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Evaluation of a new soil conditioner from *Magonia pubescens* biomass on leaching metals and cation exchange capacity in different soils

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Abstract
This work aimed to evaluate the effect of a new soil conditioning developed from the Mangonia Pubences biomass on cation exchange capacity and nutrient leaching in two different soils.It was evaluated the chemical composition of the produced soil conditioner, the physicochemical properties of cation exchange capacity and water holding capacity, as well as directly application tests were performed in two soils - sandy and clayey texture. The results indicated that the oxidative chemical treatment allows to obtain a material mainly composed by holocellulose, as evidenced by the soil conditioner produced presents water retention capacity of 35 $g.g^{-1}$ and 471 $mmol_c.kg^{-1}$ of capacity cation exchange. Tests with application of 0.5%, 1.0% and 1.5% conditioner produced inthe two selected soils showed that this application increase the CEC andwater holding capacityof the soils.The leaching tests carried out in columns showed that the soil conditioner developed reduced the leaching of calcium, potassium, sulfur, zinc and boron nutrients, showing that their use results in an increase in nutrient retention capacity. The results showed that the material produced is a potential product for the soil conditioner market.

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I. Introduction

The development of new technologies has been one of the major challenges of 21^{st}century for the industry, it is considered a great asset, once it can ensure the longevity of the companies on the market. The development of new technologies is possible by various means, among them the Know-how of companies in their respective niches of technology and scientific research.

In Brazil, several technological alternatives have been developed to improve agriculture, mainly related to the mechanization and automation, aimed at the high yield of crops and the decrease of the agricultural costs. In addition to the essential modernization of agriculture, it is necessary to invest in technologies and researches that will allow a more sustainable agriculture, then it will be possible to face the challenges of water scarcity and soil degradation.

According to FAO (2015), the United Nations Agency dedicated to the study of agriculture, a third of the soils of the planet are degraded. This soil degradation makes them less fertile and therefore influences on world food production. The irrigated agriculture in Brazil is responsible for 72% of the water consumption in the country (ANA & EMBRAPA, 2015) and therefore, considering future challenges due to limitation of water resources, it is necessary to develop of technologies that enable a more rational use of water, increase of efficiency of current irrigation systems and technologies that ensure soil fertility. In this context, this work aimed to evaluate the effect of a new soil conditioning, developed from the *Mangonia Pubences* biomass, on cation exchange capacity and nutrient leaching in two different soil types.

The soil nutrient adsorption potential is related to the presence of particles in colloidal sizes, mainly composed of clay silicates materials, in the clay fraction of the soil. In addition to the clays, the mineralized organic matter is also commonly a colloidal constituent of the soil, which presents cation adsorption potential due to hydrolysis of carboxylic and phenolic groups, present in organic acids (Chassapis, 2010).

The dynamics of nutrients in the soil is mainly regulated according to ion exchange mechanisms, through the reversible adsorption of ions, mainly cations. The negative soil loads are mainly from clays and organic matter. The ability to reversibly absorb cations from a soil can be defined by the Cation Exchange Capacity - CEC and the ability to absorb reversibly anions is called Anion Exchange Capacity - AEC.

Soil conditioners are defined as products that promote an improvement in physical, chemical or biological properties of the soil (Almeida, 2008). Although products with the aim of improving the physical and chemical properties of soils, such as animal manure and rice husks, that are used by farmers supported by long-held believes, there is significant variety in the domestic soil conditioners available on the marketed.

Rashad *et al*. (2013) studied theuse of cellulose, silica and lignin extracted from

rice straw as conditioners in soils with predominantly sandy texture. The effect of these additives at concentrations of 0.1 and 0.3% of the soil volume was monitored, as well as the hydro physical properties: apparent density, total porosity, water retention capacity, field capacity, hydraulic conductivity and electrical conductivity. The authors pointed out that the additives positively affected the properties of electrical conductivity, density, porosity and water retention capacity,cellulose was the additive with the greatest impact on the results. The authors also noted that the effects were more pronounced in predominantly sandy soils when were compared to soils with clayey texture.

The results obtained by Rashad *et al*. (2013) corroborate the one proposed by Chang *et al.* (2011) that stated that lignocellulosic materials have chemical properties that make them potential useful materials for agriculture.

Moreover, Mangwandi *et al*. (2014) studied the feasibility of producing an organomineral fertilizer using tea residues, ground limestone and carboxy-methyl cellulose like binding agent. The authors observed that granulation only of the tea residue was not possible. When the tea residue was used along with the limestone, the authors showed that a high amount of binding agent was necessary, which prevents the commercialization of the product.

In addition to the potential to improve soil properties, the use of organic conditioners applied to the soil surface can also act as soil cover, reducing moisture loss and increasing water retention capacity (Grose, 2011). Neto *et al*. (2005) have already evaluated the water retention capacity and pine bark phytotoxicity, comparing the results with commercial moss and xaxim (Dicksonia sellowianna) substrates. The authors noted that the pine bark (<5mm) had a water retention capacity of 1.5 $g.g^{-1}$, while the moss and xaxim presented a water retention capacity of 19.3 $g.g^{-1}$ and 3.7 $g.g^{-1}$, respectively, with 1 day assay. These results indicated that the use of pinus bark with the aim of increasing water retention capacity will require more frequent irrigations when compared to the studied materials.

II. Material and Methods

The biomass of *Magonia Pubescens* was collected in the city of Formosa, Goiás, Brazil. The developed soil conditioner – DSC produced was previously discussed by Vilela (2017).In order to evaluate the behavior of the conditioners produced, tests were carried out on soil columns, where changes in the physical and chemical aspects were monitored through chemical analysis of the Leached obtained and subsequent chemical analysis of the soil samples used for column assembly.Four columns were assembled for each treatment, making a total of 56 columns. The columns were constructed using acrylic material, with 20 centimeters of height and 10 of diameter.

All leaching tests have been conducted at laboratory conditions (20°C) and the leached was filtered in 0.45 µm filter. Thus, to perform the leaching tests, nutrients were added to the surface of the columns, which present a high mobility in the soil profile, in order to allow the evaluation if the use of soil conditioner improves the potential of nutrient retention and, consequently, leaching. The following products were used:

Gypsum: 22% Ca and 11% S

KCl: Potassium Chloride with 52% K

Borogran: 20% Boron

Zincogran: Zinc to 18%

The nutrients were added in the columns in real proportions as used in crops, such as 172 kg / ha of K_2O, 200 kg / ha of $CaSO_4$ and 2 kg / ha of B and Zn.

To obtain the leachates, a 500 mm rainfall process was simulated over a period of 12 weeks. For this, 70 mL of water was added daily in each column.

After the leached collection, Electric Conductivity, Ca, K, S, B and Zn were performed.

The leached were collected daily and sent to the Laboratory of Soil Analysis for chemical analysis.

The electrical conductivity determinations were performed using a conductivity meter model HI 9889, Hanna, using 1412 µS solution as calibration standard.

The determinations of Ca, K, S, B and Zn were performed using an Inductively Coupled Plasma Optical Emission Spectrophotometer - ICP-EOS, Cirus Vision model - Spectro.

It was used a Commercial soil conditioner, named CSC, with the goal to compare the results.

III. Results And Discussion

Conditioner Analysis

The results of the determination of cation exchange capacity - CEC and water retention capacity – WRC are showed in the Table 1.

Table 1 – Cation exchange capacity and water retention capacity

Material	CEC $mmol_c.kg^{-1}$	WRC $g.g^{-1}$
DSC	471 ± 41	35 ± 4
Legal Limit[1]	200 minimum	0.6 minimum

[1] According Brazilian Law IN 35/2006.

The DSC presents 471 ± 41 $mmolc.kg^{-1}$ of CEC and 35 ± 4 $g.g^{-1}$ of WRC, indicating that the DSC is in accordance with the Brazilian specifications.

The properties of CEC and WRC are mainly related to the composition of the material. By the characterization assay previously done (Vilela, 2017) is possible noted that the composition DSC is mainly cellulose and hemicelullose, both compounds whith abundance of hydroxil groups and characteristics to constitute a hydrogel. Klen (1998), showed that the capacity to form hydrogels is assigned to hemicelulloses. Cellulose, besides absorbing water, acts as a support, what ensures a greater stability to the material formed. These groups give the material a hydrophilic feature. Another important aspect is the increase in volume when in contact with water. This increase in volume or swelling occurs due to the positioning of the water molecules between the chemical cellulose and hemicellulose chains, promoting an expansion of the material. With respect to the results of CEC obtained, it is possible to infer that these are related to the numerous hydroxyl groups, which act as Lewis acids, as well as the porosity of cellulose and hemicellulose.

The obtained results corroborate the studies performed by Viera (2015) that showed CEC results between 240 and 300 $mmolc.kg^{-1}$ with Tingui biomass hydrogels. Studies by Jianzhong *et al*. (1995) also presented hydrogels produced from cellulose with a high CRA, reaching values higher than 200 $g.g^{-1}$, but these authors had altered the material matrix. It is important note that the DSC produced there is no crosslinking process.

Soil Fertilty Analisys

The results of chemical analysis of the fertility of clayey and sandy soils are presented in Table 2.

Table 2 – Chemical Analysis of Fertility of Clayey and Sandy Soils.

Parameters	**Unit**	**Sandy Soils**	**Clayey Soil**
pH water	-	5,23 ± 0,12	4,47 ± 0,21
pH $CaCl_2$	-	4,27 ± 0,06	3,9 ± 0,2
Organic Matter	%	0,78 ± 0,09	1,84 ± 0,29
Organic Carbon	%	0,45 ± 0,05	1,06 ± 0,12
Ca	$cmol_c.dm^{-3}$	0,4 ± 0,01	0,21 ± 0,01
Mg	$cmol_c.dm^{-3}$	0,41 ± 0,02	0,3 ± 0,02
Al	$cmol_c.dm^{-3}$	0,33 ± 0,01	0,78 ± 0,03
H+Al	$cmol_c.dm^{-3}$	2,86 ± 0,1	4,68 ± 0,1
S	$mg.kg^{-1}$	4,33 ± 0,31	4,55 ± 0,28
B	$mg.kg^{-1}$	0,1 ± 0,01	0,14 ± 0,01
P	$mg.kg^{-1}$	2,23 ± 0,2	2,58 ± 0,34
K	$mg.kg^{-1}$	19,75 ± 1,17	62,69 ± 2,13
Mn	$mg.kg^{-1}$	22,25 ± 0,58	25,23 ± 1,54
Fe	$mg.kg^{-1}$	66,58 ± 3,69	87,84 ± 9,41
Cu	$mg.kg^{-1}$	0,28 ± 0,09	0,64 ± 0,03
Zn	$mg.kg^{-1}$	5,7 ± 0,16	0,35 ± 0,03
CEC	$cmol_c.dm^{-3}$	3,72 ± 0,08	5,34 ± 0,1

The soils have a significant difference on composition of fertility. It is possible to observe that the pH values in water were 5.23 for the sandy soil and 4.47 for the clayey soil. In order to evaluate the difference between the pH values for the two types of soil, it is important to note that the interpretation of pH in soil should be performed based on the concepts of Brönsted-Lowry (Atkins, 2002), where soil with a lower pH is a better proton donor when compared to another soil with a higher pH value. Thus, it is showed that the pH results of clayey soil are lower than the pH of the sandy soil, which is related to the greater number of negative loads in the clays, which promotes a greater retention of protons in the soil. The same can be pointed out regarding the pH results in calcium chloride.

Furthermore, the results of organic matter showed that the clay soil presented a higher concentration of organic matter when compared to the sandy soil, however, both values can be considered low for soil fertility purposes. The organic matter content comes from the degradation of plant compounds or sources of organic matter added to the soil, such as some conditioners. An advance in agricultural technology was the adoption of a no-tillage system that, in addition to reducing soil degradation, also promotes the incorporation of straw, resulting in an organic matter increase. Both analyzed soils presented low values of organic matter because they have been collected in regions of native forest.

Regarding the aluminum content, the clayey soil presented a higher concentration of this element when compared to the sandy soil. This difference is related to the composition of this type of soil and the low pH, resulting in a greater availability of exchangeable aluminum. The same can be observed for potassium, where the content of this nutrient in the clay soil isapproximately three times higher than the concentration in the sandy soil. Potassium content in clayey soil is related to clay sites present in clayey soil, which increases the cation retention capacity.

Observing the results, it can be noticed that there is a tendency for micronutrient concentrations to be higher in the clayey soil, a fact that is related to the fraction of clay present. The higher cation retention capacity is demonstrated by the CEC values obtained. The sandy soil presents a CEC of 3.72 cmolc / dm³ and the clay soil presents a CEC of 5.34 cmolc / dm³. These results express the influence of the clay fraction in the clayey soil, since the clays contain a greater number of sites when compared with the sand fraction and therefore it presents a greater cation retention potential.

Moreover, for the WHC valuesthe clay soil has a water retention capacity of 0.41 g.g-1 and the sandy soil of 0.074 g.g-1. This difference is mainly related to the clay content in both soils, the first with 65% and the second with 15%. The clay presents a high potential for retention of water in the soil due to its porosity. These results corroborate Gimenes (2012) and Beutler (2002) proposals, that stated that sandy soils, characteristically with larger particles and smaller pore distribution, have a lower water retention capacity when compared to soils with predominantly clayey or silty texture.

Soil Water retention capacity on Field Capacity

The results of FC for the tests performed are presented in Table 3. Evaluating only the results obtained for the tests performed with the clayey soil, it can be observed that with addition of 0.5% of DSC there was a FC increase of 0.41 to 0.43 g/g^{-1}, indicating an increase of 4.9%. When the addition of 1 and 1.5% of DSC is evaluated it can be seen thattheFC increased to 0.48 and 0.56 $g.g^{-1}$, respectively. With these percentages of addition, a percentage increase of 17 and 36% is observed, for the additions of 1 and 1.5%, respectively. Considering these results it can be postulated that the use of DSC results in a significant improvement in FC in clayey soils, which is due to the water retention capacity of the DSC.

Table3: Fileld capacacity in diferent soil samples with DSC.

Treatment	Water Holding Capacity at 0,1 Bar - $g.g^{-1}$	
	Clayey Soil	Sandy Soil
Control Sample	0.41 a1	0.074 b1
Addiction of 0.5% DSC	0.43 a2	0.086 b2
Addiction of 1.0% DSC	0.48 a3	0.11 b3
Addiction of 1.5% DSC	0.56 a4	0.17 b4

Results followed by the same letter and number in the column are significantly equal to the level of significance of $\alpha = 0.05$ according to Student's t test.

When evaluating the results obtained in the tests performed with sandy soil samples, there was an increase in FC of 0.074 to 0.086 $g.g^{-1}$, which represents a percentage increase of 16%. A significant increase in FC can also be observed for the tests with addition of 1 and 1.5% of DSC in samples of sandy soils, where a field capacity of 0.11 and 0.17 $g.g^{-1}$ wererevealed, indicating a FC increase in 49% and 230%, respectively.

The increase in FC with the addition of soil conditioners was also noted by Miranda *et al*. (2011), that evaluated the effect of chemical and organic conditioners on the recovery of saline soils. These authorsshowed that there was an increase in FC with the addition of bovine manure and ovine sternum, both in the proportion of 2% in relation to the amount of soil. The increase in the FC with the addition of organic conditioners is related to their contribution to the organic matter content in soil, which results in an increase in the number of pores and reduction of the density.

Evaluation of influence in the CEC – Column leaching test

The experiments performed with samples of different soils and different dosages of conditioners aimed to evaluate if the addition of these conditioners results in an increase in the capacity of retention of the nutrients and consequently a lower concentration of these in the leached solution.

Electrical Conductivity

The results of the electrical Conductivity analysis in $\mu S.cm^{-1}$ are shown in Figure 1.

It Is possible to see a difference between the electrical conductivity values of the leached obtained with

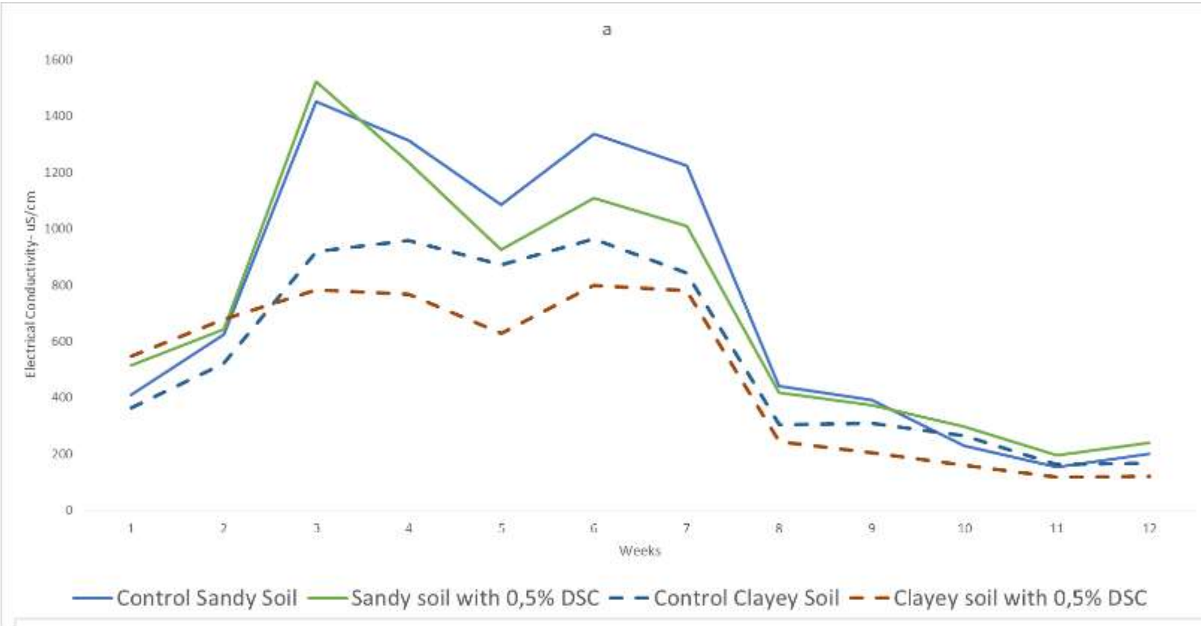


Figure 1: Electrical Conductivity in the diferent experiment

tests on sandy and clayey soils, for both CSC and DSC. A difference in electrical conductivity between soil types can benoticed. The addition of both soil conditioners tends to result in lower electrical conductivity in the leached when compared to the respective control samples.

In both soil types, there was an increase in conductivity from the first week to the third week. Subsequently, high values of conductivity were observed until week 08, when the observed electrical conductivity values started to decrease, what continued until the end of the experiment. Based on the results obtained, it can be inferred that the increase in conductivity observed between weeks 3 and 8 is related to the leaching of the added nutrients. As these nutrients were added to the top of the columns, these were not seen in the leachate Leached of the first and second weeks. Likewise, it can be inferred that the decrease and stabilization of the electrical conductivity after week 8 indicate that the leaching time was sufficient so that the added nutrients could be leached.

When comparing the effects of the conditioners evaluated in relation to the soil types, it is observed that the leached obtained from the sandy soil columns presented electrical conductivity greater than the electrical conductivity of the leached of the clayey soils, in all weeks of the experiment. This higher electrical conductivity of the leached is related to the characteristics of each soil, since the sandy soils present lower CEC which results in a greater leaching of nutrients and, consequently, a greater electrical conductivity when compared to the clayey soil. Furthermore, when evaluating the electrical conductivity of only clayey soil leached, for both conditioners tested, it is noted that up to the third week, in the samples where the conditioners were added (DSC or CSC), the electrical conductivity was higher than the electrical conductivity of the leached control samples. From the third week on, the measured values of electrical conductivity in the leachedfrom the samples with conditioners presented lower conductivity. These results may be related to the presence of nutrients in the conditioner itself, such as CSC presents 2.7% of calcium and 1.0% of potassium or in the case of DSC, may contain chloride ions resulting from the purification process.

Calcium

The results of the accumulated calcium concentration over the 12-week experiment are shown in Figure 2a for sandy soil and 2b for clayey soil.

For sandy soil, the treatments using the commercial soil conditioner at the 3 concentrations evaluated (CSC 0.5, CSC 1.0 and CSC 1.5) resulted in a higher concentration of calcium in the leached, when it was compared to the control sample, whereas the three treatments with the developed soil conditioner (DSC 0.5, DSC 1.0 and DSC 1.5) resulted in a lower concentration of calcium in the leached extract when they were compared to the control sample. Considering the function of a soil conditioner, it was expected that in all treatments the amount of calcium in the leached extract was lower than the control sample.

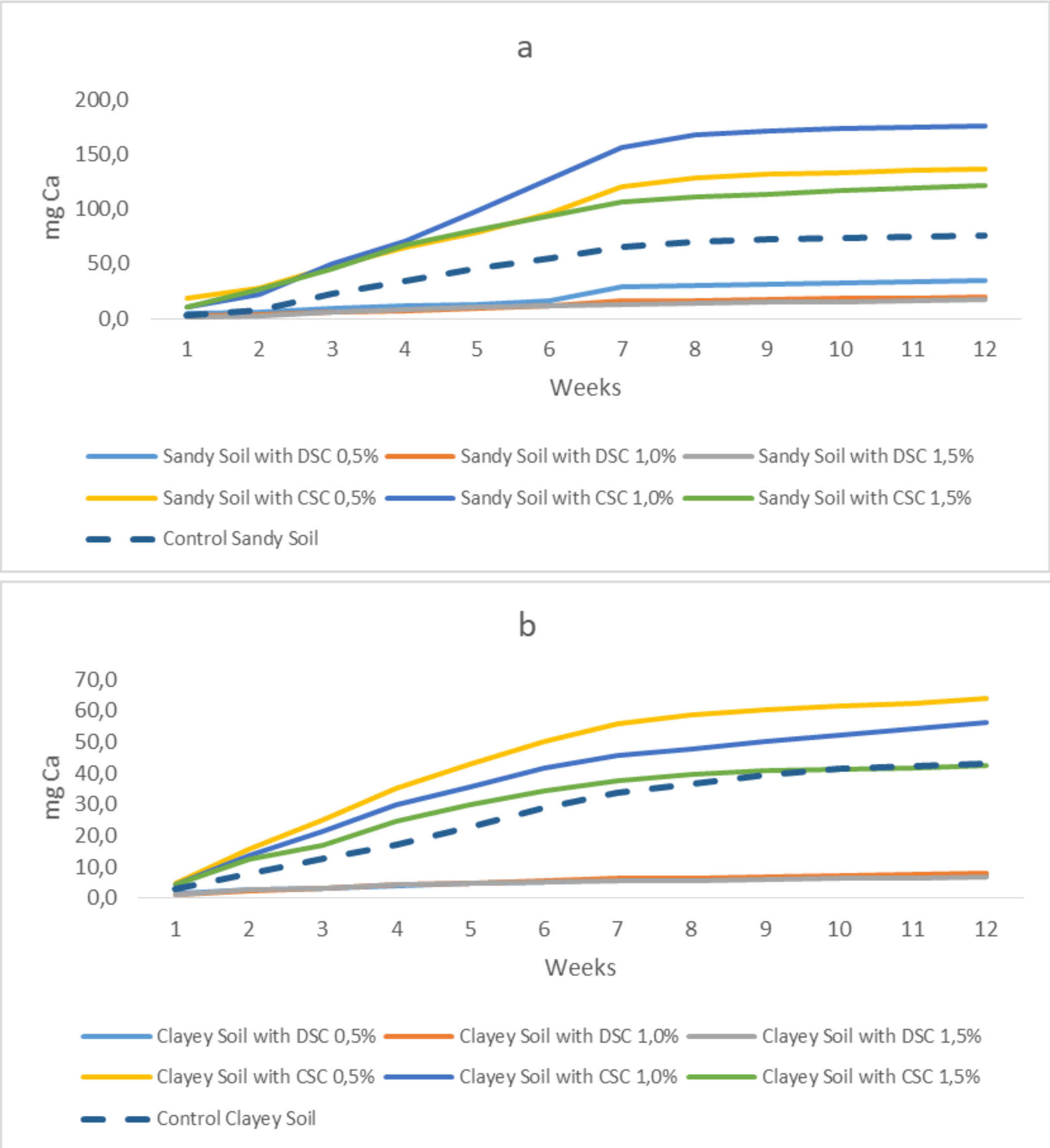


Figure 2: Leached Calcium in diferents soil with addiction of DSC e CSC.

However, when the commercial soil conditioner was used, an inverse effect was obtained. This higher concentration of calcium in the leached when the CSC was used is possibly related to the presence of calcium in the mixture of the commercial conditioner itself, which as mentioned above presents 2.7% calcium in its composition, which resulted in an addition of 360 mg of calcium only by the conditioner.

When evaluated the treatments performed with the developed soil conditioner – DSC in sandy soil, it is observed that the DSC 0.5% resulted in a lower concentration of calcium in the leachate when compared to the control sample. However, this concentration was higher than with the DSC 1.0% and DSC 1,5% treatments, which showed no difference between them. These results confirm the efficiency of the product developed as soil conditioner, mainly due to the high CEC of the DSC. The results also shown that the use of the 1% DSC dose had a higher efficiency when compared to the 0.5% dose, however, there was no significant difference when compared to the 1.5% dose, indicating that in the test conditions, the best cost-benefit would be obtained with the 1.0% DSC application. These results corroborate the proposal by Ribeiro *et al*. (1999) which states that the ideal soil conditioner dose is 1.0%.

When evaluating the results for clayey soil tests in Figure 2b, it is observed that the use of CSC resulted in a higher calcium leaching when compared to the control sample, which, as discussed before, is related to the presence of calcium in the soil commercial conditioner. When comparing the three treatments with CSC, the CSC 0.5 treatment showed the highest concentration of calcium in the leachate, while the CSC 1.5 presented the lowest concentration of this nutrient among the three treatments. This difference is possibly related to the amount of conditioner added in each treatment, once with the addition of a greater amount of conditioner, there was a greater nutrient retention capacity of the soil.

When evaluating the experiments performed with the DSC in clayey soil, there was no significant difference between the three doses tested. This may be related to high CEC of the clayey soil samples used and the higher concentration of other nutrients in this type of soil. Some nutrients can compete with calcium for the available sites, not allowing a greater retention of calcium by the soil and, consequently, a greater leaching.

Potassium

The results of the accumulated potassium concentration over the 12-week experiment are shown in Figure 3a for sandy soil and 3b for clayey soil.

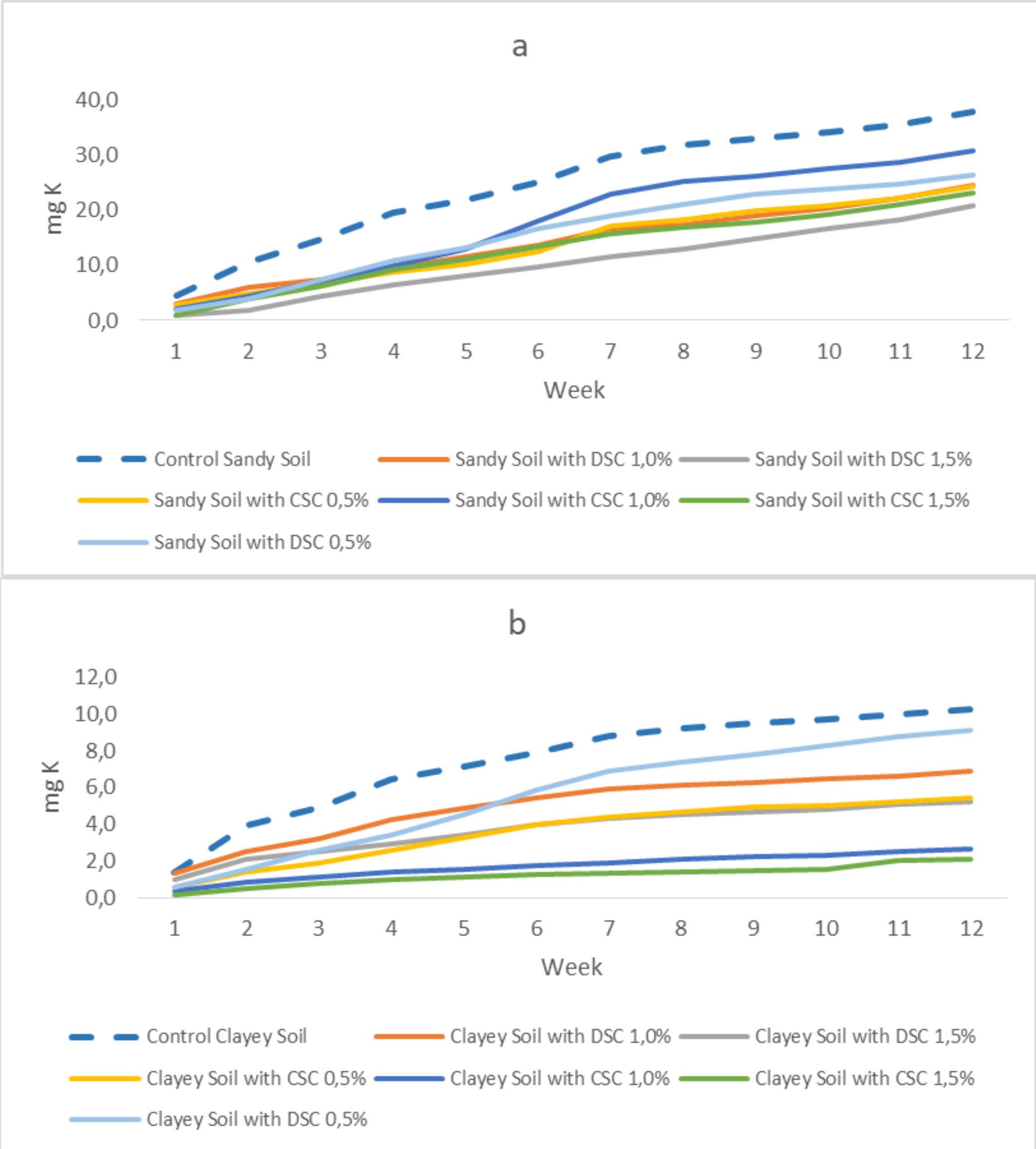


Figure 3: Leached potassium in diferents soil with addiction of DSC e CSC.

As can be seen in Figure 4a, from the first week of the experiment all the sandy soil experiments resulted in a lower potassium leaching when compared to the control sample. The DSC 1.5 treatment was the most efficient to reduce potassium leaching in sandy soil samples, followed by CSC 1.5, CSC 0.5 and DSC 1.0 treatments that presented the same efficiency. The less efficient treatments were DSC 0.5 and CSC 1.0 which presented the highest potassium results in the leachate.

Because it is a nutrient with significant mobility, it can be inferred that all soil conditioners tested at all concentrations showed efficiency in the decrease of potassium retention in sandy soils, and for the treatments performed with the DSC the amount of conditioner was proportional to efficiency. When evaluating the results obtained with the CSC, they presented a lower efficiency when compared to the DSC. It is important to note that although the CSC presented around 1% of potassium in its composition, no higher potassium leaching was observed when compared to the control sample. This is possibly related to soil nutrient balance, since according to Havlin *et al*. (1999), potassium can replace calcium at soil loading sites, which would result in lower potassium leaching and higher calcium leaching.

When the results of the tests with clayey soil are evaluated, in the first week of the experiment all the experiments showed a significant difference in relation to the control sample, being the treatments DSC 0,5 and CSC 0,5 equal to each other and the treatments DSC 1.0 and DSC 1.5 also equal. From the second week on of the experiment, it can be observed that the treatments with the DSC are differentiated from each other, as well as the treatments CSC 1.0 and CSC 1,5. On week 12, at the end of the leaching test, it was observed that the treatments DSC 1.5 and CSC 0.5 were the same between themselves and different from all other experiments, including the control sample. Thus, it can be concluded that the CSC 1.5 resulted in a reduction in the amount of leached potassium of almost 80% when compared to the control sample, whereas the best treatment with DSC showed a reduction of almost 50% in the amount of potassium leached.

As the sandy soil treatment, all treatments with clayey soil resulted in a lower leaching of potassium when compared to the control sample. The highest efficiency for reduction of potassium leaching was observed for the CSC treatment whit 1.5%, followed by the CSC 1.0% and CSC 0.5%, the latter being with the same efficiency as the DSC test. DSC 1.5 showed the best efficiency among treatments with the developed soil conditioner, followed by DSC 1.0% and DSC 0.5%. From these data, it can be inferred that, just as in sandy soils, the amount of soil conditioner added is proportional to the retention of potassium in the soil, thus reducing the amount leached. It can also be noted that the DSC showed efficiency in the reduction of potassium leaching, although this efficiency is lower than the treatments performed with the commercial soil conditioner. The higher efficiency of the commercial soil conditioner may be related to the characteristics of the peat source material of the conditioner, which may present greater potential for adsorption of smaller and monovalent adsorbates.

In a study carried out with the addition of superabsorbent hydrogels produced from a mixture of cellulose-derived compounds and acrylamide, Essawy (2016) showed that the addition of the hydrogels resulted in a lower leaching of potassium retained in the soil. The author attributed this increase in the potassium retention capacity to the increase in the number of soil sites due to the addition of the hydrogel.

Zinc

The results of the accumulated zinc concentration over the 12-week experiment are shown in Figure 4a for sandy soil and 4b for clayey soil.

During the first 3 weeks, the CSC 1.0 and CSC 1,5 treatments resulted in a lower amount of zinc in the leachate. It is also possible to observe that, from the third week on, among the treatments with the soil conditioner developed, the treatment DSC 1,5 resulted in a lower leaching of zinc. From week 8 onwards, the curves of the CSC 1.0 and CSC 1,5 treatments are close, evidencing that the two treatments had the same efficiency in the zinc retention in the soil samples and consequently resulted in smaller amounts of this leached nutrient. Evaluating the results in general, it can be inferred that all the experiments performed with sandy soil resulted in a lower amount of zinc in the leachate, evidencing that both the DSC and the CSC present efficiency.

All the experiments carried out resulted in a smaller amount of zinc leached in the clayey soils. As in the sandy soil, the lowest amounts of leached zinc were obtainedthrough the CSC 1,5 and CSC 1.0 treatments. Among the treatments with the soil conditioner developed, the DSC 1.5 treatment resulted in a lower amount of leached zinc, followed by DSC 1.0 and DSC 0.5 treatments. Evaluating the results in general, it can be inferred that all the experiments performed with clayey soil resulted in a lower amount of zinc in the leachate, evidencing that both the DSC and the CSC present efficiency decrease of the leaching of this micronutrient.

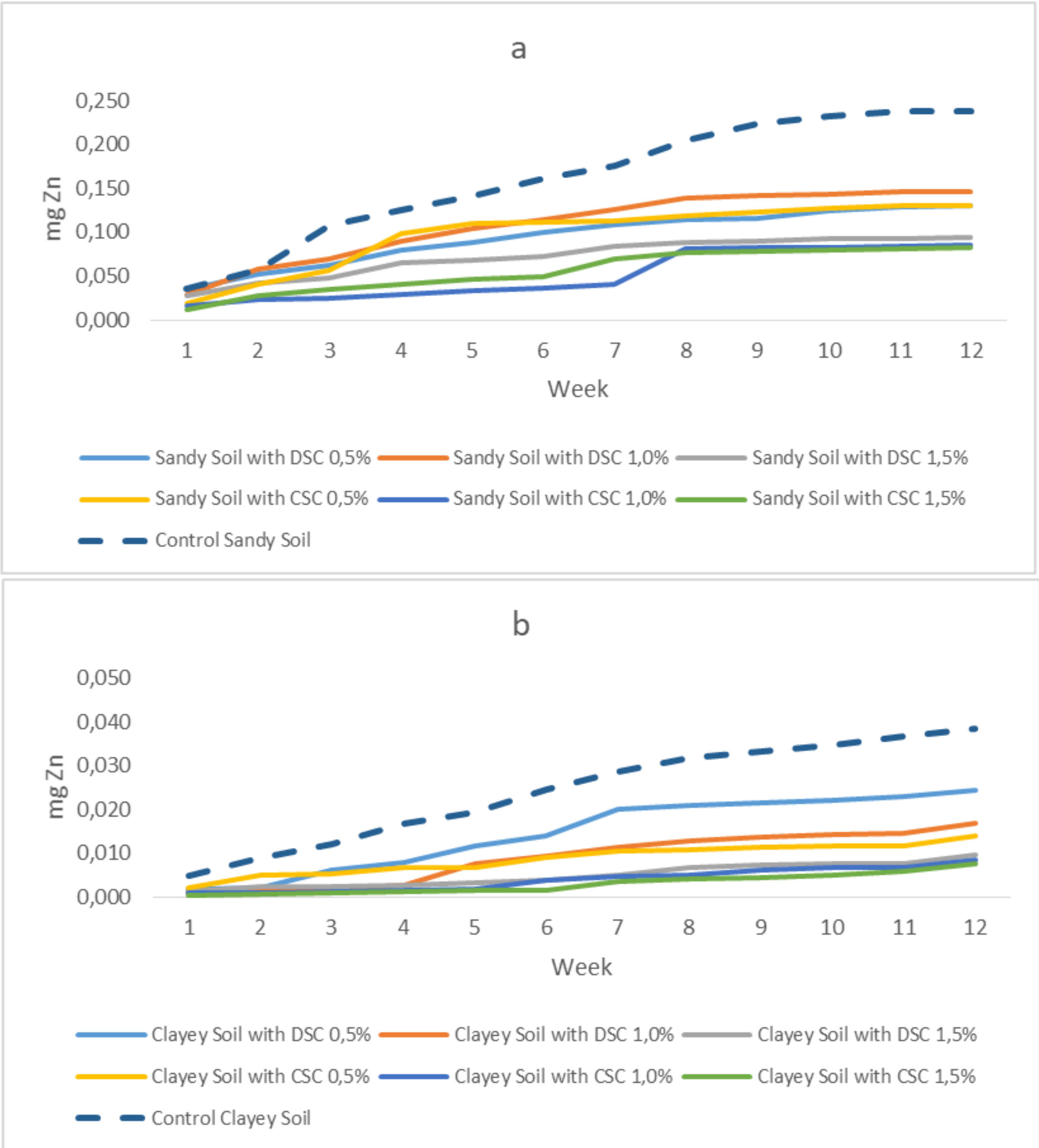
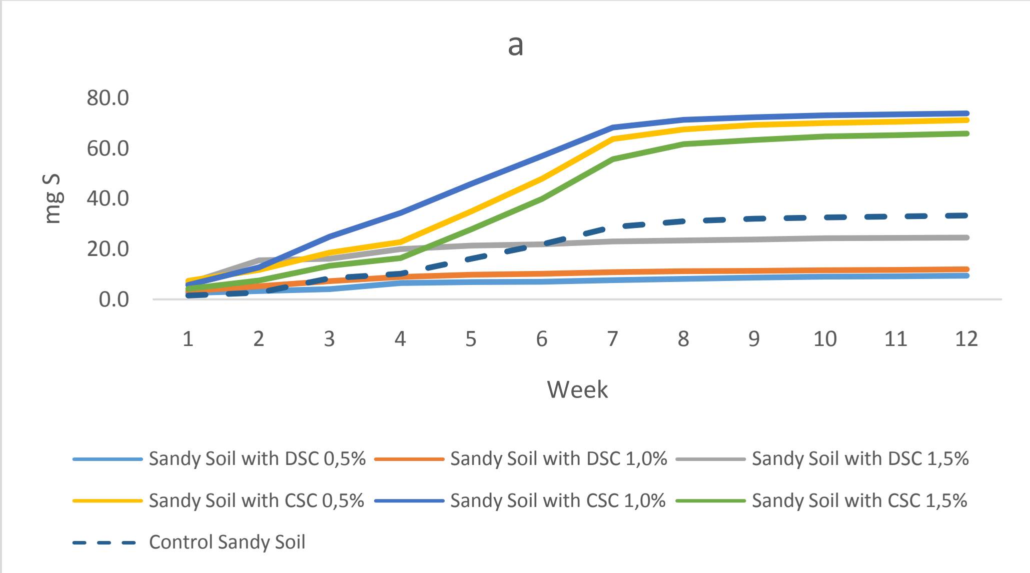


Figure 4: Leached zinc in diferents soil with addiction of DSC e CSC.

Sulfur

The results of the accumulated sulfur concentration over the 12-week experiment are shown in Figure 5a for sandy soil and 5b for clayey soil.

All treatments with CSC resulted in a higher amount of leached sulfur when compared to the control sample. This was possible because the sulfur was leached as the ionic pair for calcium, which as previously discussed was also leached in an amount greater than the control sample. These results are in agreement with Sposito (1994), who states that soil sulfur, which occurs mainly in the form of sulfate, presents high mobility in the soil profile, especially when it is in the presence of calcium.Among the treatments with the DSC, it can be observed that all three treatments resulted in a lower amount of leached sulfur, however, the lower leached sulfur results were obtained for DSC 0.5. The low sulfur leaching when using the lowest amount of DSC may be related to the water retention capacity of this material. As the DSC has a significant water retention capacity, it increases the amount of water available in the soil and, consequently, increases the potential for sulfur solubilization in the form of sulfate, which presents high solubility. With the daily addition of water, there was a greater mass of sulfate being mobilized by the soil profile during the experiment, that is, as the DSC is a hydrogel with high water retention capacity, the greater its amount in the treatments, the greater the capacity of available water in the soil, increasing the solubilization of the sulfate groups and consequently their leaching.



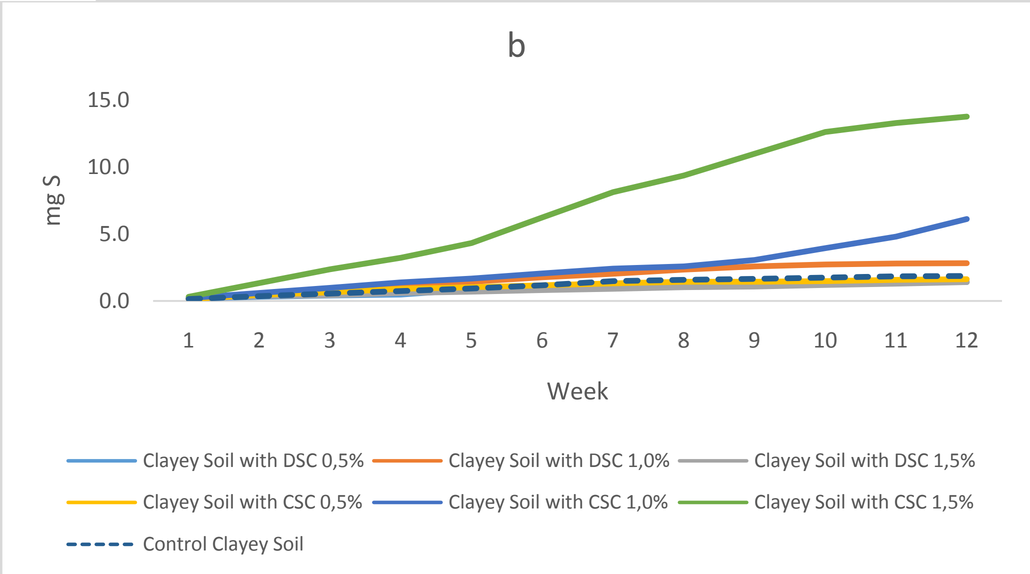


Figure 5: Leached sulfur in diferents soil with addiction of DSC e CSC.

Then, Figure 6 shows that, as it was observed in the sandy soil tests, CSC treatments resulted in a higher amount of leached sulfur when compared to the control sample. As previously discussed, the leaching of a larger amount of sulfur when using CSC occurred due to calcium leaching, resulting in leaching of the sulfur as sulfate as the ionic pair. Among the tests carried out with the DSC, the lowest amounts of leached sulfur were obtained for DSC 0,5 and DSC 1,5, which were statistically the same. As already discussed, the higher sulfur leaching when increasing the amount of soil conditioner may be related to the amount of water the conditioner allows the soil to retain, increasing the solubility of the sulfate and resulting in a higher leaching of the more soluble fractions.

Boron

The results of the accumulated boron concentration over the 12-week experiment are shown in Figure 6a for sandy soil and 6b for clayey soil

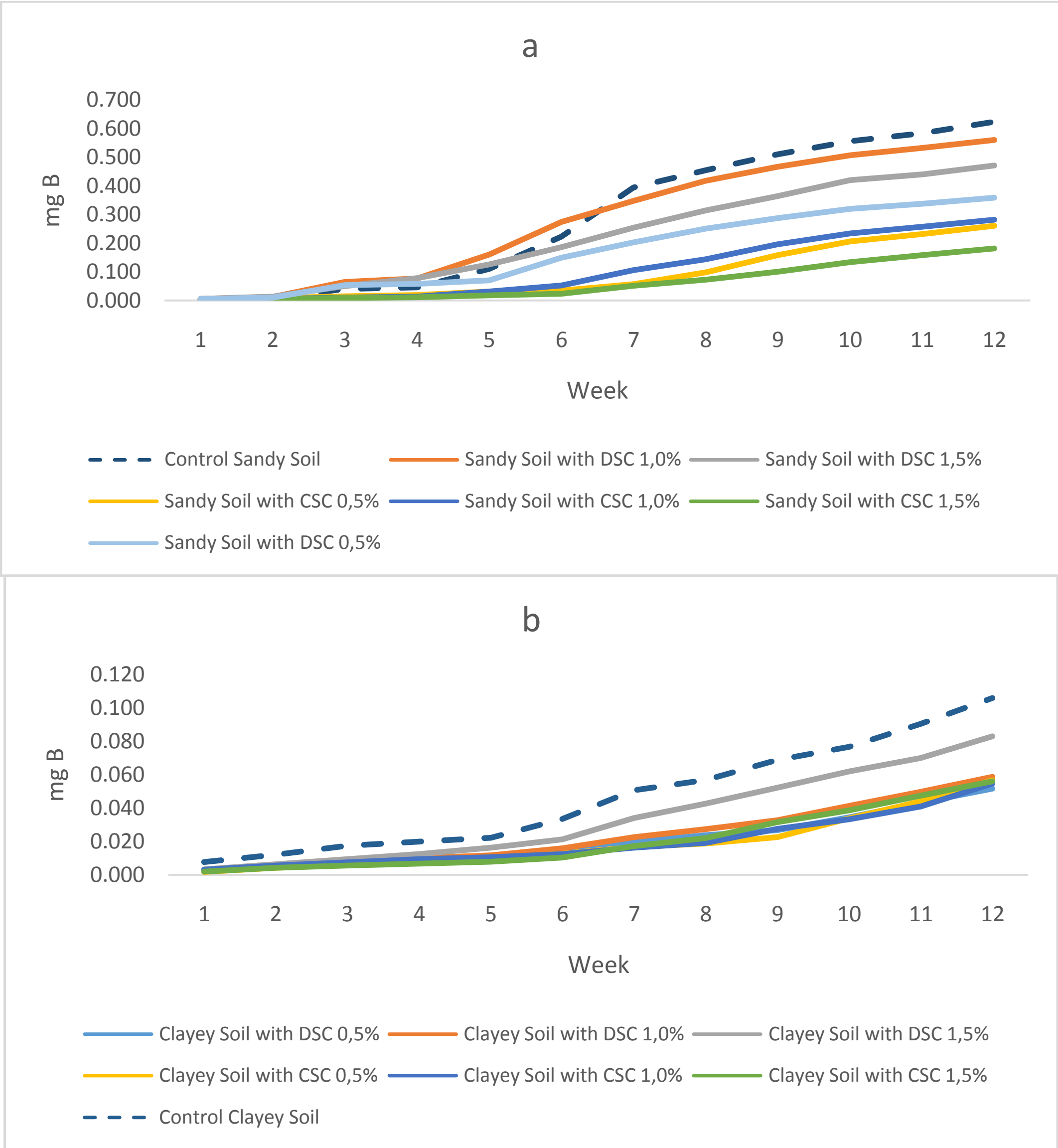


Figure 6: Leached Boron in diferents soil with addiction of DSC e CSC.

The treatments that resulted in a lower boron leaching were CSC 1.5, CSC 0.5 and CSC 1.0. The tests performed with the DSC showed a decrease efficiency of boron leaching when compared to the control sample, but this efficiency was lower when compared to the CSC. This difference is possibly also related to the potential to increase the amount of water retained in the soil. According to McBride (1994), soil boron is mainly found in the soil solution and it is slowly solubilized. As the DSC increases the amount of water available in the soil and consequently the amount of soil solution, there is a greater solubilization of the boron and consequently a greater leaching.

Figures 7 a and b show that all experiments resulted in a lower amount of leached boron, indicating the potential use of these materials as soil conditioners. The lowest values of leached boron were obtained for DSC 0.5, CSC 1.0 and CSC 1.5. Evaluating only the results of the DSC treatments, it was observed that the DSC 0.5 showed the lowest values of boron in the leachate, while the DSC 1.5 presented the highest values of boron, but still lower than the sample control. This was possibly due to the water retention potential of the DSC, as discussed above.

The results of the leaching tests in both sandy and clayey soils show that the soil conditioner developed has an efficiency in the reduction of soil boron leaching.

IV. Conclusion

When evaluating the leaching experiment in general, DSC was efficient in reducing leaching of calcium, potassium, sulfur, zinc and boron in samples of sandy and clayey soil. The dosage with the best results were 1.0% for calcium, 1.5% for potassium and zinc and 0.5% for sulfur and boron. It is worth mentioning that the results obtained for the DSC were better than the CSC in the reduction of calcium and sulfur leaching in both types of soil and potassium in sandy soil.

It was also shown that when the content of water in soil increases, this result in an increase of anions leaching, like boron and sulfur.

The DSC also presented high capacity to increase the water retention capacity in both tested soils, once it promoted increases of 36% and 230% for the addiction of 1.5% in clayey and sandy soil, respectively.

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