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Aluminum Amendment of Potting Mixes for Control of Phytophthora Damping-off in Bedding Plants

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Abstract. **Control of preemergence damping-off caused by *Phytophthora parasitica* Dastur was investigated on three bedding plant species in a 1 peat : 1 vermiculite medium (v/v) limed at 3 kg·m^{-3} and drenched with aluminum at 10, 25, or 50 meq Al/100 cm^3 medium. Aluminum as $Al_2(SO_4)_3$ was applied as a drench at 0.75, 1.9, or 3.75 g/150 ml water to the surface of infested medium in 650-cm^2 plug trays (1300-cm^3 tray volume). All concentrations of aluminum were effective in controlling preemergence damping-off of snapdragon (*Antirrhinum majus* L.) and vinca (*Catharanthus roseus* G. Don, Madagascar periwinkle), but only 50 meq Al^{+3}/100 cm^3 medium was effective for petunia (*Petunia ×hybrida* Hort. Vilm.-Andr.). At 4 days after seeding and drenching with aluminum sulfate, exchangeable aluminum was 0, 0.5, and 2.03 meq Al^{+3}/100 g medium, respectively, for the three concentrations used. Control of damping-off of snapdragon and vinca with 10 meq Al^{+3}/100 cm^3 medium with no detectable exchangeable aluminum 4 days after application suggests that *P. parasitica* was suppressed by aluminum early in the host–pathogen interaction, whereas petunia was susceptible to damping-off for a longer period before seedling emergence. Aluminum was not phytotoxic to vinca, snapdragon, or petunia grown in a limed medium.**

Damping-off caused by *Phytophthora parasitica* Dastur, *Pythium* spp., and *Rhizoctonia solani* Kuhn is an important disease problem of bedding plants for many growers. Traditionally, damping-off has been controlled by the use of soilless mixes, sanitation, manipulation of the environment, and fungicides that suppress development of damping-off pathogens. In previous studies, *Thielaviopsis basicola* (Berk. & Broome) Ferraris, cause of black root rot of burley tobacco (Meyer and Shew, 1991), and *P. parasitica* Breda de Haan var. *nicotianae* (Dastur) G.M. Waterhouse, cause of black shank of tobacco (Deluca and Shew, 1988), were suppressed by aluminum. Recently, Benson (1993a) demonstrated that drenches of aluminum sulfate to a peat : vermiculite medium controlled preemergence damping-off of *C. roseus* caused by *P. parasitica.* In a nonlimed peat : vermiculite medium at pH 4.4, as little as 17 meq of Al/100 cm^3 medium controlled damping-off; however, when the medium was limed to pH 5.8, as much as 100 meq of Al/100 cm^3 medium was needed for disease control (Benson, 1993a). Differences in amount of aluminum needed for control at pH values appropriate for bedding plant production was correlated with exchangeable aluminum in the medium. In general, as the pH of a medium increases the amount of exchangeable aluminum (Al^{+3}) decreases, such that there is very little exchangeable trivalent aluminum at pH 6 (Tisdale et al., 1985).

The objective of this research was to determine the rate of aluminum needed to control preemergence damping-off caused by *P. parasitica* on three bedding plant species in a soilless medium limed for adequate plant growth.

Materials and Methods

The soilless medium used was a 1 peat : 1 vermiculite (v/v) mixture with an initial pH of 4.1 in 1:2 $CaCl_2$. The peat had been screened through a 6-mm screen to remove large stem and root fragments. As the peat and vermiculite were mixed in a cement mixer, dolomitic limestone at the rate of 3 kg/m^3 medium was incorporated. The prepared medium was used to fill 81-cell plug trays (25.4 × 25.4 × 2.54 cm, i.e., standard 162-cell trays cut in half). The trays were then placed on a greenhouse bench and misted for 2-min intervals five times a day. This rate of misting kept the medium moist but not completely saturated. Trays were maintained under the mist system for 3 days to allow partial equilibration of the lime in the medium. After the equilibration period, the trays were seeded with ‘Little Bright Eyes’ vinca (69% germination), ‘Tetra Ruffled Supreme Mix’ snapdragon (55% germination), or with ‘Supercascade White’ petunia (86% germination) by use of a custom 81-cell vacuum seeder (Berry Seeder Co., Elizabeth City, N.C.).

Twice-autoclaved rice grains (25 g rice/19 ml deionized water) in 125-ml Erlenmeyer flasks were seeded with two to three 7-mm-diameter potato dextrose agar disks of isolate 336 of *P. parasitica* (Holmes and Benson, 1994). Flasks were incubated on the laboratory bench at ambient temperature without supplementary light. Flasks were shaken occasionally to prevent clumping of grains. After 30 to 40 days of growth, the rice grains were pulverized in a blender for 1 to 2 min, then screened through a sieve with 2-mm openings to select particles of uniform size. Pulverized rice grains (0.05 g) were mixed with 150 cm^3 peat : vermiculite medium for vinca or 100 cm^3 for petunia and snapdragon in a 850-ml plastic bottle. Moist peat : vermiculite medium had been reserved in shaded plastic bags on the greenhouse bench during the 3-day equilibration period. After mixing, the infested medium was sprinkled, through 1-cm holes in the lid, onto the surface of the seeded 650-cm^2 trays (1300 cm^3 of medium/tray). Medium without colonized rice grains was used to cover seeds in the control treatment. The trays were then misted twice for 2 min to settle the covering medium.

After misting, aluminum at 0, 10, 25, or 50 meq Al/100 cm^3 medium (0, 10, 25, 50 Al) was drenched to the surface of plug trays by dissolving the appropriate amount of aluminum sulfate [$Al_2(SO_4)_3$]—0, 0.75, 1.9, or 3.75 g, respectively—in 150 ml of water. Each solution was placed in a 850-ml plastic bottle and applied evenly to the surface of the 650-cm^2 plug trays through 0.8-mm holes in the lid. The rates of aluminum chosen were based on control of phytophthora damping-off of vinca over a pH range of 4.1 to 6 in previous experiments (Benson, 1993a).

Plug trays were arranged by treatment in a randomized complete-block design with four replications. Trays were maintained under the mist system during germination and emergence. After 16 days for vinca, and 19 days for petunia and snapdragon, trays were transferred to a capillary-mat watering system on a greenhouse bench. Stand counts were taken at emergence and at ≈2-day intervals thereafter, until tests were complete. At 18 and 32 days after seeding, six randomly selected seedlings in each tray were measured for plant width in the case of petunia and snapdragon, or for length of the first true leaf for vinca to assess aluminum phytotoxicity.

Four days after seeding, samples of potting medium were removed at random from each replication and composited by treatment for determination of pH and exchangeable aluminum. Medium pH was determined in 1:2 $CaCl_2$ (Smiley and Cook, 1972). Exchangeable aluminum, expressed as milliequivalents of Al^{+3}/

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100 g medium, was determined by 1 N KCl extraction of medium samples with a base–acid titration method that involved sodium fluoride (Yuan, 1959).

Forty-two days after seeding, six plugs for each plant species were selected at random from each plug tray and transplanted into a 82-cm^3, six-cell market pack of peat : vermiculite medium at pH 4.7. Immediately after transplanting, the corresponding rate of aluminum from the initial treatment was applied in 75 ml of water to the surface of the medium, as described above. Plants were fertilized weekly with 100 ppm N (20:20:20; Peters, Allentown, Pa.). At 45 and 60 days after seeding, plant height for the six seedlings in each market pack was measured.

Stand counts among treatments, plant widths, leaf length, and plant height measurements were compared by analysis of variance (ANOVA) with the PROC ANOVA procedure of PC SAS (SAS Institute, Cary, N.C.). Mean separation was by Waller–Duncan k ratio *t* test, k = 100, $P = 0.05$. Experiments were repeated three times and representative data from one experiment presented.

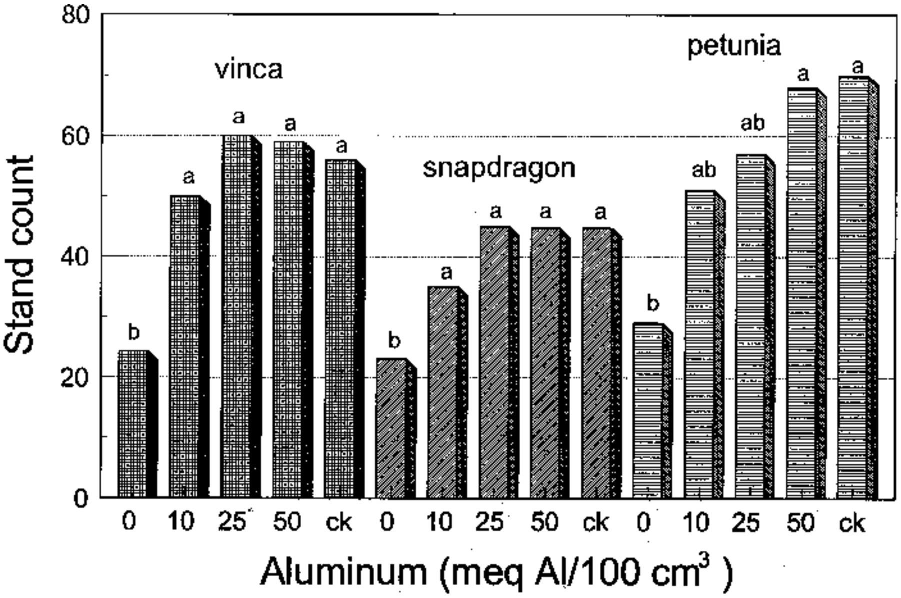

Fig. 1. Stand counts for vinca, snapdragon, and petunia grown in a peat : vermiculite medium limed at 3 kg•m^{-3} and infested with *Phytophthora parasitica.* The medium was drenched with aluminum sulfate at 0, 10, 25, or 50 meq Al^{+3}/100 cm^3 medium. The control designated "ck" was neither infested nor drenched with aluminum. Mean separation within species (means of four replications) by the Waller–Duncan k ratio *t* test, k = 100, $P = 0.05$.

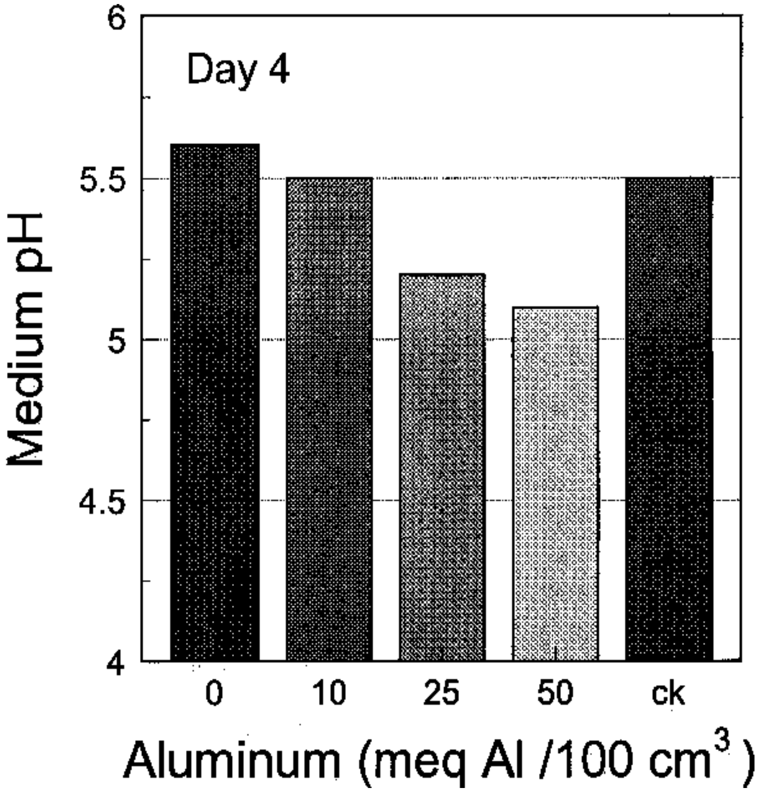

Fig. 2. Medium pH at 4 days after seeding and drenching a limed peat : vermiculite medium with aluminum sulfate at 0, 10, 25, or 50 meq Al^{+3}/100 cm^3 medium. Samples were taken at random from plug trays of vinca, snapdragon, and petunia infested with *Phytophthora parasitica.* The control designated "ck" was neither infested nor drenched with aluminum.

Results

Vinca. Stand counts of vinca seedlings were lower ($P = 0.05$) in the infested, nontreated control due to preemergence damping-off caused by *P. parasitica* compared to the noninfested control (ck) at 11 days after seeding (Fig. 1). Based on stand count in the noninfested control, preemergence damping-off caused by *P. parasitica* was 56.2% in the infested control. When drenches of aluminum at rates of 10 to 50 Al were applied to infested medium seeded with vinca, stand counts were different ($P \leq 0.05$) from the infested, nontreated control but the same as counts in the noninfested control (Fig. 1). Preemergence damping-off was 9.5%, 0%, and 0% for 10, 25, and 50 Al, respectively, based on stand count for the noninfested control.

Snapdragons. No damping-off of snapdragons occurred in medium amended with 25 or 50 Al, respectively, and stand counts were not different ($P > 0.05$) from the noninfested control (Fig. 1). Preemergence damping-off in snapdragons not drenched with aluminum averaged 48% in the infested control with *P. parasitica.* At 10 Al, damping-off was 21%, but stand count was not different ($P > 0.05$) from the noninfested control (Fig. 1).

Petunia. In petunia, 10 and 25 Al did not control preemergence damping-off (29% and 20% diseased plants, respectively), compared to the infested control (0 meq) and stand counts were similar to that of the noninfested control (Fig. 1). Damping-off in petunia was 58% in the infested control without aluminum amendment. At 50 Al, damping-off of petunia averaged only 2.4% and stand count was greater than ($P \leq 0.05$) the infested control (Fig. 1).

pH. Medium pH ranged from 5.5 to 5.6 in composite samples from treatments without aluminum amendment 4 days after seeding (Fig. 2). As the rate of aluminum amendment increased from 10 to 50 Al, medium pH dropped from 5.5 to 5.1, respectively, 4 days after seeding (Fig. 2).

Exchangeable aluminum. Four days after seeding, exchangeable aluminum from composite samples across crop species was 0 and 0.13 meq/100 g medium in the infested control (0 meq) and noninfested control (ck), respectively (Fig. 3). No exchangeable aluminum was detected in samples from medium drenched at 10 Al. Exchangeable aluminum was 0.5 and 2.03 meq/100 g medium in samples from media drenched with 25 and 50 Al, respectively, at 4 days.

Plant growth. Eighteen days after seeding, lengths of the first true leaves of vinca were similar ($P > 0.05$) among treatments (range 8.6 to 9.7 mm). At day 32, however, first true leaves in the infested control were shorter ($P = 0.0001$) than in treatments with aluminum or the noninfested control (Table 1). Heights of vinca seedlings at day 45 (range 47 to 68 mm) and day 60 (range 101 to 159 mm) after seeding were similar ($P > 0.05$) among treatments.

At day 45, snapdragon seedlings in the infested control and in medium amended with 50 Al were shorter ($P = 0.036$) than seedlings in medium amended with 25 Al (Table 1). At day 60, no differences in height of snapdragon seedlings (range 148 to 235 mm) were detected among treatments. Plant width at day 18 and day 32 (range 33 to 42 mm) after seeding was similar for all treatments.

At 32 days after seeding, petunia seedlings in the noninfested control and medium drenched with 25 Al were larger ($P \leq 0.005$) than seedlings in other treatments (Table 1). No differences in heights of petunia seedlings were detected at 45 and 60 days (range 202 to 255 mm).

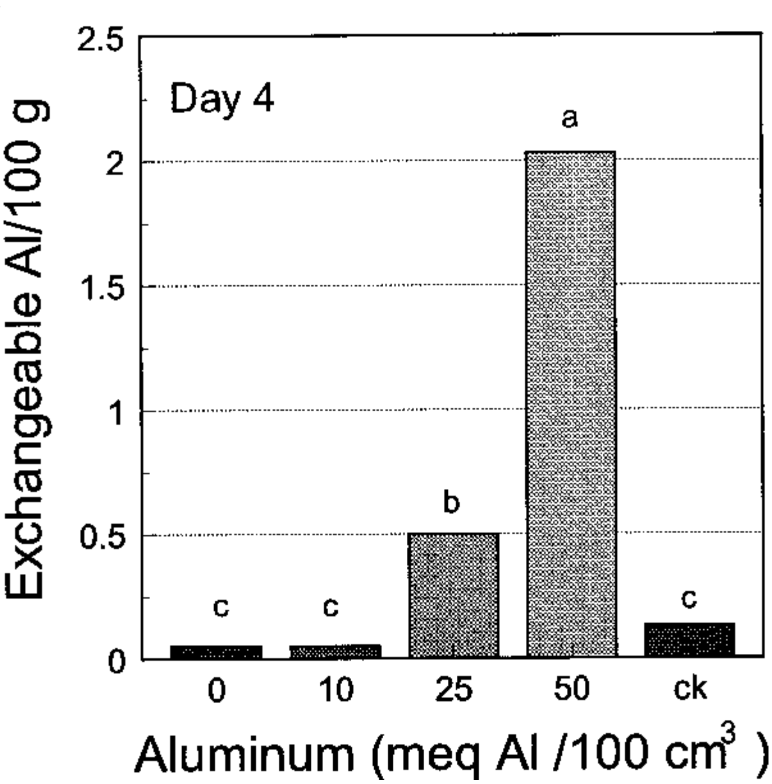

Fig. 3. Exchangeable aluminum (meq Al^{+3}/100 g medium) at 4 days after seeding and drenching a limed peat : vermiculite medium with aluminum sulfate at rates of 0, 10, 25, or 50 meq $Al^{+3}/100\ cm^3$ medium. Samples were taken at random from plug trays of vinca, snapdragon, and petunia infested with *Phytophthora parasitica.* The control designated "ck" was neither infested nor drenched with aluminum. Mean separation (means of two replications) by the Waller–Duncan k ratio *t* test, k = 100, $P = 0.05$.

Table 1. Growth of bedding plant seedlings in peat : vermiculite medium infested or noninfested with *Phytophthora parasitica* and drenched with aluminum sulfate at 0 (noninfested and infested controls), 10, 25, or 50 meq $Al^{+3}/100\ cm^3$ medium.[z]

Al sulfate	Vinca[y]	Snapdragon[x]	Petunia[w]
(meq/100 cm^3)	Length (mm)	Ht (mm)	Width (mm)
0, noninfested	24.6 a	97 ab	44 a
0, infested	16.3 b	77 b	38 b
10, infested	22.8 a	99 ab	35 b
25, infested	24.6 a	116 a	44 a
50, infested	24.7 a	82 b	35 b
$P > F$	0.0001	0.0356	0.0048

[z] Mean separation within a column by the Waller–Duncan k ratio *t* test; k = 100, $P = 0.05$.

[y] First true-leaf length measured at 32 days for vinca seedlings in plug trays.

[x] Plant height measured at day 45 for snapdragon seedlings retreated with aluminum at transplanting 42 days after seeding.

[w] Plant width measured at day 32 for petunia seedlings in plug trays.

Discussion

Drenches of aluminum to a peat : vermiculite medium at 10 to 50 Al were effective in controlling preemergence damping-off, but differences existed among bedding plants tested. Damping-off of vinca and snapdragon was controlled at all rates of aluminum tested, whereas only the 50 Al treatment completely controlled damping-off of petunia.

Previous research with *P. parasitica* has shown a close correlation between exchangeable aluminum at 4 days after seeding vinca and subsequent development of preemergence damping-off (Benson, 1993a). Apparently, the first few days after seeding are critical in emergence of healthy seedlings or development of disease even though seedlings may not actually emerge until several days later. Thus, it appears for vinca and snapdragon, where control of preemergence damping-off was good at a rate as low as 10 Al, that the critical interaction of exchangeable aluminum with pathogen suppression occurs within 4 days. In addition, the amount of exchangeable aluminum must have been very low during this period, since exchangeable aluminum was not detectable at 4 days after seeding when applied at 10 Al. The transitory nature of exchangeable aluminum when applied at low rates to a peat : vermiculite medium limed at 3 $kg{\cdot}m^{-3}$ suggests that long-term disease control would not be effective if the crop were susceptible to *P. parasitica* at other stages of growth. This situation would apply for the phytophthora blight disease that develops on foliage of vinca as a result of splash dispersal of inoculum to foliage of seedlings or even flowering plants in the landscape (Benson, 1993b).

However, for petunia, only 50 Al of aluminum was effective in disease control where exchangeable aluminum was 2.03 meq Al^{+3}/100 g medium at day 4, suggesting that germinating petunia seed were susceptible to *P. parasitica* for a longer period than snapdragon and vinca before emergence. Therefore, exchangeable aluminum must remain at levels inhibitory to *P. parasitica* for longer periods.

In acidic soils with a pH near 4, aluminum toxicity to plant growth can be a problem. In peat media with a naturally low pH, potential aluminum toxicity can be corrected by adding lime. However, the natural suppressiveness of nonlimed peat media to sensitive soilborne pathogens due to high exchangeable aluminum is lost by liming. Amendment of peat media with aluminum in the form of aluminum sulfate may be one way to restore suppression to sensitive soilborne pathogens.

Vinca, snapdragon, and petunia seedlings were not sensitive to aluminum toxicity at rates of 10, 25, or 50 Al when the peat : vermiculite medium was limed at 3 $kg{\cdot}m^{-3}$. However, Benson (1993b) found that both petunia and snapdragon emerged poorly, and had restricted root systems and top growth when exposed to aluminum at 100 Al in a nonlimed peat : vermiculite medium at pH 4.2. Although only a limited number of bedding plant crops have been tested for aluminum tolerance (Benson, 1993b), it is apparent that even aluminum-sensitive crops such as petunia and snapdragon can be grown at favorable pH in environments with enough exchangeable aluminum to control damping-off due to *P. parasitica.* In practice, growers could use aluminum amendments to create levels of exchangeable aluminum in peat-based media that were suppressive to sensitive pathogens such as *P. parasitica* yet avoid aluminum phytotoxicity problems by liming the medium.

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