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INCREASING RATES OF PHOSPHATE FERTILIZER WITH AND WITHOUT CONTROLLED RELEASE ON CORN AND SOYBEAN IN THE BRAZILIAN CERRADO REGION

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ABSTRACT

The objective of this study was to evaluate the efficiency of controlled release technology as well as testing different rates for P fertilization. This research was carried out in Midwest Brazil in the Cerrado region. The soil is characterized as a Ferralsol. We tested two commercial fertilizers with and without P controlled release technology and application rates of 50, 75, 100 and 125% of the recommended rate for each fertilizer. Our results demonstrated that phosphate fertilization significantly increased corn yield components from the second season after the operation. We could see that applications of 50% of the recommended rate resulted in the same crop yield levels of the higher rates (75, 100 and 125%) for both fertilizers. The use of controlled release technology did not result in higher crop yield levels for soybean and corn. The high soil fertility levels of the experimental area may be one of the main responsible for the non-significant effects. We conclude that in areas with high soil fertility in the Cerrado region, a maintenance fertilization with lower application rates is already enough for maintaining high crop yields. Higher rates of P fertilization as well as the use of controlled release technology did not provide better crop yields in this area.

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INTRODUCTION

The soybean (*Glycine max*) and corn (*Zea mays*) crops are the highlighted among the main crops in the world. Phosphatefertilization is one of the main responsible for crop yield (Fageria, 2016). It has become important especially in the Cerrado region due to the natural low fertility levels (de Sousa and Lobato, 2003). However, a significant part of this nutrient applied is not absorbed by the plants, being lost by mainly immobilization (Prochnow*et al.*, 2006) or leaching (Jalali and Kolahchi 2009). This lost increases the costs of fertilizers and it can cause environmental pollution by water eutrophication (Daniel *et al.*, 1998). For minimizing such problems, several companies launched technologies for reducing nitrification and controlling nutrient release. The focus of researchers are to adjust the standard of nutrients release in consonance with the plant needs (Timilsena *et al.*, 2015). Phosphorous is also a limited resource since the phosphate rock is the main material used for the fertilizer production. At some point, the demand will exceed the supply capacity. Therefore, the increase in phosphorous use efficiency is of extreme importance, since only 15 to 20% of the applied phosphorous is absorbed by the crops (Karunanithi *et al.*, 2015).Results with phosphate-controlled release are divergent in the literature,with some authors demonstrating increases in crop productivity (Liu and Lal 2014; Herrera *et al.*, 2016), negative effects (Degryse *et al.*, 2013), and no effect (Arrobas and Rodrigues 2013). Thus, we aimed at understanding the efficiency of phosphorous fertilization in the Cerrado region with and without controlled release. We tested the commercial fertilizers Stratum® (24% of phosphorous) and Top Phos® (28% of phosphorous protected with polymer for controlled release) applied in different rates on soybean crop.

MATERIALS AND METHODS

The experimental area is located at the Acaray Farm in Sapezal – MT, Midwest Brazil (13º29'19'S, 58º76'62''W). The average altitude is 545 m, sloping varies from 0 to 2%. The climate is characterized as Aw according to Koppen classification (Peel *et al.*, 2007).

The soil is characterized as a Latossolo Vermelho-Amarelo (Brazilian classification EMBRAPA (2013) equivalent to a Ferralsol (WRB classification, IUSS Working Group (2006). The crops are managed under no-till system since 2002. Every fertilization is broadcast applied since 2008. The experimental design was carried in in completely randomized blocks with nine treatments and five replicates. The parcels measurements are 50 x 50 m. We carried out the evaluations in the inner 20 m^2 (10 x 2 m) of each parcel. The fertilizers were broadcast applied in October 2, 2013 using a Hercules® seeder 5.0 4 x 4 hydro. The rates for phosphorous fertilization followed the agronomic recommendations based in the phosphorous mean content from the soil fertility analysis (Table 1) (EMBRAPA, 2013). The treatments were as follow: control (no phosphate fertilization), 50, 75, 100 and 125% of the rates recommended for Stratum® (24% of phosphorous) and Top Phos® (28% of phosphorous, protected by polymer for controlled release). For Stratum® (00-24-00 NPK) we applied 175, 263, 350 and 438 kg ha^{-1} representing 50, 75, 100 and 125 of the recommended rate, respectively. For the Top Phos® (NPK 03-28-00), the same percentages were achieved with applications of 150, 225, 300 and 375 kg ha^{-1}.

examine the data normality. Afterwards, the variables were submitted to Fisher-Snedecor test, Duncan and polynomial regression.

RESULTS

For all the analyzed variables, we observed homoscedasticity and normality of the variances. Therefore, we performed no data transformation. We observed no significant differences in the control plots regarding initial plant population (20 days after the emergence – DAE) and crop yield components either for corn as soybean. No significant effects of blocks were observed. We could not observe a significanteffect ($p > 0.05$) of both commercial fertilizers for crop yield components of soybean (Table 2). On the other hand, significant increases of corn yield component (i.e., crop yield and number of pods) in comparison to the control were observed due to the phosphate fertilization with and without controlled release (Table 3) in different rates.We did not observe any significant differences between the phosphate fertilizers regardless the rate applied. We observed significant polynomial trends ($p<0.05$) for the parameters number of pods and crop yield for corn (Figure 1).

Table 1. Soil fertility analysis at the 0 – 0.2 m depth performed in 2013 in Sapezal – MT, Midwest Brazil

pH[(1)]	H+Al	Ca	Mg	K	CEC[(2)]	P[(3)]	BS[(4)]	Al Sat[(5)]	SOM[(6)]
		----------------- $mmol_c\ dm^{-3}$ -----------------				$mg\ dm^{-3}$		-----------------%----------------	
5.0	49.6	40.7	12.4	1.5	104.2	15.8	52.3	1.8	5.0

[(1)] pH in $CaCl_2$ solution 0.01 mol l^{-1}; [(2)]CEC: cation exchange capacity at pH 7; [(3)]P extracted by $Mehlich^{-1}$ solution; [(4)]SB: base saturation; [(5)]Al Sat: Al saturation; [(6)]Soil organic matter. Clay content = 20%.

Table 2. Initial population (20 days after emergence – DAE) and crop yield components of soybean (*Glycine max*) cultivar AS3810 RR2 IPRO®, with increasing rates of phosphate fertilization Stratus® (i.e., 100% = recommended rate = 350 kg ha^{-1}; NPK = 00-24-00) and Top Phos® with controlled release (i.e., 100% = recommended rate = 300 kg ha^{-1}; NPK = 03-28-00), crop season 2014, Sapezal – MT Midwest Brazil.[1]

Treatments	Initial population (plants ha^{-1})	Final population (plants ha^{-1})	Pods per plant	Grains per pod	Mass of thousand grains (g)	Crop Yield (Mg ha^{-1})
Control[2]	285,278	277,514	41	2.7	139	4,306
Stratum® (50%)[3]	285,472	276,828	41	2.8	139	4,454
Stratum® (75%)	288,889	281,490	42	2.8	140	4,598
Stratum® (100%)	299,445	291,004	42	2.8	139	4,692
Stratum® (125%)	299,778	292,345	41	2.8	140	4,740
Top Phos® (50%)	294,667	292,211	41	2.7	140	4,578
Top Phos® (75%)	293,972	281,559	42	2.8	139	4,590
TopPhos® (100%)	291,633	284,417	41	2.8	139	4,513
TopPhos® (125%)	289,167	284,675	42	2.8	140	4,704
CV (%)	4.1	7.0	6.4	6.1	1.6	13.9

1- Not significant for blocks and treatments for all variables analyzed ($P> 0.05$).
2 - No phosphate fertilization.
3 - Recommended phosphate fertilization rate = 350 kg ha^{-1} for Stratum® and 300 kg ha^{-1} for Top Phos®.

In the crop season of 2013-14, we cultivated the soybean AS3810 RR2 IPRO®, seeded in October 3, 2013 and harvest in January 01, 2014. The phosphorous was only applied on soybean crop. All the crop management followed the recommendations of the Agronomist Engineer responsible for the area. We analyzed the initial population (20 days after the emergence – DAE) and the crop yield components. All the evaluations were manually performed. The calculation of the mass of thousand grains and the crop yield was performed considering 1% of impurities and humidity corrected for 14%. The humidity was measured with the equipment G800 Gehaka®. The mass of thousand grains was measured with a digital scale 500 Diamond®, with capacity from 0.1 to 500 g. The measurement of crop yield was performed using a digital scale DP50 Ramusa®, with capacity for 50 kg. The results were submitted to Harley test for verifying the homoscedastic of the variances. We also performed the Shapiro-Wilk test to

The maximum number of pods was achieved with 99 and 86% of the recommended rate for Stratum® and Top Phos®, respectively. The highest crop yields were achieved with 81% of the recommended rate for both fertilizers. We did not observe any significant trend for soybean and for the other parameters evaluated on corn.

DISCUSSION

The significant increase of crop yield components of corn in our experiment highlight the importance and efficiency of phosphate fertilization in the Cerrado region. The lack of response from soybean crop to the fertilizer application may be due to the long-term effect of phosphate application in soil (Fageria 2016). Since the fertilizers were applied just before the soybean cultivation, the plants may have not taken advantage of the nutrient supply.

Table 3. Initial population (20 days after emergence – DAE) and crop yield components of corn (*Zea mays*) hybrid DKB 390 PRO2®, with increasing rates of phosphate fertilization Stratus® (i.e., 100% = recommended rate = 350 kg ha^{-1}; NPK = 00-24-00) and Top Phos® with controlled release (i.e., 100% = recommended rate = 300 kg ha^{-1}; NPK = 03-28-00), crop season 2014, Sapezal – MT Midwest Brazil

Treatments	Initial population (plants ha^{-1})	Pods (ha)	Grains per pod	Mass of thousand grains (g)	Crop Yield (Mg ha^{-1})
Control[1]	70,092 a[3]	66,782 b	485 a	292 a	9,457 b
Stratum® (50%)[2]	70,089 a	69,022 a	508 a	311 a	10,893 a
Stratum® (75%)	70,116 a	69,118 a	503 a	315 a	10,930 a
Stratum® (100%)	71,867 a	70,973 a	494 a	314 a	11,043 a
Stratum® (125%)	70,089 a	69,247 a	495 a	310 a	10,609 a
Top Phos® (50%)	71,796 a	71,060 a	497 a	312 a	11,026 a
Top Phos® (75%)	70,142 a	70,336 a	499 a	309 a	10,809 a
TopPhos® (100%)	71,350 a	70,409 a	496 a	307 a	10,697 a
TopPhos® (125%)	71,268 a	70,515 a	496 a	306 a	10,713 a
CV (%)	1.9	2.0	4.6	6.0	6.8

1 - No phosphate fertilization.
2 - Recommended phosphate fertilization rate = 350 kg ha^{-1} for Stratum® and 300 kg ha^{-1} for Top Phos®.
3 – Means followed by different letters have significant differences for method of fertilization by the Duncan test ($P < 0.05$).

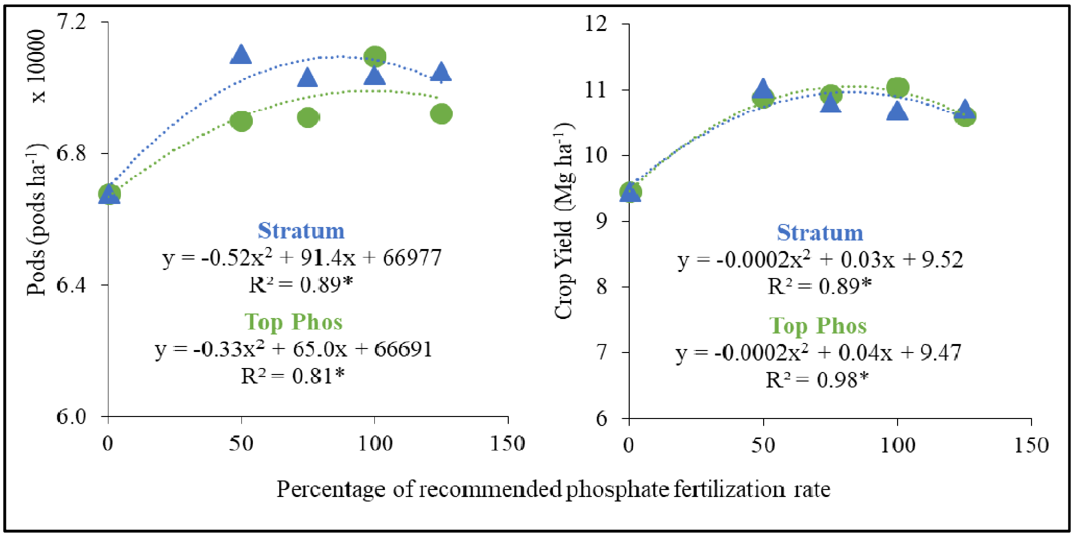

Fig. 1. Number of pods and crop yield of corn (*Zea mays*), hybrid DKB 390 PRO2®, with increasing rates of phosphate fertilization Stratus® (i.e., 100% = recommended rate = 350 kg ha^{-1}; NPK = 00-24-00) and Top Phos® with controlled release (i.e., 100% = recommended rate = 300 kg ha^{-1}; NPK = 03-28-00), crop season 2014, Sapezal – MT Midwest Brazil. * Significant at $p < 0.05$

The lack of significant difference between the rates of fertilizer application may be an important information for local farmers. The maximum values for corn yield (i.e., 81%) obtained below the recommended rate already demonstrates that such application dosages could be reduced. Although the polynomial adjustment was significant, from a practical perspective, the results obtained with 50% of the recommended rate were already similar to the higher dosages. These results show an important information for farmers from the Cerrado region, demonstrating that phosphate fertilization rates could be reduced up to 50% without resulting in loss of crop yield. This reduction could generate significant savings in fertilization operations. In addition, a reduction of phosphate fertilization may also provide an environmental benefit, since its leaching has been a major source of water eutrophication (Daniel *et al*., 1998). The high soil fertility levels of our experimental area may justify the lower responses to phosphate fertilization. The P broadcast application in our experiment may also had contributed to the higher efficiency of the phosphate fertilization as demonstrated by de Sousa and Lobato (2003) in the Cerrado Region. The authors showed that the broadcast application was more efficient than in the seeding row, mainly due to the higher P solubilization. The P soluble forms, when rapidly absorbed by plants, have lower chances of getting immobilized in soil particles (Prochnow *et al*., 2006).

Likewise, Caires *et al*. (2017) also demonstrated that the broadcast P fertilization at the sowing of cover crops increases its efficiency in elevating soybean and black oat yields. Because our study site had a relatively low clay (200 g kg^{-1}) and a high P contents (15.8 mg dm^{-3}), it may justify the lower response of the crops to increasing phosphate fertilization rates. Therefore, we demonstrated that under this field conditions, the application of phosphate fertilizers can be reduced, and higher application rates have no effect on soybean and corn yields. The lack of significant difference between the phosphate fertilization with and without use of the controlled release technology demonstrates the low potential of this technique in our experimental area in the Brazilian Cerrado. The controlled nutrient release has been highlighted as an important environmental fertilization practices as it avoids contamination by leaching(Timilsena*et al*., 2015). Different studies have demonstrated the efficiency of P controlled release in soybean and corn production (Liu and Lal 2014; Herrera*et al*., 2016). However, most part of these studies is developed with soils with low P content. In our experimental area, since the soil fertility levels were already elevated, it may had contributed for the no response of crop yield for the controlled release technology. Therefore, we emphasize that in areas with high soil fertility levels, the maintenance fertilization with lower rates of fertilization may be the best alternative for keeping the crop yields high.

Conclusions

We demonstrated that the phosphate fertilization could significantly increase crop yield components from the second season after the operation. We could observe that phosphate applications of 50% of the recommended rates resulted in similar crop yield levels of higher dosages. We highlight that in soils with a higher fertility level, higher rates of phosphate fertilization or the use of controlled release technology do not increase crop yields components.

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