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Short Communication

Short term effects of phosphorus and VA-mycorrhizal fungi on nutrition, growth and development of *Capsicum annuum* L.*

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ABSTRACT

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Seedlings of *Capsicum annuum* L. cultivar 'Early Bountiful' were grown in containers of river sand inoculated or not with the VA-mycorrhizal (VAM) fungus *Glomus deserticola* (Trappe, Bloss & Menge). Long Ashton Nutrient Solution (LANS) were modified to supply P at 11, 22 or 44 $\mu g\ ml^{-1}$. After 42 days, plants were evaluated for growth, development and leaf elemental content. Short term effects occurred with P and VAM treatment. Increasing P fertility enhanced fruit number, leaf area, shoot, fruit and root dry weight, and decreased leaf area ratio (LAR). VAM increased leaf area of plants fertilized with full strength LANS (44 $\mu g\ ml^{-1}$ P). VAM generally increased leaf tissue B, but decreased Mo. Tissue K and N in VAM plants was not decreased, as it was in non-mycorrhizal plants with increasing P fertility. Increasing P fertility generally decreased tissue Cu and Zn and increased P levels. Mycorrhizal colonization (% root length) and spores recovered per unit of soil were greater with plants fertilized with 11 than 44 $\mu g\ ml^{-1}$ P levels.

Keywords: *Glomus deserticola*; nutrition.

Abbreviations: LANS = Long Ashton Nutrient Solution; LAR = leaf area ratio; PPFD = Photosynthetic photon flux density; VAM = vesicular–arbuscular mycorrhiza.

INTRODUCTION

It is well documented that mycorrhizal fungi can enhance plant nutrient status (Maronek et al., 1982; Strong and Davies, 1982). Mycorrhizae can also increase plant tolerance of soil desiccation. Enhanced water relations of

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vesicular–arbuscular mycorrhizae (VAM) plants has been attributed to improved plant nutrition, particularly phosphorus (Safir and Nelson, 1984). Under moderately high P regimes, where tissue P was non-growth-limiting in nonmycorrhizal plants, the water status of VAM plants has been reported to be enhanced compared with non-VAM plants (Sweatt and Davies, 1984; Augé et al., 1986). A problem with most previous water relations studies, however, is that mycorrhizal plants had greater biomass and higher tissue P than control plants (Safir and Nelson, 1984; Sweatt and Davies, 1984). Our goal was to determine the short term effects of P and VAM on nutrition, growth and development of pepper. This study was used to establish a test system of VAM and non-mycorrhizal plants with comparable biomass and tissue P levels for future drought stress research.

The test species utilized was *Capsicum annuum* L. (pepper) which is morphologically suitable for water stress studies (Turner, 1985), and is highly dependent on mycorrhizae for P uptake (Haas et al., 1986, 1987). *Glomus deserticola* enhances growth and development of pepper (Ianson and Linderman, 1987), and the same species of mycorrhizal symbiont has improved drought tolerance of other plant species (Augé et al., 1986).

Objectives of this study were to determine short-term effects of 3 P fertility levels and *G. deserticola* over the same duration of time that future water stress studies would be conducted, and ultimately select P fertility regimes to assure VAM and non-mycorrhizal plants would be of similar biomass and tissue P levels.

MATERIALS AND METHODS

Commercial inoculum of the mycorrhizal fungus *Glomus deserticola* (Trappe, Bloss & Menge) was obtained from Native Plants, Inc. (Salt Lake City, UT) and quantified and diluted to 20 000 spores per liter of container medium. A water solution of a portion of the mycorrhizal inoculum was sieved through 11 μm and added to controls to equalize the background microflora. Inoculum was banded at 4 cm deep in 1-l containers of pasteurized (at 60°C for 30 min) river sand. Three-week-old seedlings of *Capsicum annuum* L. cultivar 'Early Bountiful' grown in seed flats were then transplanted into the containers and grown in a glasshouse for 6 weeks (28/15°C average day/night temperatures with supplemental lighting for a 16 h photoperiod from high pressure sodium vapor lights with average PPFD of 600 μmol s^{-1} m^{-2}). Plants were fertilized weekly with 200 ml Long Ashton Nutrient Solution (LANS) (Hewitt, 1966) at 11, 22 or 44 μg ml^{-1} phosphorus.

In February 1987, in Corvallis, OR, plants were arranged in the glasshouse in a completely randomized design to determine the short-term growth effects of 11, 22 or 44 μg ml^{-1} phosphorus on VAM and non-VAM pepper. Each of the six treatments had 15 single-plant replications.

TABLE 1

Effect of three phosphorus levels and mycorrhiza on growth and development and tissue macronutrient (% dry wt.) and micronutrient (μg g^{-1}) levels of *Capsicum annuum* L. The figures are mean values of 15 observations

Mycorrhiza	Phosphorus regime (μg ml^{-1})	Fruit no.	Leaf area (g)	Shoot dry wt. (g)	Fruit dry wt. (g)	Shoot+fruit dry wt. (g)	Root dry wt. (g)	Shoot/root ratio (g g^{-1})	Leaf area ratio (cm^2 g^{-1})	N	P	K	Cu	B	Zn	Mo
No	11	3.7^{b}	396^{f}	3.6^{c}	0.8^{b}	4.4^{c}	1.8^{c}	2.0^{a}	65.2^{a}	2.6^{a}	0.1^{c}	3.4^{a}	2.9^{b}	41.4^{b}	21.1^{b}	3.9^{ab}
No	22	3.9^{b}	507^{d}	4.7^{b}	0.8^{b}	5.8^{b}	2.4^{b}	2.0^{a}	63.3^{ab}	2.5^{ab}	0.2^{b}	2.9^{b}	2.9^{b}	45.6^{a}	28.6^{a}	4.1^{a}
No	44	4.4^{b}	564^{b}	5.4^{a}	1.3^{ab}	6.7^{a}	2.6^{ab}	2.1^{a}	61.1^{b}	2.3^{ab}	0.4^{a}	3.0^{b}	2.6^{c}	43.7^{ab}	16.2^{b}	4.2^{a}
Yes	11	3.6^{b}	420^{e}	3.8^{c}	0.8^{b}	4.6^{c}	1.9^{c}	2.0^{a}	65.1^{a}	2.5^{ab}	0.1^{c}	3.3^{ab}	3.3^{a}	46.3^{a}	24.2^{ab}	3.3^{b}

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Effect of three phosphorus levels and mycorrhiza on growth and development and tissue macronutrient (% dry wt.) and micronutrient ($\mu g\ g^{-1}$) levels of *Capsicum annuum* L. The figures are mean values of 15 observations

Mycorrhiza	Phosphorus regime ($\mu g\ ml^{-1}$)	Fruit no.	Leaf area (g)	Shoot dry wt. (g)	Fruit dry wt. (g)	Shoot + fruit dry wt. (g)	Root dry wt. (g)	Shoot/root ratio ($g\ g^{-1}$)	Leaf area ratio ($cm^2\ g^{-1}$)	N	P	K	Cu	B	Zn	Mo
No	11	3.7^{b}	396^{f}	3.6^{c}	0.8^{b}	4.4^{c}	1.8^{c}	2.0^{a}	65.2^{a}	2.6^{a}	0.1^{c}	3.4^{a}	2.9^{b}	41.4^{b}	21.1^{b}	3.9^{ab}
No	22	3.9^{b}	507^{d}	4.7^{b}	0.8^{b}	5.8^{b}	2.4^{b}	2.0^{a}	63.3^{ab}	2.5^{ab}	0.2^{b}	2.9^{b}	2.9^{b}	45.6^{a}	28.6^{a}	4.1^{a}
No	44	4.4^{b}	564^{b}	5.4^{a}	1.3^{ab}	6.7^{a}	2.6^{ab}	2.1^{a}	61.1^{b}	2.3^{ab}	0.4^{a}	3.0^{b}	2.6^{c}	43.7^{ab}	16.2^{b}	4.2^{a}
Yes	11	3.6^{b}	420^{e}	3.8^{c}	0.8^{b}	4.6^{c}	1.9^{c}	2.0^{a}	65.1^{a}	2.5^{ab}	0.1^{c}	3.3^{ab}	3.3^{a}	46.3^{a}	24.2^{ab}	3.3^{b}
Yes	22	3.9^{b}	521^{c}	4.9^{b}	1.2^{ab}	6.1^{b}	2.4^{b}	2.0^{a}	61.5^{b}	2.2^{b}	0.2^{b}	3.3^{ab}	2.7^{c}	43.0^{b}	17.4^{b}	3.3^{b}
Yes	44	5.8^{a}	587^{a}	5.5^{a}	1.5^{a}	7.0^{a}	2.8^{a}	2.0^{a}	60.9^{b}	2.4^{ab}	0.4^{a}	3.1^{b}	2.8^{bc}	49.2^{a}	18.3^{b}	4.1^{a}
Significance																
VAM		NS	*	NS	NS	NS	NS	NS	NS	NS	NS	*	*	**	NS	*
Phosphorus		**	**	**	*	*	**	NS	**	**	**	*	**	NS	*	**

Significance (Fisher's Protected LSD test): NS, non-significant; *, significant at 5% level; **, significant at 1% level.

After 42 days, plants were evaluated for number of flower primordia, fruit and leaves; stem caliper; leaf area; shoot, fruit and root dry weight; shoot/root ratio; and leaf area ratio (LAR) (leaf area (cm^2)/root and shoot dry wt. (g)). Roots were cut into 1-cm segments, cleared and stained (Phillips and Hayman, 1970) and per cent root length with VAM colonization determined (Biermann and Linderman, 1981). Leaf tissue elemental analysis was conducted on an inductively coupled plasma atomic emission spectrometer (3510ICP). The river sand used for container medium was analyzed prior to experiment initiation and had a 91% sand, 7% clay and 2% silt texture, pH 7.0, sodium absorption ratio of 1.6, macroelements of 2, 13, 111, 1396 $\mu g\ g^{-1}$ of N, P, K, Ca, and Mg, respectively and microelements of 0.32, 13.2, 1.5, 0.35 and 123 $\mu g\ g^{-1}$ of Zn, Fe, Mn, Cu and Na, respectively.

RESULTS

High phosphorus levels increased fruit number, leaf area, shoot, fruit, and root dry weight, and decreased LAR (Table 1). Inoculation with mycorrhizal fungi increased leaf area of plants fertilized with full strength LANS (44 $\mu g\ ml^{-1}$ P), but otherwise, VAM had no effect on plant growth and development. VAM generally increased tissue B, while decreasing Mo (Table 1). Increasing P fertility generally decreased tissue Cu, Zn and increased P levels. VAM plants did not have decreased tissue N and K as did non-mycorrhizal plants with increasing P fertility. Per cent root length with VAM colonization decreased with increasing P fertility as did the number of spores recovered per 100 cm^3 of soil (Table 2).

TABLE 2

Effect of three phosphorus levels on root and soil mycorrhiza colonization of *Capsicum annuum* L. The figures are mean values of 15 observations

Mycorrhiza	Phosphorus regime ($\mu g\ ml^{-1}$)	VAM% root length	No. of spores recovered from soil (per 100 cm^3 of soil)
No	11	0	0[c]
No	22	0	0[c]
No	44	0	0[c]
Yes	11	3.8	1241[a]
Yes	22	2.1	1130[ab]
Yes	44	1.0	611[b]

Mean separation within columns by Duncan's multiple range test at the 5% level.

DISCUSSION

Short term effects of P
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No. of spores recovered from soil (per 100 cm^3 of soil)
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t at the 5% level.

DISCUSSION

Short term effects of P and VAM occurred in the nutrition, growth and development of pepper. Maximum growth and development and P uptake occurred with full strength LANS (44 $\mu g\ ml^{-1}$ P). VAM and high P fertility have been reported to increase biomass and yield of field grown peppers over a 2–3 month period in P-sorbing soils (Haas et al., 1987). The container medium used in our 6 week study had a texture of 91% sand and was low in P (13 $\mu g\ g^{-1}$). Haas et al. (1986) reported that fruit development was delayed in control compared with *G. macrocarpum* inoculated pepper plants; however, we observed no VAM differences in flower primordia initiation, fruit number or fruit mass.

High P peppers had a greater biomass and decreased tissue N, K, Cu, Zn compared with low P plants. Decreased levels of N and K have also been reported owing to the dilution effect of larger biomass plants (Johnson et al., 1980). VAM affected nutrition, as mycorrhizal plants did not have decreased tissue N and K as did nonmycorrhizal plants with increasing P fertility. VAM tended to increase B and decrease Mo during this 6 week study. With other plant species VAM has been reported to increase K uptake during a 26 week study (Davies, 1987) and increase N (Johnson et al., 1980).

Using the technique of Biermann and Linderman (1981), VAM colonization on a per cent root length basis ranged from 1 to 4%, while the percentage of roots colonized was from 10 to 20% (data not reported). *Glomus desert*i*cola* has few root infection points and is much more difficult to quantify than other *Glomus* species (Ianson and Linderman, 1987). Ames et al. (1983) reported mycorrhizal effects with *G. mosseae* when less than 3% of the root system was colonized. Pepper is considered to be highly mycorrhizal-dependent under field conditions, and colonization occurs within 2–3 weeks (J.H. Haas, personal communication, 1987).

VAM do have short term effects on nutrition, growth and development of pepper plants. From this experiment, future drought stress studies were established with VAM and control peppers at 22 and 44 $\mu g\ ml^{-1}$ P fertility, respectively. This insured that ±VAM plants were of comparable shoot and root biomass, shoot/root ratio, LAR, and that controls had equal or greater tissue P. Hence, any drought resistance could be attributed to VAM effects without the confounding influence of unequal plant size and tissue P.

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ABSTRACT

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Abbreviation: PVC = polyvinyl chl

INTRODUCTION

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