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Research Article

Nodulation in bean under soluble phosphorus sources with and without polymer

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The availability of nutrients can affect the establishment of nodulation, among these, it is worth mentioning phosphorus (P). The impediment of fixation allows the availability of this element to be greater for the absorption of the culture. Thus, the objective was to evaluate the effect of two sources of phosphate fertilizers with and without polymer coating on nodulation in common bean. The experiment was carried out in a greenhouse, in the city of Patrocínio, using pots with a capacity of 3.8 dm^3, and the soil was collected at a depth of 0 cm-20 cm. The experiment was set up in a randomized block design, where the treatments consisted of the application of 70 kg ha^{-1} of P_2O_5 in the form of monoammonium phosphate (conventional and polymerized-Kimcoat®) and single superphosphate (conventional and polymerized-Kimcoat®) and the control, with four repetitions. The seeds were inoculated with Rhizobium tropici, strain SEMIA 4088. The nitrogen (N) dose was adjusted to 40 kg ha^{-1} and the potassium fertilization to 20 kg ha^{-1} of K2O for all treatments applied at planting. The evaluation was carried out at 35 days after plant emergence, measuring the production of shoot and root dry matter, number of nodules and leaf N and P content. Conventional MAP showed greater efficiency in increasing nodulation, mass shoot dry mass and root dry mass for the crop. The polymerized phosphate sources did not influence bean nodulation. The polymerized MAP resulted in the highest foliar N content. Regardless of the source, there was an increase in leaf P content. It was concluded that the polymerized phosphate sources still did not influence the nodulation of the culture.

Key words: Phosphate fertilizer, coated fertilizer, biological fixation

INTRODUCTION

Beans (*Phaseolus vulgaris L.*) are one of the main components of the Brazilian diet due to their high protein content. In addition, its composition has considerable percentages of phosphorus, iron, calcium, dietary fiber and vitamins B1 and B2. Brazil is the third largest producer of this legume with production stipulated for the 2020 crop of 3.1 million tons in an area of 2.6 million hectares (ha^{-1}) to be harvested, with an average yield of 857 kg ha^{-1} (IBGE, 2020). The states of Paraná, Minas Gerais and Goiás are the main producers of this crop, corresponding respectively for 25, 16 and 10.2% of the national production. Bean productivity is increased through Biological Nitrogen Fixation (BNF), which occurs through the symbiosis between legume roots and bacteria of the genus (Franco et al. 2002). These bacteria promote the fixation of atmospheric nitrogen, significantly reducing the cost of nitrogen fertilizers. It was demonstrate that FBN is known to be efficient in cowpea, which, when well nodulated, can dispense with fertilization with nitrogen (N) sources, in addition to achieving high yields (Freire Filho et al. 2005). Therefore, one of the best ways to increase crop productivity is to increase nodulation.

Among the edaphic factors that influence nodulation and BNF, facilitating or preventing this process, is the availability of nutrients. Among these, it is worth mentioning phosphorus (P), which, although it is extracted by the bean plant in smaller amounts compared to other macronutrients, is seen as the main limiting factor of the crop (Freire Filho et al. 2005). This nutrient is directly related to the formation of roots and consequently to the establishment of nodulation, as it increases the volume of root hairs and consequently the sites of infection for nitrogen-fixing bacteria (Okeleye et al. 1997).

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Thus, high doses of P are recommended, due to the low efficiency of fertilizers, which can be in the range of 20 to 30% of use. In this way, technological alternatives have been sought that provide greater efficiency of phosphate sources. For this purpose, sources with gradual or controlled release are used, which can help in less contact of this nutrient with soil colloids, preventing its fixation. The impediment of fixation allows the availability of this element to be greater for the absorption of the culture, which will better develop its roots, enhancing the nodulation.

Based on what has been exposed, the objective of the present work was to evaluate the effect of two sources of phosphate fertilizers: Mono Ammonium Phosphate (MAP) and Single Super Phosphate (SSP) with and without polymer coating (Kimcoat®) on nodulation in the bean plant.

METHODOLOGY

The work was carried out in a greenhouse in the city of Patrocínio, Minas Gerais, under geographic coordinates of 18°56'12.1"S and 46°58'43.5"W. According to (Köppen, 1928) the municipality has a tropical climate with dry winter (Aw), the average annual temperature is 21.4°C and the average annual rainfall is 1507 mm. Soil collected at a depth of 0-20 cm was used, presenting the following chemical characteristics: pH(H_2O)=5.3; pH($CaCl_2$)=4.8; Pme^{-1}(mg dm^{-3})=10.7; MO(dag kg^{-1})=2.4; B(mg dm^{-3})=0.17; Cu (mg dm^{-3})=1.2; Faith(mg dm^{-3})=39; Mn(mg dm^{-3})=15.3; Zn(mg dm^{-3})=1.1; K+(cmolcdm^{-3})=0.49; S-(mg dm^{-3})=17; Ca^{2+}(cmolc dm^{-3})=1.50; Mg^{2+}(cmolc dm^{-3})=0.30; Al3+(cmolc dm^{-3})=0.50; H+Al(cmolc dm^{-3})=3.8; V=37.6%; m=17.9%, obtained (EMBRAPA, 2009).

Soil correction was performed with dolomitic limestone (MgO=8.00%; CaO=42.65%; PN=95.75%; PRNT=80%) in order to raise the base saturation to 60%, 80 days before of planting. The N dose was adjusted so that all treatments had the equivalent of 40 kg ha^{-1}, using urea. Potassium fertilization was carried out at planting, applying 20 kg ha^{-1} of K_2O, in the form of potassium chloride. The seeds were inoculated with Rhizobium tropici, strain SEMIA 4088, at a dose of 250 mL 100 kg^{-1} of seed, before sowing.

Each experimental plot consisted of a plastic pot with a capacity of 3.8 dm³. Sowing took place on July 12, 2020, using the cultivar Perola-three seeds per pot, as well as the application of treatments. The treatments consisted of the application of 70 kg ha^{-1} of P_2O_5, and the control, as described in (Table 1). The experimental design was in Randomized Blocks (DBC), with four replications totaling 20 experimental plots.

Irrigation was performed daily, manually, so that 80% of the field capacity was supplied in compliance with evapotranspiration. The seedlings emerged five days after sowing. Five days after emergence, thinning was performed, leaving only one seedling per plot. The experiment was carried out for 40 days when the measurement of Dry Matter Production of Shoots (MMSPA), root (MMSR), Quantification of Nodules (NN) and determination of foliar content of N and P.

After being removed from the pots, the plants were washed with running water under a flat surface for better visualization. Then the nodules were highlighted and counted. The result was expressed in plant^{-1} nodules. To determine the dry matter mass, shoot and root were separated at the base of the stem. Subsequently, they were placed in previously identified paper bags and kept in an oven with forced air circulation at 65°C for 72 hours. After reaching constant mass, weighing was performed on a precision scale of 0.01 g, and the final result was expressed in g plant^{-1}. Finally, after weighing, the aerial part of the plants was used to perform the analysis of the leaves of N and P through sulfuric solubilization followed by the semi-micro Kjeldahl method and reading in the spectrophotometer respectively, according to the methodology (Brazilian Company of Agricultural Research, 2009). The result was given in g kg^{-1}. The data obtained were submitted to analysis of variance and the means were compared by the Tukey test, at 5% of significance, with the aid of the SPEED Stat statistical software (Carvalho et al. 2017).

RESULTS

For Root Dry Mass (MMSR), Shoot Dry Mass (MMSPA) and Number of Nodules (NN), significant results were found in (Table 2). The conventional MAP showed a greater increase in relation to the other sources, with an increase of 108%, 113% and 98.4% in relation to the control treatment regarding the production of Dry Mass of Root, shoot and Number of Nodes, respectively. The forms of polymer coated Single Super Phosphate (SST) and conventional SST did not differ from each other for any of the variables analyzed.

Table 1. Description of the treatments used in the phosphate fertilizer application experiment with and without polymer in bean nodulation. (Source: UNIPAM. Ducks of Mines, 2020).

		Nutrient concentration				
Treatments	**Description**	**N%**	**P205%**	**K20%**	**Here%**	**S%**
T_1	Conventional MAP	11	52	00	00	00
T_2	Polymerized MAP (Kimcoat®)	11	50	00	00	00
T_3	Conventional single superphosphate	03	17	00	16	11
T_4	Polymerized single superphosphate (Kimcoat®)	00	22	00	16	11
T_5	Control	-	-	-	-	-

Table 2. Root Dry Mass (MMSR), Shoot Dry Mass (MMSPA) and Number of Nodules (NN) in bean plants subjected to different sources of phosphate fertilizers with and without polymer coating. (Source: UNIPAM. Ducks of Mines, 2020).

Fertilizers	MSR (g plant^{-1})^2	MSPA (g plant^{-1})^3	NN / plant^2
Conventional Map	0.79 a	1.62 a	4.92 a
Polymerized Map	0.56 b	1.26 b	3.19 b
Super conventional	0.57 b	0.91 c	3.34 b
Super polymerized	0.53 b	0.88 c	2.72 b
Control	0.38 b	0.76 c	2.48 b
CV(%)	21.03	13.98	24.53

Note: 1-Means followed by distinct letters differ from each other by Tukey's test at 5%.
2-Data transformation: Box-Cox (x+1), λ=0.2.
3-Transformation of the data: Box-Cox (x+1), λ=0.48.

With regard to Root Dry Mass, the conventional MAP promoted a greater increase when compared to the other sources. This is due to the high solubility of the source, which makes the nutrient available more quickly, thus increasing its concentration in the soil solution. Therefore, more available in solution.

It appears that there was no significant difference between the polymerized sources. This result is possibly linked to the gradual or controlled release of the nutrient contained in the granule. How the bean crophas a high nutrient requirement, short cycle and little voluminous and superficial root system, it is necessary that there is a rapid release of nutrients, that is, use of sources with high solubility.

It was point out that when increasing the base saturation to 60%, the efficiency of the MAP coating is reduced (Figueiredo et al. 2012). This is due to the saturation of the exchange sites of these polymers with cations such as Ca and Mg, promoting, therefore, the precipitation of soluble P by the excess of these cations in the soil. For the bean crop, (Valderrama et al. 2009) did not find differences between conventional and polymerized single superphosphate for production components in soil with 60% base saturation.

The production of shoot dry matter was influenced by phosphate fertilization. The two MAP sources were superior to the SSP sources with and without polymer. In MAP source with polymer, the polymer again had a negative influence on the results, however it still proved to be more efficient in relation to SSP sources.

The conventional MAP obtained the highest production of shoot dry matter mass. As it is a highly soluble source, conventional MAP made the nutrient available to the plant faster than the polymerized source. This provided a greater amount of mass in the first weeks of greater nutritional demand of the plant, consequently allowing greater development of its leaf area. It was report that at the beginning of the cycle the plant invests its photoassimilates primarily in the differentiation of leaves (Almeida et al. 2003).

It was found that when applied at sowing the triple superphosphate fertilizer did not differ in relation to soybean dry matter production when purchased in the conventional way. The control treatment presented the lowest average for the production of shoot dry mass. This is explained by (Rodríguez et al. 1998). It was stated that the low availability of P reduces the leaf area, the number of leaves and limits their expansion. With the same results, it was reported that the dry matter of the aerial part increases significantly with the increase of phosphorus levels in the soil (Fageria, 1998).

It was described that high values of leaf area are of paramount importance for high production of photoassimilates that will be used for grain growth and, therefore, for higher productivity (Portes, 1996). It was showed that phosphate fertilization increased shoot production, which favored production components increasing productivity in the bean crop (Fageria et al. 2003).

Regarding the number of nodules, again the conventional MAP provided a higher average, obtaining the same pattern of results as the MSPA. These results are in agreement with (Silva et al. 2010) who found a correlation between the accumulation of MSPA and nodulation, revealing a positive effect of the increase in nodulation on the development of cowpea. With similar results, (Souza et al. 2008) in soybean, also found a positive correlation between the nodulation variables in relation to the quantity and mass of nodules and also the dry biomass of the aerial part. There was no significant difference in the number of nodules in the other treatments. Maximum values of 46 and 51 nodules estimated with single superphosphate and triple superphosphate at doses of 32.5 and 45.5 kg ha^{-1} of P twoTHE5, respectively in their conventional form. These results are similar to those obtained in cowpea (Xavier et al. 2008; Silva et al. 2010).

The optimal establishment of bean nodulation is crucial for the plant to assimilate nitrogen through biological fixation. It was reported that when well nodulated, cowpea can dispense with fertilization with nitrogen sources, in addition to achieving high yields (Franco et al. 2002). With similar results, highlighted that the increase in nodulation contributes substantially to increasing crop productivity (Freire Filho et al. 2005).

(Table 3) shows the results of leaf N and P content. Regarding the foliar N content, it appears that the robust MAP source showed a greater increase in relation to the control (6.11%). The control was not different from the SSP sources and the conventional MAP source due to the addition of urea in this treatment at the time of planting. These values indicate that P did not favor the accumulation of foliar nitrogen, since the control did not differ statistically from the other treatments (Gualter RM, 2011).

Table 3. Foliar analysis of nitrogen and phosphorus in bean plants subjected to different sources of phosphate fertilizers with and without polymer coating. (Source: UNIPAM. mine ducks, 2020).

Fertilizers	Leaf content N (g kg^{-1})	Leaf Content P (g kg^{-1})
Conventional MAP	45.98 ab[1]	3.18 a
Polymerized MAP	48.28 a	2.78 a
Super conventional	42.4 b	2.40 ab
Super polymerized	40.75 b	1.78 b
Control	43.33 b	0.78 c
CV(%)	5.83	22.74

Note: 1-Means followed by distinct letters differ from each other by Tukey's test at 5%.

These results contradict those found by (Fernandes, 2006). Emphasizing that P potentiates the FBN by inducing the development of the host plant, as well as the growth of nodules, increasing the activity of the rhizobia, providing a simultaneous increase in the accumulation of N. In addition, it was stated that this nutrient is directly related to the formation of roots that will establish nodulation, because it increases the volume of root hairs and therefore increases the sites of infection for nitrogen-fixing bacteria (Okeleye et al. 1997).

Phosphate sources positively influenced leaf P concentrations. The MAP with and without polymer were equal to each other and in relation to the SSP without polymer. Within the SSP sources, there was no influence from the polymer, as the sources of SSP with and without polymer were statistically equal. The control treatment did not differ from the other treatments, thus showing the plant's ability to absorb the element in conditions of good supply. These results are similar to those found by (Andrade et al. 1999) in the bean crop, who described that nitrogen, when associated with phosphorus, potentiates the plant's response to phosphorus application and improves its absorption. In addition, it was reported that the highest concentrations of P in the bean crop were verified when, in addition to fertilization in the planting with phosphorus, there was fertilization in top dressing with nitrogen and potassium (Filho, 2001).

CONCLUSION

The polymerized phosphate sources did not influence the nodulation of the culture. The MAP source, according to the results of the variables studied, proved to be a good source of fertilization for bean nodulation.

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