Fungicide Seed Treatment Effects on Seedling Damping-Off of Pumpkin Caused by *Phytophthora capsici*.

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ABSTRACT

Babadoost, M., and Islam, S.Z. 2002. Fungicide seed treatment effects on seedling damping-off of pumpkin caused by *Phytophthora capsici*. Plant Dis. 87:63-68.

Apron XL LS (mefenoxam) and Allegiance LS (metalaxyl) were highly inhibitory to growth of mycelium of *Phytophthora capsici in vitro*. ED50 of mefenoxam and metalaxyl for inhibition of mycelial growth, for all five isolates of *P. capsici* tested, was 0.98 and 0.99 µg a.i./ml of culture medium, respectively. At 200 µg a.i./ml of mefenoxam, sporangium and zoospore germination were reduced by 92 and 96%, respectively, and 21 and 24%, respectively, for metalaxyl. In greenhouse studies, seed treatment with mefenoxam (0.42 ml Apron XL LS/kg seed) and metalaxyl (0.98 ml Allegiance LS/kg seed) significantly reduced pre- and post-emergence damping-off of seedlings caused by *P. capsici* in three pumpkin cultivars, Dickinson, Hybrid-401, and Hybrid-698, tested. Thirty-one days after seeding, at inoculum levels of 0, 90, 600, 1400, and 4000 cfu/g soil, the average seedling stands for mefenoxam treatment were 98.4, 93.8,

88.3, 77.8, and 64.8%; for metalaxyl, were 99.1, 85.3, 85.8, 73.5, and 59.3; and for the untreated control were 97.5, 55.2, 45.7, 37.0, and 22.9%, respectively. In field trials, the average seedling stands 35 days after seeding were 76.7, 74.7, and 44.9% for mefenoxam, metalaxyl, and untreated control, respectively. Seed treatment with mefenoxam or metalaxyl did not have any significant effect on either seed germination or seedling vigor.

Additional key words: *Cucurbita moschata*, cucurbit, squash

Phytophthora blight, caused by the Oomycete plant pathogen *Phytophthora capsici* Leonian, is an important disease of cucurbits, eggplants, and peppers (5,13,16). The incidence of this disease has increased in recent years in the United States and worldwide (1,8,18).

Illinois ranks first in pumpkin production in the United States (US). About 70% of the commercial processing pumpkins in the US are produced in Illinois. In addition to 10,000 ha of pumpkins, approximately 3,500 ha of cucumber, melon, and squash are commercially produced in Illinois. Phytophthora blight has been epidemic in the past four years, causing up to 100% crop losses in cantaloupe, cucumber, pumpkin, squash, and watermelon fields (1).

Phytophthora capsici survives as oospores in soil and as mycelium in plant residue (5,8). The pathogen has both a sexual and asexual life cycle. It produces abundant sporangia and zoospores that rapidly colonize plant tissues. *P. capsici* can be dispersed within soil, with surface water, via water splashing, and by air currents. The pathogen can infect all parts of the plant at any growth stage, causing pre- and post-emergence seeding damping-off, leaf spot, stem lesion, foliar blight, and fruit rot (1,5,15).

At present, there is no single method to provide adequate control of *P. capsici* on vegetables, particularly cucurbits. Management of *P. capsici* on cucurbits relies on crop rotation, sanitation, management of field moisture, and judicious use of fungicides (2,11). No cucurbit cultivar with measurable resistance against Phytophthora blight is available. Rotation may not provide effective control against *P. capsici* because the pathogen survives in soil indefinitely. In areas with high relative humidity and/or rainfall, management of field moisture for effective control of the disease is not feasible. Only dimethomorph (Acrobat) fungicide has been found effective for protecting foliage and fruit of pumpkins against *P. capsici* (11).

Pre- and post-emergence seedling damping-off caused by *P. capsici* on pumpkins, especially on processing pumpkins, is a serious threat to pumpkin production in Illinois (2,12). Seedling death in some pumpkin fields was so severe that growers had to replant the fields for a second, and even a third time. Therefore, protecting plants against *P. capsici* during seedling emergence from soil and at the early growth stages is essential for successful pumpkin stand establishment.

Metalaxyl was introduced in 1977 and used to control plant disease caused by Oomycetes (10,19). Metalaxyl has been used as a soil drench, seed treatment, and spray. Mefenoxam has been used as a seed-treatment to control damping-off caused by *Phytophthora* and *Pythium* species on chickpea (14,22), cotton (6,7), soybean (4,21), sweet corn (17), and wheat (20). Bradford et al. (3) used mefenoxam as a seed-treatment to improve muskmelon seedling emergence. Mefenoxam is the active isomeric form of metalaxyl. The active isomeric form comprised 50% of metalaxyl; whereas mefenoxam is 100% active isomer. Although mefenoxam has been labeled for the use on cucurbits against *Pythium* species, there is no report available on seed treatment of cucurbits for control of *P. capsici*. To our knowledge, this is the first report on

evaluating the effectiveness of mefenoxam and metalaxyl as seed treatment to control of *P. capsici* on pumpkin seedlings. The objective of this study was to determine the effectiveness of mefenoxam and metalaxyl as a seed-treatment to protect pumpkin plants against *P. capsici* during stand establishment. A preliminary report of this study has been published (2).

MATERIALS AND METHODS

Laboratory studies. Five isolates of *P. capsici*, four from infected leaf petioles (24-D, 33-5, 34-7, 38-14) and one from an infected seedling (Pc-1), collected from commercial processing pumpkin fields in Illinois in 2000, were used in this research. The isolates were maintained on lima bean agar (LBA; Difco Lab., MI; 23 g/L) slants at 24 °C. Fungicides mefenoxam (Apron XL LS, Syngenta Crop Protection, Inc., Greensboro, NC) and metalaxyl (Allegiance LS, Gustafson LLC, Plano, TX) were evaluated for their effectiveness in inhibiting mycelial growth, sporangium and zoospore germination. All of the laboratory experiments were repeated twice.

Effect of fungicides on mycelial growth. *P. capsici* was grown on LBA for 4 days at 24 °C in darkness. Mycelial plugs, 7 mm in diameter, were removed from actively growing margins of the culture and transferred onto the center of each LBA plate previously amended with mefenoxam or metalaxyl at 0, 1, 5, 10, 20, 50, 100, 150, and 200 µg a.i./ml. Stock solution (1000 µg a.i./ml) of each fungicide was prepared in sterile distilled water (SDW) and added to the autoclaved LBA medium cooled to 45 °C. Three replicate plates per fungicide concentration were included for each isolate. Plates were incubated in the dark at 24 °C for 6 days to evaluate mycelium growth. Colony diameter of *P. capsici* was measured in two directions for each individual plate and averaged.

Effect of fungicides on sporangium germination. To evaluate the effects of the fungicides on sporangium germination, the isolates were grown on LBA under continuous fluorescent light (F20T12/CW, Phillips Lighting Co., Somerset, NJ) at 24 °C for 7 days. Then, sporangia were harvested by adding 10 ml of SDW to each Petri plate and shaking the culture plates by hand to dislodge the sporangia. Aliquots of the sporangial suspension (400 µl) were immediately pipetted onto Petri plates containing LBA amended with 0, 10, 20, 50, 100, 150, or 200 µg a.i./ml of the fungicide. The plates were shaken gently to disperse the suspension over the entire surface of the medium, and the free water was removed by exposing the open plates to airflow in a sterile hood for 10-15 min. The plates were then incubated in the dark at 24 °C for 12 h. The percentage of germinated sporangia was determined by examining 100 sporangia per plate using light microscopy.

Effect of fungicides on zoospore germination. A sporangial suspension in SDW was prepared and incubated at 20 °C for 1 h to allow the sporangia to release their zoospores. Zoospores were separated from the empty sporangia by passing the liquid through a 4-layer facial tissue. Zoospores in SDW were induced to encyst by vortexing for 5 min. Concentration of zoospores was adjusted to 10^5 zoospores/ml. Aliquots (400 µl) were pipetted onto LBA plates amended with fungicides as described above. The plates were shaken gently to dispense the zoospores over the entire surface. Free water on the surface of the medium was removed by exposing the open plates to airflow in a sterile hood. Inoculated plates were incubated in the dark at 24 °C for 12 h. The percentage of zoospore germination was assessed by examining 100 zoospores per plate using light microscopy.

Greenhouse studies. Effects of mefenoxam and metalaxyl on seedling damping-off of pumpkin, caused by *P. capsici*, were studied in the greenhouse using a naturally infested soil and

artificially infested soil mix (field soil:sand; 3:1). Naturally infested soil was collected from a processing pumpkin field near Pekin, Illinois.

Inoculum for soil infestation was prepared by culturing an isolate of *P. capsici* (Pc-1: A1 mating type), collected from a processing pumpkin seedling in 2000, on oat meal-V8JB substrate in 1-L conical flasks (10). The substrate, consisting of 200 g oatmeal and 120 ml V8 juice broth per flask, was autoclaved for 30 min at 121°C and inoculated with 7-mm-diameter plugs, taken from the margin of a 5-day-old colony of *P. capsici* grown on an LBA plate. The flasks were then incubated at 24 °C. After 6 weeks, the colonized oatmeal was added to a steamed-soil mix at different soil:inoculum ratios and mixed thoroughly. The inoculum density of *P. capsici* in naturally infested field soil and artificially infested soil mix was determined by the soil dilution-plate method using a Phytophthora selective medium (PARPH) which contained LBA (23 g/L), pimaricin (10 mg/L), ampicillin (250 mg/L), rifampicin (10 mg/L), PCNB (100 mg/L), and hymexazol (50 mg/L) (23). The inoculum density in the naturally infested field soil was 90 cfu/g soil, and the inoculum densities in artificially infested soils were 600, 1400, and 4000 cfu/g soil.

Seeds of three processing pumpkin cultivers (Dickinson, Hybrid-401, Hybrid-698) were treated with mefenoxam (0.42 ml Apron XL LS/kg seed) and metalaxyl (0.98 ml Allegiance LS/kg seed). A volume of tap water equivalent to 20% of seed weight was poured into a plastic bag and the fungicide was added to the water and mixed thoroughly. Seeds were placed in the bag and shaken for 2 min to coat the seeds with fungicide. Treated seeds were then air-dried.

Plastic pots (30-cm long × 20-cm wide × 15-cm deep) were filled with *P. capsici*-infested soil. Pots with non-infested soil were included as a control. Eighteen seeds were sown in each pot. The pots were arranged in a randomized complete block design, with three replications. All experiments were repeated twice. The experiments were conducted in a greenhouse maintained

at 18-22 °C and pots were watered daily beginning the first day of seeding. Seedling emergence was assessed 10 days after sowing seeds and seedling stand was determined three weeks after seedling emergence (31 days after seeding). Diseased seedlings were examined using light microscopy and infected tissues were plated on PARPH for isolating *P. capsici*.

Field studies. An experiment was conducted in an irrigated pumpkin field near Pekin, Illinois in 2001. The field had been planted to processing pumpkin in 2000 and severe foliar blight and fruit rot, caused by *P. capsici*, occurred in 2000. The experiment was performed in a randomized complete block design with three replications, each consisting of a 7.5-m-long row. The plots were spaced 0.9 m apart. Fifty seeds were planted in a single row in each plot. Seeds, either treated with mefenoxam (0.42 ml Apron XL LS/kg seed), metalaxyl (0.98 ml Allegiance LS/kg seed), or not treated (control), were sown approximately 5 cm deep. The experiment was repeated twice during the growing season in the same field with the first planting on 18 June, the second on 16 July, and the third on 31 August. Recorded precipitation in the field was 7 days (104 mm), 5 days (74 mm), 8 days (114 mm), and 6 days (104 mm) in June, July, August, and September, respectively. The field was irrigated 8 days (109 mm), 16 days (159 mm), 9 days (144 mm), and 3 days (56 mm) in June, July, August, and September, respectively. Average monthly high and low temperatures were 26/15, 30/19, 29/18, and 24/11 °C in June, July, August, and September, respectively. Soil samples were collected from the upper 10 cm of soil in the field (one sample per 20 m^2 area, taken randomly), at the time of planting, using a soil auger, and mixed together. The population density of *P. capsici* was determined by dilution plating of soil samples on a PARPH selective medium and was 100 cfu per g soil. The seedlings were also sprayed with a *P. capsici* zoospore suspension (10^5 spores/ml; 150 ml/2.25 m^2 area) one week after seedling emergence to provide higher inoculum pressure in the plots. Application

of foliar inoculum was to evaluate the efficacy of seed treatment on protecting plants against air-borne inoculum of *P. capsici*.

Seedling emergence was assessed 10 days after sowing seeds and seedling stand was determined 25 days after seedling emergence (35 days after seeding). Post-emergence damping-off was determined by counting plants showing girdling stem lesions with or without falling-over, wilting, and/or death of seedlings. Diseased seedlings were examined using light microscopy and infected tissues were plated on PARPH to isolate *P. capsici*.

Seed germination. Nontreated and treated seeds of processing pumpkin cultivars Dickinson, Hybrid-401, and Hybrid-698 were tested for germination. Seeds were treated either with mefenoxam (0.42 ml Apron XL LS/kg seed) or metalaxyl (0.98 ml Allegiance LS/kg seed). Seed were tested in the laboratory using plastic boxes (Fliptops, Sterilite, Townsend, MA) and in a soil mix (1 soil: 1 sand: 1 peat). In the plastic box test, 400 seeds from each treatment were tested for germination according to the International Rules for Seed Testing (9). In a seedling emergence test, 192 seeds from each treatment were sown in the soil mix in a greenhouse with the temperature ranging from 18 to 22 °C. A completely randomized block design with four replicates, each consisting of 48 seeds planted in a seed germinating flat with 48 holes (one seed per hole), was used. After 20 days, the number of emerged seedlings was counted. Seedling vigor was evaluated using a 0-4 scale, as 0 = seed not germinated, 1 = low vigor, and 4 = high vigor of seedling.

Data analysis. Data collected in laboratory, greenhouse, and field experiments were analyzed using analysis of variance (ANOVA) and general linear regression (GLM) procedures of SAS (SAS Institute, Cary, NC).

RESULTS

Laboratory studies. Mefenoxam and metalaxyl at concentrations ≥ 0.5 µg a.i./ml significantly reduced colony growth of all five *P. capsici* isolates (Fig. 1). ED50 for mefenoxam and metalaxyl for inhibition of mycelial growth, for all five isolates of *P. capsici*, was 0.98 and 0.99 µg a.i./ml of culture medium, respectively. There was no significant (P=0.05) difference between mefenoxam and metalaxyl in reducing growth of colonies of the isolates.

Mefenoxam strongly inhibited sporangium germination at concentrations of ≥ 100 µg a.i./ml (Fig. 2). ED50 of mefenoxam for inhibition of sporangium germination was 107 µg a.i./ml of culture medium. There was no significant difference in the effect of mefenoxam on sporangium germination among the isolates. Metalaxyl was not as effective on inhibiting sporangium germination as mefenoxam (Fig. 2). At the highest concentration (200 µg a.i./ml), metalaxyl reduced sporangium germination by only 21% (Fig. 2).

Zoospore germination was affected by mefenoxam (Fig. 3). ED50 of mefenoxam for inhibition of zoospore germination was 122 µg a.i./ml of culture medium. There was no significant difference in zoospore germination among the isolates. Metalaxyl was not as effective in inhibiting zoospore germination as mefenoxam (Fig. 3). At the highest concentration (200 µg a.i./ml), metalaxyl reduced zoospore germination by only 24%.

Greenhouse studies. Seed treatment with either mefenoxam or metalaxyl significantly increased seedling emergence from naturally and artificially infested soils (Table 1). There was no significant difference between mefenoxam and metalaxyl in percentage of seedlings emerged from soil. Seedling emergence from the untreated control treatments decreased significantly as

inoculum density of *P. capsici* was increased from 90 to 4,000 cfu/g soil. At the inoculum density of 4,000 cfu/g soil, the mean value of seedling emergence for three cultivars combined was 91.9, 91.3, 51.8, and 97.5% respectively for the mefenoxam, metalaxyl, untreated control with *P. capsici*, and untreated control without *P. capsici* infestation. Percentage of post-emergence seedling damping-off increased as inoculum density was increased from 600 to 4,000 cfu/g soil. Twenty-one days after seedling emergence (31 days after seeding), with an inoculum level of 4,000 cfu/g soil, the mean value of the seedling stands for three cultivars combined was 64.8, 59.3, 22.9, and 97.5% respectively for the mefenoxam, metalaxyl, untreated control with *P. capsici*, and untreated control without *P. capsici* infestation.

Seedling stand was negatively correlated with inoculum level in the soil (Fig. 4). The relationships between percentage of seedling survival and inoculum density in soil (cfu/g soil) were $Y = 109.64 - 8.32(X)$ ($R^2 = 0.95$, $P = 0.01$), $Y = 109.90 - 9.14(X)$ ($R^2 = 0.94$, $P = 0.01$), and $Y = 66.96 - 12.68(X)$ ($R^2 = 0.93$, $P = 0.01$), for mefenoxam, metalaxyl, and untreated control, respectively, where Y = percentage of seedling stand and X = inoculum density (cfu/g soil).

Field studies. In the field trial, both mefenoxam and metalaxyl significantly reduced pre- and post-emergence seedling damping-off compared to the untreated control (Table 2). Post-emergence damping-off started within one week after seedling emergence in some of plots. Twenty-five days after seedling emergence (35 days after seeding), the average seedling stand for three cultivars combined were 76.7, 74.7, and 44.9% respectively for the mefenoxam, metalaxyl, and untreated control.

Seed germination. Seed treatment with mefenoxam or metalaxyl did not affect seed germination and seedling vigor when seeds were tested on blotter paper or when sown in a sterilized soil in the greenhouse.

DISCUSSION

Both mefenoxam and metalaxyl are Acylalanine fungicides (Phenylamides) and used for control of Oomycete pathogens. These two fungicides contain the same active ingredient. Metalaxyl is a 50% solution of what is mefenoxam and 50% of an inactive isomer. Since mefenoxam is 100% active isomer, theoretically, half the amount of mefenoxam should be needed to produce the same results as a given amount of metalaxyl. Both fungicides are systemic and translocated upward to new growth (apoplastic) in the plant (5). When applied to seed, mefenoxam and metalaxyl are translocated to the shoots and protect the seedling against soilborne Oomycete pathogens.

P. capsici sporangia or zoospores germinate and infect the plants (5). *In-vitro* studies showed that both mefenoxam and metalaxyl were toxic to growth of mycelium of *P. capsici*. But, Metalaxyl was not as effective on inhibiting germination of sporangia and zoospores as mefenoxam was. Both of the fungicides, however, effectively reduced the incidence of pre- and post-emergence seedling damping-off in the greenhouse and field trials. It is, therefore, concluded that even if sporangia and zoospores germinated, both mefenoxam and metalaxyl would prevent growth of the germ tube; thus, preventing seedling infection with *P. capsici*.

Inoculum density of *P. capsici* in commercial pumpkin fields has been determined to be approximately 100 cfu/g soil (11). Both mefenoxam and metalaxyl effectively prevented seedling damping-off in soil with 600 cfu/g soil in the greenhouse studies. Thus, seed treatment

with either mefenoxam or metalaxyl is expected to effectively control seedling damping-off caused by soilborne inoculum of *P. capsici* in commercial pumpkin fields.

Ridomil Gold EC (mefenoxam) has been labeled for use as a soil-drench for control of *P. capsici* in cucurbit fields. However, this fungicide did not provide adequate protection to processing pumpkins against *P. capsici* in fields in Illinois (11). Also, due to economic reasons, the processing pumpkin growers do not practice pre-plant soil drenching with Ridomil Gold EC. Seed treatment with either Apron XL LS (mefenoxam) or Allegiance LS (metalaxyl) is a viable alternative for effective control of *P. capsici* during seed germination, seedling emergence, and early growth stages. Since Apron XL LS has already been labeled for the use on cucurbits, pumpkin growers may start using this fungicide immediately.

Seed treatment with either mefenoxam or metalaxyl would provide advantages in controlling *P. capsici* on processing pumpkins because: (i) protection against *P. capsici* would be provided for at least five weeks after seeding; (ii) the treatment is economically feasible; and (iii) since the presence of the fungicide will be limited to seedling and rhizosphere, the potential for development of resistance in the pathogen against the fungicide is expected to be low. In addition, the integration of seed treatment with mefenoxam or metalaxyl along with a foliar spray of dimethomorph (Acrobat) could provide satisfactory protection of pumpkin plants against *P. capsici* during the 4-month growing season. Currently, dimetamorph is the only effective fungicide available against Phytophthora blight of processing pumpkins (11), and its use is limited to five spray applications, which is not sufficient for season-long protection of plants against *P. capsici*.

ACKNOWLEDGEMENTS

This work was supported in part by grants from Nestle Food Company.

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Table 1. Fungicide seed treatment effects on seedling damping-off of pumpkin caused by *Phytophthora capsici* in the greenhouse.

Cultivar	Inoculum density (cfu/g soil)[w]	Seedling growth (%)	Treatment[x]		
			Mefenoxam	Metalaxyl	Control
Dickinson	0	Emergence[y]	100 a[z]	98.9 a	95.8 a
		Stand[y]	100 a[z]	98.9 a	95.8 a
	90	Emergence	97.1 a	87.3 a	52.3 b
		Stand	97.1 a	87.3 a	52.3 b
	600	Emergence	94.4 a	88.9 a	48.1 b
		Stand	85.2 a	79.6 a	33.3 b
	1,400	Emergence	88.9 a	87.0 a	48.1 b
		Stand	70.4 a	61.1 a	24.1 b
	4,000	Emergence	94.4 a	92.6 a	48.1 b
		Stand	68.5 a	57.4 a	20.4 b
Hybrid-401	0	Emergence	100 a	100 a	97.9 a
		Stand	100 a	100 a	97.9 a
	90	Emergence	95.3 a	82.0 a	60.0 b
		Stand	95.3 a	82.0 a	60.0 b
	600	Emergence	92.6 a	92.6 a	64.8 b
		Stand	88.9 a	88.9 a	57.4 b
	1,400	Emergence	90.7 a	92.6 a	59.3 b
		Stand	83.3 a	81.5 a	44.4 b
	4,000	Emergence	90.7 a	94.4 a	38.9 b
		Stand	66.7 a	55.6 a	20.4 b
Hybrid-698	0	Emergence	95.3 a	98.4 a	98.9 a
		Stand	95.3 a	98.4 a	98.9 a
	90	Emergence	89.0 a	86.7 a	53.3 b
		Stand	89.0 a	86.7 a	53.3 b
	600	Emergence	92.6 a	90.7 a	55.6 b
		Stand	90.7 a	88.9 a	46.3 b
	1,400	Emergence	87.0 a	88.9 a	61.1 b
		Stand	79.6 a	77.8 a	42.6 b
	4,000	Emergence	90.7 a	87.0 a	68.5 b
		Stand	59.3 a	64.8 a	27.8 b

[w] Soil with 90 cfu was from a commercial pumpkin field naturally infested with *P. capsici*. Soil samples with >90 cfu were prepared by adding oatmeal substrate containing *P. capsici*.

[x] Each value represents the mean of treatments in three experiments.

[y] Emergence = percent of seeds germinated and emerged from the soil 10 days after sowing seeds; Stand = percent seedlings without infection 31 days after sowing seeds.

[z] Values in each row with a letter in common are not significantly different from each other according to Fischer's protected test ($P = 0.05$).

Table 2. Fungicide seed treatment effects on seedling damping-off of pumpkin caused by *Phytophthora capsici* in field[w].

Cultivar	Days after seeding[x]	Seedling stand (%)[y]		
		Mefenoxam	Metalaxyl	Untreated check
Dickinson	11 days	80.0 a[z]	85.3 a	64.0 b
	19 days	80.0 a	80.7 a	61.3 b
	35 days	63.3 a	66.0 a	36.0 b
Hybrid-401	11 days	96.0 a	90.7 a	86.7 b
	19 days	94.0 a	90.0 a	76.7 b
	35 days	84.7 a	75.3 a	43.3 b
Hybrid-698	11 days	90.0 a	92.0 a	72.7 b
	19 days	89.3 a	91.3 a	70.7 b
	35 days	82.0 a	82.7 a	55.3 b
Dickinson, Hybrid-401, Hybrid-698 (combined)	11 days	88.7 a	89.3 a	74.4 b
	19 days	87.8 a	87.3 a	69.6 b
	35 days	76.7 a	74.7 a	44.9 b

[w] A field infested with *P. capsici* (100 cfu/g soil). The seedlings were also sprayed with a *P. capsici* zoospores suspension (10^5 spores/ml; 150 ml/2.25 m^2) one week after seedling emergence from soil.

[x] Seedlings emerged from soil 7 to 10 days after sowing seed.

[y] Each value represents the mean of treatments in three experiments.

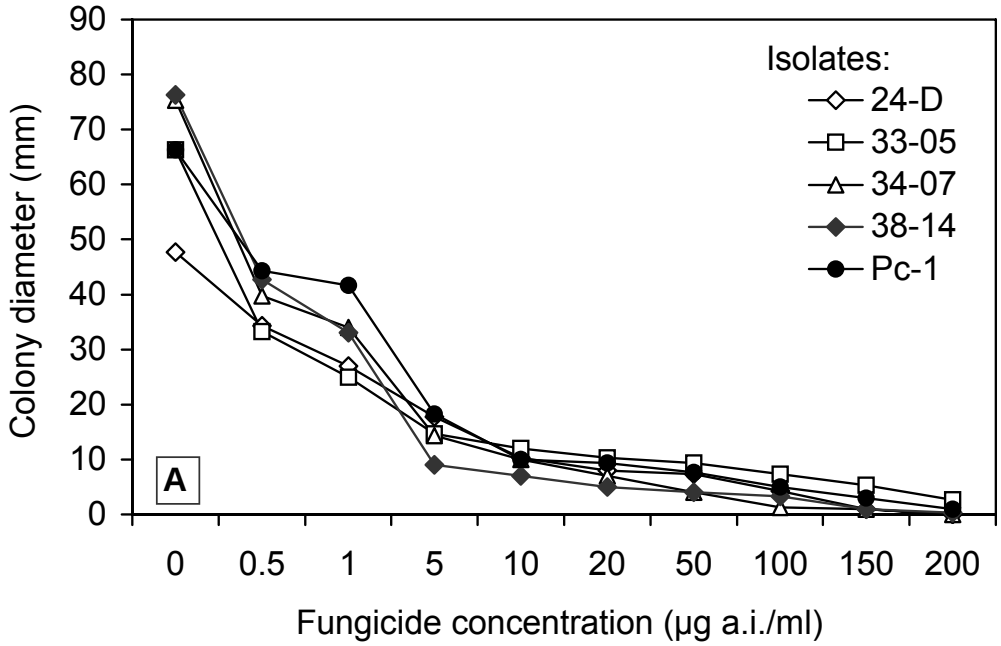
[z] Values in each row with a letter in common are not significantly different from each other according to Fischer's protected test ($P = 0.05$).

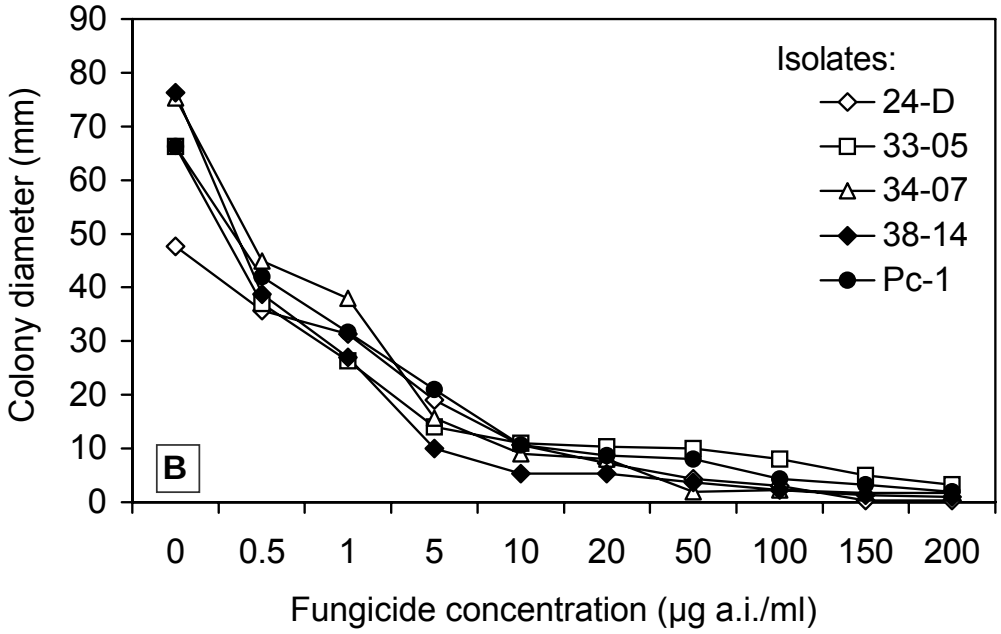
Fig. 1. Growth of mycelium of *Phytophthora capsici* on lima bean agar amended with mefenoxam (A) and metalaxyl (B). Values represent the means of treatments in three experiments.

Fig. 2. Germination of sporangia of *Phytophthora capsici* on lima bean agar amended with mefenoxam (A) and metalaxyl (B). Values represent the means of treatments in three experiments.

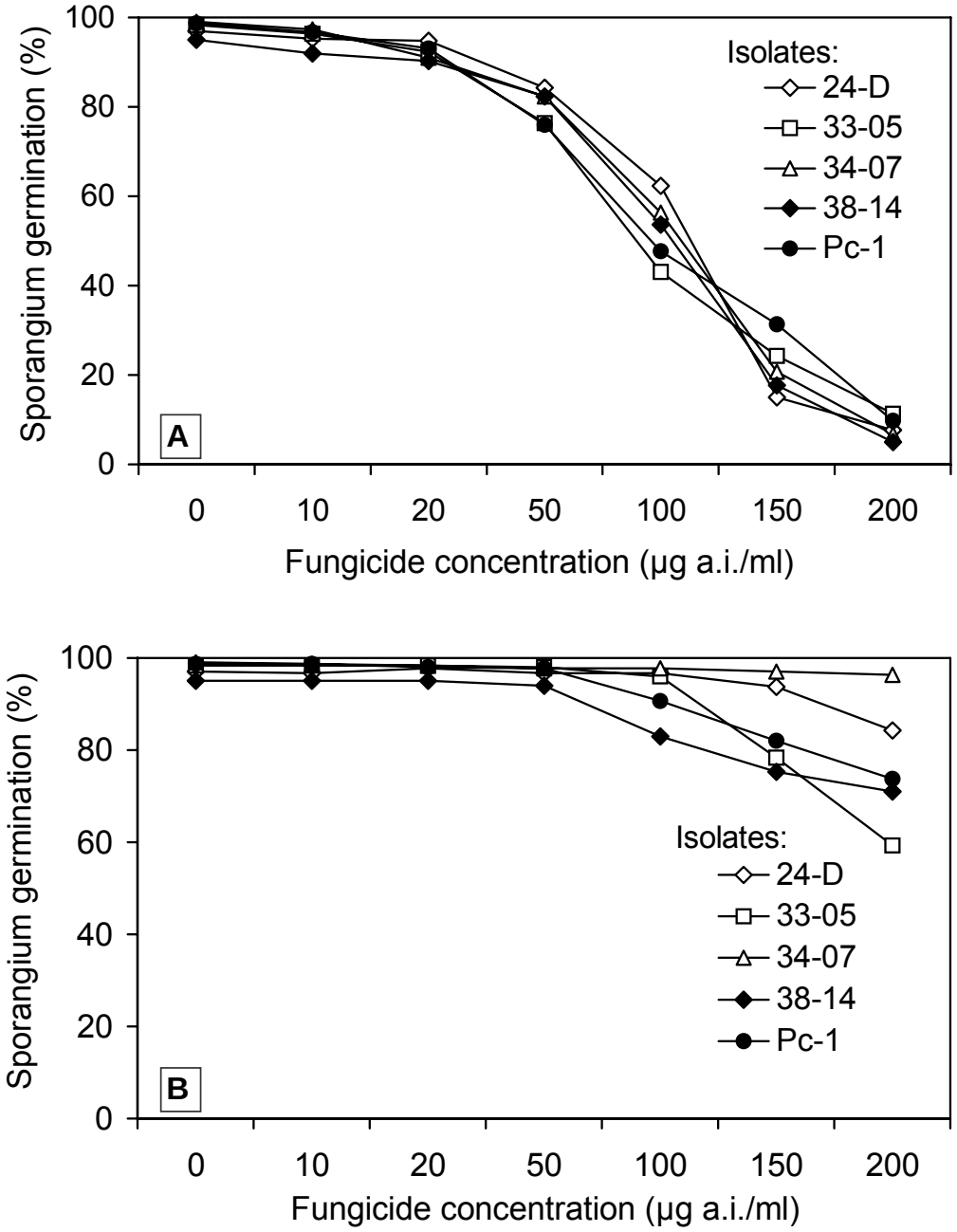
Fig. 3. Germination of zoospores of *Phytophthora capsici* on lima bean agar amended with mefenoxam (A) and metalaxyl (B). Values represent the means of treatments in three experiments.

Fig. 4. Relationship between inoculum density of *P. capsici* in soil and survival of processing pumpkin seedlings in greenhouse. Seed were either treated with mefenoxam , metalaxyl, or not treated. Data are the mean of three cultivars.


Colony diameter (mm)
90
80
70
60
50
40
30
20
10
0
Isolates:
24-D
33-05
34-07
38-14
Pc-1
A
0
0.5
1
5
10
20
50
100
150
200
Fungicide concentration (µg a.i./ml)


Colony diameter (mm)
90
80
70
60
50
40
30
20
10
0
Isolates:
24-D
33-05
34-07
38-14
Pc-1
B
0
0.5
1
5
10
20
50
100
150
200
Fungicide concentration (µg a.i./ml)

1 Fig. 1.


Sporangium germination (%)
100
80
60
40
20
0
Isolates:
24-D
33-05
34-07
38-14
Pc-1
A
0
10
20
50
100
150
200
Fungicide concentration (µg a.i./ml)
Sporangium germination (%)
100
80
60
40
20
0
Isolates:
24-D
33-05
34-07
38-14
Pc-1
B
0
10
20
50
100
150
200
Fungicide concentration (µg a.i./ml)

1 Fig. 2.

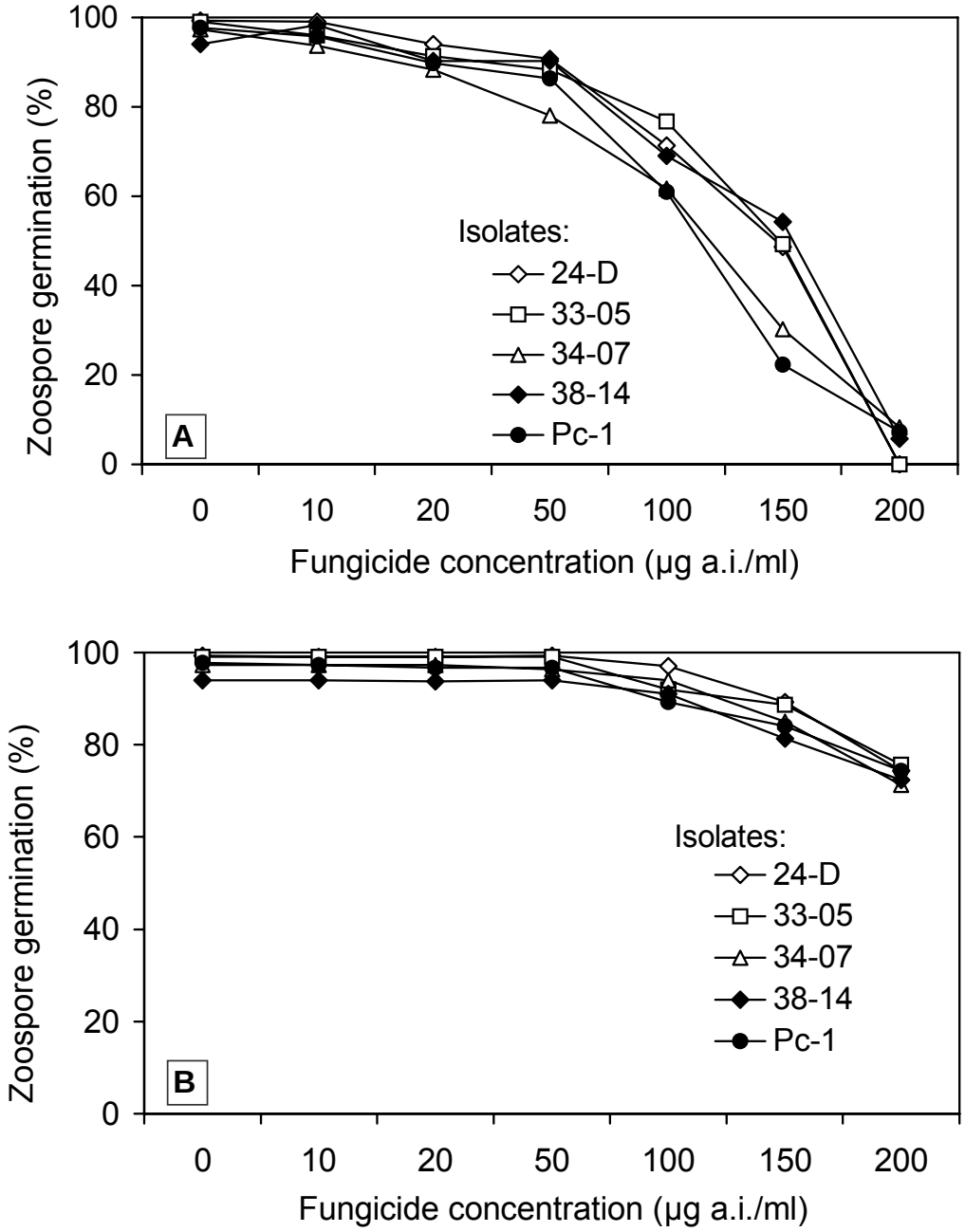

Zoospore germination (%)
100
80
60
40
20
0
Isolates:
24-D
33-05
34-07
38-14
Pc-1
A
0
10
20
50
100
150
200
Fungicide concentration (µg a.i./ml)
Zoospore germination (%)
100
80
60
40
20
0
Isolates:
24-D
33-05
34-07
38-14
Pc-1
B
0
10
20
50
100
150
200
Fungicide concentration (µg a.i./ml)

Fig. 3.

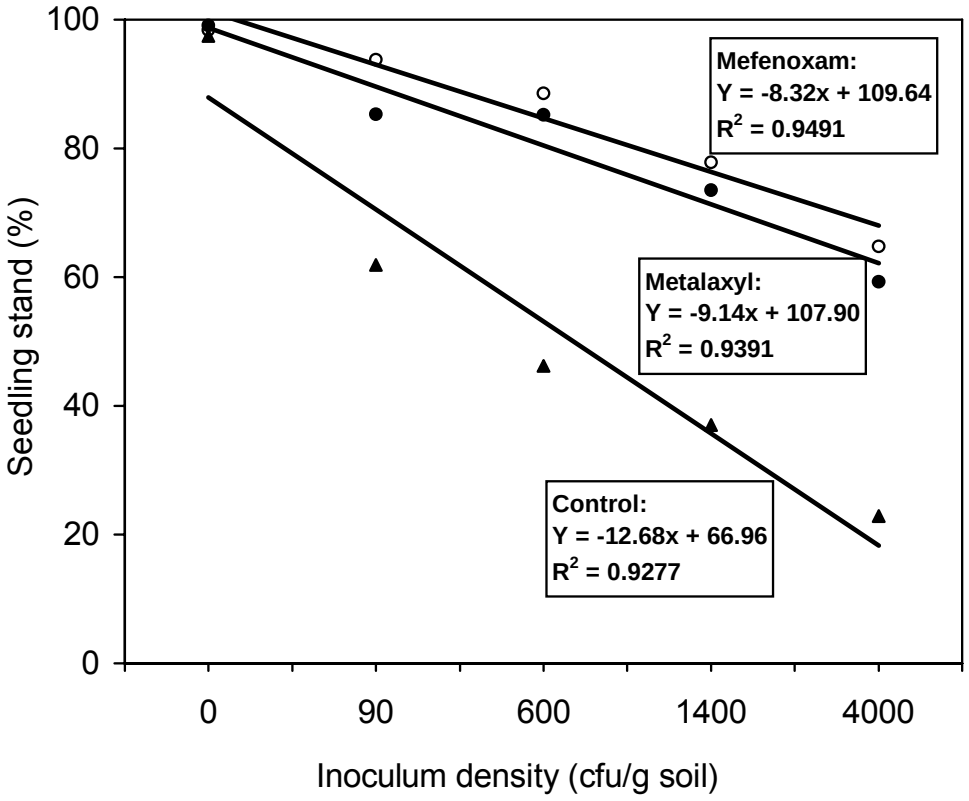

Seedling stand (%)
100
80
60
40
20
0
0
90
600
1400
4000
Inoculum density (cfu/g soil)
Mefenoxam:
Y = -8.32x + 109.64
R2 = 0.9491
Metalaxyl:
Y = -9.14x + 107.90
R2 = 0.9391
Control:
Y = -12.68x + 66.96
R2 = 0.9277

Fig. 4.