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Doses and sources of phosphorus in the maize with and without polymer coating in the mono-ammonium phosphate

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Abstract. The Brazilian soils have low levels of phosphorus available, due to high acidity, therefore, is fundamental the application of phosphate fertilizers for high yields. The objective was to evaluate the efficiency of phosphate fertilizers with mono-ammonium phosphate (MAP) associated with two doses and two sources of phosphorus in corn. Experiment was carried out under no-tillage system in Nov/2010, in Ijaci - MG. The experimental design was randomized block, 2x2 factorial + 1 (2 P rates: 70 and 140 kg P₂O₅ ha⁻¹, 2 P sources: MAP and MAP-coated with Policote® and the witness without P₂O₅). It was used the hybrid GNZ 2004. The evaluations consisted in the measuring of the plant height at 30 days after emergence (PH), leaf phosphorus content (P%), grain yield (GY) and the agronomic efficiency of the applied phosphorus (EIPA). The highest dose of P₂O₅ provided increments in the AP and P% PG. The different sources of phosphorus affect the characteristics studied in a similar manner and were independent of the source of MAP. The substitution of phosphorus from the MAP by the MAP Coated with Policote® or even in the absence of fertilizer did not affect the efficiency of the fertilizer evaluated by traits.

Keywords: Zea mays. Phosphorus, Phosphate fertilizer, Phosphorus polymerized.

Introduction

In the Brazilian soils, phosphorus "fixation" (P) occurs by the bond formed with the clay and / or the precipitation of the same together with iron (Fe) and aluminum (Al). Phosphorus, due to its complex dynamics in acidic and weathered soils, presents low efficiency of use, making it necessary to apply high amounts of phosphate fertilizer to meet the demands of the crops. The efficiency of fertilization with phosphorus is low, because of what is added to the soil, most of it becomes immobile or unavailable and only 10% of the phosphorus from fertilization is recovered by the plants (CIARELLI et al. 1998).

In Brazil, phosphate mineral fertilizers are important for maintenance or increase of crop productivity, and there is a need for further studies to verify the efficiency of phosphorus doses and sources, aiming to obtain high yields in maize in different growing conditions. For the adequate supply of the maize plant in order to obtain high yields, it is necessary to use high doses of phosphate fertilizers (COUTINHO et al., 1991).

The most commonly used sources of phosphorus in agriculture are water-soluble phosphates, such as single and triple (ST), monoammonium phosphate (MAP) and diammonium phosphate (DAP) superphosphates (Bortolon et al., 2014). The use of polymerized phosphorus coating the MAP has been presented as a new option in reducing the adsorption of P by soil colloids. The gradual release promoted by the coating of the nutrient causes that the contact of this with the oxides of Fe and Al and the clay is reduced, thus not forming stable

compounds which would decrease the availability in the soil (FIGUEIREDO et al., 2012).

The controlled release fertilizers are those that delay the initial availability of the nutrients through different mechanisms, in order to make them available to the crops for a longer period of time and optimizing the absorption by the plants, reducing losses. Several types of fertilizer granule coatings have been tested, with varying results (BANSIWAL et al., 2006; ZHANG et al., 2006, ZAVASCHI, 2010, VALDERRAMA et al., 2011, CIVARDI et al., 2011; FIGUEIREDO et al., 2012).

There are still few researches in the Brazilian literature evidencing the use of polymerized phosphorus in MAP coatings in commercial fertilizers. However, because it is a product in the beginning of research, little is known about its behavior in acid soils. The objective was to evaluate the agronomic efficiency of phosphatic fertilizers as a function of doses and sources of phosphorus with conventional MAP or polymer coated in the maize crop under no tillage system.

Methods

The experiment was installed on November 18, 2010 in Ijaci-MG, in soil classified as Distroferric Yellow Red Latosol (EMBRAPA, 2013). The results obtained with the soil chemical analysis (0-20 cm depth) were: pH in H₂O = 5,5; P = 4.6 mg dm⁻³; K = 72 mg dm⁻³; Ca = 12 mmol dm⁻³; Mg = 5mmol dm⁻³; V% = 42.5; organic matter = 25 g kg⁻¹ and clay content of 57 dag kg⁻¹. The area used to conduct the experiment was cultivated under no tillage

system, desiccated with Roundup herbicide 15 days before planting. Weed control was carried out at the five-leaf expanded stage using the atrazine blend at the dosage of 3.0 L ha⁻¹ and nicosulfuron at the dosage of 0.5 L ha⁻¹ applied at 30 days after sowing in post-emergence of weeds. All other cultural dealings were made when necessary. The predominant climate in the municipality is classified as mesothermic, with average annual temperatures of 19.3 °C, mean precipitation of 1,411 mm, with 70% of this total concentrated in the months of December to March. Rainfall data were favorable for maize crop development (FIGURE 1).

Five treatments were evaluated in a 2x2 + 1 factorial scheme, with two phosphorus doses: 70 and 140 kg P₂O₅ ha⁻¹, associated to two sources of phosphorus: MAP (10-

54-00) and MAP coated with Policote® polymer (09 -48-00) plus one additional treatment (without phosphate fertilization) (TABLE 1). The experimental design was a randomized block design with four replications. The experimental plot consisted of four rows of 5 m each and spacing of 0.8 m, the plot being useful, the two central lines. The corn hybrid GNZ 2004 was used with a population after thinning 60,000 plants per hectare. Fertilization was calculated based on the expectation of obtaining high yield corn grain (CFSEMG, 1999). In addition to the treatments, the doses of 40 kg of N ha⁻¹ and 80 kg of K₂O ha⁻¹ were supplied using Urea and KCl. In the cover fertilization 135 kg N ha⁻¹ and 90 kg K₂O ha⁻¹ were supplied, using Urea and KCl, when the plants were with four leaves expanded.

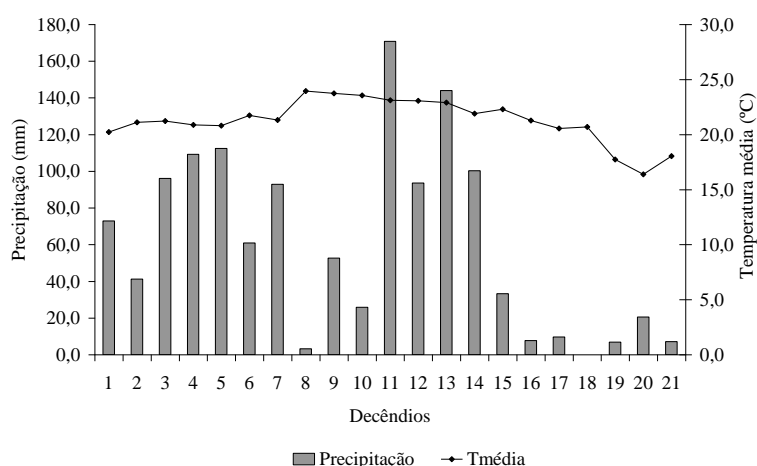


Figure 1. Average temperature and precipitation in Lavras, MG, from November 18, 2010 to June 17. Dates obtained in the Bioclimatology sector of UFLA.

Table 1. Description of the treatments evaluated in the experiment.

Treatments:	Doses P ₂ O ₅ (kg ha ⁻¹):	Sources:
1	70	MAP
2	140	MAP
3	70	MAP revestido por Policote®
4	140	MAP revestido por Policote®
5	0	-

MAP: 10-54-00; MAP coated with Policote®: 09-48-00

The following characteristics were evaluated: a) Plant height (AP) - measured in five plants in the plot area at 30 days after emergence (DAE), from the soil to the insertion in the atrium of the last fully expanded leaf; b) Leaf phosphorus content (% P): The opposite leaf was collected and below the first spike without the central vein of six plants of the plot area, in stage R2 (flowering). The leaves harvested in each plot were washed and dried in a forced circulation oven at 70°C, until constant weight, to determine the dry matter. Samples of the material of each plot were ground and sent to the Laboratory of Foliar Analysis of the Department of Chemistry of UFLA for the determinations of phosphorus contents in the dry matter of the leaf. By means of the nitric-perchloric extract, the phosphorus levels were determined (MALAVOLTA et al., 1997); c) Grain Yield (GY) - were harvested the ears of the plot area that were threshed and the grains heavy. Subsequently, its moisture content was determined. The grain yield data were corrected to standard moisture of

13% and transformed to kg ha⁻¹; c) Efficiency index of applied phosphorus (IEAP) - calculated according to the formula: IEAP = (Productivity with P, in kg ha⁻¹ - Productivity without P, in kg ha⁻¹) / Applied dose of P in kg ha⁻¹.

Tests of additivity of the model, normality of errors and homogeneity of variances were performed. There were no restrictions to the assumptions of the analysis of variance, the data were submitted to analysis of variances and the means were compared by the Duncan test at 5% of probability of occurrence of errors, through the statistical program SISVAR (FERREIRA, 2011).

Results and discussions

For plant height at 30 days after emergence (DAE), foliar phosphorus content and grain yield, significant differences were observed (P <0.05) between treatments (TABLE 2). The response to the application of

phosphorus to the agronomic characteristics was verified, since the source of the control versus factorial variation was significant, evidencing the response of the treatments contained in the factorial to the application of phosphorus and the superiority of these in relation to the control without phosphorus. For plant height and leaf phosphorus content, there were significant differences for phosphorus doses and sources. For grain yield, there were differences between the doses of phosphorus. In the case of the applied phosphorus agronomic efficiency indexes (IEAP), there were no significant differences for the sources of variation. Estimates of the coefficient of variation (CV) between 4.67 and 14.77 indicate good experimental precision for most agronomic characteristics (PIMENTEL GOMES, 2009). Except for the IEAP where the high CV value (> 20%), it is probably due to obtaining discrepant values, very low and or very high in some plots.

In the analysis of the average results of plant height, phosphorus content, grain yield and agronomic efficiency index of the phosphorus applied considering the different doses of phosphorus, it was verified that there were differences between the doses of phosphorus for most of the characteristics (TABLE 3). This indicates that the variation in the doses of phosphorus provided an improvement in the height of plants at 30 DAE, in the levels of foliar phosphorus and in the yield of grains, being that for these characters the dose of 140 kg P₂O₅ ha⁻¹ was superior to the dose 70 kg P₂O₅ ha⁻¹, demonstrating the response of maize to the application of phosphorus. Only for the agronomic efficiency index of the applied phosphorus (IEAP) there were no differences between the doses of phosphorus for these characters per unit in kg of P₂O₅ applied in relation to the control.

Table 2. Summary of analysis of variance for plant height at 30 DAE (PH), phosphorus content (% P), grain yield (kg ha⁻¹) and applied phosphorus agronomic efficiency index (IEAP).

F. V.:	GL	Q. M.			
		PH(cm)	% P	GRAIN YIELD (Kg ha ⁻¹)	IEAP
Blocks	3	28,44*	0,00003	707032,78	119,00
Treatments	4	58,17**	0,00114**	2880153,25**	-
Doses (D)	(1)	92,64*	0,00034**	4293505,16*	0,89
Sources (S)	(1)	78,76*	0,00146**	7493,93	4,99
D x S	(1)	2,64	0,00015	133811,46	17,89
Control versus Factorial	(1)	58,65**	0.001051**	7085802,44**	-
Error	12	6,92	0,000153	475036,61	79,37
C.V. (%)		8,12	4,67	14,77	63,22
Average		32,42	0,26	6665,62	14,09

*** Significant F-test at 1% or 5% probability, respectively.

TABLE 3. Mean plant height at 30 DAE (PH), foliar phosphorus content (% P), grain yield (kg ha⁻¹) and applied phosphorus agronomic efficiency index (IEAP), considering the different doses of phosphorus.

Doses P ₂ O ₅	PH (cm)	% P	GRAIN YIELD (kg ha ⁻¹)	IEAP
0	29,03 c	0,25 c	5475,18 c	-
70	32,39 b	0,26 b	6445,21 b	13,85 a
140	35,98 a	0,27 a	7481,25 a	14,32 a

The averages followed by the same letter do not differ statistically from each other by the Duncan test at the 5% probability level.

There were increases in plant height, foliar phosphorus content and grain yield with increasing P doses, with maximum values being 35.98 cm; 0.273% P and 7481 kg ha⁻¹ of grains, respectively, for the characteristics and obtained with the application of 140 kg ha⁻¹ of P₂O₅. The increase of the phosphorus doses reflects a higher availability of P₂O₅ in the soil, contributing to the increase of the dry matter yield, foliar P content, affecting the distribution of photo assimilates to the reproductive organs, and consequently, the translocation of P is especially in dry conditions, since they contribute to the final grain yield (DORDAS, 2009).

The results of grain yield of corn obtained in this work corroborate those obtained by other authors who reported the corn response in grain yield to increasing doses of phosphorus (COUTINHO et al., 1991; SOUZA et al., 1997; ERNANI et al. 2000). This also found significant responses, which were found to be significant in the grain yield with the application of phosphorus in relation to the phosphorus controls. The average for all treatments using phosphorus was higher in yield of 1488 kg ha⁻¹ of corn grains than the control.

The results of TABLE 4, considering the two sources of phosphorus supply (MAP and MAP coated with Policote), showed differences between the different sources of phosphorus supply for plant height and leaf

phosphorus content. This indicates that the form of MAP phosphoric delivery with Policote provided higher plant height at 30 DAE, in the order of 35.5 cm, that is, a higher initial growth of the culture in relation to the MAP source. Results that are similar to those obtained by Vila et al. (2010), who obtained higher values of height of corn plants in saturation by bases equal to 51.41%. The highest leaf phosphorus content of 0.27% P was found for the source of the supply of phosphate MAP coated with Policote, which is more beneficial for this characteristic in relation to the MAP source.

Regarding the grain yield and the agronomic efficiency index of the applied phosphorus, these did not present differences between the sources of phosphorus. The results of grain yield obtained in this study were different from those obtained by Sousa and Lobato (2003); Sousa and Lobato (2004); Valderrama et al. (2009); Agostinho et al. (2010) and Figueiredo et al. (2012), who found responses in grain yield with the application of phosphorus coated with polymers. It is important to emphasize that these authors worked with very low levels of phosphorus in the soil when compared to the levels observed in this work of 4.6 mg dm⁻³ P, considered low, being very close to the average level of 5 mg dm⁻³ P in the soil alone (CFSEMG, 1999)

TABLE 4. Mean plant height at 30 DAE (cm), foliar phosphorus content (% P), grain yield (kg ha⁻¹) and applied phosphorus agronomic efficiency index (IEAP), considering the different sources of phosphorus.

Sources P ₂ O ₅	PH (cm)	% P	GRAIN YIELD (kg ha ⁻¹)	IEAP
-	29,03 c	0,25 c	5475,18 c	-
MAP	31,06 b	0,26 b	6941,59 a	13,53 a
MAP com Policote	35,50 a	0,27 a	6984,87 a	14,65 a

The averages followed by the same letter do not differ statistically from each other by the Duncan test at the 5% probability level.

Increases in grain yield were observed by Figueiredo et al. (2012) in soil with a content of 0.2 mg dm⁻³ of P using the MAP coated with the Kimcoat polymer, which promoted better performance of maize, with respect to productivity, dry matter yield and plant height, compared to conventional MAP. The highest differences were observed in the 40% and 50% base saturations, in which the coated MAP promoted an increase in grain yield of 3.40 and 3.48 t ha⁻¹, respectively, in relation to the conventional MAP.

In a study by Valderrama et al. (2010) application of polymer-coated MAP provides higher corn grain yield when compared to conventional MAP. Increases in dry matter and grain yield of corn were verified by Agostinho et al., (2010) with the application of MAP coated with polymer, when compared to conventional MAP. According to Sousa and Lobato (2004), the best performance of the coated fertilizer occurs at 50% base saturation in highly weathered soils such as the Cerrado. Although the saturation by bases in this work (45.5%) is close to this value, the content of 4.5 mg dm⁻³ P in the soil is considered low P content in the soil and this value is very close to the average P content in the soil (5 mg dm⁻³), thus not obtaining responses in corn grain yield.

According to the authors cited, the use of both fertilizers provides increases in maize productivity, due to the controlled release of absorbable phosphorus along the cultural cycle, promoted by the MAP coating and also the increase of base saturation to values above 60%, decreases the efficiency of the polymer, probably by saturation of the exchange sites of these polymers with cations such as Ca and Mg, facilitating the precipitation of soluble phosphorus by the excess of these cations in the soil.

The MAP and MAP sources with Policote provided yields of 6941 and 6984 kg ha⁻¹ of grains, respectively, for phosphorus sources. The results obtained in this work are similar in terms of grain yield, due to the phosphorus content in the soil very close to the value considered in the medium, so it is not possible to detect grain productivity responses of the coated MAP in relation to the conventional MAP used in the formulation of fertilizers NPK concentrates. These productivity values are considered high for the region in which the experiment was installed, considering that the average yield of the first crop of 2010/11 in Minas Gerais was 4,953 kg ha⁻¹ (CONAB, 2013).

Conclusions

The increase of the phosphorus doses gave rise in most of the agronomic characteristics (PH, % P and GRAIN YIELD).

The different sources of phosphorus affected the characteristics studied in a similar way and were independent of the MAP source (coated or conventional).

The substitution of the phosphorus from the conventional MAP by the Policote®-coated MAP in sowing fertilization did not compromise the efficiency of the fertilizers evaluated by the agronomic characteristics.

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