30 year average.

FIGURE 4

MEAN DAILY TEMPATURE - JUNE



Some responses may be due to growth regulating properties of the chemicals. Greatest stimulation of plant growth or yield was often shown to occur at the lowest concentration of the chemical. The lowest concentration of all chemicals, except trifluralin, resulted in greatest stimulation of early and total marketable yield and except for naptalam caused greatest stimulation of bean yields. The Arndt-Schulz law states that every poison causes either a reduction or increase in physiological performance depending on concentration (54). Thimann (54) suggest that stimulation may often occur at concentrations necessary to cause inhibition; and that promotion of one reaction can be due to inhibition of another and vice-versa. Perhaps in future experiments, concentrations should be even lower to determine at what optimum concentration greatest stimulation may occur.

The chemicals influenced tomato yield at different concentrations. The intermediate concentration, or approximately the recommended level of all chemicals in 1972 caused greatest stimulation to early tomato development. The greatest total yield of tomato occurred at intermediate concentration for all chemicals except trifluralin. This dose response suggests that near optimum concentrations were used on tomatoes.

The increased final stand of beans was treatment related. Disulfoton was related to greatest increase of bean stand. Since the chemical was not applied until after bean emergence, it probably had little influence on germination. Its benefit may have been related to survival. There have been numerous reports of disulfoton influencing crop growth. Guyer, Brown, and Wells (17) reported better germination of wheat seed treated with disulfoton. Stanley and Qualset (52) found granular disulfoton at

11.2 kg/ha caused increased fall forage production for various varieties of barley, wheat, and rye. Stanley et al. (51) found increased forage production of six wheat and one rye variety with applications of disulfoton and a similar systemic insecticide phorate (O,O-diethyl-s-(ethylthio)-methyl phosphorodithioate). Kerr et al. (25) reported phorate increased grain and foliage production of both Hessian fly resistant and susceptible wheat varieties.

The increased flowering of tomatoes associated with dinoseb, disulfoton, and naptalam may be due to hormonal type activities. Many researchers have shown that various compounds do influence tomato flowering. B-napthoxy-acetic acid (30,19), 2,4-dichlorophenoxyacetic acid (19), and tolyphalthalamic acid (50) have been shown to set fruit. Wittwer (59) reported para-chlorophenoxyacetic acid increased fruit yield more effectively at temperatures below 59°. Mann (30), using all three of the above mentioned chemicals, found more fruit set, and more fasciation of flowers. He also found that the treatments resulted in vine injury. Hammer et al. (19) found that 4-chlorophenoxyacetic acid, b-naphthyoxyacetic acid, and napthalenacetic acid increased fruit set and also increased the occurrence of seedless fruit. Thus, there seem to be many similarities of what has been reported for these chemicals and what was observed to happen from several treatments in 1972. The mean temperature of June was 61.6 (Figure 4), near that described by Wittwer. The dinoseb, disulfoton, and naptalam were associated with increased occurrence of fasciated flowers and seedless fruit.

Leopold (28) suggests that N-tolypathalamic acid may restrict vegetative growth resulting in increased fruit set. Shen (50) describes the tomato plant as having sympodium buds. A simple axis develops and is termined by an inflorescence. A bud in the leaf axil subtending the inflorescene develops a new axis or branch. Therefore, determinate type plants are those where the sympodial bud is suppressed and the main axis terminates after one or two inflorescences. She observed that N-tolyphalthalanic acid increased fasciation of flowers and polychotomous type inflorences, and suggested that the chemical may aid in maintaining apical dominance by the inflorences and suppressing development of sympodical bud. The pesticides may influence the floral development by suppressing development of the vegetative sympodial bud.

How herbicides might effect growth is still not well defined. Moreland (37) described three major metabolic areas that might be influenced: respiration and electron transport, photosynthesis, nucleic acid and protein synthesis. Several of the herbicides have been proposed to incluence nucleic acid or protein synthesis. Penner and Early (41) proposed that the activity of trifluralin was associated with inhibiting and altering nucleic acid metabolism, this, eventually preventing synthesis of a required enzyme. Negi (39) demonstrated that 10^{-4}M concentration of trifluralin results in uncoupling of oxidative phosphorylation. Dinoseb apparently also functions as an uncoupling agent (60). Mitchell (36) found that uncoupling agents penetrate the membrane causing loss of selective impermeability. Thus, dinoseb would prevent the formation of ATP which is needed for many metabolic functions, perhaps nucleic acid synthesis. Bensulide may influence in some manner either nucleic acid or protein synthesis. Ashton _et al._ (2) reported that bensulide reduced enzymatic activity of squash seedling by 37%.

The mode of action of naptalam is not well explained. The herbicide has been found to interact with auxins. Keith and Baker (24) reported that naptalam inhibited basipetal polar transport of auxin in bean stems. Mentzer and Neitien (33) showed the naptalam at 10^{-3} to 10^{-6}M caused negative geotropic responses in a number of seedlings.

Little information was available on how disulfoton might influence plant growth. Bull (8) reported that the insecticide was quickly oxidized in the plant. He found the first product to be mercaptosulfuratam. Sulfoxide and sulfone were two major products found, although there were many. Metcalf _et al._ (34) found thiol phosphate sulfoxide and thiol phosphate sulfone to be the major toxic metabolites.

The pesticidial influence on various physiological systems would be of obvious importance to growth of the plant and thus, yields. Moreover, if a chemical can influence the nucleic acid metabolism, this may be of great importance in future research. Zielinsk (62) has shown that fasciation of the tomato flower is due to a single recessive gene. Several of the chemicals were observed to cause fasciation of flowers. There may be some relationship of the chemicals to the influence of this gene, and to others. Breeding programs often require extensive time to develop a new trait in crops. Perhaps in the future, the application of some pesticide may result in the unmasking or expression of some desirable trait.

Regardless of how the pesticide may influence growth, the side effects may be beneficial to some species of plant. A herbicide may prove to be more valuable to a crop at certain concentrations than the control of weeds at presently recommended levels. More research needs to be conducted to determine what side effects on crop plants may occur and at what concentrations. It is suggested that more work be done at sublethal concentrations of pesticides. More work needs to be undertaken to determine the influence of the interaction of temperature and pesticides on crops, especially in relation to flowering of tomatoes. Determination needs to be made of what crop seeds may be stimulated to germinate better by a pesticide. One needs to determine if such germination is due to a direct effect on the seed or on the soil micro- or macro-organisms.

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