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# Response of *Podocarpus macrophyllus* to Rock Phosphate and Mycorrhizae<sup>1</sup>

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## Abstract

Shoot and root dry weights of greenhouse-grown mycorrhizal and nonmycorrhizal *Podocarpus macrophyllus* were not different after 8 months. Shoot dry weights were not different for plants grown in the 2 pine bark: 1 moss peat: 1 sand (v/v/v) medium amended with Florida rock phosphate (14% P) at either 0.54, 1.08, 2.16, 4.32, or 8.64 mg P/cm<sup>3</sup> (14.5, 29, 58, 116, or 232 oz P/yd<sup>3</sup>, respectively) of medium (2300 cm<sup>3</sup>/container) or 0.27 mg P/cm<sup>3</sup> (7.25 oz P/yd<sup>3</sup>) from superphosphate (9% P). Root dry weights for plants grown without a P amendment were greater than for plants grown with rock phosphate amendments of 0.54 and 1.08 mg P/cm<sup>3</sup>. Growing medium extract P levels 51 days after potting and thereafter were 2 ppm or less for the rock phosphate treatments, while P levels for the superphosphate-amended medium decreased from 169 ppm on day 51 to 9 ppm on day 236. Phosphorus accumulated by shoot and root tissues exhibited a similar relationship to shoot and root dry weights.

**Index words:** *Glomus intraradices*, superphosphate

## Introduction

A common nursery practice is to amend soilless container media with 0.27 mg P/cm<sup>3</sup> (7.25 oz P/yd<sup>3</sup>) from superphosphate (9% P) based on the premise that P is fixed by the medium and does not leach. However, recent research indicates that superphosphate dissolves rapidly in media containing largely organic components (21) and most soilless media components have low P fixation capacities (9,23), consequently P leaches. Yeager

and Barrett (21) determined that more than 50% of a <sup>32</sup>P amendment leached in 3 weeks from media composed of varying ratios of pine bark, moss peat, and sand. In view of the fact that P from superphosphate leaches from soilless media, alternative P amendments should be evaluated.

Rock phosphate is less water soluble than superphosphate (2), consequently P should not leach as readily from rock phosphate-amended soilless media. Powell *et al.* (16) found that mycorrhizal fungi increased P uptake from a rock phosphate-amended soil and increased dry matter production of ryegrass. Other researchers have determined that mycorrhizae facilitate P absorption (4,10,11,12), particularly in growth media with low P availability (10,11,13). The purpose of this research was to determine the growth response of mycorrhizal and nonmycorrhizal *Podocarpus macrophyllus* to rock phosphate amendments and compare growth response to rock phosphate amendments with growth response to a superphosphate amendment.

## Materials and Methods

A 2 pine bark: 1 moss peat: 1 sand (v/v/v) medium was fumigated with methyl bromide and amended with

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3 kg/m<sup>3</sup> of dolomitic limestone (70% passes 100 mesh sieve) and 1.8 kg/m<sup>3</sup> of Perk (micronutrient formulation of Estech, Inc., Chicago, IL). The medium contained 16% air space (19) and a particle size distribution (by weight) of 49% less than 0.5 mm, 34% between 0.5 mm and 1.4 mm, 12% between 1.4 mm and 4.0 mm, 2% between 4.0 mm and 6.4 mm, and 3% greater than 6.4 mm (U.S. Series sieve #35, 14, 5, and 3, respectively). Particle size distribution was obtained by shaking 3 replicate samples on a Tyler Portable Sieve Shaker (W.S. Tyler Inc., 8200 Tyler Blvd., Mentor, OH) for 20 min.

Florida rock phosphate (14% total P, 2% available P) rates were 0, 0.54, 1.08, 2.16, 4.32, or 8.64 mg/cm<sup>3</sup> of total P or 0.27 mg/cm<sup>3</sup> of total P from normal superphosphate (9% total P, 8% available P). These rates for rock phosphate are equivalent to 0, 14.5, 29, 58, 116, and 232 oz P/yd<sup>3</sup> and for superphosphate, 7.25 oz P/yd<sup>3</sup>. Rock phosphate had a particle size distribution (by weight) of 31.6% less than 75  $\mu$ m, 41.4% between 75  $\mu$ m and 150  $\mu$ m, 9.0% between 150  $\mu$ m and 180  $\mu$ m, 16.0% between 180  $\mu$ m and 425  $\mu$ m, 1.0% between 425  $\mu$ m and 850  $\mu$ m, and 1.0% greater than 850  $\mu$ m (U.S.A. Standard Testing Sieve #200, 100, 80, 40, and 20, respectively). Superphosphate particle sizes ranged from 1.0 to 3.4 mm. Rock phosphate or superphosphate was mixed with the medium for each 2300 cm<sup>3</sup> container separately using a Twin Shell Dry Blender (The Patterson-Kelly Co., Inc., East Stroudsburg, PA).

A 10 cm (4 in) single stem *P. macrophyllus* liner was planted April 18, 1984 in the medium of each container. One half of the plants were inoculated during potting with the mycorrhizal fungus *Glomus intraradices* Schenck & Smith, a common mycorrhizal species in Florida (18), using a 10 g mixture of chlamydospores (100 spores/g), hyphae and infected roots. An inoculum filtrate was applied to roots of noninoculated plants. The plants were grown in a glass greenhouse (28 °C day-24 °C night, 82-75 °F) with 50% light exclusion and the dark period interrupted by incandescent lighting (14  $\mu$ mol/m<sup>2</sup>/s) from 2300 to 0200 HR during September 22 to March 21. A randomized complete block design was used with a factorial arrangement of 2 plants per amendment rate and mycorrhizal combination for each of 5 blocks. Means for the superphosphate treatment and means for the unamended medium were compared by Dunnett's test (20) with each mean for the rock phosphate treatments.

The plants were watered as needed with 460 ml per container of deionized water or 150 ppm N solution from a water soluble 25N-0P-21K (25-0-25) fertilizer (W.R. Grace & Co., Allentown, PA). The fertilizer was applied every other watering. Growing medium pour-through extracts (25) were obtained after every 3 fertilizations and the subsequent watering, by pouring 80 ml of deionized water (pH 5.5) on the medium surface of each container and collecting the extract. Extract pH and P were determined (17). A 1.4-cm diameter core of medium was removed from each container on September 19. Root segments were separated from the medium and root colonization by *G. intraradices* was determined using the clearing and staining procedures of Phillips and Hayman (14) and a modified gridline intersect method (5).

On December 13, 1984, stems of each plant were severed above the uppermost roots. Roots were washed for 1 minute in tap water and 15 sec in deionized water. Shoot and root dry weights were determined after drying for 48 hrs at 70 °C (158 °F) and shoot and root tissue P determined by standard analyses.

Total mg of P in shoot and root tissues at experiment termination was calculated by multiplying shoot and root dry weights by percent P in shoot and root tissues, respectively. Forty plants had been sacrificed at the beginning of the experiment to determine initial P content of shoots and roots. Phosphorus accumulated by shoots and roots was calculated by subtracting initial P content of shoots and roots from final P content of shoots and roots, respectively.

## Results and Discussion

There were no significant interactions in this study and *P. macrophyllus* shoot and root dry weights and tissue P levels were not different for plants grown with or without mycorrhizae. This is in contrast to previous research of Johnson *et al.* (7) where mycorrhizae resulted in increased *P. macrophyllus* growth when grown in an unshaded fiber glass house. The reason for a different response may be due to lower light intensity in this study and consequently a reduction in photosynthate for mycorrhizae (8). Infection levels in this study averaged 75%, which should be sufficient for growth response; however, Plenchette *et al.* (15) found no correlation between infection levels and subsequent mediated growth response. Data presented below are averages of mycorrhizal and nonmycorrhizal plants.

Shoot dry weights at all rates of rock phosphate were greater than when no P amendment was used (Table 1) and shoot dry weights for the rock phosphate amendments were not different from the superphosphate amendment. Even though dry weights increased to the

**Table 1.** Shoot and root dry weights of *Podocarpus macrophyllus* grown 8 months in a 2 pine bark: 1 moss peat: 1 sand (v/v/v) medium amended with rock phosphate (14% P) or superphosphate (9% P).

Rock Phosphate		Shoot dry weights (g)	Root dry weights (g)
mg P/cm <sup>3</sup>	oz P/yd <sup>3</sup>		
0	0	6.8 <sup>z</sup> ± 0.2 <sup>y</sup>	2.9 <sup>z</sup> ± 0.1 <sup>y</sup>
0.54	14.5	11.3 ± 0.3	2.2 ± 0.1
1.08	29	11.4 ± 0.3	2.4 ± 0.1
2.16	58	12.2 ± 0.5	2.6* ± 0.1
4.32	116	12.0 ± 0.5	2.5* ± 0.1
8.64	232	11.7 ± 0.7	2.5* ± 0.1
Superphosphate		Shoot dry weights (g)	Root dry weights (g)
mg P/cm <sup>3</sup>	oz P/yd <sup>3</sup>		
0.27	7.25	11.3 <sup>x</sup> ± 0.7	2.1 <sup>x</sup> ± 0.1

<sup>z</sup>Mean shoot dry weight for treatment 0 was different (Dunnett's, 5% level) from each rock phosphate treatment. Mean root dry weight for treatment 0 was different (Dunnett's, 5% level) from treatments 0.54 and 1.08.

<sup>y</sup>Standard error of mean (n = 20).

<sup>x</sup>Mean for superphosphate treatment was compared by Dunnett's to each mean for rock phosphate treatments (excluding 0). \*, indicates means are different at 5% level.

2.16 mg P/cm<sup>3</sup> (58 oz/yd<sup>3</sup>) treatment and further additions of P did not increase shoot dry weights, the shoot growth response is not explained by a quadratic model.

Shoot dry weights of plants grown with 0.54 mg P/cm<sup>3</sup> (14.5 oz P/yd<sup>3</sup>) from rock phosphate or 0.27 mg P/cm<sup>3</sup> (7.25 oz P/yd<sup>3</sup>) from superphosphate, averaged 11.3 g for each treatment. The similar response for these treatments is in contrast to the findings of others (3,6). Graham and Timmer (6) found that dry weights were similar for rough lemon grown in Candler fine sand-soil amended with rock phosphate or superphosphate if 300 times the P supplied as superphosphate was supplied as a rock phosphate amendment. Enslinger *et al.* (3) evaluated the response of clover on 13 soils and found that as much as 18 times the quantity of P in superphosphate was required to produce equivalent yields with rock phosphate. The large amount of rock phosphate required for soil compared to the soilless medium of our study, may in part be due to the low P fixation capacities of pine bark and peat (9,23) compared to mineral soils. Thus, more P was needed on the mineral soils to achieve a similar amount of available P as with the soilless medium.

Mean root dry weight of plants grown without a P amendment was greater than plants grown with a rock phosphate amendment of 0.54 or 1.08 mg P/cm<sup>3</sup> (14.5 or 29 oz P/yd<sup>3</sup>). Root dry weights of plants grown with rock phosphate amendments of 2.16, 4.32, or 8.64 mg P/cm<sup>3</sup> (58, 116, or 232 oz P/yd<sup>3</sup>, respectively) were greater than plants grown with superphosphate. The large root weight (2.9 g) for plants grown without a P

amendment may be explained by a theory of Brouwer (1), which proposes that shoot growth occurs when nutrients are supplied above that needed for roots. Thus, the small amount of extractable P for the unamended medium (Fig. 1) was preferentially utilized for root growth since shoot growth was limited.

Growing medium P levels for the superphosphate-amended medium decreased from 169 ppm on day 51 to 9 ppm on day 236 (Fig. 1). Growing medium P levels for the rock phosphate treatments were generally less than 2 ppm throughout the experiment, but shoot dry weights for all rock phosphate amendment rates were comparable to that of the superphosphate amendment. Yeager and Wright (24) determined that shoot growth of *I. crenata* Thunb. 'Helleri' was not different when irrigated with P concentrations of 17-500 ppm and growing medium P levels of 5-10 ppm (22) were optimum. However, growing medium P levels less than 2 ppm may be adequate for *P. macrophyllus*. Growing medium pH during the experiment averaged 7.1 and 5.8 for the rock phosphate and superphosphate treatments, respectively.

Amounts of P accumulated by shoots and roots of each treatment (Table 2) exhibited a similar relationship to shoot and root dry weights, respectively. The large amount of P accumulated by roots of the unamended medium indicated absorption of indigenous growing medium P (23) and since shoot growth of plants from the unamended medium was limited, accumulated P was apparently utilized for root growth.

### Significance to the Nursery Industry

These data indicate that Florida rock phosphate (14%) P at 0.54 mg P/cm<sup>3</sup> (1.26 oz P/yd<sup>3</sup>) results in comparable *P. macrophyllus* shoot growth to that obtained when using 0.27 mg P/cm<sup>3</sup> (7.25 oz P/yd<sup>3</sup>) of superphosphate (9% P). Higher rates of rock phosphate amendments did not increase growing medium P levels above 2 ppm, 51 days after potting. The quantity of P

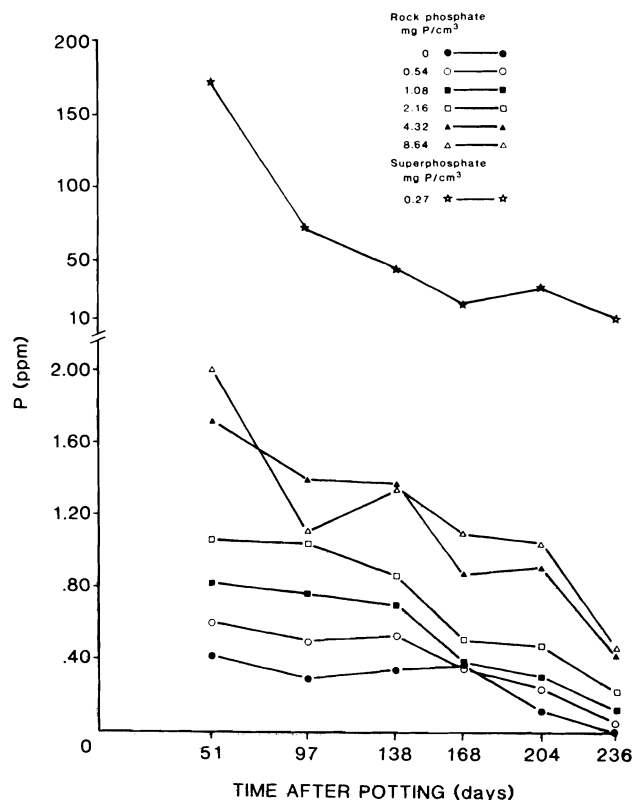


Fig. 1. Water soluble extract P levels for a 2 pine bark: 1 moss peat: 1 sand (v/v/v) medium amended with rock phosphate (14% P) or superphosphate (9% P).

Table 2. Phosphorus accumulated by shoots and roots of *Podocarpus macrophyllus* grown 8 months in a 2 pine bark: 1 moss peat: 1 sand (v/v/v) medium amended with rock phosphate (14% P) or superphosphate (9% P).

Rock phosphate		P accumulated (mg)	
mg P/cm <sup>3</sup>	oz P/yd <sup>3</sup>	Shoots	Roots
0	0	11.2 <sup>2</sup> ± 1.7 <sup>y</sup>	6.7 <sup>2</sup> ± 0.8 <sup>y</sup>
0.54	14.5	19.7 ± 2.4	4.6 ± 0.6
1.08	29	18.6 ± 1.9	4.8 ± 0.6
2.16	58	21.4 ± 2.4	5.7 ± 0.7
4.32	116	20.9 ± 1.7	5.4 ± 0.6
8.64	232	21.6 ± 2.6	5.6 ± 0.8
Superphosphate			
0.27	7.25	21.0 <sup>x</sup> ± 2.4	4.1 <sup>x</sup> ± 0.4

<sup>2</sup>Mean shoot P accumulated for treatment 0 was different (Dunnett's, 5% level) from each rock phosphate treatment, while root P accumulated was not different.

<sup>y</sup>Standard error of mean (n = 20).

<sup>x</sup>Mean shoot or root P accumulated for the superphosphate treatment was not different (Dunnett's, 5% level) from each rock phosphate treatment (excluding 0).

accumulated by shoots and roots of plants grown in the superphosphate-amended medium was similar to P accumulated by plants grown with the rock phosphate amendments. Additional studies are needed to evaluate the response of *P. macrophyllus* and other woody plants to mycorrhizae and rock phosphate-amended media when grown for more than one year without controlled environmental conditions.

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