

Genotypic variation in vesicular-arbuscular mycorrhizal dependence of the pejibaye palm

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ABSTRACT: Two experiments were undertaken to determine the degree of mycorrhizal dependency of pejibaye (*Bactris gasipaes*, Palmae) seedling progenies from two Amazonian (Pampa Hermosa; Putumayo) and one Central American (Guatuso) land races. Plants were grown in subsurface samples of either an Oxisol (the Amazonian progenies) or an Ultisol, with or without inoculation with the vesicular-arbuscular mycorrhizae fungus (VAMF) *Glomus aggregatum*, at three concentrations of soil solution phosphorous (P). VAMF inoculation enhanced leaf P concentration and dry matter accumulation at the intermediate soil P concentration in all progenies. Dry matter accumulation was enhanced by 17%, 54% and 64% in the Pampa Hermosa, Putumayo, and Guatuso progenies, respectively. They are therefore classified as being marginally (Pampa Hermosa) or highly dependent. This infra-specific genetic variation with respect to mycorrhizal dependency merits further study for possible exploitation in plant improvement for sustainable agriculture.

INTRODUCTION

The pejibaye or peach palm (*Bactris gasipaes* Kunth, Palmae) is the only domesticated Neotropical palm and it may have originated in Amazonia (3). It has recently attracted considerable research and commercial attention, both for its fruit and its heart of palm (5,6). Pejibaye is thought to be well adapted to the low nutrient availabilities of the acid Oxisols and Ultisols that predominate in the Neotropics (3). It forms vesicular-arbuscular mycorrhizal (VAM) symbioses which may explain its high yield potential in these soils (13). Several *Glomus* species occur in the rhizosphere of pejibaye in Amazonian Peru (17). Palms have very coarse roots and few or no root hairs, suggesting that they rely on VAM fungi for phosphorous (P) absorption (18). Response of pejibaye seedlings to P availability has recently been examined (4) but the degree to which the VAM symbiosis mediates this response is not yet clear.

Infra-specific genetic variation affects VAM colonization in coconut (*Cocos nucifera* L.) (19), with the more primitive tall varieties showing higher levels of colonization than the more derived dwarf varieties. One possible interpretation of these findings is that, in domesticated species, more primitive varieties depend more on mycorrhizae than do more derived varieties. Habte and Manjunath (11) point out, however, that degree of colonization is not necessarily correlated with mycorrhizal dependency, as defined by them (10). VAM fungi differentially enhance growth of African oil palm (*Elaeis guineensis* Jacq.) clones and reduce the inherent differences in P absorption efficiency observed among them (2). One interpretation of these findings is that even among highly derived breeding lines, with significant genetic similarities, there are still clear differences in mycorrhizal effectiveness. Because pejibaye is a domesticate, with extensive infra-specific variation (3), differences in VAM dependency may exist among pejibaye populations also.

The aim of the current investigation was to determine the extent to which pejibaye is dependent on VAM fungi for seedling growth and P uptake and the extent to which there is infra-specific genetic variation for mycorrhizal dependency. This seedling stage of growth is extremely

important for early yields, as a vigorous seedling will recover more quickly from transplant shock and develop more rapidly thereafter. The existence of genetic variation for mycorrhizal dependency will allow its exploitation in plant improvement for sustainable agriculture also.

MATERIAL AND METHODS

Germplasm: In Experiment 1, progenies B13 (INPA 3.8.16) and Y1 (INPA Yu-29) were used, while in Experiment 2, progeny C4 (ANAI C4M) was used. All were open-pollinated (half-sib) progenies obtained either from the National Research Institute for Amazonia - INPA, Manaus, AM, Brazil, in February 1992, or from the Asociación ANAI, Sabanilla de Montes de Oca, Costa Rica, in October 1993. The B germplasm originated from the Benjamin Constant, Amazonas, Brazil, population of the Putumayo 'macrocarpa' land race, considered one of the two most derived pejibaye land races (16). The Y germplasm originated from the Yurimaguas, Loreto, Peru, population of the Pampa Hermosa 'mesocarpa' land race, considered an intermediate land race (16). The C germplasm originated from the San Carlos, Alajuela, Costa Rica, population of the Guatuso 'mesocarpa' land race, also considered an intermediate land race (15).

The seeds were treated with the fungicide Captan® before germination. The Amazonian germplasm was germinated in plastic bags, without substrate, in the dark, with 30°C bottom heat. The seedlings were greened in plastic bags in the laboratory and held with sufficient moisture until use. This germination and greening sequence guaranteed that the seedlings were free of mycorrhizal fungi and received no additional phosphorous until the beginning of the study. The Central American germplasm was germinated in steam-sterilized, fine volcanic cinder substrate in the University of Hawaii's Magoon nursery facility's screen house, with two daily sprinkler irrigations.

Soil: In Experiment 1, the soil was a subsurface sample (15-25 cm) of a moderately weathered Oxisol (Rhodic Eutruxox, Wahiawa series, clayey, kaolinitic, isohyperthermic), obtained from the Poamoho Experimental Farm, University of Hawaii, Oahu, HI. This soil had a pH (H₂O) of 5.4, adjusted to 5.9 by the addition of dolomite. After fumigation with methyl bromide, the soil was removed from the pot, fluffed, re-potted and left for 10 days to allow the fumigant to dissipate.

In Experiment 2, the soil was a subsurface sample (10-25 cm) of a moderately weathered Ultisol (Typic Kandihumult, Leilehua series, clayey, oxidic, isothermic), obtained from the Waiawa Correctional Facility, Oahu, HI. This soil had a pH (H₂O) of 4.5, adjusted to 5.3 by the addition of dolomite. After fumigation with Methyl Bromide, the soil was removed from the pot, fluffed, re-potted and left for 3 months to allow the fumigant to dissipate.

Phosphorous: In Experiment 1, the soil was either unamended or amended with KH₂PO₄ to establish three target soil solution P concentrations (0.008 (the native soil level), 0.02 and 0.2 mg/L) by using a P sorption isotherm (7). The P was added in 300 mL H₂O per pot 3 days before transplanting.

In Experiment 2, the soil was either unamended or amended with KH₂PO₄ to establish three target soil solution P concentrations (0.02 (the native soil level), 0.04 and 0.2 mg/L). The P was added in 300 mL H₂O per pot 4 days after transplanting.

Mycorrhizal Inoculation: One half of the pots were inoculated with a crude inoculum of *Glomus aggregatum*, the other half remained uninoculated. In Experiment 2, the uninoculated pots were treated with Benlate© (50 mg kg⁻¹) to eliminate possible contamination from the nursery.

Experimental Design: Experiment 1 was a factorial combination of 2 progenies by 3 soil P concentrations by 2 mycorrhizal inoculation levels. The design was completely randomized, with 4

replications per treatment and 1 pot per plot (n = 48). Analysis was done with Minitab 8.2's GLM routine (14).

Experiment 2 was a factorial combination of 1 progeny by 3 soil P concentrations by 2 mycorrhizal inoculation levels. The design was completely randomized, with 3 replications per treatment and 1 pot per plot (n = 18). Analysis as above.

Transplanting: Experiment 1 was installed on 3 December 1992 in the glasshouses at the University of Hawaii, Mauka campus. The plants were hand-watered as appropriate to maintain approximately maximum water-holding capacity.

Experiment 2 was installed on 27 May 1994 in the glasshouses at Mauka campus, then transferred to the Magoon nursery facility screenhouse on 11 August 1994 because of excessive heat in the glass house. The plants were watered as above.

Blanket Nutrients: A blanket nutrient solution was applied on all plants at the beginning of the experiment and monthly thereafter. Each application consisted of 0.143 g NH_4NO_3 , 0.2965 g K_2SO_4 , 1.09 g $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 0.044 g $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, 0.0195 g $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, 0.007 g $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$, and 0.00125 g $\text{Na}_2\text{MoO}_4 \cdot 2\text{H}_2\text{O}$ kg^{-1} soil.

Leaf Tissue P Status: Leaf tissue P content was determined monthly in Experiment 1 and bimonthly in Experiment 2. A single disk (28.3 mm² in area) was taken from near the tip of the newest fully expanded leaf (1,4).

Biomass Evaluation: At the end of the experiment the plants were harvested, the roots were separated from the crown, all components were weighed, dried at 70°C for five days, and reweighed.

RESULTS AND DISCUSSION

VAM fungus effectiveness, measured in terms of P concentration of leaf disks, showed that the greatest mycorrhizal inoculation effect was observed when plants were grown at soil P concentrations of 0.02 and 0.04 mg L⁻¹ (Fig. 1). Phosphorus concentration in leaf disks of mycorrhizal and non-mycorrhizal plants did not differ significantly at the lowest and highest soil P concentrations tested. These observations are in good agreement with recent observations on various dicotyledonous species (8,9,12), although the concentration of soil P at which maximum effectiveness was observed in the Guatuso progeny is unusual. The lack of appreciable response at the highest soil P concentration reflects the fact that at this soil P concentration the unaided root was able to take up sufficient P to meet growth demands. The very limited mycorrhizal inoculation effect observed at the lowest soil P concentration, on the other hand, indicates that this level of P was sub-optimal for the expression of VAM effectiveness (11). The general tendency of leaf P content to decline with time could be explained by the translocation of P from leaves to other tissues as the plant developed.

Mycorrhizal inoculation effect observed in terms of leaf P status above closely paralleled that observed in terms of dry matter accumulation (Fig. 2), with the maximum difference in dry matter yield between mycorrhizal and non-mycorrhizal plants observed at the intermediate soil P concentration. Among the genotypes evaluated, the least responsive to mycorrhizal colonization was the Pampa Hermosa progeny, while the Putumayo and Guatuso progenies were substantially more responsive.

In the Pampa Hermosa progeny, mycorrhizal inoculation enhanced dry matter accumulation by 17% at soil P concentration of 0.02 mg L⁻¹, the critical level in this Oxisol (Fig. 3). The corresponding value for the Putumayo progeny was 54%. In the Guatuso progeny,

mycorrhizal inoculation stimulated growth to the extent of 64% at target soil P concentration of 0.04 mg L⁻¹, the critical level in this Ultisol. The difference between the soils with regard to the soil solution P concentration that is critical for mycorrhizal effectiveness may be due to the very slow initial development of the plants in the Ultisol, because of the high temperatures to which they were exposed initially (summer glasshouse temperatures approach 40°C in Honolulu). This relatively long period of slow growth may have allowed a shift in the concentration of soil P to which the plants were exposed by the time appreciable growth occurred. Alternatively, or in conjunction with the above, this long period may have magnified the inherent differences in the P buffering capacity of the soils, with the Ultisol being less buffered than the Oxisol.

According to the scheme proposed by Habte and Manjunath (10), the Pampa Hermosa progeny is classified as marginally dependent, while the Putumayo and Guatuso progenies are classified as highly dependent. Among these three pejibaye populations, the Putumayo is most derived, the Guatuso and Pampa Hermosa are intermediate (15,16), although the Pampa Hermosa is probably less derived than the Guatuso. The trend observed by Thomas and Ghai (19) in coconut, with respect to VAM colonization, is not observed here, with respect to mycorrhizal dependency. Nonetheless, we feel that the possible change in mycorrhizal dependency during the domestication process warrants further investigation, both for theoretical reasons and for practical use in plant improvement for sustainable agricultural systems. The clear genotypic differences observed by Blal and Gianinazzi-Pearson (2) in African oil palm clones are equally evident in this set of pejibaye progenies, which suggests that significant genetic variability for mycorrhizal dependency probably exists. With a larger germplasm sample it would be an easy task to determine the heritability of mycorrhizal dependency, as a first step towards exploiting it in improvement programs.

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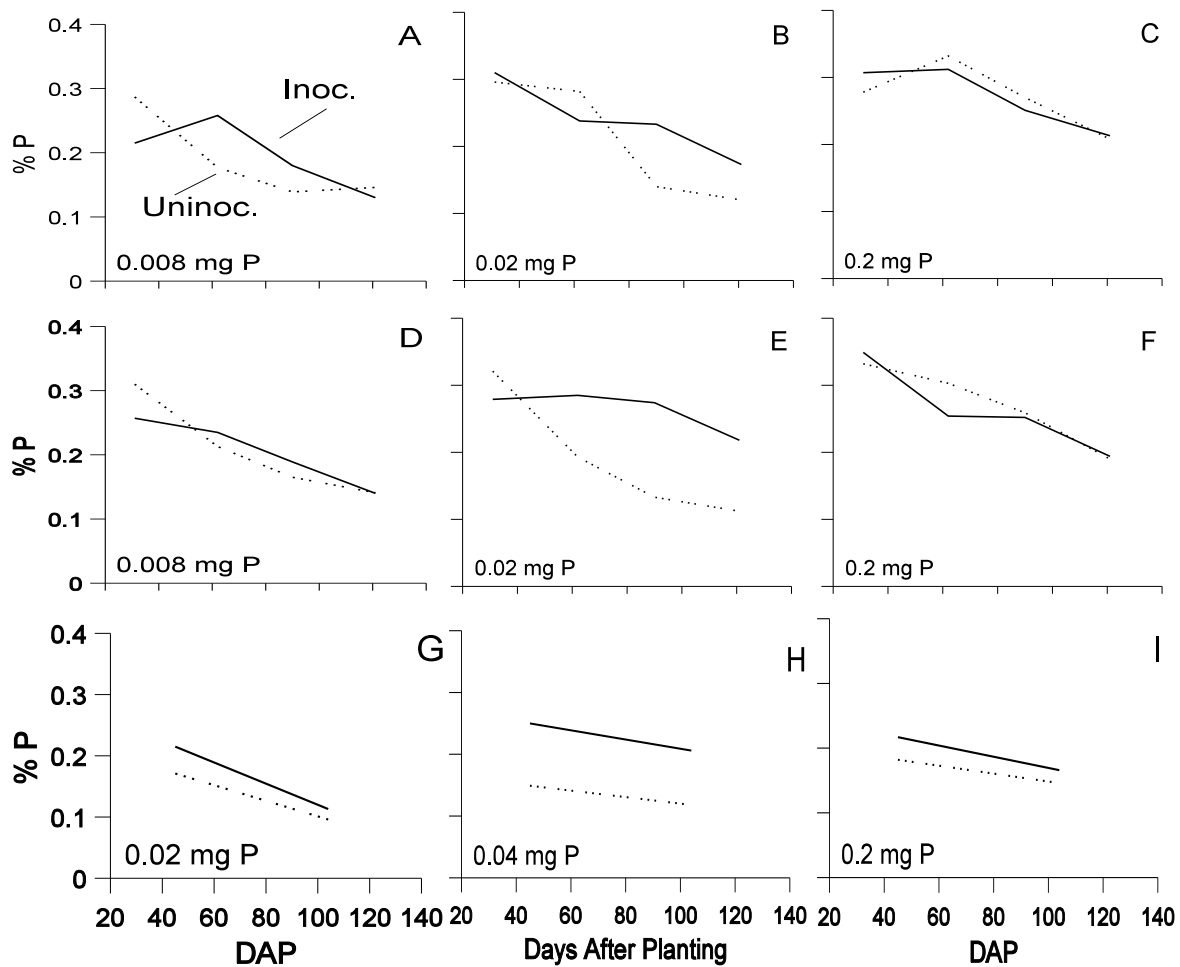


Figure 1. Changes in leaf P status of mycorrhizal and non-mycorrhizal *Bactris gasipaes* at different soil solution P concentrations. A-C. Pampa Hermosa progeny, mycorrhizal treatments were different at 90 days only for 0.008 and 0.02 mg P/L ($LSD_{0.05} = 0.036$). D-F. Putumayo progeny, mycorrhizal treatments were different at 90 ($LSD_{0.05} = 0.026$) and 121 days ($LSD_{0.05} = 0.019$) for 0.02 mg P/L. G-I. Guatuso progeny, mycorrhizal treatments were different at 45 days only for 0.04 mg P/L ($LSD_{0.05} = 0.052$).

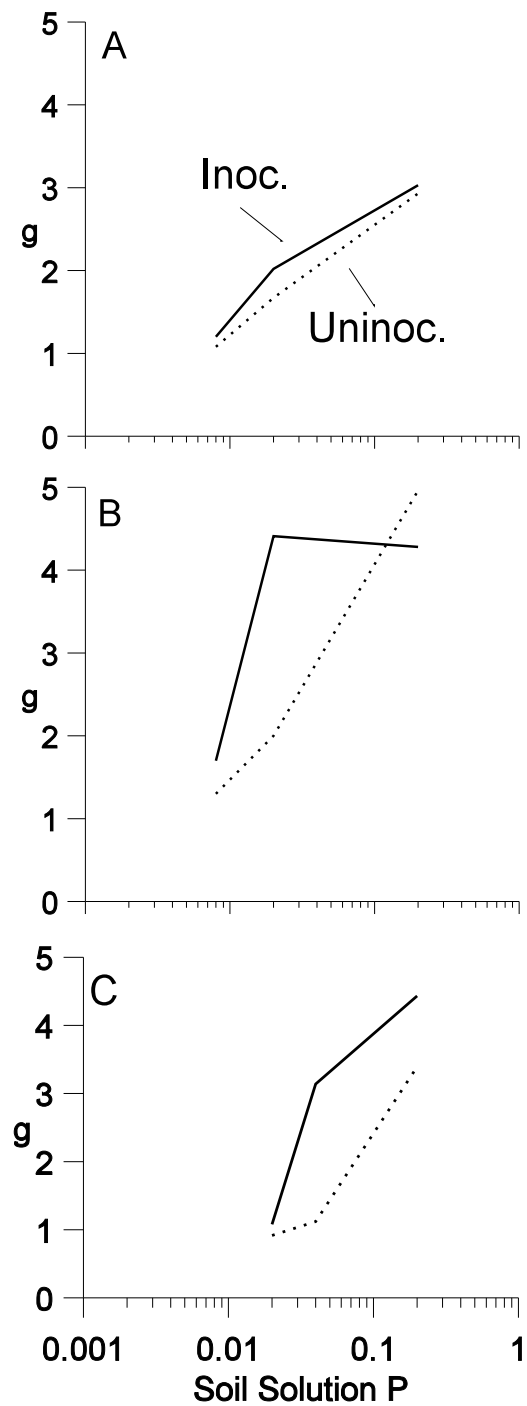


Figure 2. Shoot dry matter accumulation in *Bactris gasipaes* progenies in response to vesicular-arbuscular mycorrhizae fungi infection and soil solution P concentration (mg L^{-1}). A. Pampa Hermosa progeny. B. Putumayo progeny. C. Guatuso progeny.

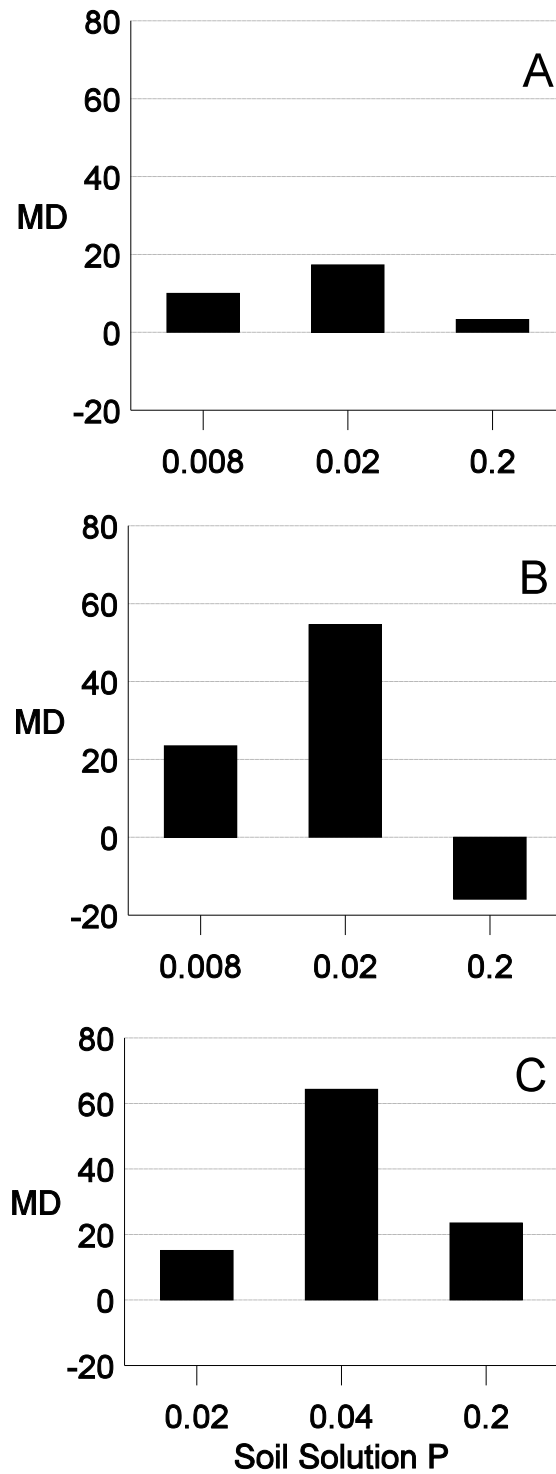


Figure 3. Vesicular-arbuscular mycorrhizal dependency of *Bactris gasipaes* at three soil solution P concentrations (mg L⁻¹). A. Pampa Hermosa progeny. B. Putumayo progeny. C. Guatuso progeny.