The Effect of Benomyl on the Growth of American Elm Seedlings

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ABSTRACT

Benomyl was applied either as a drench to 10-month-old American elm seedlings or incorporated directly as a dry mix into media (sand, soil, potting mix) subsequently planted with elm seed. Benomyl at concentrations of 1,000 and 1,500 ppm had no significant effect on height, dry weight, leaf area, or root:shoot ratio. Germination of elm seed in planting media containing dry benomyl was generally poor. Fourteen weeks after germination, growth was approximately the same in benomyl-treated sand and soil, but substantially greater in benomyl-treated potting mix. The size of inhibition zones around tissue sections from benomyl-treated plants indicates acropetal transport of this fungicide in the xylem, appreciable lateral movement into the phloem, and substantial accumulation in the foliage.

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Present evidence suggests that benomyl is an effective fungicide for reducing symptom development in Dutch elm disease, DED (1, 4, 12, 13). Although some information has been accumulated on factors that affect uptake, concentration, and persistence of benomyl in American elm, *Ulmus americana* L. (5, 11), there are few data on the effect of benomyl on growth of this species. Such information is essential in determining the usefulness of any systemic material in the control of DED. This study was initiated to investigate the influence of benomyl on seedling growth of *U. americana*.

MATERIALS AND METHODS.–*Benomyl applied to young elm seedlings*.–Seventy-five 10-month-old dormant American elm seedlings were transplanted individually into washed silica sand in 7-inch plastic containers. The plants were kept in the greenhouse under supplementary illumination (16-hr photoperiod; 1,800 ft-c combined incandescent, cool-white fluorescent light) for 1 month, during which time new growth was initiated. Each seedling received water on a regular basis, and was treated weekly with 200 ml of a modified Hoagland's nutrient solution (7).

Initially, the seedlings were divided into three lots of 25 plants each. One lot was harvested immediately, and plant height; dry weights of leaves, stems, and roots; root:shoot ratio; and leaf surface area were recorded for each seedling. Leaf area was determined by means of a linear regression ($Y=-0.36 + 0.86X$) that relates leaf area to leaf dry weight for American elm (*unpublished data*). A second lot of plants received one application of benomyl which was supplied as a drench at the rate of 200 ml of a 1,500 ppm aqueous suspension of active material per container. The third group of plants, which served as controls, received 200 ml of distilled water in place of the benomyl treatment. After the treatment, all 50 plants were kept in the greenhouse for an additional 60 days, then harvested. In addition to measurements of plant height and dry weights of leaves, stems, and roots, each seedling was bioassayed (5) to determine the presence of fungitoxic material in leaf, wood, and bark tissue. The experiment was repeated once, except that in the second trial a benomyl suspension containing 1,000 ppm active ingredient and 16 seedlings/treatment were used.

Benomyl applied to elm seed planted in different planting media.–Benomyl, at the rate of 300 mg active material/volume of planting medium contained in a 7-inch plastic container, was incorporated into either white silica sand, soil (Morley silt loam), or a potting mix (soil:peat:perlite, 1:2:2, v/v) by mixing in a cement mixer for 5 min. Ten American elm seeds were planted in 10 containers each of sand, sand + benomyl, soil, soil + benomyl, potting mixture, and potting mixture + benomyl. Water and nutrients were provided in amounts described above. All containers were kept in the greenhouse under a 16-hr photoperiod for 2 weeks. The germination percentage was recorded for each treatment, and the seedlings in each container were thinned to the single tallest plant whose height was recorded. The height of each plant was measured weekly for 14 weeks. At the end of this time the plants were harvested; and leaf areas, heights, and dry weights of leaves, stems, and roots were determined.

RESULTS AND DISCUSSION.–The application of 1,500 ppm or 1,000 ppm benomyl applied as a drench did not significantly affect growth of *U. americana* seedlings (Table 1). Since the molecular configuration of benomyl is similar to other growth-regulating compounds (6), we had anticipated that the physiological response of elm seedlings to benomyl might be different between 1,000 and 1,500 ppm. Differences in growth response in relation to benomyl concentration have been reported by Raabe

TABLE 1. Effect of benomyl on the growth of 10-month-old container-grown American elm seedlings[a]

Treatment	Height (cm)	Dry weight (g) Stem	Leaves	Roots	Root/shoot[b]	Leaf area (cm^2)
Experiment I[c]						
benomyl (1,500 ppm)	105.2	15.3	9.2	15.4	0.64	1,151
Control	98.2	15.9	9.9	17.8	0.71	1,211
Experiment II[d]						
benomyl (1,000 ppm)	118.5	19.0	7.3	13.0	0.52	904
Control	107.1	18.8	7.2	12.5	0.51	659

[a] Benomyl as an aqueous suspension was applied once as a drench at the rate of 200 ml of active ingredient per container.
[b] Ratio of root dry weight to shoot dry weight.
[c] Values represent the mean of 25 seedlings.
[d] Values represent the mean of 16 seedlings.

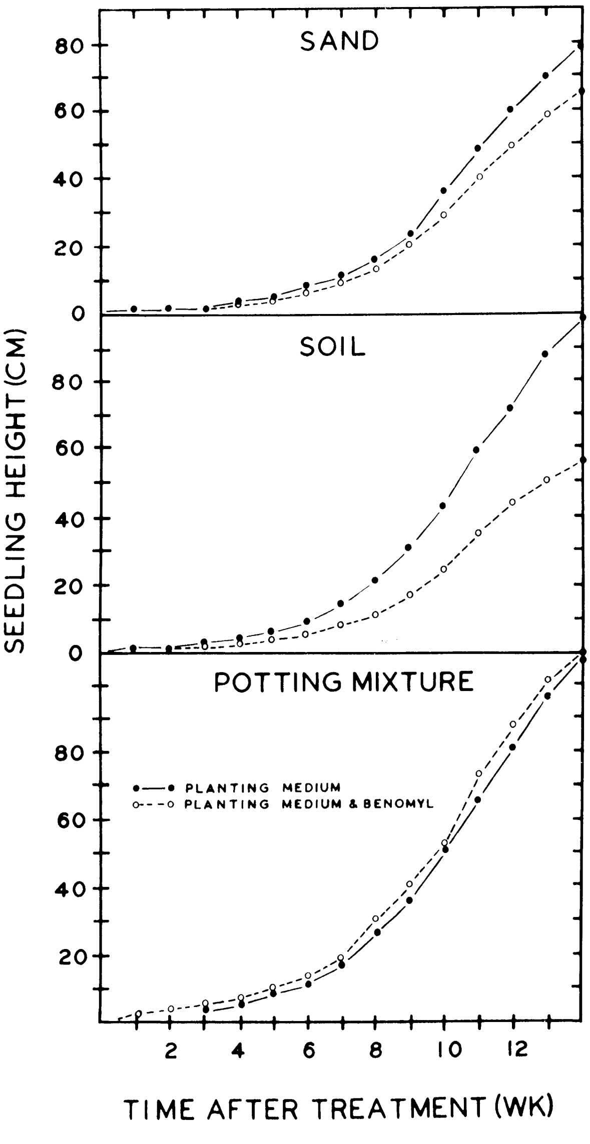

Fig. 1. Weekly height measurements of American elm seedlings grown in various planting media incorporated with benomyl at the rate of 300 mg active ingredient/container.

& Hurlimann (10) for poinsettia. Cole et al. (3) reported a decline in dry weight of container-grown cucumbers treated with 40, 80, 100, or 1,000 ppm benomyl, but observed a stimulation in dry weight at a concentration of only 10 ppm. Cimanowski et al. (2) found that 0.05% benomyl applied either as a soil drench or as a foliar spray increased leaf surface area of *Prunus avium*. Perhaps the benomyl concentrations used in our study were too far below the physiologically sensitive range for American elm to cause any difference in response.

In the second experiment, germination of elm seed in planting media containing benomyl was substantially less than germination in comparable media without benomyl. Inhibition of seed germination by benomyl was most apparent in soil (50% germination without benomyl versus 29% germination with benomyl) and sand (37% versus 19%), and less in the potting mix (27% versus 24%). That benomyl did not significantly reduce seed germination in the potting mixture probably was due to decreased availability of the material in a mixture containing relatively high organic matter. It has been shown in previous studies that benomyl uptake is enhanced in planting media with relatively low organic matter content (5, 11).

Unlike others (14), we observed a significant reduction in height growth of American elm seedlings grown in benomyl-treated soil (Fig. 1 and Table 2). This effect became apparent 3 weeks after germination, and by the end of 14 weeks, plants grown in benomyl-treated soil were 42% shorter than comparable plants grown in soil without benomyl. On the other hand, height growth of plants grown in potting mixture that contained benomyl was not retarded. Rather, the benomyl-treated seedlings were always slightly taller than plants grown in potting mix alone, although the differences were not significant. This latter observation might also be explained on the basis of the potting mixture composition and the apparent decline in availability of benomyl with increased organic matter content.

If higher concentrations of benomyl depress growth of American elm, it seems strange that there was not a greater disparity in the growth of seedlings in benomyl-treated sand as opposed to sand alone.

TABLE 2. Effect of benomyl applied to different planting media on the growth of American elm seedlings[a,b]

Treatment	Height (cm)	Dry weight (g)			Root/shoot[c]	Leaf area (cm^2)
		Stem	Leaves	Roots		
Sand[d]	79.4 y	2.0 z	3.1 z	1.1 x	0.23 x	438 z
Sand + benomyl	64.7 yz	1.6 z	3.2 yz	1.1 x	0.24 x	445 z
Soil[e]	98.2 x	3.9 y	4.9 y	1.9 x	0.22 x	654 y
Soil + benomyl	57.2 z	1.1 z	1.9 z	0.7 x	0.24 x	293 z
Mix[f]	108.3 x	5.6 x	7.3 x	2.4 x	0.19 x	924 x
Mix + benomyl	109.5 x	5.9 x	8.0 x	2.6 x	0.18 x	1,007 x

[a] Values represent the mean of 10 seedlings. Means followed by different letters in the same column are significantly different at the 5% level using "Student" t-test.
[b] Benomyl applied at the rate of 300 mg active ingredient mixed dry per container of planting medium.
[c] Ratio of root dry weight to shoot dry weight.
[d] White silica, grain size 34.
[e] Morley silt loam.
[f] Soil: peat: perlite (1:2:2, v/v).

Data in Table 2 provide a possible explanation, as elm growth in treated sand and treated soil did not differ significantly, yet growth of seedlings in soil alone was substantially greater than in sand alone. Thus, although benomyl-treated sand was effective in slowing elm growth, this effect was masked by the relatively poor growth of elm in sand alone. The effects of different planting media on height growth of American elm seedlings observed in this study are in agreement with those reported by Schreiber et al. (11).

The distribution of fungitoxicant in elm tissue as determined by the bioassay procedure was similar to that reported for previous studies from this laboratory (5, 11). In general, the average diameter of inhibitory zones decreased for tissue sections of wood, bark, and foliage sampled acropetally. These data suggest a normal translocation pattern up the stem from a fungicide reservoir in the potting medium. Bioassays from stem tissue showed the greatest amount of fungitoxicant activity in the xylem, confirming observations by Peterson & Edgington (9) and by Meyer et al. (8) on the transport pathway of benomyl in bean and grass, respectively.

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