Mycoscience 35: 213–217, 1994

The effect of Mg on Ca, K and P content of date palm seedlings under mycorrhizal and non-mycorrhizal conditions

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Accepted for publication 14 April 1994

The effects of the presence or absence of Mg in the nutrient solution and of vesicular-arbuscular mycorrhizal fungi (VAMF) on the content and partitioning of Ca, K and P between root and shoot of date palm (*Phoenix dactylifera*) seedlings were examined under greenhouse conditions using soil as basal medium. Mg content of the soil was 14.95 μmol/g dry soil. The infection percentages after inoculation of VAMF were 66.0% and 55.5%, respectively, on application of −Mg and +Mg nutrient solution. Ca content of both roots and shoots did not change by these treatments; but a highly significant decrease in shoots was recorded on −Mg and +VAMF treatment. K content of root was significantly elevated by −Mg and +VAMF treatment but no changes were observed in shoots. P content of both roots and shoots increased significantly with +VAMF regardless of the presence or absence of Mg.

Key Words——Ca; date palm; K; Mg; P; VA mycorrhiza.

Introduction

The vesicular-arbuscular mycorrhizal fungi (VAMF) establish symbiotic associations with living roots of many higher plants. In nature, more than 80% of plant species have VAMF associations (Smith and Gianinazzi-Pearson, 1988). The benefit of mycorrhizae to plants is increased P absorption (Gerdemann, 1964; Mosse, 1973; Krishna and Bagyaraj, 1981). Absorption of other ions that normally diffuse slowly towards roots, such as NH_4^+, K^+ and NO_3^-, could also be enhanced by mycorrhizae. Raju et al. (1990) reported that VAMF association with sorghum roots enhanced mineral nutrient uptake when P level was sufficiently low in the soil.

Date palm has been and is still an important crop plant in Saudi Arabia. Since date palm grows mainly in desert oases that are characterized by harsh and unfavorable growing conditions, such as low organic matter and deficiency in some other nutrients coupled with a high rate of evaporation, mycorrhizal association could be helpful for the plant survival. Indeed, Khaliel and Abou-Hailah (1985) have found VAMF associated with the roots of date palm tree in the Qassim region of Saudi Arabia. No other studies seem to have been carried out on date palm and VAMF association. On the other hand, Forster and Mengel (1969) have reported that omitting K^+ from the nutrient solution resulted in a considerable increase in Ca, Mg and Na content of young barley plants. Therefore, this study was conducted to throw light on the effect of Mg and mycorrhiza on Ca, K and P contents and their partitioning between shoot and root systems of date palm seedlings.

Materials and Methods

Date palm (*Phoenix dactylifera* L. cv. Khedhri) seeds (1991 season) were washed thoroughly, surface-sterilized with 1% sodium hypochlorite and then rinsed with distilled water. Seeds were soaked in water for 2 days and then put in pots containing perlite. After germination and when the first leaf was about 1 cm long, seedlings were carefully transplanted into a sterilized mixture of sandy soil and perlite (1 : 1 v/v). Seedlings were divided into two groups: One group was inoculated with VAMF and the other was not.

The VAMF *Glomus deserticola* Trappe, Bloss & Menge maintained on Sudan grass (*Sorghum vulgare* Pers.) for one month was used as a source of inoculation. In the first group, 5 g of soil containing spores and VAMF-infected roots were inoculated into each pot, while in the second group, which constituted the uninoculated pots, 5 g of sterilized inoculum was added to each pot.

Each group was divided further into two sets, with five replicates each. A nutrient solution was composed as follows (mM): KCl, 1.0; $Ca(NO_3)_2$. $4H_2O$, 1.0; $MgSO_4$. $7H_2O$, 0.25; NaH_2PO_4. H_2O, 0.904; and Na_2HPO_4, 0.048. The pH was adjusted to 5.5–5.8. This nutrient solution was denoted as 1X nutrient solution (Etherton, 1963). One set was treated with 1X nutrient solution without Mg (−Mg in 1X), where K_2SO_4 was substituted for $MgSO_4$, while the other set was treated with full 1X nutrient solution (+Mg in 1X).

Phosphorous content of the original soil was 38.9 μmol/g dry soil. The level of P in 1X solution for all treatments was 1.0 mM. Mg content of the original soil

was 14.95 μmol/g dry soil. Pots were placed in a greenhouse (temperature 30°C, 12 h photoperiod, and light intensity maximum of 293 μE S^{-1} m^{-2}). However, the greenhouse conditions were not precisely fixed during the experiment, and some fluctuations in temperature occurred. Treatment lasted for six months.

Seedlings were carefully harvested to uncover the youngest roots. A composite of about 1 g of these roots was collected from the seedlings, washed with tap water and preserved in a plastic vial containing formalin, acetic acid and alcohol fixative solution (FAA). The FAA-fixed roots were cut into 1-cm segments, washed with tap water, cleared in 10% KOH and stained in trypan blue with lactophenol by the method of Phillips and Hayman (1970). Twenty-five segments of fine roots were mounted in clear lactophenol and scanned microscopically for VAMF infections.

Roots and shoots of the seedlings were separated, dried and acid-digested for Ca, K and P determinations. Ca was determined by absorption flame spectrophotometry, and K by flame emission (Pye Unicam Sp9 equipped with Sp9 computer). P was determined colorimetrically by the method of Watanabe and Olsen (1965). For statistical analysis of the data, one-way analysis of variance and Duncan's New Multiple Range Test were used according to the procedure described by Steel and Torrie (1960).

Results

After six months of treatment, the infection percentage of date palm seedlings by VAMF in +Mg in 1X was 55.5±6.01%, whereas that in −Mg in 1X was 66.0±2.00%. Obvious morphological differences between treatments, such as Mg deficiency symptoms, were not noticed at the end of the treatment. Table 1 presents the correlation coefficients between the fungus infection percentages for both Mg-treated seedlings and Mg-free-treated seedlings, and the Ca, P, and K content in roots and shoots of the seedlings.

There was no significant difference in Ca contents in the roots due to the presence or absence of either Mg or VAMF (Fig. 1). However, Ca content of shoots was significantly lower (0.01 level) in the absence of Mg, although VAMF was associated with roots (Fig. 1).

In contrast to the Ca status of seedlings, the K content of shoots did not change (0.01 level) but that in the roots varied according to treatment (Fig. 2). In −Mg

Table 1. Correlation coefficients between VAMF infection and the presence or absence of Mg in 1X nutrient solution and the Ca, P and K content of date palm seedlings. (% infection is shown as mean±SD.)

Treatment	Plant part	Correlation Coeffient with			% infection
		Ca	P	K	
−Mg in	root	−0.22	0.96	0.05	66.0±2.00
1X solution	shoot	0.93	−0.86	−0.91	66.0±2.00
+Mg in	Root	0.33	0.73	0.89	55.5±6.01
1X solution	shoot	−0.93	−1.00	−0.24	55.5±6.01

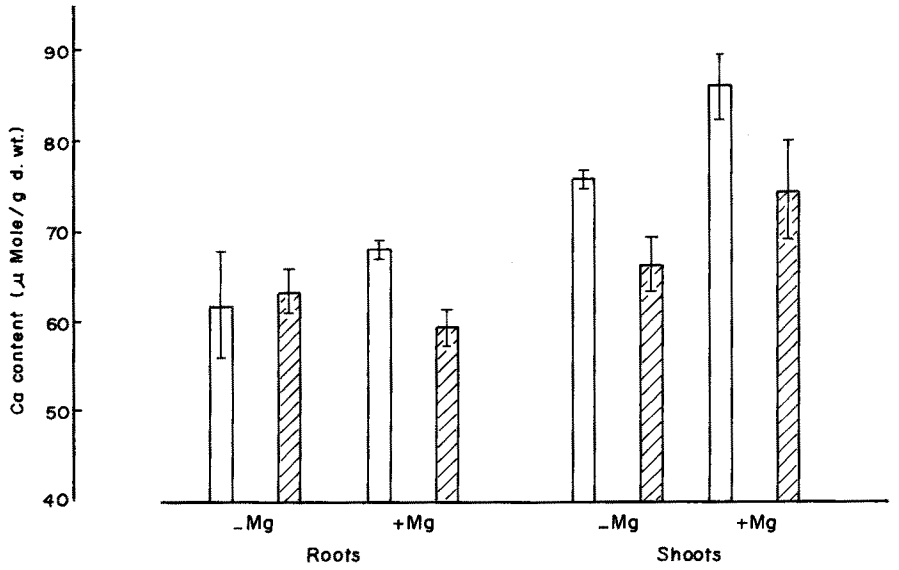

Fig. 1. Calcium content of roots and shoots of date palm seedlings after six months of treatment with −Mg in 1X or +Mg in 1X solution in the absence (open bars) or presence (hatched bars) of VAM. Vertical lines represent the standard deviation.

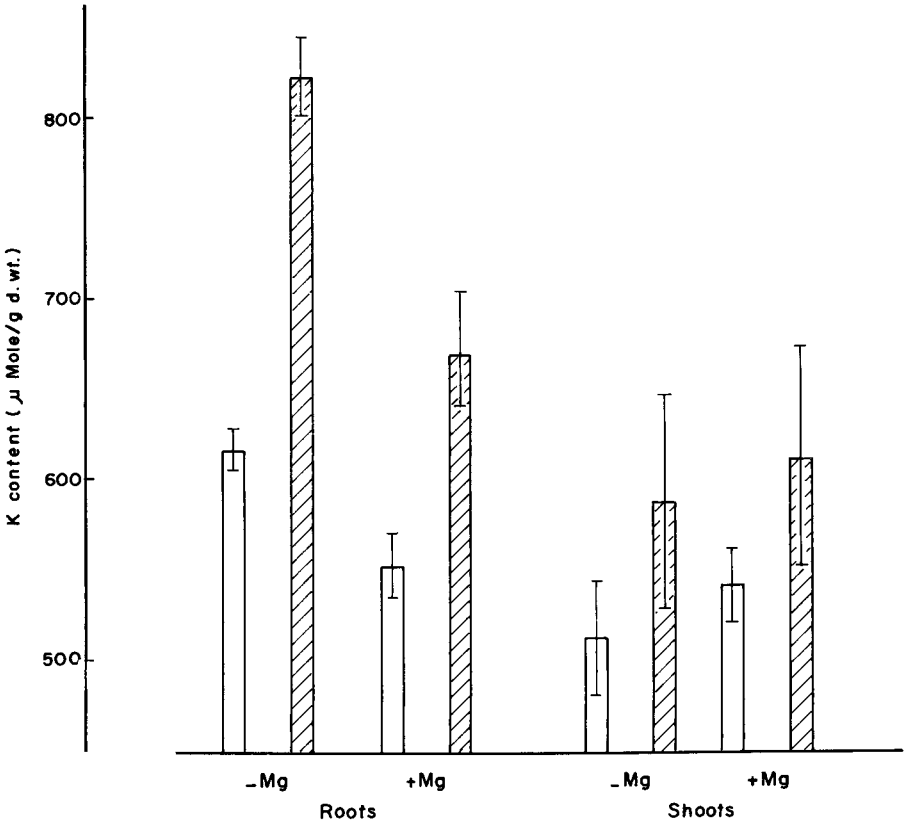

Fig. 2. Potassium content of roots and shoots of date palm seedlings after six months of treatment with −Mg in 1X or +Mg in 1X solution in the absence (open bars) or presence (hatched bars) of VAMF. Vertical lines represent the standard deviation.

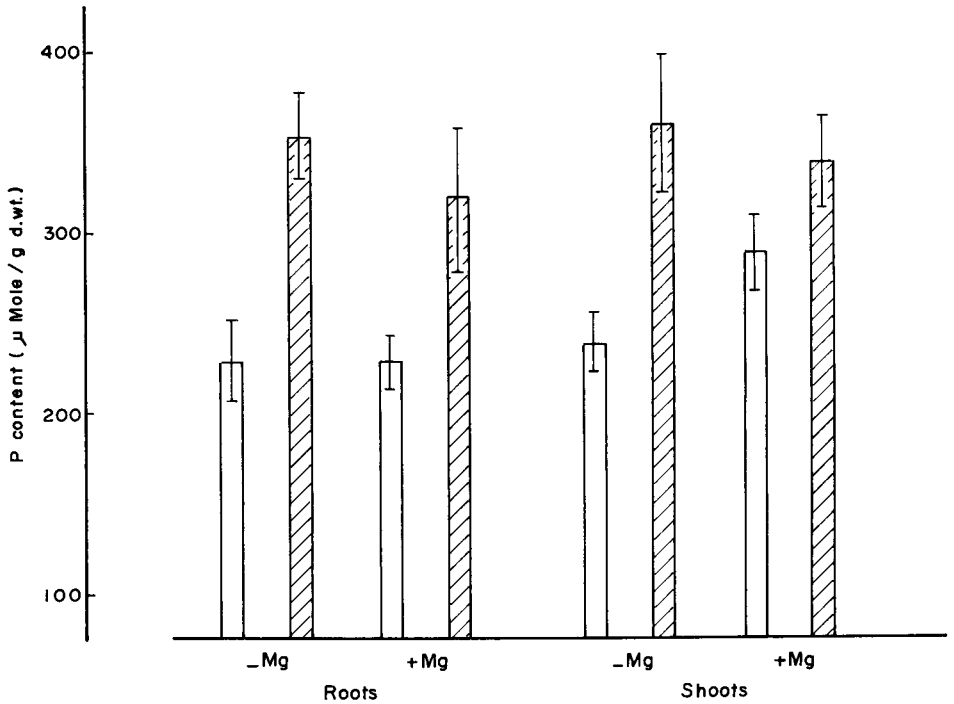

Fig. 3. Phosphorus content of roots and shoots of date palm seedlings after six months of treatment with −Mg in 1X or +Mg in 1X solution in the absence (open bars) or presence (hatched bars) of VAMF. Vertical lines represent the standard deviation.

Table 2. One-way analysis of variance for date palm seedlings content of Ca, P and K as affected by the presence or absence of Mg and VAMF.

Source of variation	Root				Shoot			
	SS	df	MS	F	SS	df	MS	F
a) Ca								
Treatments	24.54	3	8.18	0.14	688.81	3	229.60	3.61**
Error	459.54	8	57.46	0.14	572.52	9	63.61	
Total	484.20	11			1261.32	12		
b) P								
Treatments	43476.18	3	14492.06	18.32**	31211.07	3	10403.69	17.18**
Error	803.68	11	791.24		6661.00	11	605.63	
Total	52179.85	14			37873.00	14		
c) K								
Treatments	118085.50	3	39361.63	67.02**	17509.80	3	5836.60	2.18
Error	4698.31	8	587.29		21396.72	8	2674.59	
Total	122783.81	11			38906.52	11		

** Significant at 0.01 level.

treatment, the presence of VAMF resulted in a highly significant increase of K content (Fig. 2); in +Mg treatment, the presence of VAMF also caused a highly significant increase of K content. The level of K in this treatment was approximately equal to that of −Mg and −VAMF treatment. The lowest K content of roots occured by +Mg and −VAMF treatment (Fig. 2).

Phosphorus content of both roots and shoots increased significantly in VAMF-infected seedlings regardless of the presence or absence of Mg (Fig. 3).

Discussion

Plants must maintain a balance of ions inside their cells. When some ion is not sufficiently available, they absorb more of other available ions to compensate —to some extent— for the function, of the dificient ion especially by balancing the charges. Scharrer and Jung (1955), as a classical example, reported that the total sum of cations in sunflower changed little despite variations in the level of the individual cations in the nutrient media. Forster and Mengel (1969), using young barley plants, have shown that withholding K from the nutrient solution for 8 days resulted in a considerable increase in Ca, Mg and Na content but did not significantly affect the total content of the four cations.

This is probably the case in the present study, and the situation could be a replacement effect rather than competition between ions (Mengel and Kirkby, 1982). In this study, the decrease of Ca content in shoots of VAMF-infected seedlings in the presence or absence of Mg (Fig. 1) is probably related to an increase in the absorption of other ions due to VAMF association (cf. Figs. 2 and 3 showing increased content of both K and P). These results are in agreement with other studies (Harley and Smith, 1983; Saif, 1987; Raju et al., 1990).

This study also indicates that VAMF enhanced the absorption of both K and P (Figs. 2, 3). This is in agreement with the published evidence of increased P absorption in other plants by VAM association (Mosse, 1973; Krishna and Bagyaraj, 1981). Our data for K also support the findings of Raju et al. (1990), who reported that VAMF increased the content of P, K, Zn and Cu in sorghum shoot. However, no data on the content of these ions in root were mentioned in their study. Our data show that the K content of roots also increased. The significant increase in K content of VAMF-uninfected seedling roots by −Mg treatment could be explained as a replacement effect, as was suggested above for the Ca increase in barley plants.

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