Upward and Lateral Translocation of Benomyl in Strawberry

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ABSTRACT

Root uptake and translocation of benomyl and its breakdown product, methyl-2-benzimidazolecarbamate (MBC), was studied in cultivated strawberry (*Fragariae* × *ananassa* 'Tioga') in single plants and in two stolon-connected plants. Treatment of roots of single plants with 1,000 mg/liter benomyl for 24, 48, or 72 hr resulted in upward translocation of benomyl or MBC to the growing point and throughout all tissues except those of newly emerged leaflets. Treatment of the roots of either a daughter plant or mother plant connected by a single stolon with 1,000 or 2,000 mg/liter benomyl for 96 hr resulted in translocation of benomyl or MBC through the stolon to nontreated tissues of the other plant. Translocation from the daughter plant through the stolon to mother plant tissues was considered "lateral" translocation of the fungitoxic compounds.

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The systemic fungicide, benomyl (E. I. duPont), has been used as a foliar spray to control various strawberry diseases (2, 3, 4, 5, 6, 8, 11). Benomyl applied as a soil drench has been reported to control *Verticillium dahliae* (3, 7, 12). Since systemic movement of benomyl and its breakdown product, methyl-2-benzimidazolecarbamate (MBC), in strawberry plants has not been demonstrated, a study was made of their movement in single plants and stolon-connected plants.

Strawberry plants (*Fragariae* × *ananassa* 'Tioga') (1) were rooted and grown in styrofoam cups (0.45 liter) containing vermiculite (Terralite brand) for 30 days prior to treatment of the roots with fungicide. All plants were maintained in a growth chamber programmed for 22 ± 2 C, 70% relative humidity, and a daily 16-hr photoperiod. Twelve plants were potted individually. In addition, 12 mother plants were selected, each connected by a single stolon to a daughter plant growing at the end of the second node. The mother plant and stolon-connected daughter plant were potted in separate cups (9). All leaves and petioles, except for one mature leaf and an emerging leaf, were removed from each plant 2 days prior to fungicide application.

Benomyl suspension (1,000 mg active ingredient/liter of water) was applied as a drench (150 cc/cup) to each of six cups that contained individual plants; roots of six control plants were drenched with an equal volume of water. Benomyl suspension (150 cc of 1,000 or 2,000 mg active ingredient/liter) also was added to each of six cups that contained either a mother plant or a daughter plant.

Bioassays for benomyl or MBC were made at 24, 48, and 72 hr for individual plants and at 96 hr for mother-daughter plants. Plants were washed thoroughly in tap water to remove any vermiculite and surface benomyl from the roots, then placed in plastic bags and frozen (−20 C for 24 hr). Eleven different samples excised from individual plants and 25 samples removed from the two plants connected by a stolon (Fig. 1) were placed on Difco potato-dextrose agar (PDA) (9). The agar surface in each

TABLE 1. Translocation of benomyl in strawberry plants as indicated by fungitoxicity activity against *Penicillium atrovenetum* of tissue samples 23, 48, and 72 hr after treatment of the roots[a]

Plant part sample[b]	Time after treatment in hr		
	24	48	72
1	32	43	45
2	33	43	48
3	22	43	47
4	7	38	41
5	12	40	43
6	12	37	45
7	0	25	38
8	0	26	36
9	0	24	36
10	4	13	30
11	0	0	4
LSD[c]	23	37	23

[a]Benomyl (150 cc of 1,000 mg active ingredient/liter) applied as drench to plant roots. Fungitoxic activity based on mean diameter of inhibition zones for six replications and average of two experiments.

[b]1 = root; 2 = crown; 3 = petiole of mature leaf; 4,5,6 = base of leaflets; 7,8,9 = tip of leaflets; 10 = petiole of immature leaf; and 11 = immature leaflets; there were no inhibition zones associated with samples from control plants.

[c]Least significant difference (5% level).

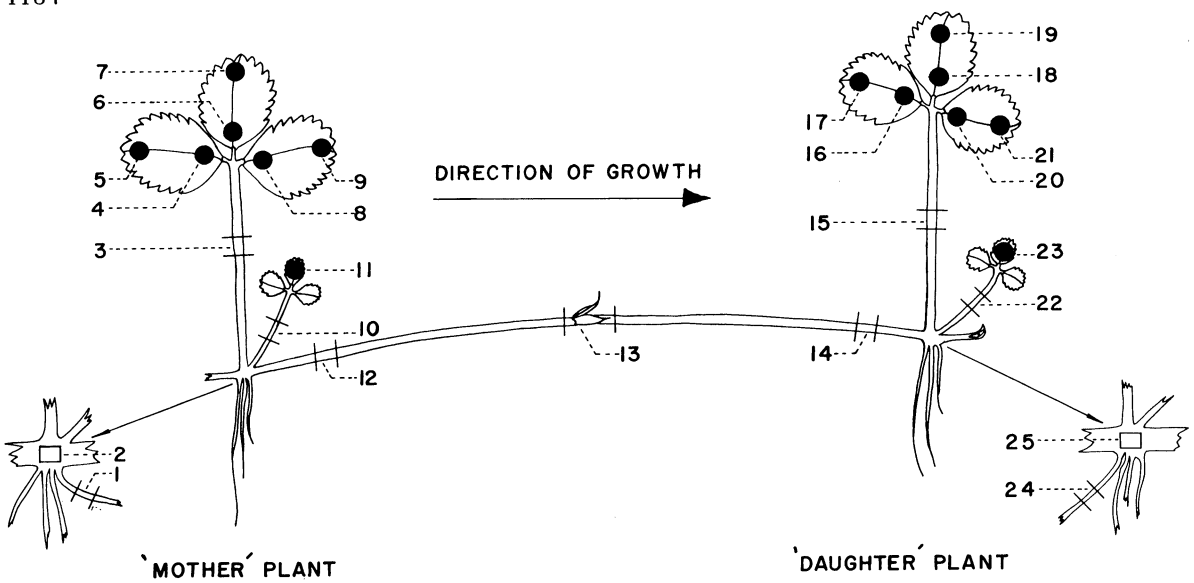

Fig. 1. Diagrammatic representation of technique by which plants were sampled to determine uptake and translocation of benomyl between two strawberry plants connected by a stolon. Numbers indicate location of tissues used in bioassay. One = first root system; 2 = crown; 3 = petiole; 4, 5, 6 = bases of leaflets; 7, 8, 9 = tips of leaflets; 10 = newly emerging petiole; 11 = newly emerging leaflet; 12 = stolon; 13 = center node of stolon; 14 = stolon; 15 = crown second plant; 16 = root; 17 = petiole; 18, 19, 20 = bases of leaflets; 21, 22, 23 = tips of leaflets; 24 = newly emerging petiole; and 25 = newly emerging leaflet.

plate was sprayed, using an atomizer, with conidia of *Penicillium atrovenetum* G. Smith suspended in sterile distilled water (100,000 spores/ml), and the plates were kept for 3 days at 30 C. Presence of benomyl or MBC in a sample was indicated by a zone around the sample in which growth of *P. atrovenetum* was inhibited.

Characterization of the fungitoxic compound(s) was determined by the thin-layer chromatography and bioassay techniques of Peterson & Edgington (10). One-g samples of leaf tissue from individual plants that were incubated for 72 hr in 1,000 mg/liter benomyl were used. Extracts were made using acetone (9) and compared with a 25 mg/liter commercial formulation of benomyl spotted on thin-layer chromatographic plates. Following drying, the plate was sprayed with a suspension of PDA and spores of *P. atrovenetum*.

Bioautographs showed the presence of benomyl and MBC in leaf tissues of treated strawberry plants. Therefore, inhibition zones associated with treated plant tissues reflected the fungitoxicity of both compounds. Benomyl was taken up by the roots of strawberry plants and translocated throughout the plant within 72 hr. Activity was highest in tissues of root, crown, and petiole of the mature leaf; low in the tissues at the base of the leaflets and petiole of the immature leaf; and absent in the other tissues bioassayed at 24 hr. Activity was higher in all tissues at 48 and 72 hr (Table 1). Fungitoxic activity was not detected in newly formed leaflets until 72 hr.

When the root system of a mother plant was treated with benomyl, fungitoxic activity was detected in all tissues of the daughter plant except those of the roots, petiole, and leaflets of a newly formed leaf (Fig. 2). When the root system of a daughter plant was treated, only the crown, petiole, and base of leaflets of the mother plant had fungitoxic activity (Fig. 2). Therefore, movement through stolon from daughter plant to mother plant apparently was slower. This suggested that the movement of the fungitoxicants was against the direction of growth of the stolon, since the compounds could be detected within 24 hr after treatment. This was considered to be "lateral" translocation of the fungitoxicants rather than downward translocation. Similar lateral movement was found in stolons of creeping bentgrass (9).

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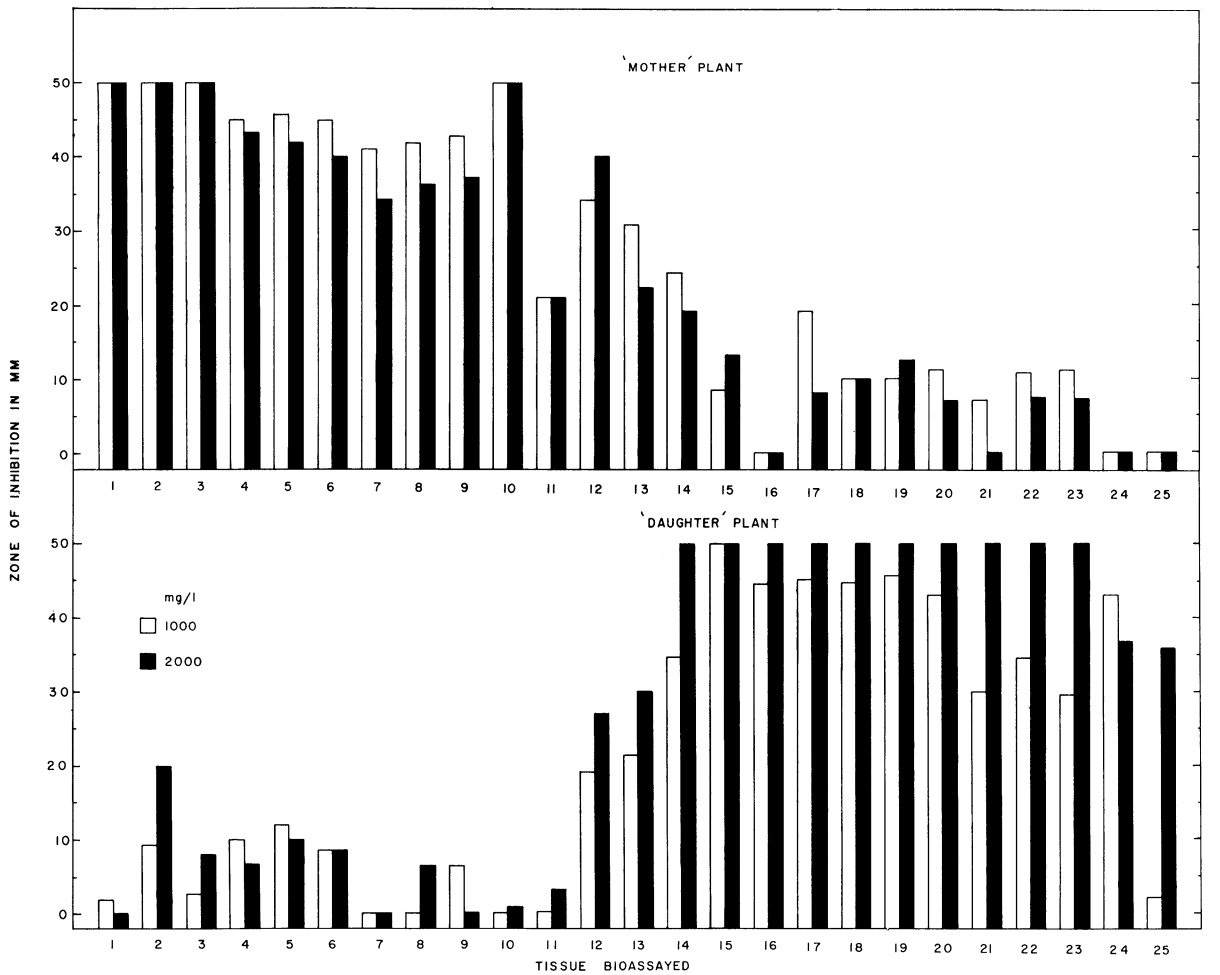

Fig. 2. Translocation of benomyl in strawberry plants as indicated by inhibition zones reflecting fungitoxic activity against *Penicillium atrovenetum* in bioassay of tissues (see Fig. 1) of plants sampled 72 hr after treatment of the roots with benomyl (150 cc of 1,000 or 2,000 mg active ingredient/liter).

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