Pythium Root Rot of Seedling Geraniums Associated with Various Concentrations of Nitrogen, Phosphorus, and Sodium Chloride

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ABSTRACT

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Seven-week-old seedling geraniums (*Pelargonium* × *hortorum* 'Showgirl') planted in soilless media received soluble fertilizer with each irrigation. A complete base fertilizer (20% nitrogen, 10% phosphorus, 20% potassium) was amended to supply nitrate nitrogen, ammonium nitrogen, or phosphorus in suboptimum, optimum, or excessive concentrations. In a separate treatment, sodium chloride was added to the base fertilizer to simulate the electrical conductivity of the excessive fertilizer solution. Half the plants in each treatment were inoculated with *Pythium ultimum*. Few of the noninoculated plants given excessive fertilization died and none of the plants given the suboptimum level of fertilization died, even when inoculated with *P. ultimum*. Mortality of the inoculated plants increased as the concentration of nitrogen or phosphorus increased. Mortality could not be associated with increased electrical conductivity of the saturated paste extract of the potting medium.

Plants have a wide range of fertilizer requirements for optimum growth. Soil fertility also can influence the effect that pathogens have on inducing plant diseases. It has been observed that the reaction of plants to pathogenic organisms may be altered by changing the mineral composition of the fertilizer solution applied to the plants (2–4,7,14).

Moorman (10,11) reported that geranium and poinsettia losses from root rot caused by *Pythium ultimum* Trow increase with increased fertilizer concentration. Low fertilizer levels controlled plant losses from Pythium root rot, but Menzies and Calhoun (9) noted that Phoma root rot of chrysanthemum could be controlled by applying excess fertilizer.

It is thought that the relationship between the mineral conditions of the host plant and the severity of attack by pathogenic organisms is related to both the nutrient concentration and the availability to the plant of the minerals that compose the nutrient solution (14). For example, it has been theorized that the form of nitrogen, either nitrate or ammonium nitrogen, available to the host or the pathogen affects disease severity more than the amount of nitrogen (5).

The objective of this study was to determine whether nutrient solutions that differ in ion composition and concentration influence seedling geranium mortality caused by Pythium root rot.

MATERIALS AND METHODS

The geranium (*Pelargonium* × *hortorum* L. H. Bailey 'Showgirl') was used throughout the experiments. The isolate of *P. ultimum* Trow (American Type Culture Collection no. 32231), and all inocula used in this study, were obtained from repeated subcultures from the original culture. Inoculation procedures follow. A 1-wk-old culture of *P. ultimum* on cornmeal agar (30 g of cornmeal, 20 g of agar, 1 L of distilled water) in 15 × 100 mm plastic petri plates was homogenized in tap water, 100 ml per plate. Ten milliliters of the suspension were poured on the surface of the potting medium. In all experiments, a peat:vermiculite:sand:bark-ash medium was used (Metro-Mix 350, W. R. Grace & Co., Fogelsville, PA). Throughout all experiments, a 20% nitrogen (N), 10% phosphorus (P), 20% potassium (K) soluble fertilizer (Peters Fertilizer Products, division of W. R. Grace & Co., Fogelsville, PA) was used as the nutrient source. This fertilizer contains 5.6% nitrate nitrogen, 3.9% ammoniacal nitrogen, and 10.4% urea as the nitrogen source and 10% phosphoric acid and 20% soluble potash as the phosphorus and potassium sources, respectively. The concentrations of nutrients used were considered suboptimum, optimum, or excessive based on previous reports (8). The nutrient solutions were applied using a Hyponex Siphon Mixer (1:16) proportioner (The Hyponex Co., Copley, OH). When the fertilizer was applied, about 10–15% of the liquid applied leached through the potting medium.

The objective of experiment 1 was to determine if nitrogen form was associated with increased plant mortality from Pythium root rot. This experiment was conducted from June to August in 1986. Two-week-old seedling geraniums were planted in Metro-Mix 350 in 10-cm plastic pots. Beginning 6 wk after planting, fertilizer was added at each irrigation. The plants were irrigated either once or twice daily depending on environmental conditions.

Fertilizer treatments used included 20% N, 10% P, 20% K as a control at 10.7, 21.4, and 42.8 mM N or the 20% N, 10% P, 20% K fertilizer as a basal nutrient solution at 7.1 mM N amended with ammonium nitrate, ammonium sulfate, or sodium nitrate to bring the total nitrogen level of the nutrient solution to 10.7, 21.4, or 42.8 mM N (Table 1).

The objective of experiment 2 was to determine if the form of additional phosphorus or if an increase in the soluble salt concentration of the irrigation liquid was associated with increased plant mortality from Pythium root rot. A sodium chloride treatment, which

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results in an increase in soluble salts without affecting the N-P-K concentration, was included in this experiment. This experiment was conducted during September–November of 1986, using the same plant culture techniques as before. Fertilizer treatments included 20% N, 10% P, 20% K as a control at 10.7, 21.4, and 42.8 mM N; 20-10-20 base at 7.1 mM N plus dibasic ammonium phosphate; 20-10-20 base at 7.1 mM N plus monobasic potassium phosphate; and 20-10-20 base at 7.1 mM N plus sodium chloride. The phosphorus-containing compounds were added to provide phosphorus to the plants at the rates of 4.8, 9.7, and 19.4 mM (Table 1). The concentrations of sodium chloride (2.7, 16.4, and 49.3 mM NaCl) were selected so that the electrical conductivity of the irrigation liquid and the saturated paste extracts of the potting media were similar to those conductivities obtained when 20-10-20 was used alone to supply 10.7, 21.4, and 42.8 mM N.

Experiment 3 combined all of the treatments in experiments 1 and 2. Temperatures in the greenhouse during this experiment, which was conducted from February to April 1987, ranged from 15 to 30 C. All techniques remained the same. In all experiments, two samples of the potting mix of each fertilizer type and each fertilizer level were taken each week, and a saturated paste extract was prepared (12). The electrical conductivity, a measure of the total soluble salt concentration of the extract, was determined using a Beckman SD-B15 Solu-Bridge (Beckman Instruments, Inc., Cedar Grove, NJ). The pH of the extract was measured with a Corning M-120 pH meter (Corning Science Products, Corning Ltd., Halstead, Essex, England). Statistical analysis was performed to determine the correlation between the average electrical conductivity of the saturated paste extract over the whole period of the experiment and the plant mortality on the last observation date (16).

In all experiments, plants that were permanently wilted, had basal stem rot, or were obviously dead were considered to be no longer viable. These plants, hereafter termed "dead", were counted weekly following the date of inoculation. Area under the disease progress curve (AUDPC) was calculated for plant mortality using the following formula: $AUDPC = \Sigma_{i=1}^{n-1} ([Xi + 1 + Xi]/2) \cdot (Ti + 1 - Ti)$, where Xi = cumulative disease incidence, expressed as a proportion of the ith observation, Ti = time (days after the inoculation date) at the ith observation, and n = total number of observations of plant mortality (per unit) at the ith observation (17).

In all experiments, 16 plants were treated at each of the three fertilizer levels. Eight plants in each level were inoculated with *P. ultimum* 7 wk after potting, as noted above. Each fertilizer treatment was replicated three times. Each fertilizer treatment used one greenhouse bench. The benches were blocked in the greenhouse in experiments 2 and 3 to account for the environmental gradient throughout the greenhouse.

Data on cumulative plant mortality on the last observation date were subjected to analysis of variance of a split-split plot design using the statistical analysis system (SAS). Bonferroni's procedure was used with the aid of the general linear model to compare the treatment means (13).

RESULTS

Only experiment 3 is reported because the results were very similar to those obtained in experiments 1 and 2. Average conductivity and pH readings of the saturated paste extracts recorded in the experiment are given in Table 1. As the level of nitrogen and sodium chloride in the saturated paste extract increased, the conductivity of the extract also increased. As the level of phosphorus in the saturated paste extract increased, corresponding increases in conductivity were not noted. The pH ranged between 5.0 and 7.0 for all nutrient treatments. Figure 1 represents the trends observed when the plants were given the 20-10-20 basal nutrient solution at 10.7, 21.4, and 42.8 mM N and inoculated or not inoculated with *P. ultimum*. Figure 1 is representative of the treatments, with the exception of the sodium chloride treatment.

An average AUDPC value was calculated for the number of dead plants

Table 1. Average area under the disease progress curve (AUDPC), average percent mortality on the last sampling date, electrical conductivity (EC), and pH of the saturated paste extracts of the potting mix of geranium seedlings in experiment 3[y]

Treatment	Total mM N	Total mM P	mM NaCl	pH	EC ($\times 10^{-5}$ mhos/cm)	Inoculated AUDPC	Not inoculated AUDPC	Average percent mortality of plants inoculated with *Pythium ultimum*	Average percent mortality of non-inoculated plants
20% N, 10% P, 20% K	10.7	1.6	···	6.7	1.9	0.0	0.0	0.0 a[z]	0.0 a[z]
20% N, 10% P, 20% K	21.4	4.8	···	6.7	2.9	131.3	0.0	4.2 a	0.0 a
20% N, 10% P, 20% K	42.8	9.7	···	6.5	5.0	947.9	233.3	95.8 b	8.3 a
20% N, 10% P, 20% K (base)	7.1	3.2							
Ammonium sulfate + base	10.7	1.6	···	6.3	2.0	0.0	0.0	0.0 a	0.0 a
Ammonium sulfate + base	21.4	1.6	···	6.4	2.6	43.8	0.0	12.5 a	0.0 a
Ammonium sulfate + base	42.8	1.6	···	6.5	5.6	1,472.9	247.9	95.8 b	12.5 a
Sodium nitrate + base	10.7	1.6	···	6.6	2.4	0.0	0.0	0.0 a	0.0 a
Sodium nitrate + base	21.4	1.6	···	6.8	4.0	364.6	525.0	12.5 a	16.7 a
Sodium nitrate + base	42.8	1.6	···	7.0	5.8	1,764.6	875.0	95.8 b	58.3 b
Ammonium nitrate + base	10.7	1.6	···	6.8	1.9	0.0	0.0	0.0 a	0.0 a
Ammonium nitrate + base	21.4	1.6	···	6.4	3.3	233.0	0.0	8.3 a	0.0 a
Ammonium nitrate + base	42.8	1.6	···	6.5	4.5	1,195.8	145.8	75.0 b	8.3 a
Ammonium phosphate + base	14.5	4.8	···	6.7	1.3	0.0	0.0	0.0 a	0.0 a
Ammonium phosphate + base	36.5	9.7	···	6.7	2.0	145.8	0.0	8.3 a	0.0 a
Ammonium phosphate + base	80.5	19.4	···	6.6	2.2	1,735.4	0.0	95.8 b	0.0 a
Potassium phosphate + base	7.1	4.8	···	7.0	1.6	0.0	0.0	0.0 a	0.0 a
Potassium phosphate + base	7.1	9.7	···	6.9	1.9	4.6	14.6	0.0 a	4.2 a
Potassium phosphate + base	7.1	19.4	···	6.7	2.3	2,114.6	131.3	95.8 b	12.5 a
Sodium chloride + base	7.1	1.6	2.7	7.1	2.3	0.0	0.0	0.0 a	0.0 a
Sodium chloride + base	7.1	1.6	16.4	6.9	3.7	43.8	0.0	4.2 a	0.0 a
Sodium chloride + base	7.1	1.6	49.3	7.0	4.8	43.8	262.5	4.2 a	8.3 a

[y] Plants were fertilized with a 20 nitrogen (N), 10 phosphorus (P), 20 potassium (K) fertilizer solution at increasing concentrations, or with a 20 N, 10 P, 20 K base fertilizer amended with different nitrogen salts, phosphorus salts, and sodium chloride at increasing concentrations and inoculated or not inoculated with *P. ultimum*.

[z] Means followed by the same letter within a column are not significantly different from each other ($P = 0.05$) according to Bonferroni's procedure.

in each experiment over the entire experiment (Table 1). In general, the AUDPC values calculated for each fertilizer treatment were significantly lower ($P = 0.05$) for the noninoculated populations (Table 1). The exception to this was the sodium nitrate and potassium phosphate treatments. Excluding the highest sodium chloride treatment in the noninoculated population, there was no significant difference ($P = 0.05$) in the AUDPC values for the inoculated plants as compared with the noninoculated populations, given the basal nutrient solution amended with sodium chloride.

This means that as the level of nitrogen and phosphorus in the nutrient solutions supplied to the plants increased, significantly more plants died in the population inoculated with *P. ultimum*, whereas there was no significant difference in plant mortality for the plants given the excessive sodium chloride treatment and inoculated with *P. ultimum*. The few noninoculated plants that died at the highest concentration of sodium chloride were probably killed by the high salt concentration alone.

Death of inoculated plants usually began 2 wk after inoculation and continued for another 3–5 wk. With the exception of the sodium chloride treatments, all viable noninoculated plants at all nutrient concentrations were of marketable quality.

DISCUSSION

These experiments demonstrate that when high nutrient salt concentrations are applied to young seedling geraniums there is greater risk of serious losses from Pythium root rot than at low nutrient levels. Although increased concentrations of specific nutrients alone were associated with some plant mortality, this was greatly intensified when the plants were inoculated with *P. ultimum*.

Correlation analysis ($P = 0.05$) between the conductivity of the nutrient solution and the total number of dead plants in all of the treatments in the experiment indicated a very weak correlation ($r = 0.578$). An increased concentration of phosphorus resulted in a smaller increase in the electrical conductivity of the nutrient solution than the increase resulting from increasing the nitrogen concentration. Increasing the phosphorus concentration of the nutrient solution significantly increased ($P = 0.05$) plant mortality from Pythium root rot. The effect of increased sodium chloride is an increase in the conductivity of the solution applied to the plants without an increase in the concentration of nutrients supplied, but increased sodium chloride was not associated with significantly increased ($P = 0 .05$) plant losses. These data suggest that nutrient concentration, rather than ion concentration, is associated with greater geranium losses when *Pythium* was present. The data also show that the level of nutrient salt in combination with the presence of *P. ultimum*, and not the type of nutrient salt, is associated with increased plant death.

Disease severity in general can be altered by changing the balance of nitrogen and phosphorus supplied to the plants (15), but our findings indicate that a specific imbalance between nutrients is not associated with increased geranium losses. There was no significant difference in the results obtained when high nitrogen/low phosphorus or low nitrogen/high phosphorus nutrient solutions were used. In this system, a high concentration (i.e., greater than or equal to 42.8 mM N or 9.7 mM P) of either nitrogen or phosphorus, and not the balance of nitrogen and phosphorus, used in the nutrient concentrate is associated with increased plant mortality.

Whereas previous studies on host:parasite combinations have indicated that the type of nitrogen (nitrate or ammonium nitrogen) applied to the plant may influence plant mortality (5), our work demonstrates that nitrogen forms do not differ in their influence on Pythium root rot of geraniums. The survey of Huber and Watson (5) makes it apparent that each pathogen is influenced by the form of nitrogen that it is supplied. Kraft and Erwin (6) reported that *P. ultimum* did not have a change in growth rate on synthetic media that were supplied with different forms of nitrogen. They concluded that *P. ultimum* was able to use a much wider range of nitrogen sources than other *Pythium* species, perhaps explaining the basis for the findings reported here that nitrogen forms do not differ in their influence on geranium mortality.

Our results are similar to those reported for Pythium root rot of poinsettia (10,11), which demonstrated that as fertilizer concentration increased, the mortality of poinsettia plants inoculated with *P. ultimum* also increased. These results are unlike those for Pythium damping-off of vegetable seedlings (1), in which low fertilizer concentrations were associated with decreased plant quality and plant death.

No cause and effect relationships have been demonstrated in these experiments. Much work remains to be done to determine in what manner the concentration of nutrients alters the geranium-*Pythium* interaction. However, one conclusion can be drawn based on the data reported here. The use of a fertilizer that contains 10.7–21.7 mM N, as opposed to 42.8 mM N, appears to be a sound recommendation to assist in the control of Pythium root rot of seedling geraniums caused by *P. ultimum*.

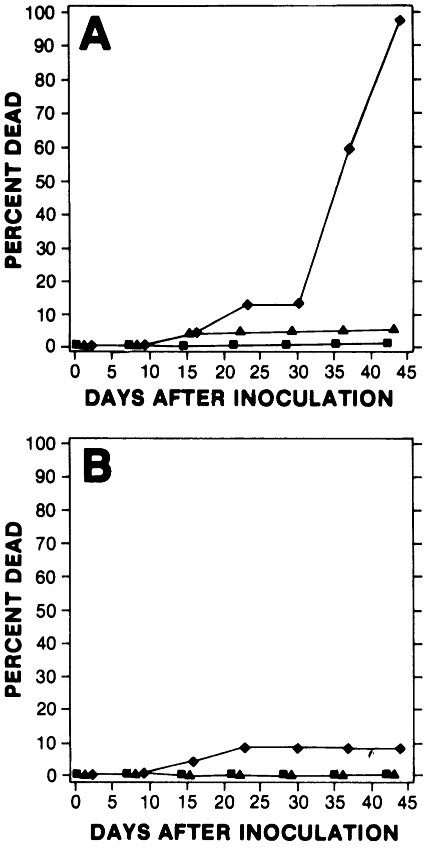

Fig. 1. Plant mortality of geraniums given 20% nitrogen, 10% phosphorus, 20% potassium soluble fertilizer at 10.7 mM N (square), 21.4 mM N (triangle), and 42.8 mM N (diamond). Plants were **(A)** inoculated with *Pythium ultimum* or **(B)** not inoculated.

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LITERATURE CITED

1. Beach, W. S. 1949. The effect of excess solutes, temperature, and moisture upon damping-off. Pa. Agric. Exp. Stn. Bull. 509. 29 pp.
2. Bingham, F. T., Zentmeyer, G. A., and Martin, J. P. 1958. Host nutrition in relation to Phytophthora root rot of avocado seedlings. Phytopathology 48:144-148.
3. Castano, J. J., and Kernkamp, M. F. 1956. The influence of certain plant nutrients on infection of soybeans by *Rhizoctonia solani*. Phytopathology 46:326-328.
4. Chase, A. R., and Poole, R. T. 1984. Investigations into the roles of fertilizer level and irrigation frequency on growth, quality, and severity of Pythium root rot of *Peperomia obtusifolia*. J. Am. Soc. Hortic. Sci. 109:619-622.
5. Huber, D. M., and Watson, R. D. 1974. Nitrogen form and plant disease. Annu. Rev. Phytopathol. 12:139-165.
6. Kraft, J. M., and Erwin, D. C. 1967. Effects of nitrogen sources on growth of *Pythium aphanidermatum* and *Pythium ultimum*. Phytopathology 57:374-376.
7. MacDonald, J. D. 1982. Effect of salinity stress on the development of Phytophthora root rot of chrysanthemum. Phytopathology 72:214-219.
8. Mastalerz, J. W., and Holcomb, E. J. 1982. Geraniums: A Manual on the Culture of Geraniums as a Greenhouse Crop. Pennsylvania Flower Growers, University Park, PA.
9. Menzies, S. A., and Calhoun, J. 1976. Control

of Phoma root rot of chrysanthemums by the usage of fertilizers. Trans. Br. Mycol. Soc. 67:445-462.
10. Moorman, G. W. 1986. Pythium root rot of geraniums associated with high fertilization rates. (Abstr.) Phytopathology 76:656.
11. Moorman, G. W. 1986. Increased plant mortality caused by Pythium root rot of poinsettia associated with high fertilization rates. Plant Dis. 70:160-162.
12. Richards, L. A., et al. 1954. Diagnosis and improvement of saline and alkali soils. Pages 8-9 in: U.S. Dep. Agric. Agric. Handb. 60.
13. SAS Institute, Inc. 1985. SAS User's Guide: Statistics. Version 5 ed. Cary, NC. 956 pp.
14. Shear, G. M., and Wingard, S. A. 1944. Some ways by which nutrition may affect severity of disease in plants. Phytopathology 34:603-605.
15. Spencer, E. L., and McNew, G. L. 1938. The influence of mineral nutrition on the reaction of sweet-corn seedlings to *Phytomonas stewarti*. Phytopathology 28:213-223.
16. Steele, R. G. D., and Torrie, J. H. 1980. Principles and Procedures of Statistics. A Biometrical Approach. McGraw-Hill Book Co., NY. 633 pp.
17. Tooley, P. W., and Grau, C. R. 1984. Field characterization of rate-reducing resistance to *Phytophthora megasperma* f. sp. *glycinea* in soybean. Phytopathology 74:1201-1208.