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Availability of boron in clayey and sandy soil due to the application of different borated sources in soybean cultivation

K. F. Bento[1], E. Carniel[1], C. B. Raiumundo[1], R. R. Rocha[2], E. L. Schoninger[1]

[1] Universidade do Estado de Mato Grosso – Campus Nova Mutum
[2] Universidade do Estado de Mato Grosso – Campus Tangará da Serra

*** Author for correspondence: rafaelrochaagro@outlook.com**

Abstract. Boron deficiency in the soil is commonly found throughout the country, mainly in cerrado soils, making it extremely necessary to fertilize such a micronutrient. Therefore, this study aimed to evaluate the availability of boron in clay and sandy soils with different sources of borated fertilizers in soybean cultivation in the 2018/19 soybean harvest. The availability of boron was evaluated by the method with hot water extraction in a soil sample in different soil layers and at a different time of collection. The experiment was assembled in randomized blocks (DBC), with 5 treatments and 4 replications, as follows: split boric acid: twice, total boric acid: one application of the integral dose, Granulex ®, Produbor® and control treatment Granulex provided higher B content in the soil in the 1st collection, in the 10-20 cm layer in cl In sandy soil, the different sources did not defer under the availability of B at all depths and collections. In general, clayey soils retain B more when compared to sandy soils
Keywords: Soil fertility, Micronutrient , Boron, Fertilizers, Leaching

Introduction

Brazil is the second largest grain producer in the world, second only to the United States of America (USA), standing out in soybean cultivation (*Glycine max*) with a planted area of 35.1 million hectares and an estimated production of 116,996 million tons in the 2017/2018 harvest (CONAB, 2018).

The state of Mato Grosso is the largest soybean producer at the national level, with an estimate for the 2018/19 harvest of 9.66 million hectares of cultivation and production of 32.50 million tons (IMEA, 2019), representing about 28.5% of all national soybean production.

The use of technologies allowed the expansion of agricultural areas, especially in areas of the cerrado, characterized by flat or smooth wavy relief, with good possibilities for the use of mechanized agricultural practices (MONTEZANO et al., 2006). Most soils located in Mato Grosso are classified as Latosols: deep with little differentiation of subsequent horizons, low CTC, low fertility and very weathered (OLIVEIRA, 2006).

In the Midwest region there are acidic soils, poor in organic matter and with low supply of phosphorus (P), nitrogen (N), sulfur (S) and boron (B) (MALAVOLTA; KLIEMANN, 1985). Nutrients are classified as macro and micronutrients, and this distinction is by purely quantitative aspects, totaling seventeen fundamental elements for plant development: N, P, K, Ca, Mg and S, B, Cl, Cu, Fe, Mn, Mo, Zn, Ni, C, H and O, respectively (FAQUIN, 2005).

Among the main responsible for the increase in agricultural productivity is soil fertility, which, in recent years, has improved considerably in these agricultural areas. However, it is necessary to highlight that little information is found in the literature for micronutrients, including boron (B) for these soils in the Midwest region.

Boron is closely related to physiological processes, participating in several segments of metabolism, important participation in pollen germination and pollen tube growth, and these processes are strictly inhibited in their absence (KIRKBY; RÖMHELD, 2007). I ts movement in the soil to the roots is by mass flow, being considered a very soluble element, in soils that have a high degree of weathering and low fertility as the soils of the Brazilian cerrado B is easily leached or adsorbed by the oxides of Fe, Al and Mn, organic matter (SOARES; ALLEONI; CASAGRANDE, 2005), then there is a great need to replace this element through fertilization.

Currently there are different sources of boron that can be applied in agricultural production. And the choice of the best source of B for application in the soil depends on solubility, soil type, pH, organic material, crop and water regime (GONDIM, 2009; YAMADA, 2000).

Given the above, the objective was to evaluate the availability of B in soils with sandy and clay texture, after the application of borated fertilization sources, namely: Granulex ®, Produbor® and Boric Acid.

Methods

A field experiment was developed in the municipality of Nova Mutum, in the middle northern region of Mato Grosso in the 2018/19 soybean harvest carried out in two locations, Fazenda Sertaneja (clayey soil) and Fazenda Colorado (sandy soil), from March to September 2018. The soil was classified as a Dystrophic Red-Yellow Oxisol. The climate is of the Aw (Koppen) type, tropical hot and semi-humid, with two well-defined seasons, divided into rainy season from October to April and dry season from May to September and the average annual temperature of 24 ºC (NOGUEIRA et al., 2010). (Figure 1).

To check the chemical fertility conditions of the soil of the respective properties, samples were collected at a depth of 0 to 20 cm, to carry out the chemical and physical analysis before the installation of the experiment. The main characteristics of the soils are presented in Tables 1, 2, 3 and 4.

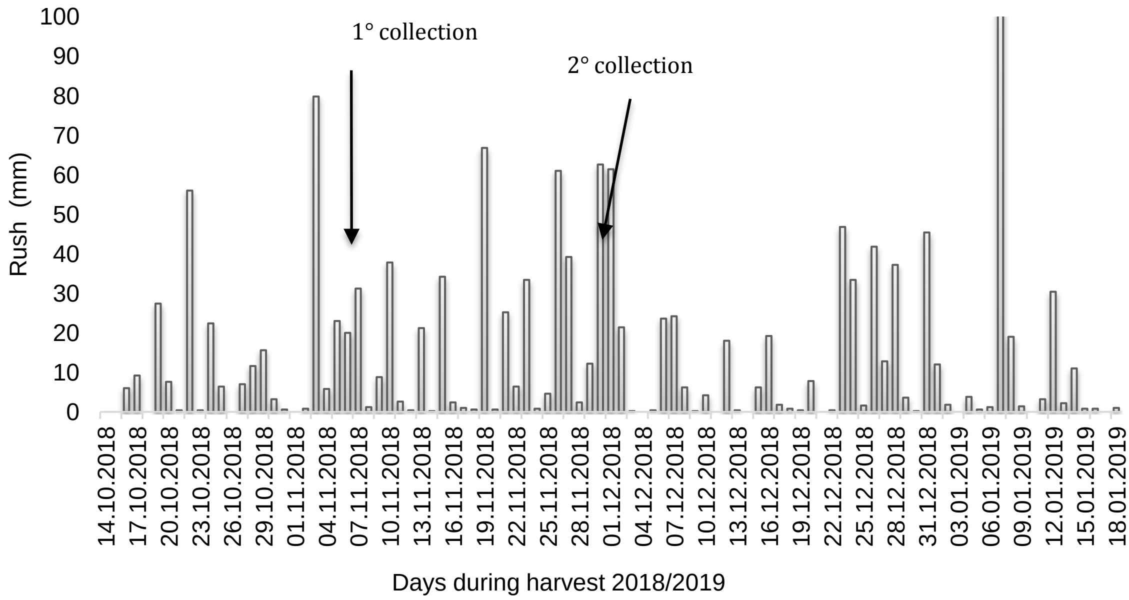

Figure 1. Rainfall data that occurred in the soybean crop cycle in Nova Mutum-MT in the 2018/19 harvest and times of soil sample collection. Source: Author (2020).

Table 1. Chemical analysis of macronutrients, exchangeable acidity (Al), sum of bases (SB), cation exchange capacity (CTC), base saturation (V%) and organic matter (MO) in the sampled layer of 0-20 cm. Clayey soil. Nova Mutum -MT

Soil Depth	pH H_2O	P[1]	K	S	Ca	Mg	Al	H+Al	SB	CTC	V	MO[2]
Cm		----mg dm^{-3}----				---------------cmol$_c$ dm^{-3}-------------					-------%----	
0 – 20	5,7	6,0	39,70	5,8	2,5	0,9	0,1	4,1	3,5	7,6	46	2,2

(1) Mehlich Extractor 1
(2) Hot water

Table 2. Chemical analysis of micronutrients and particle size characterization of the soil for the sampled layer of 0-20 cm. Clayey soil. Nova Mutum -MT.

Soil Depth	B[2]	Cu[1]	Fe[1]	Mn[1]	Zn[1]	Sand	Clay	Silt
Cm		----------mg dm^{-3}--------					----------g kg^{-1}-------	
0 – 20	0,4	0,7	77,6	5,7	4,9	340	580	80

(1) Mehlich Extractor 1
(2) Hot water

Table 3. Chemical analysis of macronutrients, exchangeable acidity (Al), sum of bases (SB), cation exchange capacity (CTC), base saturation (V%) and organic matter (MO) in the sampled layer of 0-20 cm. Sandy soil. Nova Mutum -MT.

Soil Depth	pH H_2O	P[1]	K	S	Ca	Mg	Al	H+Al	exBas	CTC	V	MO[2]
Cm		----mg dm^{-3}---			----------cmol$_c$ dm^{-3}---------						---%---	
0 – 20	5,5	13,0	8,50	5,7	1,1	0,4	0,1	2,0	1,4	3,4	42	0,9

(1) Mehlich Extractor 1
(2) Organic matter

Table 4. Chemical analysis of micronutrients and particle size characterization of the soil for the sampled layer of 0-20 cm. Sandy soil. Nova Mutum -MT.

Soil Depth	B[2]	Cu[1]	Fe[1]	Mn[1]	Zn[1]	Areia	Argila	Silte
Cm	------------dm^{-3}-----					----------g kg^{-1}----------		
0 – 20	0,3	0,4	90,6	15,9	2,2	874	101	25

(1) Mehlich Extractor 1
(2) Hot water

The experimental design was a randomized block design (DBC), with 5 treatments and 4 replications, as follows: split boric acid: twice, total boric acid: an application of the integral dose, Granulex ®, Produbor ® and control. For each plot (20 m2) 1.7 kg of B ha-1 was applied regardless of the source used, except for control. Mechanized sowing of soybeans was carried out on the day (09/04/2018) and (09/04/2018) on the respective farms.

Throughout the experimental period, all the cultural managements necessary for the proper conduct of the culture were performed.

Fertilizers were carried out 2 days before sowing and the 2nd fertilization of piecemeal boric acid was carried out on November 1. 2 soil samples were collected in the layers of 0 - 10 and 10 - 20 cm in each area. The first collection took place on October 26 and the second on November 28.

The soils collected were sent to the Soil Laboratory of the State University of Mato Grosso in Nova Mutum, in which the containers of each sample were open outdoors for moisture loss facilitating the sieving process. After droughts, they were sifted with a 2 mm sieve for relief and removal of impurities, and then proceeded to the B analysis. The methodology followed was Embrapa, with hot water extraction (SILVA, 2009).

The variable analyzed was boron (mg dm-^{3}). The data were submitted to analysis of variance (F test) at 5% probability, and when there was a significant effect of the treatments, they were compared by the t test (LSD), using the SAS software (SAS INSTITUTE INC., 2009).

Results and discussion

The results of B availability obtained suggest that the dynamics of mobility of this micronutrient is influenced by the type of soil, the composition of fertilizer and dependent on dynamism in the periods of long rainfall, because in very rainy areas, where B can be leached (COMMUNAR; KEREN, 2007; SILVA et al., 1995).

Figure 1 shows that the collections and fertilizers that coincided in the rainiest months (October and November) may influence the results obtained throughout the work, because this volume of rain provides greater leaching of soil nutrients. Silvestrin (2011), when analyzing the dynamics of B in an Oxisol of medium texture found that high precipitation in the period of borated fertilization until soil collection can provide leaching of this nutrient at depths greater than 40 cm.

It was found that at a depth of 0-10 cm both in the 1st and 2nd collection there was no significant difference between the different borated sources.

At a depth of 10-20 cm at the 1st collection in the clay soil, there was a significant difference by the F test, the Granulex was superior to the other treatments. Total and Installed Boric Acid showed no distinction between the means between them and the Witness and the Produbor presented lower values (Table 5).

Because it is a granulated and slow-release fertilizer, Granulex stood out from the other treatments, showing higher values at a depth of 10-20 cm. One of the factors that may have contributed to this result is the pH value, which is one of the factors that helps the release of Boron into the soil. According to Nascimento (1989), there is a lower rate of precipitation and adsorption of the borate anion with Al and by iron and aluminum oxides in this pH range (5.0 to 7.0, and 4.0 to 7.0).

In the 2nd collection at depth 10-20 cm, Total Boric Acid, Parceled Acid and Granulex presented averages higher than the Witness and Produbor at a depth of 10-20 cm.

Freitas et al. (2013), under continuous cultivation of sugarcane at depths of 0-10 and 10-20 cm, and observed that in areas that had higher B levels at both depths, where higher levels of clay and organic matter are concentrated.

Rosolem and Bíscaro (2007), in an analysis of soil samples from the State of Mato Grosso, grown with soybeans for three years, with doses of limestone and boron with boric acid, observed that the amounts of B present in percolated water were ten times higher than those found in the treatment without the addition of fertilization, showing the high sol In the same way as this experiment, because Boric Acid may have solubilized in the most superficial layers (Table 5).

In the produndity 10-20 cm in which the fertilization was made with the fertilizer Produbor based on ulexite, it presented similar results from the control, having the lowest levels of B (Table 5). A similar result obtained by Abreu (2015), when evaluating the leaching potential and the availability of B in sandy, clayey and very clay soils under application of the sources, and concludes that ulexite did not differ from the control with lower boron content and greater amount of accumulated B leached in sandy soil, followed by clayey. Corraborating with the results of this experiment.

Table 5. Availability of boron in the soil at depths of 0-10 and 10 to 20 cm, after the application of different borated sources in a clay soil. Fazenda Sertaneja, Nova Mutum - MT, 2019.

Treatment	Collection			
	1°		2°	
	Depth (cm)			
	0-10	10-20	0-10	10-20
	Boron in the soil (mg dm^{-3})			
Witness	0,31 a	0,35 c	0,31 a	0,35 b
Parceled Boric Ácid	0,49 a	0,54 b	0,49 a	0,54 a
Total Boric Ácid	0,25 a	0,52 b	0,42 a	0,51 a
Produbor	0,39 a	0,30 c	0,39 a	0,24 b
Granulex	0,24 a	0,70 a	0,35 a	0,60 a
F Value	2,42 $^{n.s.}$	38,74*	2,01 $^{n.s.}$	13,09*
CV	38	10	24	18

ns : not significant, * significant at 5% probability by the F test. Averages followed by the same letter do not differ from each other, by the t test. CV: Coefficient of variation.

Table 6. Availability of boron in the soil at depths of 0-10 and 10 to 20 cm, after the application of different borated sources in sandy soil. Fazenda Colorado, Nova Mutum - MT, 2019.

Treatment	Collection			
	1°		2°	
	Depth (cm)			
	0-10	10-20	0-10	10-20
	Boron in the soil (mg dm^{-3})			
Witness	0,21 a	0,21a	0,19a	0,18 b
Parceled Boric Ácid	0,25 a	0,24a	0,25a	0,24 ab
Total Boric Ácid	0,23 a	0,24a	0,18a	0,29 a
Produbor	0,18 a	0,26a	0,20a	0,26 a
Granulex	0,18 a	0,21a	0,22a	0,18 b
F Value	0,45 $^{n.s.}$	1,27 $^{n.s.}$	0,52 $^{n.s.}$	4,16 $^{n.s.}$
CV	28	18	35	19

ns : not significant, * significant at 5% probability by the F test. Averages followed by the same letter do not differ from each other, by the t test. CV: Coefficient of variation

Table 6 shows that in the sandy soil there was no significant difference for any of the treatments in both collections, in the 0-10 and 10-20 cm layers. This response may be associated with the high levels of sand (87%) and the high rainfall rates that occurred at the time of the experiment (Figure 1).

Soils that have low organic matter content and low structures that help in the adsorption of B such as Fe and Al oxide, especially in the more superficial layers, which is one of the characteristics commonly found in sandy soils, showing little availability of this element that can be the result of excessive leaching (ROSOLEM; BÍSCARO, 2007).

Soils of sandy texture, poor in organic matter, tend to have low availability of B. This is especially important in very rainy areas, where B can be leached (COMMUNAR; KEREN, 2007; SILVA et al., 1995). However, soils with more clayey textures tend to retain added B for longer periods, which also occurs in soils with more organic carbon and greater cation exchange capacity.

This behavior was expected, in relation to the differences in the chemical and physical attributes of the soils analyzed, highlighting the textural differences and the levels of Fe and Al oxides, which directly influence the availability of this nutrient their presence in the soil solution.

Conclusion

Granulex provided higher B content in the soil in the 1st collection, in the 10-20 cm layer in clay soil because it is granular fertilizer and of slow release. In sandy soil, the different sources did not defer under the availability of B at all depths and collections.

Clayey soils retain more B when compared to sandy soils. B leaching in these conditions tends to be slower.

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