INFLUENCE OF *GLOMUS MICROCARPUM* AND ROCK PHOSPHATE ON PHOTOSYNTHETIC CO_2 ASSIMILATION AND TISSUE PHOSPHORUS CONTENT IN SWEET POTATO

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ABSTRACT

A study was conducted to examine the influence of arbuscular mycorrhizal (AM) fungus *Glomus microcarpum* and rock phosphate (RP) fertilization on photosynthetic CO_2 assimilation and tissue phosphorus (P) content in sweet potato. Sweet potato (cv. Kanjangad) was maintained under glasshouse condition for 45 days in earthen pots containing sterilized laterite (Oxisol) soil with three levels of RP fertilization 2.8, 5.6 and 8.4 mg kg^{-1} soil in addition to the available P in the soil. The investigation revealed that mycorrhizal inoculation resulted in improvement of the percentage root colonization by AM, CO_2 assimilation and tissue P content in sweet potato at all stages of growth. Percentage root colonisation, Pn rate and tissue P was comparatively more under low to medium level of RP fertilization. Values of the measured parameters showed a general decline as the days after inoculation (DAI) advanced. Tissue P content did not show any definite relationship with net photosynthesis (Pn) rate.

Keywords: Glomus microcarpum, rock phosphate, tissue P, sweet potato

INTRODUCTION

The current tendency for a reduced use of agrochemicals and efficient application of natural minerals in agroecosystems, a renewed interest in direct application of rock phosphate (RP) has arisen (Pfleger & Linderman 1996; Vassilev et al. 2001). Application of RP can be an alternative to expensive processed fertilizers as superphosphate, especially in developing countries. The RP is a sparingly soluble phosphorus (P) source, which is considered a suitable source of P for acidic soils and is often used for improving tuber crop production. Thus, several researches have commonly been aimed to increase the RP availability. Microbial based approaches have been proposed to improve the agronomic value of RP materials (Barea et al. 2002; Sieverding 1991). It is well established that without the help of arbuscular mycorrhizal (AM) fungi the RP would be too unreactive to benefit most plants (Lange Ness & Vleck 2000). Uptake of mineral elements by the mycorrhizal

mycelium and subsequent transfer to the plant tissue has been demonstrated in particular for P (Sanders & Tinker 1973; Li et al. 1991). Plants with optimum tissue P concentration are reported to be more vigorous with higher photosynthetic rate and stomatal conductance than plants with limiting P (Dietz & Foyer 1986).

Sweet potato (*Ipomoea batatas* L.) is an important food crop of the humid tropics with high photosynthetic potential in terms of root calorie production ha^{-1} day^{-1} (De Vries et al. 1967). Incidence of AM fungi (Potty 1978; Harikumar & Potty 2002a) and improvement of growth and yield characteristics of the crop due to P fertilization (Akinrinde 2006) has already been reported. However, very little information is available on the influence of mycorrhizal inoculation and RP fertilization on photosynthesis and tissue P content of the crop. Hence the objective of this study was to determine the influence of mycorrhizal inoculation and RP fertilization on photosynthesis and tissue P content in sweet potato.

MATERIALS AND METHODS

Sweet potato (*Ipomoea batatas* L. cv. Kanjangad) was grown in earthen pots filled with laterite soil (Oxisol) mixed with riverine sand (Entisol) (soil: sand 1:1 v/v). The properties of the soil mix before the start of the experiment were pH 5.8 (soil: water 1:2.5), organic matter 9.2 g kg^{-1} and available P 7.7 mg kg^{-1}. The soils mix was sterilized using formalin 15 d prior to planting. The pots were fertilized with nitrogen (N) and potassium (K) as urea and muriate of potash at 2.8 mg kg^{-1} and 4.2 mg kg^{-1} respectively, while P was applied as Mussorie rock phosphate under three levels 2.8 (P1-low P), 5.6 (P2-medium P) and 8.4mg kg^{-1} soil (P3-high P) in addition to the available P in the soil. Half of the pots received mycorrhization by way of planting rooted *Glomus microcarpum* Tul. & Tul. (Local isolate CTAM 69) infected vine cuttings (Harikumar & Potty 2002b), one vine cutting per pot. In all pots native microflora (except AM fungi) was given as filtered washings from the soil.

The experiment was set up in a glass house, randomised in complete blocks with two mycorrhizal levels (mycorrhizal (M1) and non mycorrhizal (M0)) and four fertilizer levels (P0 (no added P), P1, P2 and P3) to give a 2 × 4 factorial each with 12 replications. Three plants were harvested from each treatment and separated into root stem and leaf tissues at 10 d intervals up to 45 d after inoculation (DAI). All the samples except for the quantification of mycorrhizal colonisation were oven dried (60^0C, 48h) powdered and stored in a dessicator. The root samples for mycorrhizal colonization were stored in 50% alcohol till further processing. The roots were cleared with 10% (w/v) KOH and stained with 0.05% (v/v) trypan blue in lactophenol as described by Phillips & Hayman (1970).

The proportion of root infected by AM was evaluated microscopically by the grid line intersect method (Giovanetti & Mosse 1980). Photosynthetic (Pn) measurement was made on the youngest fully expanded leaf (leaf 3 counting from the vine apex) at ambient atmospheric CO_2 of ~350 µmol mol^{-1} at 28^0C and

irradiance of ~1800 µmol photons m^{-2} s^{-1} on clear sunny days between 10.00 to 12.00 hours. Leaf was inserted in the closed transparent chamber of the Infrared Gas Analyser ADC 225 (Hoddesdon, UK) as such that, the normal position is not disturbed. The Pn rate was studied through the measurement of net CO_2 uptake per unit area as a function of time. Initial CO_2 level used for the experiment was 340 µmol mol^{-1}. Tissue (root, stem and leaves) P content was estimated colorimetrically by vanadomolybdate yellow colour method (Jackson 1973) after triple acid (concentrated HNO_3, H_2SO_4 and 60% $HClO_3$) digestion (~385^{0}C). Data were subjected to two-way analysis of variance (ANOVA). Means were separated by Duncan's Multiple Range Test (Little & Hills 1978). Pearson's correlation coefficients were used to describe the relationship between Pn rate and tissue P content.

RESULTS AND DISCUSSION

Inoculation of *G. microcarpum* significantly improved percentage mycorrhizal colonisation in sweet potato. Highest colonisation in inoculated treatment was observed under low to medium level of RP fertilization (Plenchette et al. 1983). Percentage mycorrhizal colonisation showed significant difference with DAI. Uninoculated plants remained non-mycorrhizal (Table 1).

Table 1. Effect of *G. microcarpum* inoculation and RP fertilization on percentage mycorrhizal colonization in sweet potato.

AM	P level	Root colonization (%)			
		15DAI	25DAI	35DAI	45DAI
M0	P0	0.00^{d}	0.00^{c}	0.00^{c}	0.00^{d}
	P1	0.00^{d}	0.00^{c}	0.00^{c}	0.00^{d}
	P2	0.00^{d}	0.00^{c}	0.00^{c}	0.00^{d}
	P3	0.00^{d}	0.00^{c}	0.00^{c}	0.00^{d}
M1	P0	100.00^{a}	96.00^{a}	100.00^{a}	92.00^{b}
	P1	90.00^{b}	89.00^{ab}	89.00^{b}	100.00^{a}
	P2	91.00^{b}	92.00^{a}	85.00^{b}	97.00^{ab}
	P3	78.00^{c}	82.00^{b}	88.00^{b}	76.00^{c}

Means with the same superscript do not differ significantly at $P < 0.05$ level by Duncan's Multiple Range Test. MO, non-inoculated sweet potato plant with mycorrhiza; M1, inoculated sweet potato plant with mycorrhiza. RP, rock phosphate.

In general, Pn rate in terms of CO_2 uptake was more in mycorrhizal sweet potato, though some sort of inconsistent variation occurred often (Figure 1). Increased rate of CO_2 and high rate of conversion of photosynthate in response to mycorrhizal inoculation is very important and worth considering as far as tuber crops are concerned. In sweet potato a few roots are converted to storage organs of photosynthate within short period of root initiation and mycorrhizal infection at the early stages has therefore much influence on both nutrition and tuber yield. The existence of a narrow root and tuber ratio in mycorrhizal sweet potato under different P regimes in an early study of Potty (1990) clearly indicated that the number of roots converted to tuber was more in mycorrhizal plants. In the present study the increase in Pn rate was quite obvious in mycorrhizal plants which received low to medium level of RP fertilization though it differed with DAI (Javadi et al. 1991). However, the inconsistency in Pn rate noted at certain stages of growth (25 DAI) merits consideration. It is speculated that the drying of leaves during the experiment, loss of integrity of chloroplast with the advancement of age (Thornton & Wample 1980) or inadequate sink demand for photosynthesis (Delgado et al. 1994) have contributed to this.

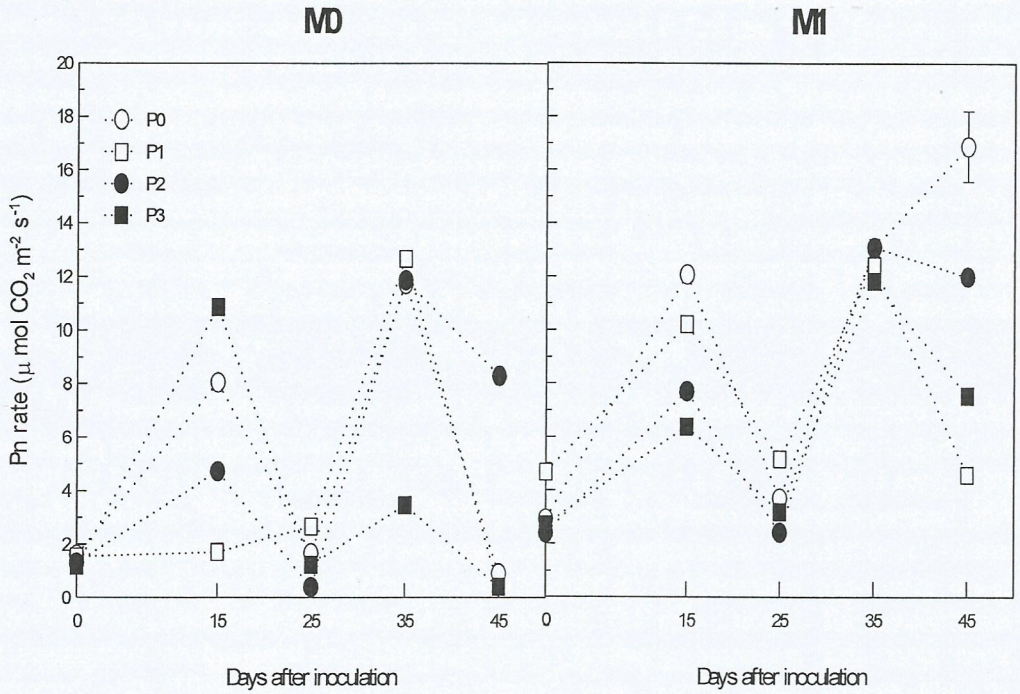

Figure 1. Effect of *G. microcarpum* inoculation and RP fertilization on Pn rate in sweet potato. Values shown are the mean of three replications, ± standard error of mean. MO, non-inoculated sweet potato plant with mycorrhiza; M1, inoculated sweet potato plant with mycorrhiza.

Tissue P content varied significantly between mycorrhizal and non-mycorrhizal plants, different levels of RP fertilization and DAI (all $P<0.001$). Tissue P showed comparatively higher values in mycorrhizal plants (Figure 2). Nevertheless, it responded differentially to levels of RP fertilization. In mycorrhizal plants, root P content was more in treatments received high level of RP as compared with non-mycorrhizal plants. In non-mycorrhizal plants the stem P content increased at medium to high level of RP fertilization at 15 and 45 DAI. Whereas, in mycorrhizal plants, the stem P content was more in treatments of no added P to low level of RP fertilization irrespective of DAI. It is well established that mycorrhiza can improve P nutrition of host particularly in low to moderate fertility due to exploration of soil by the external hyphae beyond the root hairs and P depletion zone (McArthur & Knowles 1993). In the case of leaf P, the application of high level of RP did not give any added benefit on the increase of this parameter indicating that mycorrhizal colonisation improves P nutrition of host plants even in the absence of extraneous P input utilizing the already available P resources in soil (Powell & Daniel 1978). Tissue P content showed a general decline as the days advanced. This is probably because of the removal of P by the plant to meet the increasing demand during growth.

Pearson's correlation analysis revealed that root and leaf content did not show any significant relationship with Pn rate in both non-mycorrhizal and mycorrhizal plants (Figure 3 and 5). However, in the case of stem P the relationship was linear and positive in both non-mycorrhizal and mycorrhizal plants (Figure 4). Several experiments have shown that in heavily colonised mycorrhizal plants, the carbon assimilation is significantly higher than in non-colonised plants and the observed effect is often non-nutrient (i.e., phosphorus) mediated (Dosskey et al. 1990, Conjeaud et al. 1996). The high rate of Pn observed in the present study may therefore be attributable to altered phytohormone production affecting photosynthesis or possibly due to the reason that some nutrients other than P or N may be limiting photosynthesis in non-mycorrhizal plants (Nilsen & Orcutt 1996).

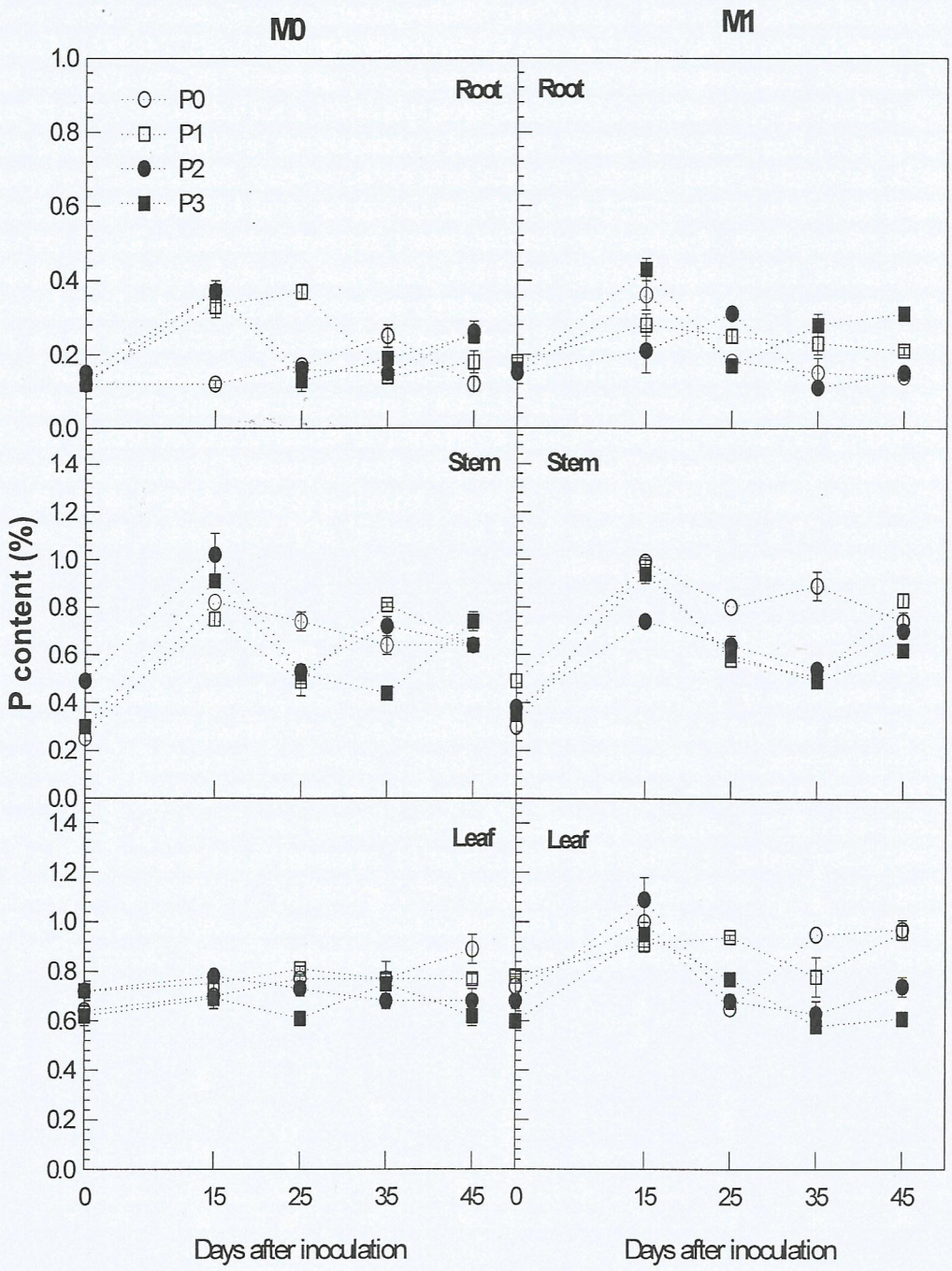

Figure 2. Tissue P content as influenced by *G. microcarpum* inoculation and RP fertilization in sweet potato. Values shown are the mean of three replications, ± standard error of mean. MO, non-inoculated sweet potato plant with mycorrhiza; M1, inoculated sweet potato plant with mycorrhiza.

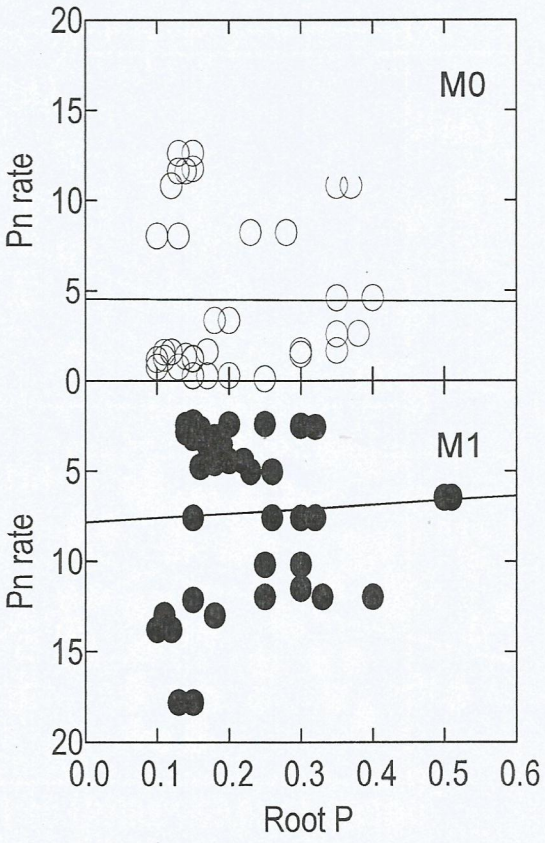

Figure 3. Relationship between Pn rate (μmol CO_2 m^{-2} s^{-1}) and root P content (%) in non-mycorrhizal (r=0.044, p=0.787, n=40) and mycorrhizal (r=0.040; p=0.806; n=40) inoculated sweet potato plants. MO, non-inoculated sweet potato plant with mycorrhiza; M1, inoculated sweet potato plant with mycorrhiza.

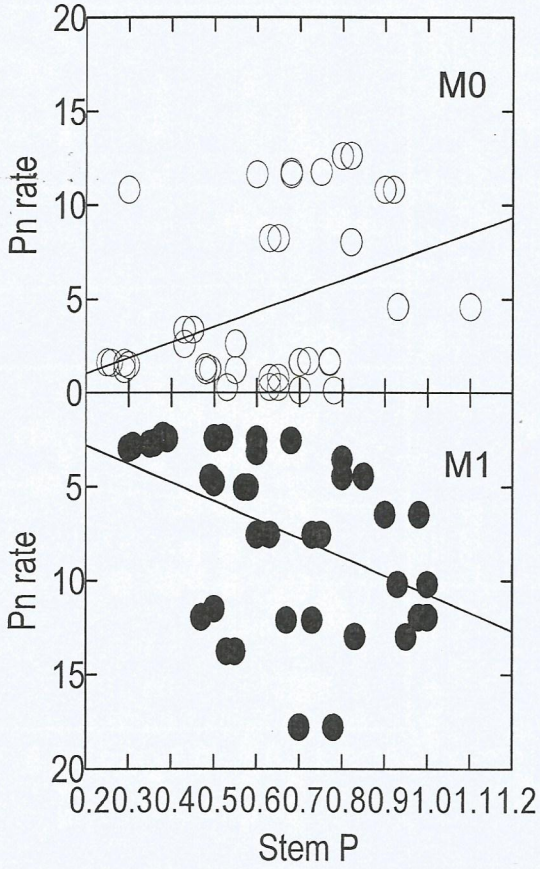

Figure 4. Relationship between Pn rate (μmol CO_2 m^{-2} s^{-1}) and stem P content (%) in non-mycorrhizal (r=0.483, p=0.002, n=40) and mycorrhizal (r=0.365, p=0.020, n=40) inoculated sweet potato plants. MO, non-inoculated sweet potato plant with mycorrhiza; M1, inoculated sweet potato plant with mycorrhiza.

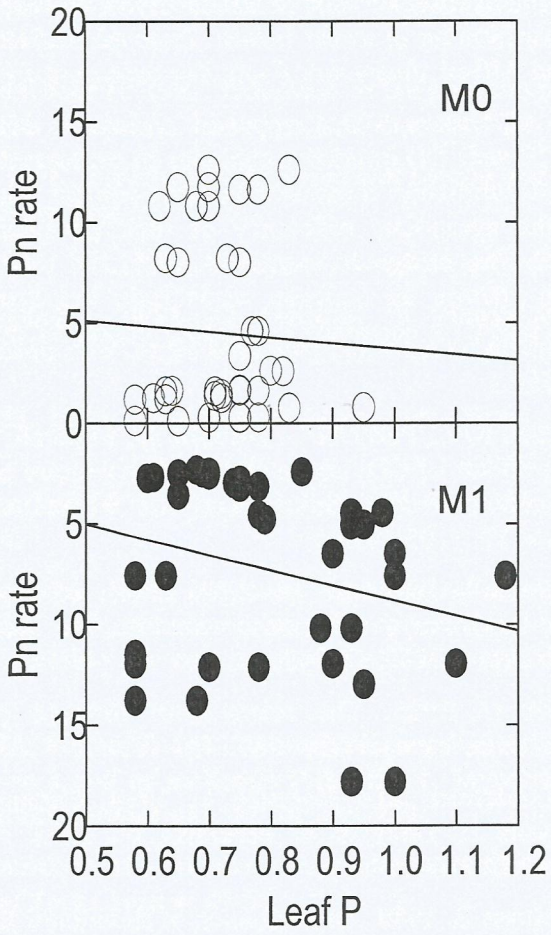

Figure 5. Relationship between Pn rate (μmol CO_2 m^{-2} s^{-1}) and leaf P content (%) in non-mycorrhizal (r=0.026, p=0.875, n=40) and mycorrhizal (r=0.239, p=0.138, n=40) inoculated sweet potato plants. MO, non-inoculated sweet potato plant with mycorrhiza; M1, inoculated sweet potato plant with mycorrhiza.

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