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Reactive natural phosphate enriched with filter cake enhances soil P content and noni seedlings growth*

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ABSTRACT
One of the major challenges in crop production is increase efficiency of non-renewable P sources, or replace them with renewable sources. The objective of this study is to evaluate the effects of phosphorus (P) fertilization using reactive natural phosphate, filter cake, peat and biofertilizer on soil P content, foliar P content and growth of noni seedlings. The treatments were: control (without P fertilization); phosphorus; filter cake; phosphorus + filter cake; phosphorus + filter cake + peat; and phosphorus + filter cake + peat + biofertilizer. All treatments were replicated four times and arranged in a completely randomized design. The treatments phosphorus + filter cake; phosphorus + filter cake + peat; and phosphorus + filter cake + peat + biofertilizer increased phosphorus content in soil and in leaf, and the growth of noni seedlings. Our results indicates that natural reactive phosphate enriched with filter cake can be used as phosphate fertilizer on noni seedlings cultivation.

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Medicinal plant; *Morinda citrifolia*; phosphate fertilizer; rubiaceae; renewable P sources

Introduction

Noni (*Morinda citrifolia* L.) is known due to its therapeutic effects in human beings (Ahmad et al. 2016). Studies associated to its nutritional requirement have been done in the past years, especially with mineral and organic fertilization in plants already transplanted to the field (Kumar and Ponnuswami 2013; Cavalcante et al. 2014; Souto et al. 2016). However, nourished seedlings is also of relevance for further establishment and growth of plants in the field phase and, so far, the only recommendation for Noni's seedlings was reported by Sousa et al. (2010), in which the use of cattle manure associated to mineral fertilizers was stated as the best management option.

Among the plant essential nutrients, P has been reported as one of the most challenger nutrient in crop production. Because phosphate fertilizer is a non-renewable and finite sources of P, there is a need to increase its efficiency or find alternative sources to supply this nutrient. The use of organic and renewable sources have been suggested as an alternative for P fertilization (Faucon et al. 2015). Reports have shown that filter cake, a residue from sugarcane mill, has the potential of partially replace mineral P fertilizers, as it contains in average 1.1% of phosphorus (Camargo et al. 1984; Khwairakpam and Bhargava 2009; Santana et al. 2012; Prado et al. 2013). Thus, it is important to study the agricultural potential of filter cake as an alternative to improve phosphorus nutrition on noni plants. Another alternative that has been recently suggested by many authors is the use of biofertilizers. This technology is cheap and increases both phosphorus content in the soil (Biswas and Narayanasamy 2006; Chen et al. 2006) and phosphorus uptake by the plant (Stamford et al. 2006; Singh and Reddy 2011). The association between biofertilizers or organic sources to mineral fertilizers might be a relevant strategy to reduce the dependence of phosphorus supplementation on chemical fertilizer application (Mahfouz and Sharaf-Eldin 2007).

In this context, the hypothesis of this study is that phosphorus mineral fertilizers associated to organic fertilizers increase the availability of phosphorus in the soil, with further increase on phosphorus uptake and growth of noni seedlings. The objective of this study is to evaluate the effect of phosphorus fertilization using reactive natural phosphate, filter cake, peat and biofertilizer on soil and foliar phosphorus content, plant growth and chlorophyll fluorescence of noni seedlings.

Materials and methods

The experiment was conducted between April and July-2012 in a greenhouse located at São Paulo State University

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(UNESP) School of Agricultural and Veterinarian Sciences, Jaboticabal, Brazil. Each plot was composed by one black plastic bag (polyethylene fanfold) with holes (sized 15 cm wide and 28 cm long), and filled with soil samples collected from 0.20 to 0.50 cm of a clayey Red Dystrophic Oxisol (Santos et al. 2013). The soil chemical analysis followed van Raij et al. (2001) methodology, resulted in: pH ($CaCl_2$) = 5.5; organic matter = 11 g dm^{-3}; P-resin = 8 mg dm^{-3}; K = 1.1 $mmol_c$ dm^{-3}; Ca = 20 $mmol_c$ dm^{-3}; Mg = 9 $mmol_c$ dm^{-3}; H + Al = 18 $mmol_c$ dm^{-3}; sum of the bases = 30.1 $mmol_c$ dm^{-3}; cation exchange capacity = 48.1 $mmol_c$ dm^{-3} and base saturation = 63%.

Five noni seeds were sowed at 0.5 cm deep in each bag. After the emergence, thinning was done in order to leave one plant per bag. The treatments were: control (blanked soil); phosphorus; filter cake; phosphorus + filter cake; phosphorus + filter cake + peat; and phosphorus + filter cake + peat + biofertilizer. The experiment was laid out in a completely randomized design with four replications containing three bags each.

The natural phosphate Bayóvar® (P_2O_5 soluble = 14% soluble in 2% citric acid) was used as soluble phosphorus source. The phosphorus's rate was 200 mg dm^{-3}, according to Malavolta (1980) recommendation for pot experiments. It was applied 160 t ha^{-1} of filter cake on dry basis (80 g dm^{-3} of filter cake corresponds to 736 mg dm^{-3} of phosphorus), which was considered as an intermediate rate by Coutinho et al. (2006) on sesbania seedlings. The filter cake used for fertilization was already decomposed. The biofertilizer composition was natural compounds, polysaccharides, low molecular weight organic acids, humates, purified phosphate, apatite (10% P_2O_5) and microorganisms selected by the load of 1×10^{-6} colonies cm^{-3} product (480 mL kg^{-1} of cake); and liquid peat containing humic acids (4 mL cake kg^{-1}).

The composition of the filter cake followed by Bataglia et al. (1983) methodology (in dry matter basis at 60–65 °C) was: N = 14.0 g kg^{-1}; P = 9.2 g kg^{-1}; K = 3.4 g kg^{-1}; Ca = 25.3 g kg^{-1}; Mg = 9.0 g kg^{-1}; S = 3.3 g kg^{-1}; B = 16.0 mg kg^{-1}; Cu = 43.0 mg kg^{-1}; Fe = 9.37 mg kg^{-1}; Mn = 753 mg kg^{-1} e Zn = 70.0 mg kg^{-1}.

All treatments received nitrogen (200 mg dm^{-3} of N) as ammonium sulfate (20% of N), and potassium (150 mg dm^{-3} of K) as potassium chloride (60% of K_2O), according to Malavolta (1980) recommendations. Both fertilizers were mixed to the soil before its addition to plastic bags. The irrigation was daily implemented in order to keep 60–70% of soil water holding capacity.

The plants were evaluated after 90 days of seedlings emergence (DSE). Stalk diameter was measured 3 cm from the soil surface using a digital caliper, while the plant height was measured from the soil surface to the stalk apex using a measuring tape. The developed and photosynthetic active leaves were the ones considered for the number of leaves. Phosphorus foliar content was determine by Bataglia et al. (1983) using the first totally developed leaf. After 90 DSE soil samples was collected from each bag to determine the available phosphorus content according to van Raij et al. (2001) methodology. The dry matter accumulation of seedlings was not analyzed as it is an invasive procedure and seedlings are designed to field planting.

The resulting data were analyzed by analysis of variance and averages were compared by the Tukey test ($P < 0.05$). The statistical program Sisvar (Ferreira 2011) was used on this comparison following the proposed experimental design.

Results and discussion

Plants parameters analyzed was affected by all fertilizations tested, except for the number of leaves which did not show any influence of the treatment applied (Table 1).

Initially, we confirmed the hypothesis that association between mineral P fertilizer and organic P fertilizer increases P availability in the soil, since phosphorus application enriched by filter cake presented one of the highest soil phosphorus content. It was observed an increase by 185 mg dm^{-3} in P content using phosphorus application enriched by filter cake compared to the control. However, no significant difference from phosphorus enriched by filter cake was observed for treatments that included peat and peat + biofertilizer.

Chemical analysis of filter cake presented 9.2 g P kg^{-1}, and for the application (80 g of filter cake dm^{-3} of soil) it corresponded to 736 mg of P dm^{-3}. Therefore, filter cake application delivered a higher amount of phosphorus than the natural phosphorus application (200 mg dm^{-3}). However, it is relevant to remind that filter cake's phosphorus is not ready available since mineralization is required for it.

Table 1. Phosphorus content on soil and on leaf, plant height (PH), stalk diameter (SD), and number of leaves (NL) of noni (*Morinda citrifolia* L.) seedlings.

Treatments	*P* soil mg dm^{-3}	*P* leaf g kg^{-1}	PH cm	SD mm	NL
Control	15 d	4.4 b	4.34 c	3.24 bc	8 a
Phosphorus	240 c	4.7 b	6.80 b	5.05 ab	10 a
Filter cake	360 b	6.7 a	5.69 bc	2.83 c	8 a
Phosphorus + filter cake	425 a	6.3 a	7.68 ab	4.49 abc	9 a
Phosphorus + filter cake + peat	436 a	6.4 a	7.33 b	4.87 abc	8 a
Phosphorus + filter cake + peat+ biofertilizer	440 a	6.7 a	9.63 a	5.70 a	10 a
CV (%)	5.2	10.6	13.3	21.4	12.6

Note: Values followed by different letters within a column are significantly different ($P < 0.05$) by Tukey's test.

The phosphorus foliar content was higher for filter cake application followed by phosphorus + filter cake; phosphorus + filter cake + peat; and phosphorus + filter cake + peat + biofertilizer, all of these different only from control and single phosphorus treatments. This result is due to the high content of soil phosphorus found on treatments containing residues (Table 1). Plants grown in enriched phosphorus with filter cake showed 42% higher phosphorus foliar content than plants grown in phosphorus only. So far, there was no information regarding P leaf content in noni seedlings, only in adult plants (Silva et al. 2011; Cavalcante et al. 2014; Silva et al. 2014). Leaf P content of noni plants changes according to its development stages (Kumar and Ponnuswami 2014).

Plants were taller under phosphorus enriched by filter cake application as well as under peat and biofertilizer, which did not differ from phosphorus + filter cake treatment. The other treatments were higher than the control but did not differ from each other, except for the single filter cake which did not demonstrate difference from the control. Therefore, we observed that phosphorus association to filter cake and other organic residues increased plant height compared to isolated mineral fertilization or organic application (filter cake). These results demonstrate that organo-mineral fertilization was important to seedlings production.

The application of phosphorus enriched by filter cake, peat and biofertilizer promoted higher stalk diameter of noni seedlings than control and single filter cake applications, which were lower by 43 and 50.5%, respectively (Table 1). In general, the treatment with reactive natural phosphate enriched with filter cake increased P content in the soil, as well as leaf P and growth of noni seedlings. Our results indicates that natural reactive phosphate enriched with filter cake can be used as phosphate fertilizer in noni seedlings.

Disclosure statement

No potential conflict of interest was reported by the authors.

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