Influence of Various Soil Incorporated Fungicides and Nematocides on Macro and Micro Element Constituents of Zea Mays and Phaseolus Vulgaris

by H. COLE, D. MACKENZIE, C. B. SMITH and E. L. BERGMAN
Pesticide Research Laboratory
Departments of Plant Pathology and Horticulture
Pennsylvania State University
University Park, Pennsylvania

Observations of fungicide and nematocide effects on plant growth has been reported (3). However, almost no quantitative experimental work on the mechanisms inducing these changes has been presented.

With the current interest in metallic element levels in foods and crops as related to human and animal nutrition an understanding of the role of pesticide treatments in altering these levels is needed. The research reported here involves influence of certain pesticides on the macro and micro element constituents of bean and corn plants. Five fungicides which are commonly used for both foliar and soil applications, one fumigant action nematocide, and a systemic insecticide - nematocide were incorporated into steam treated soil in ceramic crocks in the greenhouse. The application amounts selected for the fungicides approximate the maximum commercial dosages which might be applied as drenches, or

[1] Authorized for publication on August 29, 1967, as paper No. 3289 in the journal series of the Pennsylvania Agricultural Experiment Station.

mixed into soils for soil borne pathogen control. The fumigant-nematocide rates approximate commercial dosage ranges for both greenhouse and field. The systemic insecticide-nematocide application amount approximates a commercial nematocidal treatment dosage.

Experimental Methods

The test plants were grown in the greenhouse in glazed ceramic crocks containing a 3:1:1 mixture of Hagerstown silty clay loam, peat, and fine sand. The containers had 20 mm openings in the bottom which were covered with a 1/16 inch layer of porous fiber glass cloth to allow drainage without soil loss.

The soil mixture was steam treated at 212°F for one hour. Soil moisture content at the end of steam treatment approximated field capacity. It was then allowed to cool to room temperature and the test chemicals were added to the soil. All chemicals were mixed with soil on a "chemical weight/soil weight at field capacity" basis to achieve the desired ppm concentration. Because of the small quantities needed each chemical was blended with 30 g of vermiculite which in turn was mixed with the soil. In the control series vermiculite alone was added to the soil. All chemicals tested were commercial formulations with the quantities computed on the basis of active ingredient. The materials tested in Series #1 were disulfoton (Di-Syston), at the dosages of 10 and 100 ppm; and DBCP (Nemagon) at the dosages of 3 and 30 ppm. The disulfoton formulation was a 2% granular while the DBCP was a 67% by weight liquid emulsifiable concentrate. The materials tested in series #2 were captan, 50% wettable powder, 100 and 200 ppm; thiram, 65% wettable powder, 200 ppm; PCNB (Terrachlor) 75% wettable powder, 200 ppm; P-dimethylamino-benzenediazo sodium sulfonate, (Dexon) 35% wettable powder, 200 ppm; and zinc ion maneb (Dithane M-45) 80% wettable powder, 200 ppm. After the pesticides were blended with the soil, the containers, which had been previously steam treated, were immediately filled with 9 lbs. of soil-pesticide mixture per container. Test plants were corn (*Zea mays* var. *saccharata* (Sturtev.) Bailey, hybrid, NK87) and beans (*Phaseolus vulgaris* L., cultivar Bountiful). Series No. 1 was seeded Sept. 22, 1966, with 8 bean or 8 corn seeds per pot, which were thinned to 4 plants per pot soon after emergence. The seeds were free of any chemical treatment. The plants were maintained in a greenhouse at 74°F $\pm$ 8°. No supplemental plant nutrients were added during the duration of the experiment. The plants were watered by adding equal amounts of water to each container. The levels added were such that slight drainage occurred from each container after watering. The watering intervals were sufficiently close so that any plant size differences with corresponding H_2O extraction rate differences would not significantly influence soil moisture levels among containers. This method of watering was evaluated previously by the authors on both wet and dry weights of corn plants in the greenhouse with various statistical procedures (5). No differential effects due to soil moisture could be detected. Each treatment was replicated three times (3 pots) for each plant species, pesticide treatment, and treatment dosage. The containers were randomly redistributed on the greenhouse bench at 7 day intervals to avoid position effects.

Care was taken to avoid contamination of the plants or soil with plant pathogens. No recognized plant pathogens or diseases could be detected by visual observation or tissue isolation procedures on the plant roots or foliage of series No. 1. On November 3 the above ground portions of the plants were harvested, fresh weights taken, and then dried in an oven at 140°F for 48 hours. All leaf and stem tissues from a replicate were ground together in a Wiley mill to pass a 40 mesh screen. The Wiley mill had been specially altered to prevent trace element contamination. All samples were analyzed for 12 elements. A semi-micro Kjeldahl procedure was used in determining nitrogen. An emission spectrometric procedure was employed to determine simultaneously phosphorous (P), potassium (K), calcium (Ca), Magnesium (Mg), manganese (Mn), iron (Fe), copper (Cu), boron (B), aluminum (Al), strontium (Sr), and zinc (Zn). The procedures and equipment employed have been presented in detail by Baker _et al_ (1). The spectrometric data conversion, data transformation and statistical procedures including analyses of variance[1] and Duncans

---

[1] The analyses of variance and LSD for the plant's fresh weight were computed by hand.

multiple range tests were accomplished with Fortan programs on the IBM 7074 computer at The Pennsylvania State University Computation Center.

Series 2 was planted on October 6, 1966 and harvested December 1, 1966 after 8 weeks growth. Three replications of each plant species, pesticide treatment, and treatment dosage were employed. Series 2 was grown in a greenhouse at 69°F $\pm$ 8°. All other procedures including plant species, variety, drying and analysis were the same as for Series #1.

Experimental Results

Series No. 1. The addition of disulfoton at 10 ppm and DBCP at 3 ppm level significantly increased the fresh weight of above ground portions of bean and corn plants (stems and foliage) after 6 weeks growth while the 100 ppm disulfoton significantly decreased the fresh weights of bean and corn. The 30 ppm level of DBCP did not significantly affect plant weights (Table No. 1). Both macro and micro elements in beans and corn were affected by these chemicals at all dosages. Disulfoton at 100 ppm in beans increased N, P, K, Ca and Mg but decreased Fe, Cu, Al, and Zn in beans. With beans all chemicals and dosages decreased Cu levels. With corn all chemicals and dosages decreased Mn levels while increasing Zn levels. DBCP at both dosages decreased N, Ca, Mg, Mn, and Sr while increasing K, Fe, Cu, and An (Table No. 2).

Series No. 2. The addition of captan, 100 ppm, thiram, Dexon, and zinc ion maneb significantly increased the fresh weight of corn plants after 8 weeks growth. At the same time captan 100 and 200 ppm, thiram, Dexon, and zinc ion maneb increased the fresh weight of bean plants. The fungicides affected both macro and micro element levels in varying degrees (Table No. 4).

Discussion

Most prior observers of growth stimulation by soil pesticides have attributed the response to either the effect of the pesticides on plant pathogens or to the release of plant nutrients including nitrogen by death of the soil microbial population due to the action of the pesticides. To this end Hollis and Rodriguez-Kabana (4) formulated a theory dealing with the quantitative aspects of release of nitrogen from the dead microbial population.

In the present study the initial effects of the soil microorganism-chemical interaction were eliminated by steam treatment of the soil as well as the containers prior to addition of the chemicals. It is recognized that spore forming bacteria would survive 212°F steam treatment and that microbial contaminants on seeds and from the greenhouse air will tend to re-colonize the steam treated soil at varying rates. It is also recognized that the chemical treatments could influence the microbial re-colonization activities. However, this would be anticipated to occur to a far lesser extent that if untreated field soil were used.

TABLE 1

Series No. 1

Mean fresh weight of above ground portions of plants as harvested after 6 weeks growth.

		Grams	
		beans	corn
Check		11.4	10.4
Disulfoton	10 ppm	14.7	15.0
	100 ppm	6.6	7.3
DBCP	3 ppm	16.0	21.1
	30 ppm	10.6	11.4
	LSD @ 0.05	2.1	3.0

TABLE 2

Series No. 2

Mean fresh weight of above ground portions of plants as harvested after 8 weeks growth.

	Grams	
	beans	corn
Check	21.7	35.9
Captan 100 ppm	29.3	51.0
Captan 200 ppm	26.0	34.1
Thiram 200 ppm	25.4	50.6
Dexon 200 ppm	27.1	49.3
PCNB 200 ppm	15.3	9.8
Zinc-ion Maneb 200 ppm	25.4	44.2
LSD @ 0.05	2.7	7.0

TABLE 3

Series No. 1 - INFLUENCE OF CERTAIN SOIL INCORPORATED PESTICIDES ON ELEMENT CONTENT OF CORN AND BEAN PLANTS

Treatment	Percent of dry weight					ppm of dry weight						
Beans 6 weeks	N	P	K	Ca	Mg	Mn	Fe	Cu	B	Al	Sr	Zn
Check	5.14	.153	3.03	1.75	.304	377	500+	15.6	36	500+	29	91
Disulfoton 10 ppm	0[a]	0	0	0	0	0	0	-5.3[b]	0	0	0	0
Disulfoton 100 ppm	+1.78[c]	+.228	+1.81	+.19	+.072	0	-331	-7.0	0	-185	0	-50
DBCP 3 ppm	0	0	0	0	0	0	0	-7.6	-10	0	0	-62
DBCP 30 ppm	0	0	+.82	0	+.092	0	0	-5.7	+15	0	0	-39
Corn 6 weeks												
Check	5.30	.175	4.41	1.36	.376	469	329	10.2	21.5	372	24	68
Disulfoton 10 ppm	0	+.038	+1.70	-.52	0	-247	0	0	0	0	0	+26
Disulfoton 100 ppm	0	+.257	-.90	+.77	+.116	-171	0	+3.3	0	0	+14	+34
DBCP 3 ppm	-.93	0	+1.25	-.44	-.088	-229	+171	+1.5	0	0	-8	+38
DBCP 30 ppm	-.93	+.103	+.71	-.51	-.102	-320	+109	+2.1	0	0	-10	+34

a. "0" indicates that mean for 3 replications did not differ significantly from check mean when subjected to Duncans multiple range test at .05 probability level.

b. "-" indicates that treatment mean was significantly lower than the check, i.e. the treatment was 5.3 ppm lower than the check mean.

c. "+" indicates that treatment was significantly higher than the check, i.e. the treatment mean was 1.78% higher than the check mean.

TABLE 4

Series No. 2 - INFLUENCE OF CERTAIN SOIL INCORPORATED PESTICIDES ON ELEMENT CONTENT OF CORN AND BEAN PLANTS

Treatment	Percent of dry weight					ppm of dry weight						
Beans 8 weeks	N	P	K	Ca	Mg	Mn	Fe	Cu	B	Al	Sr	Zn
Check	3.97	0.164	2.62	1.82	0.317	170	278	5.3	35	261	24	24
Captan 100 ppm	0[a]	0	0	0	0	+95[b]	0	0	0	0	0	0
Captan 200 ppm	0	0	0	0	0	+113	0	0	0	0	0	0
Thiram 200 ppm	0	-0.049[c]	-0.61	0	0	0	0	0	-12	0	+2	-8
PCNB 200 ppm	0	0	-0.31	-0.40	0	0	0	0	-8	0	-3	+10
Dexon 200 ppm	0	0	0	0	0	+118	0	0	0	0	0	0
Zinc-ion Maneb 200 ppm	0	0	0	0	0	+247	0	0	0	0	0	+16
Corn 8 weeks												
Check	3.31	0.176	4.89	0.81	0.311	117	149	6.6	13	116	12	69
Captan 100 ppm	0	0	0	+0.25	+0.082	+72	0	0	0	0	+4	-18
Captan 200 ppm	0	0	0	0	0	+108	0	0	0	0	0	0
Thiram 200 ppm	+1.22	0	0	-0.35	+0.131	+90	0	0	+1	+4	-6	-25
PCNB 200 ppm	0	0	0	0	0	0	0	0	0	0	0	+62
Dexon 200 ppm	0	0	0	0	-0.023	+71	0	0	0	0	0	0
Zinc-ion Maneb 200 ppm	0	0	+0.85	0	0	+166	0	+2.0	0	0	0	0

a. "0" indicates that mean for 3 replications did not differ significantly from check when subjected to Duncans multiple range test at 0.05 probability level.

b. "+" indicates that treatment mean was significantly higher than the check, i.e. that the treatment mean was 95 ppm higher than the check mean.

c. "-" indicates that treatment mean was significantly lower than the check, i.e. the treatment mean was 0.049% lower than the check mean.

It is felt that the present study has demonstrated that the pesticides tested did have significant effects on plant growth, and that these effects resulted in shifts in both macro and micro element levels in corn and bean plants of the cultivars tested. Manganese, zinc and copper were the micro elements most profoundly affected depending on the test chemical and the plant species.

The results with disulfoton support the findings of Brodie and Burton, 1967 (2), who reported that disulfoton induced a growth response to any nematode reduction. They believed the response to be biological in nature and that it involved control of unknown soil organisms. The present study, although it cannot completely rule out disulfoton-microorganism interactions, strongly suggests that direct effects of disulfoton on growth of the test plants did take place under the conditions of the experiment.

The growth increase obtained with captan supports the work of Roberts and Stipes, 1967 (6), who reported that captan stimulated root growth of Ulmus americana in sand culture. Increased root absorptive capacity may be one possible mechanism to explain the increased top growth that was observed in the present study.

It is apparent from these results and those of other investigators that the role of fungicides and nematocides in influencing plant metabolism and metallic element levels needs much further investigation in all aspects. It is conceivable that many currently unexplainable plant growth problems may be related to the influence of pesticides on element uptake. Further studies are under way in these areas.

Literature Cited

1. Baker, D. E., G. W. Gorsline, C. B. Smith, W. I. Thomas, W. E. Grube, and J. L. Ragland, Agron. J. 56; 133-136 (1964)
2. Brodie, B. B., and G. W. Burton, Plant Dis. Reptr. 51; 562-566 (1967)
3. Groves, A. B., and H. A. Rollins, Hort. Science, 1(1); 11-12 (1966)
4. Hollis, J. P. and R. Rodriquez-Kabana, Phytopathology 55; 1062 (1965)
5. MacKenzie, D. and H. Cole. 1967. Unpublished data.
6. Roberts, B. R., and R. J. Stipes, Phytopathology 57; 827 (1967)