

# Influence of vesicular-arbuscular mycorrhizae on biomass production by the cactus *Pachycereus pecten-aboriginum*

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**Abstract.** This study reports the effect of vesicular-arbuscular mycorrhizal (VAM) fungi on dry matter production by *Pachycereus pecten-aboriginum* (Engelm.) Britt & Rose, an arborescent cactus of arid and tropical dry forest in Mexico. Seedlings in the presence or absence of VAM fungi were grown in soil between two plates of glass (20 × 30 cm) for 8 months inside growth chambers (30/25° C, 13/11 h day/night and a light intensity of 400  $\mu\text{mol m}^{-2} \text{s}^{-1}$ ). VAM seedlings had significantly ( $P < 0.01$ ) higher dry matter production (0.418 versus 0.169 g), root/shoot ratios (0.26 versus 0.14) and specific root length (0.65 versus 1.41  $\text{mm mg}^{-1}$ ) than non-VAM seedlings, suggesting a more efficient exploitation of soil resources by the VAM cacti. The data point to a role for VAM fungi in the establishment, growth, water relations and nutrition of cacti in the arid tropics.

**Key words:** Biomass production – Cacti – Mycorrhiza – *Pachycereus pecten-aboriginum* – Tropical dry forest

## Introduction

The widespread occurrence of mycorrhizae and their beneficial influence on plant growth of different genera, in particular temperate species, has been well documented (Harley and Smith 1983; Allen 1991). However, the study of mycorrhizal plants from arid and tropical ecosystems has received considerably less attention (Janos 1980; Mikola 1980; Diem et al. 1981; Rose 1981; Bethlenfalvay et al. 1984; Allen and Allen 1986). This is the case for cacti, and in particular cacti occurring in tropical deciduous forest. This lack of information is surprising in view of the fact that 40% of all forests in tropical and subtropical regions are dry or deciduous forests and experience a seasonal drought (Murphy and Lugo 1986). In addition, little is known about the role

of mycorrhizae in cactus seedling establishment in the North American tropical deciduous forest.

In the highly diverse tropical deciduous forest of the Pacific coast of Mexico, cacti comprise 15 species (Lott 1985), including arborescent species such as *Opuntia excelsa*, whose relative contribution to the total, living, above-ground phytomass of the forest of 3.3% (Martinez-Yrizar et al. 1992) indicates the importance of cacti in this forest. However, lack of information about almost all aspects of the ecology of cacti in tropical deciduous forest makes it difficult to assess in detail their importance in communities subject to seasonal drought.

The objective of the present investigation was to determine the influence of vesicular-arbuscular mycorrhizal (VAM) fungi on biomass production in seedlings of *Pachycereus pecten-aboriginum*. This arborescent columnar cactus of the tribe Pachycereeae (Gibson and Horak 1978; Nobel 1988) ranges in habitat from the deserts of southwestern USA and northwestern Mexico south into the tropical deciduous forests of western Mexico.

## Material and methods

Mature seeds of *P. pecten-aboriginum* (Engelm.) Britt. & Rose (Cactaceae) were collected at the Tropical Dry Forest Biological Station of Chamela (19° 30'N, 105° 03'W) in the state of Jalisco on the Pacific coast of Mexico. After scarification with sulphuric acid, the seeds were germinated on sterilized, humid, pure silica sand inside a germination chamber at 35/25° C day/night. Ten days after germination, the seedlings were transplanted to a system of two sheets (3 mm) of glass (20 × 30 cm) 1 cm apart filled with soil from deciduous forest (Friese and Allen 1991). The soil was collected from the top 10 cm of the profile around the base of five mature individuals of *P. pecten-aboriginum*. The soil was sieved (4 mm) and sterilized. The soil collected was characterized as a sandy loam (64% sand, 13% loam, 23% clay) with pH 6.5–7.1 and an organic matter content of 3–5%.

Spores for inoculation were isolated from 4-month-old soil pot cultures from tropical deciduous forest (Ianson and Allen 1986). *Acaulospora* spp. and *Glomus* spp. spores were among those observed in the pot cultures.

The 10-day-old seedlings were placed randomly inside growth chambers (Conviron E-15, Winnipeg, Canada). Growth condi-

tions were set to 30/25°C day/night a 13-h photoperiod. Light at an intensity of 400  $\mu\text{mol m}^{-2} \text{s}^{-1}$  was provided by fluorescent and tungsten lamps. The seedlings were watered daily with distilled water. The design of the experiment comprised 10 replicates inoculated with 2000 spores and 10 replicates without spore addition. However, 20 ml of spore washings derived from the pot cultures, following the procedure described by Koide and Mingguang (1989), were added to both treatments in order to incorporate nonmycorrhizal and rhizosphere soil microorganisms into the sterile soil.

The plants were harvested after 8 months. Three replicates for each treatment were randomly selected and the roots stained to determine the presence of infection. For the remaining seven replicates, shoots and roots were separated and the root systems were carefully removed from the soil and washed in distilled water. Root length was measured in a Delta-T image analysis system. After performing the root measurements, roots and shoots were dried at 80°C for 48 h and weighed. In mean dry weights for root and shoot and the root/shoot dry weight ratios were calculated. Total root length and the ratio of total root length to total weight (specific root length, SRL) were also determined. The significance of differences between the treatments for each measured parameter were tested by analysis of variance, using log-transformed data where necessary to meet assumptions of normality.

## Results and discussion

Staining of the roots revealed the presence of vesicles, arbuscules and a dense net of hyphae only around VAM roots. No attempt was made to determine percentage of root length infected, as this measurement has little meaning if the efficiency of a particular fungus species is not established.

The dry weights of both roots and shoots of *P. pecten-aboriginum* were significantly ( $P < 0.01$ ) greater in plants receiving VAM fungi inoculation. This was also true for root/shoot ratios (Fig. 1) and total root lengths (Fig. 2). However, specific root length was significantly greater in the treatment without mycorrhiza inoculation (Fig. 2).

The total root lengths of the mycorrhizal cacti were significantly greater than those of the noninoculated individuals. Total root length is important in the acquisition of water and mineral nutrients, and it seems that one of the effects of VAM fungi on the cacti was to increase the potential for soil resource exploitation by favouring a greater biomass allocation to roots. In the noninoculated individuals, the amount of root length per unit root biomass (SRL) was significantly greater, indicating that the non-VAM cacti invested less biomass per unit root length. In this case, it appears that the mycorrhizae increase in general the vigour of the cactus, favouring water and nutrient uptake.

More results are needed to assess the influence of VAM fungi on the growth and physiological attributes of crassulac acid-metabolising plants, in particular the influence of VAM on the efficiency of water and nutrient use in seasonally variable systems. This would also open the way to investigations of VAM associations in seedlings from the North American tropical deciduous forest and the possible role of nondeciduous, drought-tolerant cacti in maintaining the fungal mycelium (Read 1984) in the forest during the severe dry period.

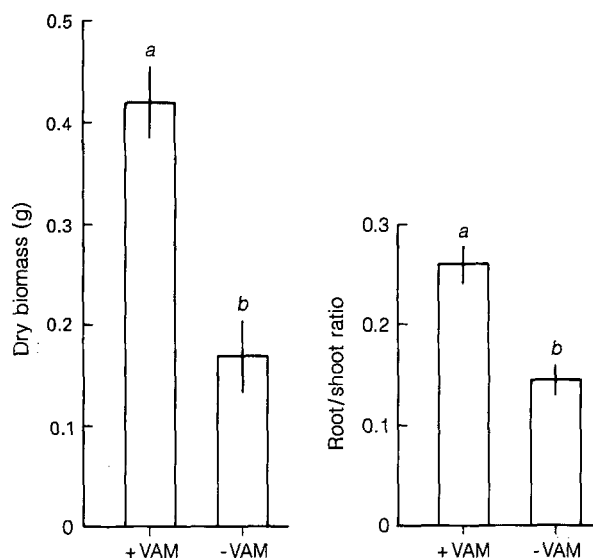


Fig. 1. Mean total dry weights and root/shoot ratios of the cactus *Pachycereus pecten-aboriginum* with or without vesicular-arbuscular mycorrhizal (VAM) fungi. Vertical bars indicate standard deviations. Different letters indicate a significant difference between treatment means at the  $P < 0.01$  level.

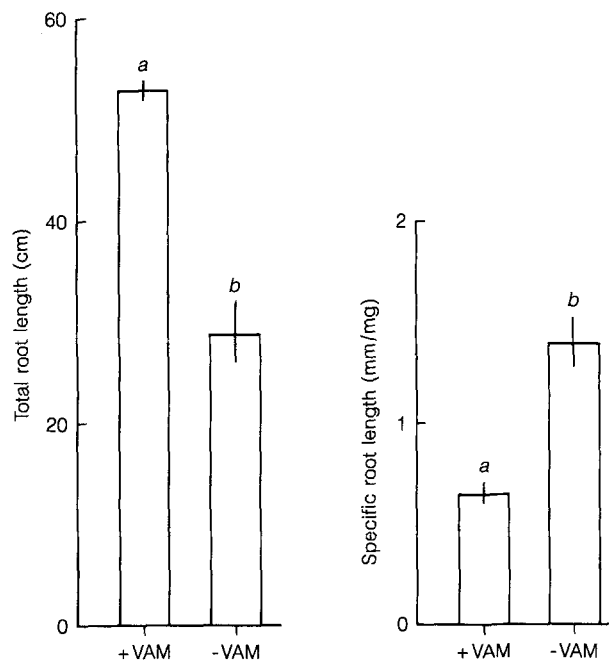


Fig. 2. Total root lengths and specific root lengths of the arborescent cactus *P. pecten-aboriginum* with or without VAM fungi. Vertical bars indicate standard deviations. Different letters indicate a significant difference between treatment means at the  $P < 0.01$  level.

Research in species establishment and regeneration of cacti in tropical dry forest is very scarce. However, it may be assumed under this climatic regime that seedling establishment occurs during the wet season, when water and nutrients are not drastically limited. In this sense, it is reasonable to suppose that mycorrhizae may affect es-

establishment success. In addition, light and soil resources, in particular water, nutrient availability and mycorrhizae, may affect establishment success. It is also important to consider the role of mycorrhizae and so-called nurse plants in the establishment of cacti in tropical deciduous forest, where precipitation, diversity and density of species are higher than in arid environments.

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