Individual and Combined Effects of Flooding, Phytophthora Rot, and Metalaxyl on Asparagus Establishment

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ABSTRACT

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Asparagus (*Asparagus officinalis*) crowns (cultivar U.C. 157) were transplanted into noninfested plots or plots that had been infested with both *Phytophthora megasperma* var. *sojae* and *P. cryptogea* before transplanting. Immediately after transplanting, metalaxyl was sprayed over half of the infested and half of the noninfested plots at 1.12 kg a.i./ha. Plots were then flooded for 48 hr every 2, 3, 4, or 8 wk or not flooded at all. In 1984, flooding frequency was the same, but flooding duration was reduced to two 8-hr flooding periods separated by 16 hr of drainage. There was no effect of *Phytophthora* on asparagus establishment in 1983, but emergence was delayed and survival was reduced as flooding frequency increased. In 1984, emergence was delayed, root and crown rot was more severe, and vigor and survival were lower in infested plots. Disease severity in infested plots increased as flooding frequency increased but was reduced by metalaxyl. Metalaxyl was more effective for controlling Phytophthora rot as flooding frequency decreased. There was only a small advantage from dipping crowns in solutions of metalaxyl at concentrations of 20–200 mg a.i./L or from in-furrow applications to seedling or crown transplants at 0.07–1.12 kg a.i./ha. Thus, *Phytophthora*-related establishment failures can be controlled with metalaxyl, or avoided by transplanting crowns or seedling transplants, when field conditions are dry and warm.

The traditional and most frequently used method of establishing asparagus (*Asparagus officinalis* L.) in California is by transplanting 10-mo-old to 1-yr-old crowns from a nursery block to the production field (1). Dormant crowns are usually dug from the nursery in January or February and are either transplanted immediately or held in cold storage until field conditions are suitable for transplanting. Direct seeding has been used in the past but is now done only in the desert production areas in the Coachella and Imperial valleys. A third method that has been developed recently, and which is gaining in popularity, is the use of 10- to 12-wk-old seedling transplants (3) that are raised in a greenhouse and transplanted to the production field during the spring.

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Difficulties in re-establishing asparagus in fields previously planted to asparagus have been attributed to disease caused by *Fusarium oxysporum* Schlechtend.:Fr. f. sp. *asparagi* S. I. Cohen (11). With the release in 1975 and subsequent widespread planting of the cultivar U.C. 157, which has tolerance to *F. o.* f. sp. *asparagi* (4), *Fusarium*-related re-establishment problems have occurred less frequently.

In 1982, a field virgin to asparagus in the Salinas Valley was planted with crowns grown in the Sacramento-San Joaquin Delta. Heavy rains before and after transplanting resulted in an average establishment of only 27%. *Phytophthora megasperma* Drechs. var. *sojae* A. A. Hildebrand was isolated from crowns, spears, and soil collected from the field. In a preliminary trial in this field where Phytophthora rot had been controlled by a postplanting application of metalaxyl, establishment exceeded 80% (A. S. Greathead and P. G. Falloon, *unpublished data*).

This paper reports the results of six field trials to determine the effect of *Phytophthora* and metalaxyl on the establishment of asparagus under various soil moisture regimes and the effect of metalaxyl on asparagus establishment when either crown or seedling transplants are used.

MATERIALS AND METHODS

Production of inoculum. V8 vermiculite inoculum of one isolate of *P. m.* var. *sojae* (PmACA014) and one isolate of *P. cryptogea* (PmACA004), both of which had been isolated from asparagus in California (9), was prepared as previously described (8). After the fungus had grown throughout the vermiculite, equal volumes of each isolate were mixed and spread over the surface of half of the plots at the rate of approximately 1.9 L of V8 vermiculite inoculum per half plot. The inoculum was applied on 22 April 1983 and worked into the soil to a depth of approximately 100–150 mm with a rototiller.

Effect of *Phytophthora*, soil moisture, and metalaxyl on establishments. The cultivar U.C. 157 was used in all trials. In 1983, a trial was established in Reiff loam soil at Davis. Basins were constructed by building levees approximately 0.5 m high × 1.0 m wide around each double plot, which measured 6.7 × 5.5 m. Another levee was built across the center of each double plot, making two single plots each measuring 1.85 × 3.5 m. Each double plot was separated from its nearest neighbor by approximately 1.5 m.

One-year-old crowns that had been grown in soil virgin to asparagus were transplanted into the plots on 9 and 10 May 1983. Each planting hole was excavated to a depth of approximately 150 mm with a motorized soil auger with a 200-mm-diameter bit. Twenty crowns were transplanted into each plot and covered with 25–50 mm of soil. On 15 May 1983, a broadcast application of metalaxyl was made with a compressed CO_2 sprayer to half of the infested and half of the noninfested plots at the rate of 1.12 kg a.i./ha in approximately 1,500 L/ha of water.

Starting on 31 May 1983, plots were flooded for 48 hr once every 2 wk for a total of 8 wk (i.e., four times), once every 3 wk for a total of 9 wk (i.e., three times), once every 4 wk for a total of 8 wk (i.e., two times), once for 48 hr, or were not flooded. Thus, three factors were investigated: the presence or absence of *Phytophthora*, presence or absence of metalaxyl, and flooding frequency. The treatments were randomized in a split-plot design with flooding and inoculum as the main plots and metalaxyl application as the subplot. Each treatment was replicated four times.

Approximately 17 days after transplanting, spears had started to emerge and counts of the number of plants that had emerged were made every 2 or 3 days. A final count of the number of surviving plants was made on 15 October 1983. Plots were irrigated throughout the summer to ensure vigorous growth and weeds were controlled with glyphosate or hand weeding.

A similar trial was done in 1984 on a new site without a previous history of asparagus culture. Eight-month-old crowns were grown in soil virgin to asparagus from seed treated with benomyl applied with an acetone infusion technique (5) to eradicate surface contamination by *F. o.* f. sp. *asparagi* and *F. moniliforme* J. Sheld.

Plots were infested on 16 December 1983 with U.C. mix (13) infested with PmACA004 and PmACA014 from glasshouse inoculation studies and on 15 January 1984 with V8 vermiculite inoculum. Inoculum was mixed into the soil to a depth of 100–150 mm and crowns were transplanted on 27 and 28 February 1984. An additional 50 ml of V8 vermiculite inoculum was placed in each planting hole after the crowns had been covered with 25–50 mm of soil. Half of the plots were sprayed with metalaxyl on 6 March 1984 at 1.12 kg a.i./ha, and flooding treatments began 7 days after transplanting. The same flooding treatments as in 1983 were used, except instead of flooding continuously for 48 hr at each flooding period, plots were flooded for 8 hr, drained for 16 hr, and flooded the following day for 8 hr.

Plant emergence counts started on 27 March and ended on 16 May 1984 when 10 plants were sampled from each plot. The fern stalks were cut at ground level and their dry weight was determined after oven-drying at 56 C for 14 days. The same plants were then dug, the soil washed from their roots, and the proportion of rotten roots was determined for each plant on a scale where 0 = no rot and 4 = >50% of roots rotten (7). A disease severity index (DSI) where 0 = no plants with root rot and 100 = all plants with >50% rotten roots (14) was calculated from the root rot data. Each crown was then cut longitudinally and evaluated for crown rot on a scale of 1–9 where 1 = no rot and 9 = crown completely rotten, plant dead. Isolations were made from crown and root tissue by surface-treating excised tissue (approximately 5 mm square) for approximately 5–10 min in 1% NaOCl and plating on either acidified potato-dextrose agar (A-PDA) or antibiotic PDA (prepared by adding 50 mg of pimaricin and 100 mg of vancomycin to each liter of melted PDA) (7). *Phytophthora* was never isolated on A-PDA, so antibiotic PDA was used for all subsequent isolations.

The 10 remaining plants in each plot were fertilized with ammonium sulfate at the rate of 522 kg/ha. Plots were flood irrigated as required and weeds were controlled either with linuron or hand applications of glyphosate. A count of surviving plants was made on 7 November 1984 when the fern of healthy plants was still green. The fern from all plants was cut at ground level and the combined dry weight of all plants in each plot was determined after oven-drying at 56 C for 18 days. The plants were dug, the soil washed from roots, and each plant was evaluated for root rot. Isolations were made by plating surface-sterilized crown and root tissue on antibiotic PDA.

Effect of metalaxyl on asparagus stands established from crowns and seedling transplants. Four trials were established in 1984 to determine the optimum rate and method of applying metalaxyl for the control of Phytophthora rot during stand establishment of asparagus. In all cases, fields with a previous history of Phytophthora rot were chosen (Table 1).

In trials A and B, 20-mo-old crowns were dipped in solutions of metalaxyl at concentrations of 20, 50, 100, or 200 mg a.i./L and transplanted. For comparison, crowns that had not been dipped were transplanted and covered with 25–50 mm of soil before a 0.3-m-wide band of metalaxyl was sprayed over the row at rates of 0.07, 0.14, 0.28, 0.56, or 1.12 kg a.i./ha in approximately 230 L/ha of water applied with a compressed CO_2 sprayer. In trial B, 10- to 12-wk-old seedlings were transplanted into neighboring plots on 12 May 1984. Immediately after transplanting, treatment plots were sprayed with in-furrow applications of metalaxyl at rates of 0.07, 0.14, 0.28, 0.56, or 1.12 kg a.i./ha applied in bands 0.3 m wide. Control plots were neither sprayed nor dipped in metalaxyl.

In trial C, crowns were transplanted into 150-mm-deep trenches on 23 February 1984 and covered with 25–50 mm of soil before an in-furrow (0.3-m-wide band) application of metalaxyl was made at rates of 0.07, 0.14, 0.28, 0.56, or 1.12 kg a.i./ha in approximately 470 L of water per hectare. In Trial D, 12-wk-old seedlings were transplanted on 11 April 1984. Metalaxyl was applied at the same rates as in trial C in approximately 200 L of water per hectare in a band 0.3 m wide over the seedlings after transplanting. Control plots in both trials were not sprayed.

In all trials, each plot consisted of one row. Plants were spaced 0.3 m apart in

Table 1. Details of field trials established in 1984 to determine the effect of metalaxyl on asparagus stands established from either crown or seedling transplants

			Transplant type			
			Crowns		Seedlings	
Trial	Location	Soil type	Pre-plant dip	In-furrow spray	In-furrow	Plot length (m)
A	Salinas Valley	Macho sandy loam	+[a]	+	−	30.5
B	Salinas Valley	Cropley silty clay	+	+	+	15.3
C	Sacramento-San Joaquin Delta	Burns clay loam	−	+	−	30.5
D	Sacramento-San Joaquin Delta	Venice peaty muck	−	−	+	30.5

[a]+ = Treatment applied, − = treatment not applied.

Table 2. Total precipitation and mean air temperatures at Davis, CA, during February through July 1983 and 1984

	Precipitation (mm)		Temperature (C)	
Month	1983	1984	1983	1984
February	160	32	9.7	8.9
March	219	26	11.4	13.9
April	71	9	12.2	14.2
May	10	0	18.3	20.5
June	2	3	21.9	21.9
July	0	0	22.5	25.3
Total	462	70		

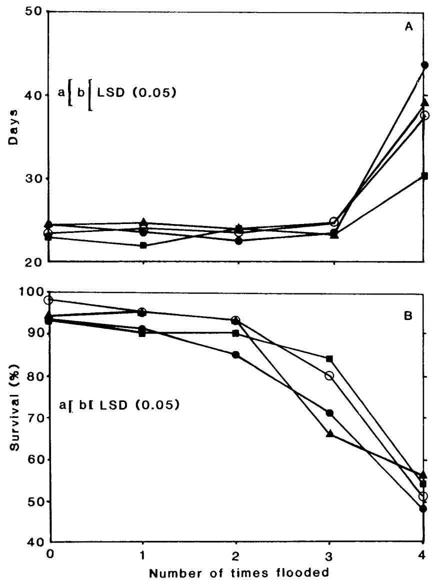

Fig. 1. Effect of *Phytophthora*, metalaxyl, and post-transplanting flooding frequency on **(A)** days to 50% emergence and **(B)** survival of 1-yr-old crown transplants at Davis, CA, in 1983. ▲ = Not infested with *Phytophthora*, not sprayed with metalaxyl, ○ = not infested with *Phytophthora*, sprayed with metalaxyl at 1.12 kg a.i./ha, ● = infested with *Phytophthora*, sprayed with metalaxyl at 1.12 kg a.i./ha, and ■ = infested with *Phytophthora*, not sprayed with metalaxyl. a = LSD for comparing metalaxyl levels at a given flooding and infestation treatment, b = LSD for comparing flooding levels at a given infestation and metalaxyl level.

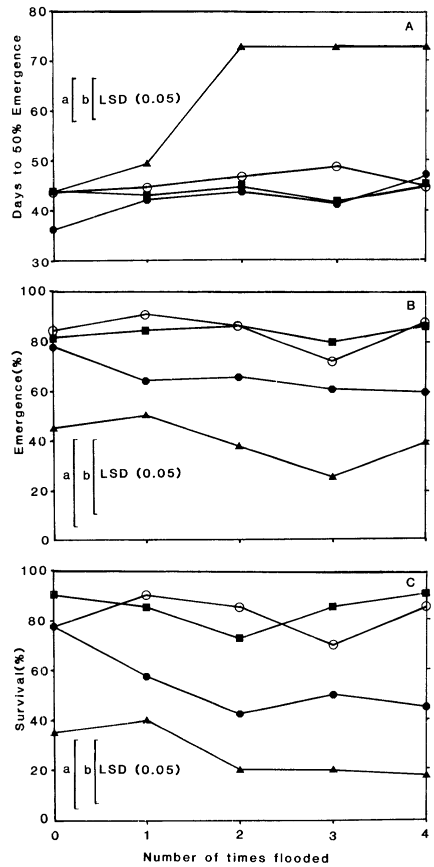

Fig. 2. Effect of *Phytophthora*, metalaxyl, and post-transplanting flooding frequency on **(A)** days to 50% emergence, **(B)** emergence 2.5 mo after transplanting, and **(C)** survival 8 mo after transplanting 1-yr-old crown transplants at Davis, CA, in 1984. ■ = Not infested with *Phytophthora*, not sprayed with metalaxyl, ○ = not infested with *Phytophthora*, sprayed with metalaxyl at 1.12 kg a.i./ha, ● = infested with *Phytophthora*, sprayed with metalaxyl at 1.12 kg a.i./ha, and ▲ = infested with *Phytophthora*, not sprayed with metalaxyl. a = LSD for comparing metalaxyl levels at a given flooding and infestation treatment, b = LSD for comparing flooding levels at a given infestation and metalaxyl level.

each row and rows were 1.5 m apart. The treatments were arranged in a randomized complete block design with four replications. The plots were sprinkler- or furrow-irrigated throughout the summer to ensure vigorous plant growth. For each trial, counts were made of surviving plants at 1- to 2-mo-intervals beginning 1 mo after transplanting and continuing throughout the spring and summer.

Statistical analysis. Data from all six trials were subjected to analysis of variance and regression analysis. Differences between treatment means were determined, where appropriate, with an unrestricted least significant difference test.

RESULTS AND DISCUSSION

Effect of *Phytophthora*, soil moisture, and metalaxyl on establishment. Rainfall data collected from the Davis Climatic Benchmark Station situated approximately 1.5 km from the trial site showed that almost no rain fell after transplanting in May 1983 (Table 2). In comparison, there was significant precipitation (26 mm) in the month after transplanting in February 1984, although in subsequent months there was a total of only 12 mm of rainfall. Air temperatures were 4.4–7.5 C higher in the 2 mo after transplanting in 1983 than in 1984.

In 1983, there was no significant difference in days to 50% emergence or in survival of plants between noninfested plots or plots infested with *Phytophthora* or between untreated plots or plots treated with metalaxyl (Fig. 1). However, there was a negative quadratic response (r^2 = 0.49, linear r^2 = 0.06) to flooding and days to 50% emergence and a positive quadratic response (r^2 = 0.77, linear r^2 = 0.20) in plant survival. Plants in plots flooded four times took between 6 and 16 days longer to reach 50% emergence than plants flooded three times or less (Fig. 1A). Average survival of plants was highest in plots flooded only once or not at all (average over all treatments = 93 and 95%, respectively) and was decreased significantly (P = 0.05) in plots flooded three times (average over all treatments = 75%) or four times (average = 52%). Excessive soil moisture has long been recognized as adversely affecting asparagus production (12). Whether this was because of the direct effect of water or related to increased disease was not stated. Flooding in the absence of *Phytophthora* had no effect on plant vigor or survival in 1984 (average over all treatments = 83%), but the longer duration of flooding in 1983 (48 hr) in comparison with 1984 (two 8-hr periods separated by 16 hr of drainage) resulted in delayed emergence and reduced plant survival when plots were flooded every 2 or 3 wk. Although these results suggest that flooding per se can adversely affect establishment of asparagus, continuous surface flooding for 48 hr every 2 or 3 wk is unlikely to occur in California under normal conditions in May through July.

In 1984, there was little difference in time to 50% emergence between infested plots that had been treated with metalaxyl and noninfested plots (Fig. 2A). In infested plots that had not been sprayed, however, emergence was considerably slower, especially in plots flooded two, three, or four times, and several plots in these treatments never attained 50% emergence. As flooding frequency decreased, emergence was usually faster. The proportion of plants that had emerged after 2.5 mo was highest in noninfested plots and lowest in infested plots that had not been sprayed with metalaxyl (Fig. 2B). Treatment with metalaxyl increased total emergence, although not to the higher level of noninfested plots. Emergence in the infested plots was generally higher as flooding frequency decreased, especially in plots not flooded and sprayed with metalaxyl. There was also a similar trend for data on plant survival 8 mo after transplanting (Fig. 2C). Survival was highest in noninfested plots, lower in infested plots that had been sprayed with metalaxyl, and lowest in infested plots not treated with metalaxyl. In infested plots, survival increased as frequency of flooding decreased, especially in plots treated with metalaxyl.

In the absence of *Phytophthora*, neither metalaxyl nor frequency of flooding had any effect on fern dry weight of plants 2.5 mo after transplanting (Fig 3A). In infested plots, treatment with metalaxyl increased fern dry weight, especially as flooding frequency decreased. By 8 mo after transplanting, fern dry weight had increased in all treatments and was highest in noninfested plots and lowest in infested plots that had not been sprayed (Fig. 3B). Both the single application of metalaxyl and reductions in flooding frequency increased fern dry weight. The mean number of fern stalks per plant 8 mo after transplanting (Fig. 4) followed a similar trend as fern dry weight measured at the same time.

Root rot was most severe in infested plots at both 2.5 and 8 mo after transplanting (Fig. 5). Although metalaxyl reduced the amount of root rot in infested plots, it did not reduce rot to the level of noninfested plots except at 2.5 mo after transplanting in plots that were not flooded. Root rot severity was decreased in infested plots as flooding frequency decreased and was generally higher at 2.5 than at 8 mo after transplanting.

Crown rot 2.5 mo after transplanting was highest in infested plots that had not been sprayed with metalaxyl (Fig. 6). Metalaxyl reduced crown rot in infested plots but had no effect in noninfested plots. Therefore, while metalaxyl should improve growth when *Phytophthora* is present, no advantage would be expected from applying metalaxyl to crowns if *Phytophthora* was not present in the soil.

Results from the trial at Davis, CA, in 1984 showed that *Phytophthora* caused delayed emergence and increased root and crown rot and thereby reduced vigor of summer fern growth and survival of plants. The effect of *Phytophthora* increased with more frequent flooding. *P. m.* var. *sojae* has also been associated with stand establishment failures in New Zealand when field conditions were cool and wet after transplanting of asparagus crowns (6,7,10).

In 1984, applications of metalaxyl to plots infested with *Phytophthora* at Davis, CA, reduced root and crown rot and resulted in increased vigor and survival of plants. However, as flooding frequency increased, the effect of metalaxyl decreased. Metalaxyl has a relatively low potential for absorption onto soil particles with absorption constants ranging from 0.43 to 1.14 g/g and is subject to leaching in soils with high sand content, low organic matter, and high rainfall (2). Therefore, the greater disease severity in infested and sprayed plots at flooding frequencies of 2, 3, or 4 wk probably resulted from higher leaching losses of metalaxyl and, consequently, reduced control of Phytophthora rot. Although metalaxyl sprayed as a broadcast application at 1.12 kg a.i./ha provided some control of Phytophthora rot in the Davis trial, vigor and survival of plants in infested plots treated with metalaxyl was not as high as in plots that were not infested. Therefore, a different method or a higher rate of application may be required.

Both *Phytophthora* spp. were isolated on antibiotic PDA 2.5 mo after transplanting from storage roots and crown tissue from plants grown in plots infested with *Phytophthora* whether or not they

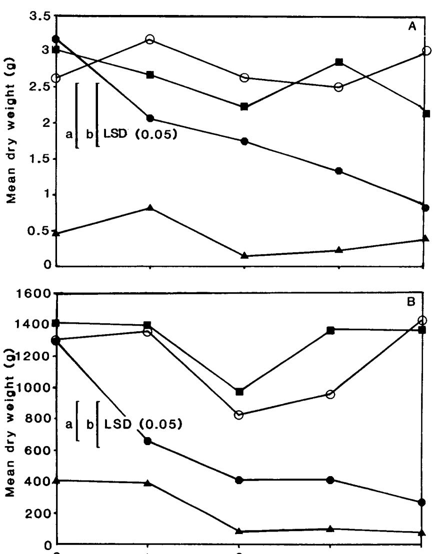

Fig. 3. Effect of *Phytophthora*, metalaxyl, and post-transplanting flooding frequency on mean dry weight per plant of fern **(A)** 2.5 mo and **(B)** 8 mo after transplanting at Davis, CA, in 1984. ■ = Not infested with *Phytophthora*, not sprayed with metalaxyl, ○ = not infested with *Phytophthora*, sprayed with metalaxyl at 1.12 kg a.i./ha, ● = infested with *Phytophthora*, sprayed with metalaxyl at 1.12 kg a.i./ha, and ▲ = infested with *Phytophthora*, not sprayed with metalaxyl. a = LSD for comparing metalaxyl levels at a given flooding and infestation treatment, b = LSD for comparing flooding levels at a given infestation and metalaxyl level.

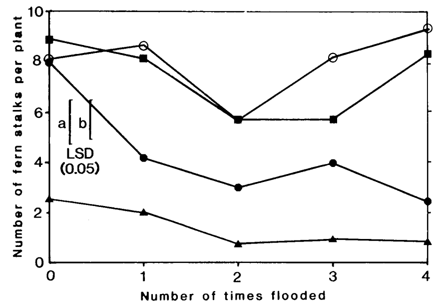

Fig. 4. Effect of *Phytophthora*, metalaxyl, and post-transplanting flooding frequency on mean number of fern stalks per plant 8 mo after transplanting at Davis, CA, in 1984. ■ = Not infested with *Phytophthora*, not sprayed with metalaxyl, ○ = not infested with *Phytophthora*, sprayed with metalaxyl at 1.12 kg a.i./ha, ● = infested with *Phytophthora*, sprayed with metalaxyl at 1.12 kg a.i./ha, and ▲ = infested with *Phytophthora*, not sprayed with metalaxyl. a = LSD for comparing metalaxyl levels at a given flooding and infestation treatment, b = LSD for comparing flooding levels at a given infestation and metalaxyl level.

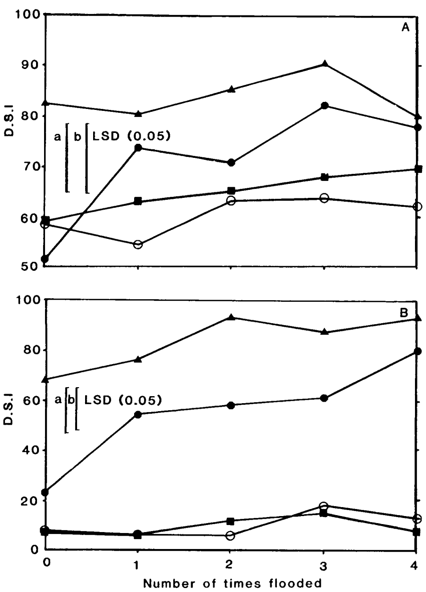

Fig. 5. Effect of *Phytophthora*, metalaxyl, and post-transplanting flooding frequency on disease severity index (DSI) where 0 = no plants with root rot and 100 = all plants with >50% rotten roots **(A)** 2.5 mo and **(B)** 8 mo after transplanting at Davis, CA, in 1984. ■ = Not infested with *Phytophthora*, not sprayed with metalaxyl, ○ = not infested with *Phytophthora*, sprayed with metalaxyl at 1.12 kg a.i./ha, ● = infested with *Phytophthora*, sprayed with metalaxyl at 1.12 kg a.i./ha, ▲ = infested with *Phytophthora*, not sprayed with metalaxyl. a = LSD for comparing metalaxyl levels at a given flooding and infestation treatment, b = LSD for comparing flooding levels at a given infestation and metalaxyl level.

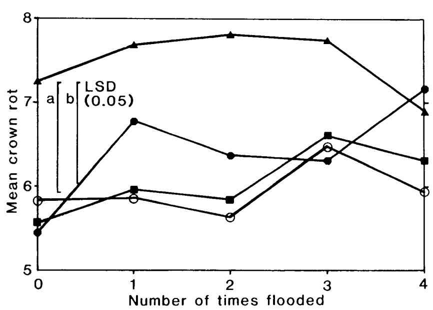

Fig. 6. Effect of *Phytophthora*, metalaxyl and post-transplanting flooding frequency on crown rot (1 = no rot; 9 = crown completely rotten, plant dead) 2.5 mo after transplanting 1-yr-old crowns at Davis, CA, in 1984. ■ = Not infested with *Phytophthora*, not sprayed with metalaxyl, ○ = not infested with *Phytophthora*, sprayed with metalaxyl at 1.12 kg a.i./ha, ● = infested with *Phytophthora*, sprayed with metalaxyl at 1.12 kg a.i./ha, ▲ = infested with *Phytophthora*, not sprayed with metalaxyl. a = LSD for comparing metalaxyl levels at a given flooding and infestation treatment, b = LSD for comparing flooding levels at a given infestation and metalaxyl level.

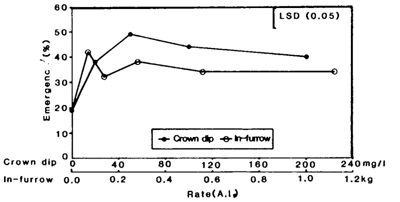

Fig. 7. Effect of metalaxyl either applied to crowns dipped in solutions at 20, 50, 100, or 200 mg a.i./L (●) or in-furrow at 0.07, 0.14, 0.28, 0.56, or 1.12 kg a.i./ha (○) on emergence 1 mo after transplanting 20-mo-old crowns.

had been treated with metalaxyl. *Phytophthora* was isolated more frequently from plants in plots that had been flooded two, three, or four times than from plants flooded once or not flooded at all. *Phytophthora* was not isolated on A-PDA from any plot. Inability to isolate either *P. m.* var. *sojae* or *P. cryptogea* on A-PDA from plots infested with both species emphasizes the importance of using media selective for *Phytophthora* when attempting to determine the etiology of root and crown rot problems in asparagus.

Effect of metalaxyl on asparagus stands established from crown and seedling transplants. In trial A 1 mo after transplanting, significantly ($P = 0.05$) more plants had emerged in plots where crowns had been dipped in metalaxyl or where transplanted crowns had been sprayed at 0.07 or 0.28 kg a.i./ha than in control plots (Fig. 7). There was a positive quadratic response in percentage emergence to increased rates of metalaxyl for both the crown dip ($r^2 = 0.69$, linear $r^2 = 0.18$) and in-furrow applications ($r^2 = 0.23$, linear $r^2 = 0.05$). There was no significant difference between treatments in plant survival and mean numbers of fern stalks per surviving plant 2 and 3 mo after transplanting. Although survival in this trial was generally low (average of all treatments 3 mo after transplanting = 46%) because crowns were covered with too much soil shortly after they emerged, there was no evidence that either crown-dip or in-furrow applications of metalaxyl were phytotoxic at the rates used.

Average survival of crowns was higher in trial B (88%) 2 mo after transplanting. There was no significant ($P = 0.05$) difference between treatments at either 2, 3, or 5 mo after transplanting. In-furrow applications of metalaxyl at 0.56 or 1.12 kg a.i./ha resulted in significantly ($P = 0.05$) greater survival of seedling transplants 2 mo after transplanting. On average, survival of seedlings was similar to that of crowns. There was no evidence of phytotoxicity to seedlings or crowns at any of the rates used.

There was no significant difference in trial C or D ($P = 0.05$) between treatments in survival of crowns 5 or 3 mo after transplanting, respectively. Survival, which averaged 87 and 95% over all treatments, respectively, was generally high. There was no evidence of phytotoxicity at any of the rates used.

In conclusion, the results from the 1983 trial at Davis, CA, and the four field trials in the Salinas Valley and Sacramento-San Joaquin Delta, CA, in 1984 indicated that *Phytophthora* had relatively little effect on establishment of asparagus when field conditions were dry (<28 mm rainfall during the 3 mo after transplanting) and warm (soil temperatures >18 C). Under these conditions, survival of crown transplants was generally high whether or not they had been treated with metalaxyl, especially in trials B and C. In trial A, in-furrow applications, at rates as low as 0.07 kg a.i./ha, increased emergence as did dipping of crowns in a 50 mg/L solution of metalaxyl. There was no advantage and also no apparent phytotoxicity from higher rates. However, these results were obtained under conditions of virtually no rainfall. More work is required to determine the optimum method and rates of application of metalaxyl for control of *Phytophthora* when establishing asparagus from crowns. Cold storage of crowns until soil conditions are drier and warmer or, alternatively, the use of seedling transplants which are usually transplanted later in the spring, are both effective methods for avoiding *Phytophthora*-related establishment problems.

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