Direct use of low grade phosphate rock from Brazil as fertilizer

II. Effects of mycorrhizal inoculation and nitrogen source

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Summary The response of plant dry matter to addition of a low grade Brazilian (Patos) phosphate rock was increased by mycorrhizal inoculation (strain E) of Stylosanthes guianensis and Desmodium intortum, but less so by inoculation of Cenchrus ciliaris and Paspalum plicatulum. The effect was related partly to the extent of root development. In the presence of a nitrification inhibitor the utilisation of Patos rock phosphate by Paspalum was higher with NH₄⁺-N than with NO₃-N. This effect was attributed to acidification which in turn was related to the organic anion content of the plants. The results indicate the potential for improving the utilization of the low grade phosphate rock on an acid oxisol by mycorrhizal inoculation of herbage legumes and by soil acidification when growing grasses.

Introduction

In the previous paper reasons were given for investigating the direct use of a Brazilian phosphate rock (Patos) as a fertilizer. Experiments reported in that paper showed Patos phosphate rock to have a very low solubility, and to provide only small amounts of phosphate for plant (sorghum) growth.

There is abundant evidence that a low soil pH is necessary for the utilization of phosphate rocks and there is also evidence that high phosphate and calcium buffer capacities increase the rate at which they dissolve. The soils for which the Patos phosphate rock is required are acid and have a high phosphate buffer capacity, although in some soils at least the adsorbed phosphate becomes immobilised (fixed). Conditions for making effective direct use of Patos rock phosphate are therefore reasonably propitious.

The purpose of the present work was to assess the effects of (a) the source of nitrogen, and (b) mycorrhizal inoculation, on the utilisation of Patos phosphate rock by four plant species. Mycorrhizal inoculation was investigated because of the evidence that it can increase the utilization of more soluble phosphate rocks such as Gafsa. As the source of nitrogen, ammonium was compared with nitrate. It is well known that nitrification of NH₄⁺-N increases soil acidity and may therefore increase the solubility of phosphate rocks; but in the experiments reported here nitrification was inhibited in order to compare NH₄⁺-N and

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NO$_3^-$–N as plant nutrients, based on earlier work$^5$ showing that uptake of NH$_4^+$ by plants causes H$^+$ excretion from plant roots.

**Materials and methods**

*Soil and phosphate rock*

The soil used in the pot experiment was an oxisol from southern Bahia, Brazil, named Haplorthox crystalino. Before use, the soil was irradiated with 0.5 Mrad of gamma radiation to destroy indigenous mycorrhizal fungi. The phosphate rock was a low-soluble source from a deposit at Patos in Minas Gerais State, Brazil. The properties of the soil and of the phosphate rock have been given earlier$^2$.

*Plants*

The four test plants were: (i) *Stylosanthes guianensis*, (ii) *Desmodium intortum*, (iii) *Cenchrus ciliaris* L. var. Buffel Biloela, and (iv) *Paspalum plicatum*. The first two are herbage legumes, the second two are grasses, and all are grown in Brazil. Seeds were washed with a surface active agent, surface-sterilized with 0.1% NaOCl for 20 seconds, washed with 0.5% sodium thiosulphate solution and then thoroughly with water. The seedlings were raised in sterilized sand plus de-ionized water.

*Inoculation*

The soil was inoculated with *Glomus fasciculatus*, spore type E$^3$ isolated at Rothamsted Experimental Station. It is similar to type E$^3$ described by Gilmore$^3$.

*Growth conditions*

The experiment consisted of two parts, using a randomized factorial design for each part of: 2 plant species, 2 P-treatments (0 and 100 μg P g$^{-1}$ soil) as Patos rock phosphate mixed thoroughly with the soil, 2 N-treatments (NO$_3^-$ and NH$_4^+$), and inoculation with mycorrhiza (with and without). In the first part the plant species were Stylosanthes and Desmodium at 4-fold replication, and in the second (later part) they were Cenchrus and Paspalum at 3-fold replication. All soils receiving NH$_4^+$–N were treated with N-serve at 2 μg g$^{-1}$ to inhibit nitrification.

For each treatment 200 g soil was weighed into a pot with 7.5 cm diameter base, and standing on a saucer. Three seedlings were grown in each pot. The mycorrhizal inoculum consisted of spores, sporocarps and mycelium obtained by wet sieving$^9$. Half was placed in each planting hole and half between the plants. For the control pots, a suspension of sterilized inoculum in non-sterile filtrate was added to the soil to ensure addition of contaminating micro-organisms but not mycorrhiza.

Before transplanting the seedlings, nutrients were mixed with the soil as shown in Table 1. Based on previous experience, monocalcium phosphate was added to all pots at 20 μg P g$^{-1}$ soil to ensure some initial growth of the plants. The plants were grown in a growth room at 25°C and a relative humidity of 57% with a 16 h day and a light intensity (photosynthetically active radiation) of 94 watts m$^{-2}$. Nutrients were added during growth (Table 1), and water was added once, twice or three times daily to keep constant weight. The additions of calcium as calcium sulphate in the NH$_4^+$–N treatments (Table 1) were made equal to those in the NO$_3^-$–N treatments.

*Measurements*

After harvest (51 days after planting Stylosanthes and Desmodium, 62 days after planting Cenchrus and Paspalum) shoots and roots were dried at 72°C for 72 h, weighed and analysed for phosphate$^5$. Before drying, small samples of root were taken to measure the extent of mycorrhizal infection$^9$. 