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Original article

The phosphorus source determines the arbuscular mycorrhizal potential and the native mycorrhizal colonization of tall fescue and wheatgrass

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Abstract

The study assesses the effect of two phosphate (P) sources (soluble superphosphate (SP) and rock phosphate (RP)) on the arbuscular mycorrhizal potential (AMP), the root arbuscular mycorrhizal colonization (AMC) and the growth of tall fescue and wheatgrass of a grassland soil from Argentina. Mycorrhizal potential was assessed with soil samples collected from 2 years for tall fescue and wheatgrass swards before and after field plots were fertilized with 0 and 60 kg P ha^{-1} as SP or RP. Mycorrhizal potential both at unfertilized and at RP fertilized plots was high (12–14 AM propagules g^{-1}), however fertilization with SP caused a decrease in AMP (0.70–0.95 AM propagules g^{-1}). A range of soil P between 4 and 46 mg P kg^{-1} and a range of root AMC between 6% and 50% were obtained after fertilization with four rates of SP and RP (0, 15, 30, and 60 kg P ha^{-1}) in plots where tall fescue and wheatgrass were grown during 2 years. Soil P and root mass were higher in the top 10-cm depth than in the 20-cm of the soil profile, but AMC did not change with depth. Shoot dry matter (SDM) production of both grasses did not differ after fertilization with SP or RP, particularly at second year. The AMP positively correlated with the indigenous AMC, and they were not different between tall fescue or wheatgrass. Lineal-plateau relationships between soil P, relative SDM and AMC were established. Highest relative SDM was attained at 6.5 mg P kg^{-1} in plots fertilized with RP, and at 15.2 mg P kg^{-1} with SP. Variability in colonization was well accounted by the soil P (at 0–10 cm depth) fertilized with SP ($r^2 = 0.48$, P 0.01), but any relationship was found with RP. The AMC decreased with increasing available soil P from plots with SP until 18.3 mg kg^{-1} (a decrease of 2.2% per mg P kg), after that AMC was stabilized at about 6.9%. Our study clearly showed that fertilization with SP or RP produced similar available soil P content and grasses SDM production. Mycorrhiza root colonization and propagules decreased after fertilization with SP, but fertilization with RP did not decrease mycorrhizal propagules nor colonization. It can be concluded that RP fertilization instead SP could allow obtaining acceptable tall fescue and wheatgrass yield enhancing mycorrhizal potential of soils and indigenous colonization of plants and thus maximizing the use of fertilizer.

Keywords: Arbuscular mycorrhizal potential; Arbuscular mycorrhizal colonization; Soil phosphorus; Rock phosphate; Superphosphate; Tall fescue; Wheatgrass

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1. Introduction

In many soils, a substantial amount of applied phosphorus (P) as fertilizer is rendered unavailable and frequent applications of soluble forms of inorganic P are needed to maintain adequate P levels for plant growth. Thus, fertilization with commercial soluble P sources as superphosphate (SP) is commonly used to improve plant growth. However, with 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 [38,50]. Application of RP can be an alternative to expensive processed fertilizers as SP, especially in developing countries. The RP is a sparingly soluble P source, which is considered a suitable source of P for acidic soils and is often used for improving forage grass under organic management. 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 [7,49]. Although the advantages and disadvantages of using RP instead SP are still debated, it has been well established that without the help of arbuscular mycorrhizal (AM) fungi the RP would be too unreactive to benefit most plants [28]. Thirty years ago, Murdoch et al. [34] showed that AM fungi were able to solubilize P from RP. Later, most of researches aimed to clarify the mechanisms by which they manage to extract P from the apatite matrix [3,7,28].

The lower solubility of RP in relation to soluble fertilizers, allows increasing the benefits of P application particularly in crops that can use available nutrients during several months after fertilization. In general, pastures could use the P applied during several years. At the Pampas region, the main area of livestock production in Argentina, pastures represent approximately 70% of the grazed surface. Tall fescue (*Festuca arundinacea* Schreb.) is the most seedling forage crop in this region (95,000 ha year^{-1}) due to its general adaptability. Additionally, wheatgrass (*Thinopyrum ponticum* Podp = *Agropyron elongatum* Beauv) is a naturalized perennial grass in the depressed Argentinean Pampas. It is spread over 500,000 ha year^{-1} and offer a good forage aptitude [11,31]. Soils of this region have shown native arbuscular mycorrhizal colonization (AMC) of wild and cultivated plants [4,14] as of mixed pastures under different crop systems [15]. Agricultural production in the Argentinean Pampas is limited by a generalized soil P deficiency, as soils are lightly acidic with low concentrations of native available P. Consequently, in the last years the SP fertilization begins to spread in the meat production systems [8,40].

It is well documented that high levels of P coming from synthetics and highly soluble P sources, as SP, may result in a pronounced depression of soil mycorrhizal propagules and root colonization [6,21,38]. However, there are few and contradictory reports concerning the effect of RP on the occurrence of mycorrhizal propagules and mycorrhizal symbiosis. Whereas Diederichs [18] reported detrimental effects of SP and RP on AM fungi, Manjunath et al. [30] showed that RP increased the AMC. Rubio et al. [44] reported that RP fertilization depressed AMC but increased the number of spores in relation to SP.

A number of reports have described the response of forage production to P application [22,42,45], and the spread of AMC in herbaceous forage plant communities [25,55]. Regarding the positive effect of the AMC on plants growth, the question raises of how fertilizer application can be managed using the appropriate doses and sources for reaching optimum nutrient-AMC. Thus, quantitative relationships between soil P levels from both synthetic and natural sources of fertilizers and AMC are needed in order to define the less detrimental source and to adjust the fertilizer rate to obtain high forage growth without depress the symbiosis. We assumed that AMC plays an important role in plant growth and nutrition in conventionally managed pasture systems, but how fertilization affect mycorrhizal fungi under field conditions need to be explored.

In the present study, we investigated the effect of fertilization with two phosphate sources (SP and RP) on the occurrence of AM propagules, on the native mycorrhizal colonization and on growth of tall fescue and wheatgrass.

2. Materials and methods

2.1. Experimental site

The experiment was located at the Instituto Nacional de Tecnología Agropecuaria-Facultad de Ciencias Agrarias (INTA-FCA) Balcarce Experimental Station, Buenos Aires, Argentina (37°45′S, 58°18′W; altitude 130 m). The climate of the region is humid–subhumid mesothermal. The annual mean temperature is 14 °C, and the annual rainfall is 867 mm with 80% of rainfall during spring–summer. The soil was fine, illitic, Hapludol Series Mar del Plata, fine-loamy, mixed, thermic (USDA soil classification). The topsoil (0–20 cm, A horizon) had the following properties: pH 5.7 (1:2.5