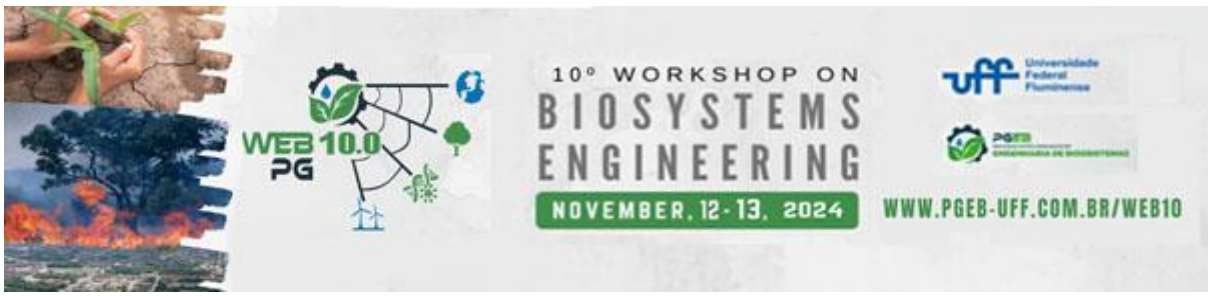

EVALUATION OF THE EFFECT OF BIOCHAR-BASED PHOSPHATE FERTILIZERS ON MAIZE GROWTH

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Abstract

Biochar is a product derived from pyrolysis, a carbonization process at high temperatures and with low oxygen availability. By many, it is considered an alternative for reducing phosphate loss in soils due to its high capacity to retain nutrients and water. This study assessed the effects of different types of fertilizers, including biochar-based fertilizers, on phosphorus (P) supply, corn growth, and soil properties. These fertilizers, made from Eucalyptus charcoal and blended with MAP (monoammonium phosphate) or thermophosphate, were compared to traditional mineral fertilizers and a control group without fertilization. The study revealed that all fertilizers resulted in more robust growth of corn plants compared to the control treatment and, among the tested fertilizers, MAP and ORGMAP were the treatments where plants showed higher dry matter (11.87g and 9.54g respectively) and greater P accumulation in the plant 50 mg and 42 mg). For the soil, thermophosphate and ORGTermo exhibited higher concentrations of P. The results demonstrated that biochar-based fertilizers show technical viability for use as alternatives to mineral fertilizers, given that the outcomes are comparable.

Keywords: phosphorus, soil, agriculture

INTRODUCTION

Global fertilizer consumption has risen by over 60% in the past 50 years, with strong demand for NPK fertilizers (IFA, 2020). In 2021, Brazil's fertilizer consumption reached 45.85 million tons, with 85% being imported, showing the country's reliance on external markets (ANDA, 2021). Therefore, it is crucial to study alternatives and efficiency use to reduce this dependency.

Phosphorus plays a key role for plant growth. However, its availability in soil is often restricted due to fixation in insoluble compounds. Commercial phosphate fertilizers have low phosphorus availability efficiency, as they are readily adsorbed by soil minerals, leading to low residual phosphorus levels (Sá et al., 2017). In this context, biochar-based fertilizers emerge as a promising strategy to enhance phosphorus availability in the soil and benefit plant growth, seeing as biochar serves as a nutrient source for the soil (Souza, 2011).

This study aimed to investigate the characteristics and use of biochar-based phosphate fertilizers, focusing on their ability to release phosphorus into the soil. Different mineral sources were examined to understand the relationship between the physicochemical properties of biochar and its effectiveness as a fertilizer in pot experiments.

MATERIALS AND METHODS

The fertilizers used in this study were developed based on research by Reis (2020). The biochar utilized was produced by pyrolyzing Eucalyptus wood at 400°C and the chosen mineral additions were MAP (monoammonium phosphate) along with thermophosphate, in a 1:1 ratio of biochar and the mineral additions, resulting in the production of two fertilizers: ORGMAP and ORGTermo.

The soil used was collected from the surface layer of 0 to 30 cm of a Red-Yellow Argisol and the experiment was conducted in a greenhouse, using a completely randomized experimental design, with vases containing 1 kg of the Argisol, six seeds of hybrid corn and doses of 100 mg of P of five treatments, including a control, each with four replications.

The first harvest was carried out after 55 days, keeping the roots in the soil and replanting new seeds for the second plantation, carried out for 64 days. Both the aerial parts of the plants and the soils form the vases were collected and everything was dried in a drying oven at 65°C. Foliar analyses from the harvests and soil fertility analyses were conducted and the data was processed using the SISVAR software, evaluating significant differences using Tukey's test ($p < 0.05$). Together with the nutrient and fertility analyses, both the agronomic efficiency and the phosphorus recovery efficiency were also calculated according to Fageria et al. (2003).

RESULTS AND DISCUSSION

During the incubation period, all fertilized treatments showed superior growth compared to the control (no fertilization), indicating the effectiveness of the fertilizers in promoting plant development. Fresh and dry matter production showed quantitative and statistical differences between the two planting cycles, as shown on Table 1. In terms of plant growth and dry matter production, MAP and ORGMAP were the most effective treatments, producing dry mass values of 11.87g and 9.54g, respectively, in the first planting, approximately twice the production of the control treatment.

This high biomass output correlates with the faster phosphorus (P) release provided by MAP, which is known for its high solubility, supplying readily available P that supports initial plant establishment (Santos, 2012). The biochar-based ORGMAP also showed strong results, benefiting from both the immediate nutrient availability from MAP and the biochar's retention properties, which may prolong nutrient availability over time.

Thermophosphate and ORGTermo treatments, on the other hand, as shown in Table 1, resulted in lower biomass production, with values closer to the control, suggesting slower P release. Thermophosphate, which has a lower solubility than MAP, releases phosphorus gradually, making it less effective for short-cycle crops like corn (Braga, 2006). In a long-term cultivation scenario, however, these fertilizers might show increased benefits as the slow nutrient release aligns better with longer plant development cycles.

Table 1. Average dry matter of aerial parts for the two corn plantings carried out.

Treatment	1° Planting		2° Planting	
	Fresh Weight	Dry Weight	Fresh Weight	Dry Weight
	g			
Control	31,46 **c**	5,33 **c**	5,27 **a**	1,32 **a**
MAP	62,95 **a**	11,87 **a**	4,14 **ab**	1,10 **ab**
Thermophosphate	38,57 **bc**	7,44 **bc**	3,64 **b**	0,91 **b**
ORGMAP	54,15 **ab**	9,54 **ab**	4,36 **ab**	1,12 **ab**
ORGTermo	32,80 **c**	6,27 **bc**	3,76 **ab**	0,96 **ab**
CV (%)	16,05	22,02	16,78	15,43

Numbers followed by the same letter in the column indicate that the weights do not differ significantly by Tukey 5%.

The P accumulation observed was higher in the MAP and ORGMAP treatments in the first cycle (Figure 1a), with MAP having a faster P release, resulting in greater plant absorption. In the second cycle (Figure 1b), ORGMAP showed higher P accumulation but still statistically equal to the MAP treatment, suggesting that the slower release of the biochar-based fertilizers favors prolonged P absorption, a differential in longer-cycle crops.

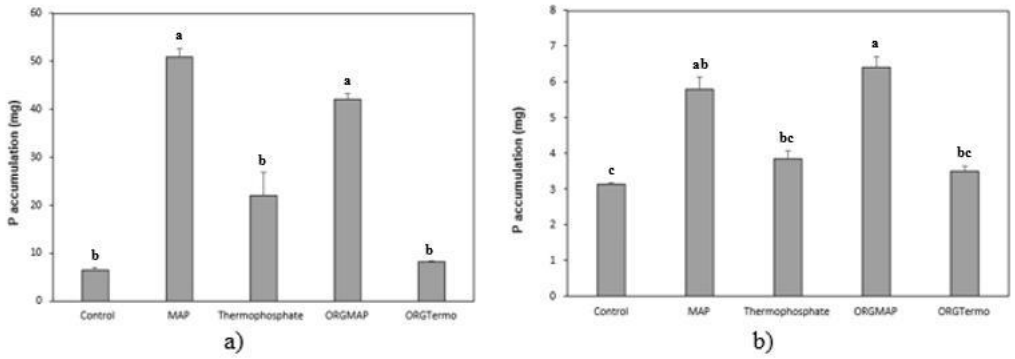

Figure 1. Accumulation of P in plants from the first (a) and second (b) planting for each treatment. Bars indicate the standard error of 4 repetitions and the columns with the same letter on top of the bars indicate that the P accumulation do not differ significantly by Tukey 5%.

As indicated on Table 2, MAP and ORGMAP had the highest agronomic efficiency (AE) rates, while thermophosphate and ORGTermo had lower efficiency due to lower water solubility of P, that delays nutrient release and reduces fertilizer effectiveness in short-cycle crops. The agronomic efficiency index (AEI) suggest that the gradual release of P by the biochar favors nutrient availability in longer-cycle crops. MAP and ORGMAP stood out with PRE, while thermophosphate and ORGTermo showed lower P recovery, consistent with the slow release of these fertilizers.

Table 2. Agronomic efficiency (AE), agronomic efficiency index (AEI) and phosphorus recovery efficiency (PRE) of each phosphorus treatment.

Treatment	AE (%)	AEI (%)	PRE (%)
MAP	65,42 **a**	100 **a**	44 **a**
Thermophosphate	21,05 **b**	100 **a**	15 **bc**
ORGMAP	42,15 **ab**	64,37 **a**	35 **ab**
ORGTermo	9,37 **b**	44,55 **a**	17 **c**
CV (%)	50,56	52,72	39,86

Numbers followed by the same letter in the column indicate that they do not differ significantly by Tukey 5%.

The soil fertility analysis (Table 3) showed that thermophosphate and ORGTermo provided higher residual P concentration in the soil, due to its slow release and high soil fixation rate. ORGTermo, on the other hand, showed higher potassium (K) concentration, statistically differentiating from other treatments. The organic carbon analysis showed no statistically significant difference between treatments, likely due to the short incubation time, which limits the impact of biochar on the soil, that could be more evident in long-term studies.

Table 3. Analysis of soil fertility after the plantings.

Teatment	P	pH	K	Org. Carb.
	mg/dm³	1:2,5	mg/dm³	g/kg
Control	6,07 c	5,22 c	14,23 b	2,67 a
MAP	72,53 bc	5,42 bc	16,57 b	2,52 a
Thermophosphate	213,17 a	6,92 a	19,30 b	2,50 a
ORGMAP	60,53 bc	5,60 bc	9,85 b	3,17 a
ORGTermo	148,67 ab	6,32 ab	33,44 a	2,07 a
CV (%)	55,03	6,90	30,58	22,07

Numbers followed by the same letter in the column indicate that they do not differ significantly by Tukey 5%

CONSIDERATIONS

During the incubation period, treatments with fertilizers, especially MAP and ORGMAP, promoted vigorous growth of corn plants compared to the control group. Both MAP and ORGMAP showed higher phosphorus content in the plants, suggesting more efficient nutrient absorption. In contrast, thermophosphate and ORGTermo, being less soluble, exhibited lower effectiveness. The fertilizers showed positive influence on the soil, with thermophosphate and ORGTermo increasing phosphorus concentrations. Thus, in this study, biochar-based fertilizers emerged as viable alternatives to conventional fertilizers, not only for plant growth but also for soil health in more sustainable agricultural practices.

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