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SHORT NOTE

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Effects of vesicular-arbuscular mycorrhiza on *Tagetes erecta* and *Zinnia elegans*

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Abstract Seeds of *Tagetes erecta* and *Zinnia elegans* were planted in soil inoculated with the vesicular-arbuscular mycorrhizal fungus *Glomus etunicatum.* This procedure produced positive effects on both *Tagetes* and *Zinnia* compared with the control: faster flowering and an increased number of flowers. Shoot height, shoot and root dry weights and percentage infected root length were also measured. The reactions of these plants to mycorrhizal infection were shown to be independent of changes in the phosphorus, potassium and sodium contents of the plants.

Key words *Glomus etunicatum* · Flowering · VAM · Phosphorus · Potassium

Introduction

The mutual association between higher plants and vesicular-arbuscular mycorrhizal (VAM) fungi improves plant growth, particularly under unfavourable growth conditions (Peuss 1958; Sieverding 1981; Dehne 1987). Under low-fertility conditions, the mycorrhizal effect is primarily based on improved uptake of nutrients, especially phosphate (Mosse 1957; Abbott and Robson 1984). Growth responses even with high nutrient availability indicate further, nonnutritional, physiological mechanisms (Peuss 1958; Baltruschat 1987; Pedersen et al. 1991). For commercial crops, one of the most effective VAM is *Glomus etunicatum*; however, its effect on flowering plants has rarely been tested.

The purpose of the present work was to study the effect of a VAM fungus (*G. etunicatum*) on the number of flowers per plant, the growth parameters and the phosphorus, potassium and sodium contents of shoots and roots of *Tagetes erecta* and *Zinnia elegans*.

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Materials and methods

Seed germination and transplanting were carried out in the Faculty of Agriculture (Saba-Bacha), Alexandria University, during the 1990 and 1991 growing seasons.

The VAM fungus *G. etunicatum* was isolated at the Experimental Station of Alexandria University. Seeds of *Tagetes erecta* and *Zinnia elegans* were germinated in 25-cm-diameter pots and then transplanted after 2 weeks into plastic pots, 10 cm in diameter, with one seedling per pot. Each treatment included at least 25 plants. Plants were irrigated as required and fertilized with a complete nutrient solution (Wuxal Normal, Schering; N:P:K, 12:4:6). Inoculation with VAM was carried out according to Aboul-Nasr (1987); noninoculated controls were also set up.

In the 1990 growing season, the number of flowers per plant and shoot and root fresh weights were determined at the end of the experiment (63 days). In the 1991 growing season, plant heights were measured when plants were 21, 31, 41 and 51 days old. The number of flowers and the shoot and root dry weights were also measured (when plants were 70 days old). VAM colonization of inoculated and noninoculated plants was determined (Phillips and Hayman 1970). Four samples per treatment from leaves and roots were analysed for phosphorus, potassium and sodium content (Jackson 1973; Chapman and Pratt 1978).

The experiments were carried out with a completely randomized design; statistical analysis was according to Mudra (1958).

Results and discussion

The effects of VAM on *Tagetes* and *Zinnia* during the 1990 and 1991 growing seasons

Table 1 shows the effect of *G. etunicatum* on growth parameters of *T. erecta* and *Z. elegans*. The percentage infected root length increased to 46.67% in the VAM-inoculated plants. VAM had significant positive effects on the number of flowers per plant and on shoot and root fresh weights. The noninoculated plants had no flowers. Similar results were obtained for *Z. elegans*. The results are in agreement with those obtained by Kough and Gianinazzi-Pearson (1986) and by Read (1986).

Table 1 Effect of *Glomus etunicatum* on growth parameters of *Tagetes erecta* and *Zinnia elegans* during the 1990 and 1991 growing seasons. The values are the means of 25 plants. The plants were 63 days old in 1990 and 70 days old in 1991 (*AM* Mycorrhizal, *NM* nonmycorrhizal, *ns* not significant)

Plant		1990			1991		
		NM	AM	LSD 0.95	NM	AM	LSD 0.95
T. erecta							
Flowers		0	3.00	0.43	6.60	8.50	ns
Shoot	Fresh wt./plant	0.94	3.94	0.88	—	—	—
	Dry wt./plant	—	—	—	5.63	6.25	ns
Root	Fresh wt./plant	0.35	1.41	0.39	—	—	—
	Dry wt./plant	—	—	—	0.18	0.23	ns
% Infection		0	46.67		0	52.00	
Z. elegans							
Flowers		0	1.20	0.47	0.76	1.24	0.4
Shoot	Fresh wt./plant	1.98	7.53	2.81	—	—	—
	Dry wt./plant	—	—	—	2.12	4.21	1.4
Root	Fresh wt./plant	0.17	1.96	0.57	—	—	—
	Dry wt./plant	—	—	—	0.12	0.14	ns
% Infection		0	58.33		0	55.00	

The effects of VAM on *Tagetes* and *Zinnia* during the 1991 growing season

Figures 1 and 2 show the effects of VAM on the heights of *Tagetes* and *Zinnia* shoots. VAM significantly increased shoot height compared with the noninoculated plants; this effect was quite clearly seen during the early stages of plant development.

Table 1 also shows the effect of *G. etunicatum* on the percentage infected root length and on shoot and root dry weights of *T. erecta* during the 1991 growing season. At the end of the experiment the infected root length was 52%; however, there was no significant difference between the treatments in the case of shoot and root dry weights.

During the 1991 growing season, the infected root length of *Z. elegans* increased to 55%, and shoot dry weight of the inoculated *Zinnia* was significantly higher than that of the noninoculated plants.

Figures 3 and 4 show the effect of VAM on the number of flowers in *Tagetes* and *Zinnia* during the 1991 growing season. The inoculated plants produced more flowers faster than the noninoculated plants.

The effect of VAM on the total number of flowers in the case of *Tagetes* was not statistically significant, but an increase was recorded in the case of *Zinnia*.

Table 2 shows the effect of *G. etunicatum* on the phosphorus, potassium and sodium contents of *Tagetes* and *Zinnia* during the 1991 growing season. At the end of the experiment there were no significant effects of VAM on the shoots. Root analysis showed that inoculated *Tagetes* had a decrease in phosphorus of 40%. Inoculated *Zinnia* showed a decrease in phosphorus, potassium and sodium root contents compared with the noninoculated plants. Similar results were recorded by Edriss et al. (1984), who also found higher shoot dry weights and increased cytokinin contents in leaves of VAM *Citrus* but no changes in phosphorus content. Therefore, it seemed that enhancement of cytokinin production in VAM *Citrus* was associated with infection rather than with increased phosphorus uptake.

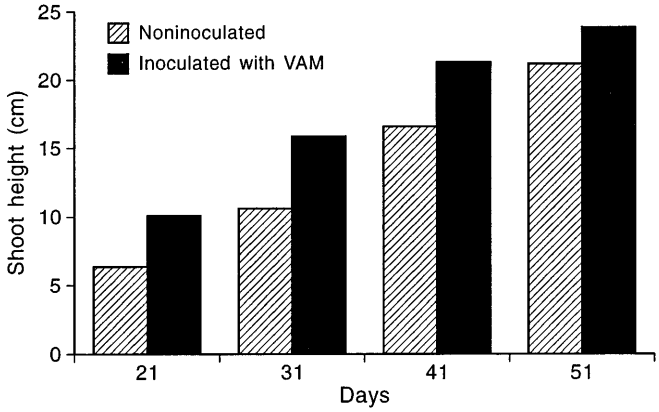

Fig. 1 Effect of VAM on *Tagetes* shoot height during the 1991 growing season

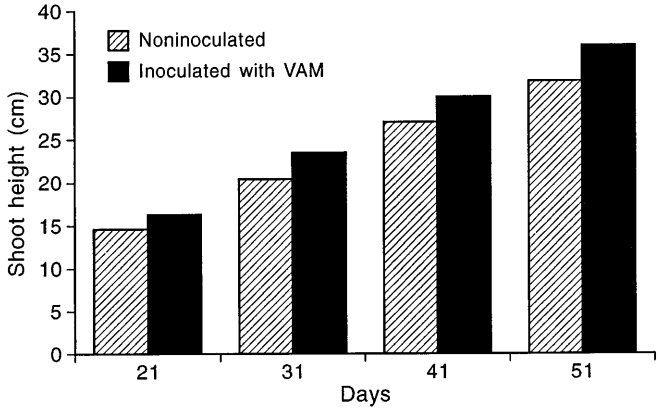

Fig. 2 Effect of VAM on *Zinnia* shoot height during the 1991 growing season

Ratnayake et al. (1978) suggested that the quantity of root exudation was the most important factor controlling VAM formation and not the level of root phosphorus. Dissing-Nielsen (1989) studied the effect of VAM on growth and uptake of nutrients in lucerne and found

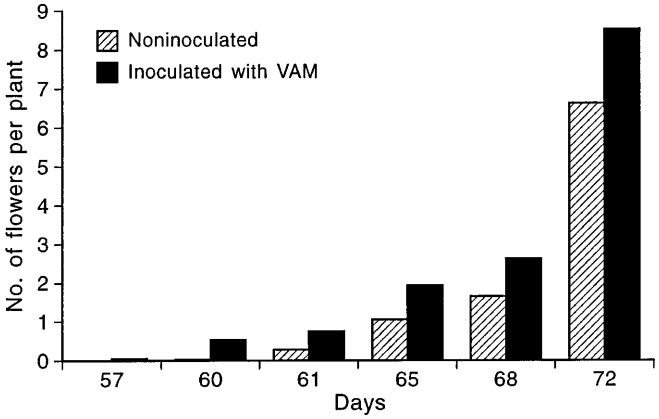

Fig. 3 Effect of VAM on the number of flowers on *Tagetes* plants during the 1991 growing season

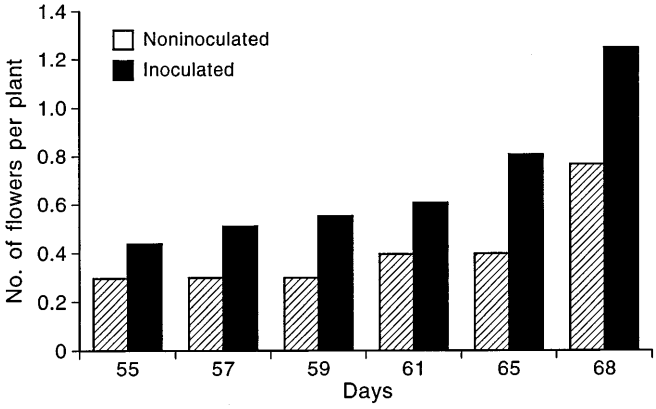

Fig. 4 Effect of VAM on the number of flowers on *Zinnia* plants during the 1991 growing season

Table 2 Effect of *G. etunicatum* on the phosphorus, potassium and sodium contents of *T. erecta* and *Z. elegans* during the 1991 growing season. The values are the means of 4 samples. Abbreviations as in Table 1

Plant	Shoot			Root		
	NM	AM	LSD 0.95	NM	AM	LSD 0.95
T. erecta						
P (mg/g dry wt.)	4.37	4.98	ns	3.20	1.93	0.64
K (%)	1.96	1.98	ns	0.54	0.70	ns
Na (%)	0.69	0.66	ns	0.88	0.76	ns
Z. elegans						
P (mg/g dry wt.)	3.86	3.66	ns	3.66	2.71	0.46
K (%)	0.85	0.91	ns	1.00	0.33	0.60
Na (%)	0.25	0.24	ns	1.03	0.43	0.39

that potassium concentration decreased with increasing P fertilizer and was not influenced by VAM treatment.

Over the last few years, there has been an increasing number of reports that root colonization with VAM fungi enhances transpiration rates or stomatal conductances and improves photosynthesis independent of the phosphorus status of the host plant (Levy et al. 1983; Johnson 1984; Auge et al. 1986; Brown and Bethlenfalvay 1987; Auge 1989; Sanchez-Diaz et al. 1990). Druge and Schönbeck (1992) investigated the growth response of flax (*Linum usitatissimum* L.) to VAM infection and found that stomatal gas exchange and zeatin riboside levels were not related to increases in the nitrogen, phosphorus or potassium contents of the plant. Allen et al. (1982) and Allen (1984) reported that mycorrhizal blue grama grass had higher cytokinin contents in roots and leaves as well as altered levels of gibberellin-like substances and abscisic acid compared with controls.

There is good reason to believe that at least some of the mycorrhizal effects on physiological processes have a nonnutritional basis. The results of the current study provides definite evidence that VAM fungi produce positive effects on both *Tagetes* and *Zinnia*, especially faster flowering and an increased number of flowers. The reaction of these plants to mycorrhizal infection was shown to be independent of increased phosphorus or potassium contents of the plants.

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