Aplicação foliar de molibdênio e cobalto na soja cultura: rendimento e qualidade de sementes

Foliar application of molybdenum and cobalt in soybean crop: yield and seed quality

DOI:10.34117/bjdv7n5-011

Recebimento dos originais: 07/04/2021
Aceitação para publicação: 03/05/2021

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ABSTRACT
The incorporation of new technologies has provided large yield increases, the most recent being related to the seed industry. Especially in large farms, in order to speed up the planting process and reduce the number of employees and the time of exposure of the seeds to adverse conditions, these are being purchased already treated with insecticides and fungicides or without industrial treatment. The present work had as objective to evaluate the foliar application of a commercial product containing molybdenum and cobalt in the soybean crop, aiming to increase the yield components and physiological quality of the seeds produced. The seeds were treated with Maxim fungicide and Avicta insecticide from the company Syngenta. Yield components (thousand seed weight, grain yield, number of pods per plant and number of seeds per pod) and physiological quality of seeds (first germination count, germination, accelerated aging, field emergence and tetrazolium) were analyzed.The experimental design was randomized blocks with four replications and six treatments with different doses.The results obtained for the variables thousand seed weight, number of pods per plant and grain yield were not influenced by the application of the different treatment doses. For the variable number of seeds per pod, the treatments had a significant effect, there was an increase up to the dose of 240 mL.ha-1 with the application of the product containing cobalt and molybdenum.The decrease in the number of seeds per pod from this dose may be due to the phytotoxic effect of cobalt. Excess cobalt can cause toxicity and symptoms are necrotic spots on cotyledons and leaves with chlorotic leaflets.For the variables regarding first germination count, germination and field emergence of the seeds produced, coming from plants that received the application of different doses of the product containing the micronutrients molybdenum and cobalt in the V5 stage of development of the soybean crop, there was a significant effect of application of the product.Regarding the accelerated aging test, no significant effect was observed in the different treatments.The molybdenum and cobalt doses have a positive effect on the physiological quality.

Keywords: *Glycine max* L., micronutrients, *Bradyrhizobium*, yield, physiological quality.

RESUMO
A incorporação de novas tecnologias proporcionou grandes aumentos de rendimento, sendo a mais recente relacionada com a indústria de sementes. Especialmente nas grandes explorações agrícolas, a fim de acelerar o processo de plantação e reduzir o número de empregados e o tempo de exposição das sementes a condições adversas, estas são adquiridas já tratadas com insecticidas e fungicidas ou sem tratamento industrial. O presente trabalho tinha como objectivo avaliar a aplicação foliar de um produto comercial contendo molibdénio e cobalto na cultura da soja, visando aumentar os componentes de rendimento e a qualidade fisiológica das sementes produzidas. As sementes foram tratadas com o fungicida Maxim e insecticida Avicta da empresa Syngenta. Foram analisados os componentes de rendimento (peso das sementes em mil, rendimento de grãos, número de vagens por planta e número de sementes por vagem) e qualidade fisiológica das sementes (primeira contagem de germinação, germinação, envelhecimento acelerado, emergência do campo e tetrazólio). O desenho experimental foi feito em blocos

aleatórios com quatro replicações e seis tratamentos com doses diferentes. Os resultados obtidos para as variáveis peso das sementes em mil, número de vagens por planta e rendimento de grãos não foram influenciados pela aplicação das diferentes doses de tratamento. Para o número variável de sementes por vagem, os tratamentos tiveram um efeito significativo, houve um aumento até à dose de 240 mL.ha-1 com a aplicação do produto contendo cobalto e molibdénio.A diminuição do número de sementes por vagem a partir desta dose pode ser devido ao efeito fitotóxico do cobalto. O excesso de cobalto pode causar toxicidade e os sintomas são manchas necróticas em cotilédones e folhas com folíolos cloróticos.Para as variáveis relativas à primeira contagem de germinação, germinação e emergência do campo das sementes produzidas, provenientes de plantas que receberam a aplicação de diferentes doses do produto contendo os micronutrientes molibdénio e cobalto na fase V5 de desenvolvimento da cultura da soja, houve um efeito significativo da aplicação do produto. Em relação ao teste de envelhecimento acelerado, não se observou qualquer efeito significativo nos diferentes tratamentos. As doses de molibdénio e cobalto têm um efeito positivo na qualidade fisiológica.

Palavras-chave: Glycine max L., micronutrientes, Bradyrhizobium, rendimento, qualidade fisiológica.

1 INTRODUCTION

The importance of soybeans nowadays is undeniable, the Brazilian production in the 2014/2015 harvest reaching 94,250.5 million tons (CONAB, 2016), a result achieved thanks to scientific advances and the availability of technologies in the production sector.

The incorporation of new technologies has provided large yield increases, the most recent being related to the seed industry. In this context, micronutrients, whose importance has been known for decades, have been used more routinely in fertilization for the most diverse soil, climate and cultural conditions in Brazil (LOPES, 1999).

It is noteworthy that of all the micronutrients necessary to the soybean development, molybdenum and cobalt are the most important (BRAGA, 2009), since they play a key role in the fixation of atmospheric nitrogen by *Bradyrhizobium* bacteria, which require both nutrients. Another function of molybdenum in plants is associated with nitrogen metabolism, being necessary for the synthesis and activation (functioning) of nitrate reductase, an enzyme that reduces nitrate in the plant.

In addition to molybdenum, cobalt is a micronutrient that influences the symbiotic fixation of nitrogen,and is part of the structure of B12 vitamins, necessary for the synthesis of cobalamin, which participates in the metabolic reactions to the formation of leghemoglobin, which, in turn, has great affinity with oxygen and regulates its concentration in the nodules preventing the inactivation of the enzyme nitrogenase (CERETTAet al., 2005).

As the amount of molybdenum and cobalt required for plant establishment and nutrition is very low, its application in seed treatment has long been the most practical, efficient and economical form of application (VIDOR AND PERES, 1988). However, especially in large farms, in order to speed up the planting process and reduce the number of employees and the time of exposure of the seeds to adverse conditions, these are being purchased already treated with insecticides and fungicides or without industrial treatment. Therefore, leaving the micronutrient applications to be carried out later, i.e., via foliar treatment, since, like the roots, the leaves of plants have the ability to absorb the nutrients deposited in the form of solution on their surface.

In view of the above, the present work had as objective to evaluate the effect of the foliar application of a commercial product containing molybdenum and cobalt on the yield and physiological quality of seeds.

2 MATERIALSAND METHODS

The experiment was carried out at the Sucupira farm, in the municipality of Sorriso, state of MatoGrosso, during the agricultural year of 2014/2015. The soil where the experiment was installed is classified as Dystrophic Red-Yellow Latosol.In the base fertilization, 500 $kg.ha^{-1}$ of the formulation 02-16-26 wereapplied by throwing. Eight seeds per linear meter were used, in 2.5 m long rows spaced at 0.45 m, totaling 6.75 m^2in each block of the experiment. The seeds were treated with Maxim fungicide and Avicta insecticide from the company Syngenta. The commercial product used was the Nectar of the company “Microquímica” (1.43% cobalt and 14.25% molybdenum, water-soluble nutrients and density of 1.58 at a temperature of 20 °C; electrical conductivity of 23.78 $mS.cm^{-1}$ and 31.0% saline content), applied with a costal sprayer in a volume of 160 $L.ha^{-1}$. Spraying occurred at the V5 development stage of soybean, and applications were made according vSoybean sowing was carried out on November 14, 2014 and the harvest was done manually on February 21, 2015. The cultivar sown was the Monsoy 8210 IPRO.

The germination, tetrazolium (viability) and accelerated aging tests were performed for the initial verification of seed quality (Monsoy 8210 IPRO), showing the results of 99, 96 and 97%, respectively.

Germination test (G) performed according to the Rules for Seed Analysis (BRASIL, 2009), using four replications of four germitest paper rolls, each with 50 seeds, totaling 200 seeds at 25 °C; and seedling evaluation five and eight days after the test set-up.

Tetrazolium test (TZ)100 seeds (two subsamples of 50 seeds per replication) were used, as indicated by FrançaNeto et al. (1988). The samples were pre-conditioned between paper towels moistened with water to 2.5 times the dry paper weight, for 16 h, at 25 °C. The seeds were then placed in plastic containers and kept submerged in 0.075% 2,3,5-triphenyltetrazolium chloride, at 40 °C, in the dark, for 150 minutes. After this period, the seeds were washed in running water and analyzed one by one,along with computing the number of viable seeds. The test is divided into 8 classes referring to seed quality: 1 to 3 (vigor); 1 to 5 (viability) and 6 to 8 (non-viable seeds) (FRANÇA NETO et al., 1988).

Accelerated aging test (AA) performed according to the methodology of Marcos Filho (2005), using gerbox-type boxes for the test, which contained an aluminum screen that was fixedin the interior thereof, the seeds being distributed over it. 40 ml of distilled water were also added to the bottom of the boxes. The gerboxes were sealed and placed inside a BOD chamber, under controlled environment with a temperature of 41 °C, for a period of 48 hours. Subsequently, the seeds were placed to germinate as described in the first count of germination test (BRASIL, 2009).

The experimental design was randomized blocks with four replications and six treatments with different doses. The averages obtained were submitted to analysis of variance and polynomial regression (FERREIRA, 2000). Statistical analysis was performed using the statistical package Sisvar.For the evaluation of the yield, 0.25 meters of each end of the line were designated asplot borders, each line remaining with two meters, totaling 16 plants per treatment in each replication. The seeds harvested manually in each treatment were submitted to water content determination by the greenhouse method, at 105ºC, for 24 hours (BRASIL, 2009),being then corrected to a moisture content of 12%. The following evaluations were performed: number of pods per plant (NPP), number of seeds per pod (NSP), and thousand seed weight (TSW), obtained by counting all seeds in the lot, according to the Rules for Seed Analysis (BRASIL, 2009). The yieldwas computed through the harvest of all the plants of the useful area of each plot, being expressed in sacks of 60 $kg.ha^{-1}$.

First germination count (FGC) performed together with the germination test, according to the Rules for Seed Analysis (BRASIL, 2009), five days after the test installation. Germination test (G) and accelerated aging test (AA) already reported (initial seed quality). Seedling emergence in the field (SE): consisting of four samples of each treatment, with sowing of 200 seeds per replication, distributed in 1-m-long and 3-cmdeep furrows, spaced at 20 cm between rows. The count was carried out at 14 days after sowing (concomitantly to the stabilization of emergence), by observing the number of emerged seedlings, considering only those with protrusion of the cotyledons above the soil surface. Tetrazolium test (TZ): previously reported. What differed in this evaluation of the seeds produced was that the viability and vigor of the seeds were evaluated. The test was divided into eight classes referring to seed quality: 1 to 3 (vigor); 1 to 5 (viability) and 6 to 8 (non-viable seeds). In the vigor analysis, by analyzing each seed individually, the types of damage (humidity and bugs) were also quantified to express the reason for the reduced quality.

In the classification of seed vigor for soybean, there are 8 classes to be analyzed (FrançaNeto et al., 1988): class 1: corresponding to the highest vigor - equal to or greater than 85% viable seeds; class 2: high vigor - between 84 and 75% viable seeds; class 3: average vigor - between 74 and 60% viable seeds; class 4: low vigor - between 59 and 50% viable seeds; class 5: very low vigor - equal to or less than 49% viable seeds; and classes 6, 7 and 8: classified as non-viable.

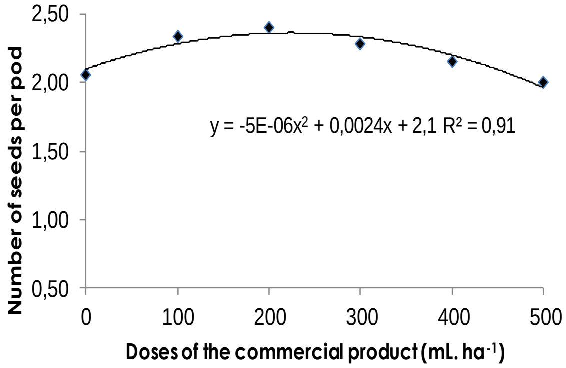
3 RESULTS AND DISCUSSION

The results obtained for the variables thousand seed weight, number of pods per plant and grain yield were not influenced by the application of the different treatment doses ($P \leq 0.05$). Similar results were obtained by several researchers, such as Diesel et al. (2010), who reported no significant differences between treatments of foliar application of molybdenum and cobalt for seed yield (Figure 1).

Possenti and Villela (2010), investigating the effect of molybdenum application in soybean seeds or leaves, did not obtain significant differences for yield and thousand seed weight between the treatments adopted and the zero dose. Likewise, Rossi et al. (2012), in soybean crop, did not obtain significant results for plant height, number of seeds per pod and 100-seed weight. Notwithstanding, for number of pods per plant and yield, they found significant results in the doses of 45 and $56 g.ha^{-1}$ molybdenum, respectively. According to Gris et al. (2005), the use of molybdenum in soybean did not provide an increase in grain yield, which can be attributed to the low concentration of nutrients, not being sufficient to influence crop yield.

Milani et al. (2008) did not obtain significant results for soybean yield with the foliar application of molybdenum. In this way, the molybdenum concentration was not toxic to the plant, there was neither accumulation of this nutrient in the plant nor increased production.

Figure 1. Number of seeds per pod of soybean plants submitted to different doses of commercial product containing molybdenum and cobalt via foliar application at the V5 development stage of the soybean crop. Sorriso - MatoGrosso – 2017



Different results were found by DouradoNeto et al. (2012), when observing that the foliar application of molybdenum and cobalt provided increases in the number of pods, number of grains per pod and thousand seed weight, in addition to significant increases in soybean yield, up to 240 $kg.ha^{-1}$. Similarly, Nakao et al. (2014), studying the effects of the foliar application of molybdenum on the yield and physiological quality of seeds, observed significant differences in the variables yield and thousand seed weight; yet for the variables number of pods per plant and number of seeds per plant, no significant results were found. Golo et al. (2009) reported that molybdenum and cobalt presented significant results in soybean.

The availability of molybdenum is affected by the amount of organic matter, the available phosphorus content and the soil texture (LOPES, 1999). Possibly, the non-significant results for the variables thousand seed weight, number of pods per plant and grain yield may have occurred due to high soil fertility and organic matter content, which supplied the required amount of molybdenum and cobalt for soybean. By soil analysis, it can be seen that the contents of phosphorus and organic matter are high and that the pH is in the range suitable for the availability of molybdenum.

For the variable number of seeds per pod, the treatments had a significant effect. The results obtained for the number of seeds per pod were adjusted to a quadratic function. For this variable, there was an increase up to the dose of 240 $mL.ha^{-1}$ with the application of the product containing cobalt and molybdenum. The decrease in the number of seeds per pod from this dose may be due to the phytotoxic effect of cobalt. Excess cobalt can cause toxicity and symptoms are necrotic spots on cotyledons and leaves with chlorotic leaflets. This excess effect can induce iron deficiency. Despite the importance of cobalt in the process of symbiotic fixation of atmospheric nitrogen, there are doubts about the necessity of its application to obtain a high grain yield in soybean. There is evidence of positive responses of cobalt application in the biological fixation of atmospheric nitrogen and in soybean yield in case the plant is well supplied with molybdenum (HUNGRIA et al, 2001), but other studies have not demonstrated this to be true (GALRÃO, 1991; SFREDO et al., 1997). Moreover, the cobalt doses that could cause toxic effects to soybean cultivation, applied via foliar spraying, are not well known.

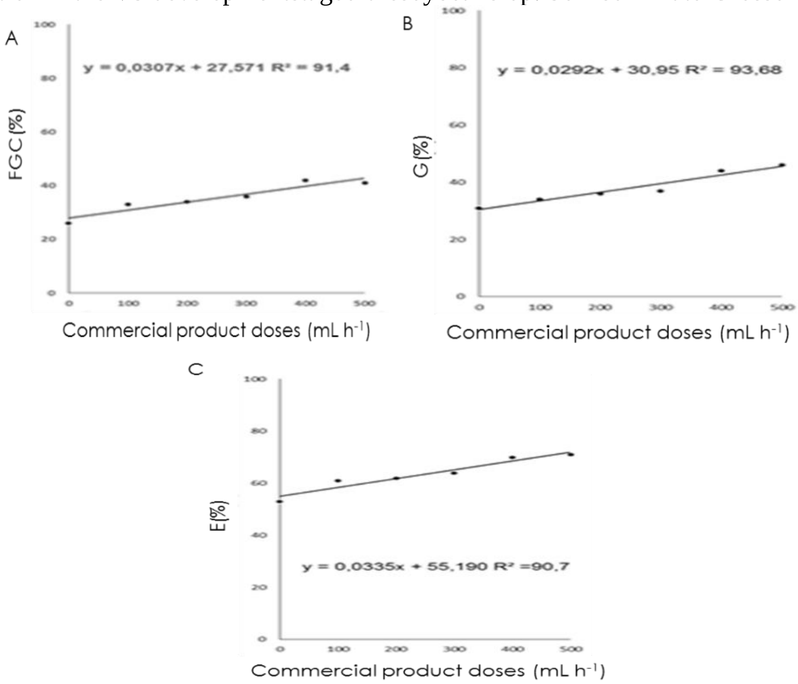
According to Lantmann (2002), molybdenum and cobalt are essential micronutrients for the soybean crop. But the decision as to its application as fertilizer must be made with care. Quantity, form of application (leaves or seeds), soil conditions and nutrient sources are factors that must be considered and associated to a diagnosis of the real need for application, as a function of soil and leaf chemical analysis and area history with observations on the symptoms of the deficiency of these nutrients.

For the variables regarding first germination count, germination and field emergence of the seeds produced, coming from plants that received the application of different doses of the product containing the micronutrients molybdenum and cobalt in the V5 stage of development of the soybean crop, there was a significant effect of application of the product.

Regarding the accelerated aging test, no significant effect was observed in the different treatments. Figure 2 (A; B; C) shows the regression graphs referring to the quality of the seeds produced, by the first germination count (FGC); germination (G) and field emergence (SE) tests, submitted to different doses of the commercial product, by foliar application, at the V5 development stage of the soybean crop. The three physiological quality assessments showed linear growth as the product doses increased. The same was verified by Nakao et al. (2014), where it was found that the foliar fertilization with cobalt and molybdenum during the process of seed formation, with subsequent accumulation of this nutrient, interferes in the physiological quality of soybean seeds in an increasing way.

The low germination percentage (Figure 2B) may be associated with the incidence of fungi in the seeds, considering that the germination test conditions (ideal conditions of temperature and humidity) may contribute to the proliferation of these microorganisms, which does not occur with the field emergence test (Figure 2C). It may also be related to the type of substrate used in each quality test, taking into account that in the field emergence (soil), there is a greater area of contact assisting in the respiration and, consequently,decreased incidence of microorganisms, which does not occur with the germination paper. Furthermore, in field emergence, the cotyledons are detached from the seedlings with ease by their friction with soil particles, causing the microorganisms adhered to this structure to spend less time in contact with the seedlings, a fact that does not occur in the germination test.

Figure 2. Qualityofseedproduced: (A) firstgerminationcount (GPC); (B) germination (G) and (C) fieldemergence (E); Submittedtodifferent doses ofcommercialproductcontainingmolybdenumandcobalt via foliar application in the V5 developmentstageofthesoybeancrop. Sorriso - Mato Grosso - 2017



The variables regarding first germination count, germination and field emergence had a linear increase with the increase of the product dose, reaching increases of 3.07; 2.09 and 3.35 percentage points, respectively, with each addition of 100 mL.ha^{-1} of the commercial product.For the analysis of the physiological quality through the topographical test of the seeds, tetrazolium test was used, according to the methodology of FrançaNeto et al. (1988). It is a biochemical test that estimates seed viability based on the change in the color of living tissues of the embryo.

In the evaluation of vigor and viability, there was no effect of treatments. The evaluation of the physiological quality of soybean seeds through the tetrazolium test has provided, in the last years, a significant contribution in the identification of the levels of vigor and viability, fundamental to seed quality control in Brazil (COSTA et al., 1997; MARCOS, 1999; BRASIL, 2009).

The tetrazolium test is a major achievement in decision-making by soybean-producing companies. The data obtained by the test are of great value throughout the production process.In addition to the importance of this test in the evaluation of vigor, it is particularly noteworthy the monitoring of deterioration in the field, since it affects seed quality, especially in low latitude-regions, where climatic conditions are generally more drastic. Moreover, the test allows the evaluation of the percentage of seeds with moisture damage and the percentage of seeds attacked by bugs (Table 1).

Table 1. Damageobserved in thetopographictestoftetrazolium in seedsproducedbyplantssubmittedto different doses of comercial product containing molybdenumandcobalt via foliar application in the stage of development V5 of the soybeancrop. Smile - Mato Grosso - 2017

Dose mL.ha^{-1}	**Damagetype**	
	Humidity (%)	**Bug (%)**
0	98	5
100	97	3
200	91	2
300	94	2
400	97	0
500	91	16
Média	95	5

Soybean seeds had a high incidence of moisture damage, with a mean of 95% in all treatments. Studies in the field of seed technology have highlighted the severity of this damage during the production of soybean seeds (PINTOet al., 2009). The characteristic symptoms of seeds with deterioration by“moisture” damage result from the exposure of soybean seeds to alternating cycles of wet and dry conditions in the final phase of maturation, before harvest. Such damage is of greater magnitude when occurring in hot environments, typical of tropical and subtropical regions.

Bug damage affects seed quality, even in low populations, and may greatly reduce seed production, due to the large number of seedlings that are aborted or poorly formed in the pods (FORTI et al., 2008).Regarding the final quality results, it can be added that during the conduction of the field experiment, more accurately, at the grain filling stage (January 2015), the average rainfall was 50 mm and during the period of physiological maturity (February 2015), it exceeded 350 mm until the day of harvest. These facts may help explain the low germination values in all treatments. Furthermore, the variety

Monsoy 8210 IPRO was unstable in terms of water deficit in January, with the death of some plants being verified before the cycle was completed.

4 CONCLUSIONS

The foliar application of the commercial product containing molybdenum and cobalt, in the V5 stage, does not promote significant increases in soybean yield.

The foliar application of the commercial product containing cobalt and molybdenum up to 240 mL. ha^{-1} positively influences the number of seeds per pod of the crop.

Molybdenum and cobalt doses may have a positive effect on physiological quality.

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