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RESEARCH ARTICLE

# Soybean seedling performance in diferente seed treatments

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## ABSTRACT

The objective of this work was to evaluate the performance of soybean seedlings in different seed treatments. The experiment was conducted in the municipality of Mineiros, GO. The soil was classified as Quartzarenic Entisol. The experimental design was randomized blocks in factorial 5x4, corresponding to seed treatments (Water, Cruiser, Fipronil Alta, Fortenza and Standak Top) in four soybean cultivars (Bonus, Ultra, Extra and BKS7830), in four replications. Before planting, pre-planting desiccation was performed. The fertilization used was 450 kg ha$^{-1}$ of fertilizer 05-25-15 applied in the furrow and in a single dose next to the sowing. During the conduction of the experiment the control of pests, diseases and weeds were carried out as necessary, respecting the best practices and integrated management. The data obtained were subjected to the assumptions of the statistical model, verifying the normality and homogeneity of the residual variances, as well as the additivity of the model. Uni and multivariate tools were applied. The analysis were performed at the interface Rbio and R. The interaction of soybean cultivars and types of seed treatment showed variations in all analysis evaluated in soybean seedlings. The best performances were verified among the cultivars BKS7830 that expressed the largest shoot fresh matter when submitted to Cruiser seed treatment, while the highest root length was expressed in the cultivar Ultra in the Fortenza seed treatment.

**Keywords**: *Glycine max*, seed health, quality seed, canonical correlation, oil, protein.

## INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is a legume originating in China and one of the main agricultural commodities in Brazil and in the world (Bernardeli et al., 2020; Ferreira et al., 2022). Its high importance is due to the fact that it has high levels of oil (20%) and, mainly, protein (40%) (Lopes, Vello, Pandini, Rocha, & Tsutsumi, 2002), as well as nutrients such as nitrogen (51.9 g Kg-1), phosphorus (3.7 g kg-1) and potassium (17 g kg-1) (Loro et al., 2021), which justifies its economic importance, as it is used for the manufacture of animal feed (Ministério da Agricultura, Pecuária e Abastecimento [MAPA], 2018).

World soybean production in the 2017/2018 harvest was 336.699 million tons, occupying a planted area of 124.580 million hectares. The United States is the world's leading soybean producer, accounting for 35.51% of world production and 3299 kg $ha^{-1}$ yield (Empresa Brasileira de Pesquisa Agropecuária [EMBRAPA], 2018).

Soybean in Brazil has established itself as one of the prominent products in agriculture, being one of the fastest growing crops in the last three decades (MAPA, 2018). The country is the second largest soybean producer in the world, being responsible for producing on mean 34.76% of world crop production, with a mean yield of approximately 3333 kg $ha^{-1}$. Among the Brazilian states, the state of Mato Grosso is the largest soybean producer, with an area of 9,519 thousand hectares, and the state of Paraná has the highest yield in the country, with 3503 kg $ha^{-1}$ (EMBRAPA, 2018).

The application of seed treatment products to increase production has become an increasingly common agricultural practice. Among the products, we highlight fungicides, insecticides, inoculants, antibiotics, hormones and amino acids (Bernardes, Silveira, & Mesquita, 2010). As well, it has become common to treat seeds with insecticides that have physiological action on plants, with a tendency for them to establish vigorous growth and better use of their productive potential. This growth is known as phytotonic effect, which is characterized by positive advantages in plant growth and development, provided by the application of some active ingredient (Castro, Bogiani, Silva, Gazola, & Rosolem, 2008).

The variety and diversity of products used for seed treatment have increased considerably in recent years, changing the timing of application of products that were commonly applied prior to sowing and currently has been carried out at the end of processing being stored and treated. There are few studies that analyze the performance of seed treatment in soybean, which generates clear demand for research that evolves this theme. In this sense, the objective of this work was to analyze the performance of soybean seedlings in different seed treatments.

## MATERIAL AND METHODS

The study was conducted from November 24 to December 19, 2018, at the Luís Eduardo de Oliveira Salles Experimental Farm, belonging to UNIFIMES, rural area of Mineiros, GO, Brazil. Geographically it is at 17º 58' S latitude and 45º 22' W longitude and approximately 800 m altitude. Mean temperature of 22.7 °C and annual mean rainfall of 1695 mm, occurring mainly in spring and summer. The experimental area is classified as Aw (hot dry) climate (Köppen, 1936).

The results of chemical analysis of soil samples in the 0-20 cm layer collected in the area of the experiment were: hydrogen potential 5,7; calcium 3, magnesium 0.8, aluminum 0.2, hydrogen + aluminum 2, cation exchange capacity 5.9, in cmole $dm^{-3}$; potassium 53, phosphorus 59, sulfur 1.7, boron 0.2, copper 1.4, iron 51, manganese 23, zinc 8.3, sodium 1.5, in mg $dm^{-3}$; clay 223, silt 50, sand 728, organic matter 20 and organic carbon 12, in g $dm^{-3}$. Data were taken according to methodology of the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) (2009). The soil was classified as a sandy texture Quartzarenic Entisol (Empresa Brasileira de Pesquisa Agropecuária [EMBRAPA], 2013).

The experimental design was randomized blocks in factorial 5x4, totaling 20 treatments, corresponding to seed treatments (Water, Cruiser, Fipronil Alta, Fortenza and Standak Top) in four soybean cultivars (Bonus, Ultra, Extra and BKS7830), in four repetitions, totaling 80 experimental units, where each unit was composed of four lines of five meters in length distanced every 0.45 m, with density of 15 seeds per meter of furrow. The main morphoagronomic characteristics of soybean cultivars were described (Table 1).

**Table 1.** Main morphoagronomic characteristics of soybean cultivars. Mineiros, GO, UNIFIMES, Brazil, 2019.

| Cultivar | Maturation group | Seed Genetics | Thousand seed mass (g) | Plant architecture | Cycle (days after emergence) |
|---|---|---|---|---|---|
| Bônus | 7.9 | Brasmax | 190 g | Undetermined | 105 to 122 |
| Ultra | 7.5 | Brasmax | 175 g | Undetermined | 100 to 110 |
| Extra | 7.4 | Brasmax | 157 g | Undetermined | 100 to 110 |
| BKS7830 | 7.3 | Embrapa | 174 g | Undetermined | 100 to 110 |

Before sowing, pre-planting desiccation was performed (Cobucci, Stefano, & Kluthcouski, 1999). The fertilization used was 450 kg $ha^{-1}$ of fertilizer 05-25-15 applied in the furrow and in a single dose next to the sowing. The seeds were treated one day before sowing in polyethylene bags, with the recommended doses of each product for 100 kg of seeds. The main characteristics of the products used as seed treatments were described (Table 2).

**Table 2.** Main characteristics of the products used as seed treatment. Mineiros, GO, UNIFIMES, Brazil, 2019.

| Product | Form. | Active ingredient | g.a.i ha-1 | Dose (ml or g ha-1) |
|---|---|---|---|---|
| Water | - | - | - | - |
| Fortenza | 750 FS | Antranilamida | 600 | 40 a 200 |
| Cruiser | 350 FS | Tiametoxan | 350 | 100 a 300 |
| Fipronil Alta | 250 FS | Fipronil | 250 | 80 a 200 |
| Standak Top | | Piraclostrobina, Tiofanato Metílico and Fipronil. | | 80 a 200 |

During the conduction of the experiment, the control of pests, diseases and weeds were carried out as necessary, respecting the good practices and integrated management (Quintela, 2001). At the end of the experiment, ten randomized plants were collected in the useful area of the experimental plot and then the agronomic attributes were evaluated: stem diameter (SDI) in cm, hypocotyl height (HHE) in cm, epicotyl height (EHE) in cm, seedling height (SHE) in cm, root length (RLE) in cm, shoot fresh mass (SFM) in g and root fresh mass (RFM) in g (Benincasa, 2004).

The obtained data were submitted to the assumptions of the statistical model, verifying the normality and homogeneity of the residual variances, as well as the additivity of the model. Afterwards, the analysis of variance was performed in order to identify the interaction between soybean cultivars x positioning of the seed treatments. When verifying significant interaction, they were broken down to simple effects through the Scott-Knott grouping test at 5% probability.

Subsequently, the variables were submitted to linear correlation in order to understand the tendency of association, and their significance was based on 5% probability by the t test, after genetic dissimilarity by the Mahalanobis algorithm, where the residual matrix was weighted. After the distance dendrogram was constructed through the UPGMA grouping, the biplot canonical variables method was used to visualize the general variability of the experiment and the multivariate trends. The analysis were performed at the interface Rbio and R (Bhering, 2017).

## RESULTS AND DISCUSSION

The analysis of variance summary with the mean square MS and significance by the F test revealed significant interaction between cultivar x seed treatment in all variables (p <0.01) (Table 3). The results found corroborate with Moraes Dan, Almeida, Piccinin, Ricci and Ortiz (2012), Mattos et al. (2018), Silva, Oliveira and Neres (2018) and Ferreira et al. (2020), when diagnosing changes in the means of their respective works.

**Table 3.** Analysis of variance summary (calculated MS and CV (%)) for stem diameter (SDI), hypocotyl height (HHE), epicotyl height (EHE), seedling height (SHE), root length (RLE), shoot fresh mass (SFM) and root fresh mass (RFM) of soybean cultivars submitted to different seed treatments. Mineiros, GO, UNIFIMES, Brazil, 2019.

| V.F. | DF | SDI | HHE | EHE | SHE | RLE | SFM | RFM |
|---|---|---|---|---|---|---|---|---|
| C x ST | 12 | 0.0005** | 0.4499** | 0.2852** | 0.9312** | 3.4522** | 59.3619** | 1.8430** |
| Cultivar C | 3 | 0.0013** | 0.9626** | 1.3790** | 0.8423** | 0.4407 | 36.3333** | 10.2138** |
| Seed treatment ST | 4 | 0.0002 | 0.6887** | 0.1382** | 0.5080** | 2.9414** | 23.3328** | 0.7930 |
| Block | 3 | 0.0001 | 0.0843 | 0.0052 | 0.0519 | 0.2200 | 17.666 | 0.2338 |
| Residue | 57 | 0.0001 | 0.0311 | 0.0181 | 0.0549 | 0.1772 | 21.635 | 0.3303 |
| C.V | | 6.65 | 4.42 | 3.86 | 3.13 | 5.96 | 8.08 | 14.20 |

** Significant at 1% probability by F test.

Based on the results found in Table 4, it was observed that the SDI in cv. Ultra stood out among the others with an mean of 0.21 cm in the ST Cruiser, which, in turn, was the ST that provided the highest means among the seed treatments in the cultivars studied. Similar results were found by Silva et al. (2017); however Oliveira et al. (2015) and Silva et al. (2018) found no statistical difference for SDI, attributing to this result good quality seeds, which standardizes this variable.

For the variable seedling hypocotyl height (HHE), it was observed that cv. Ultra (4.69 cm) was the one that obtained the highest mean in the ST Cruiser among the cultivars, and among the seed treatments, the one that stood out was Fortenza, providing an increase in the BKS7830, Bônus and Ultra materials (Table 4). According to the study developed by Mattos et al. (2018), the HHE ranged from 1.32 to 2.35 cm, and similar results were found in the study by Santana et al. (2018) who aimed to perform genetic analysis for HHE, reporting that hypocotyl elevation makes seedlings more resistant to factors such as soil crusting and sowing depth. For the seedling epicotyl height (EHE), it was observed that in ST Standak Top, the cv. Extra obtained the highest mean with 4.22 cm. ST Fipronil Alta showed the best performance among the others (Table 4). Similar results were evidenced by Souza et al. (2015) where they obtained positive responses in vigor of soybean seedlings with seed treatments composed by Standak Top.

**Table 4.** Breakdown of interaction (Cultivar x seed treatment) for stem diameter (SDI), hypocotyl height (HHE), epicotyl height (EHE) and seedling height (SHE) of soybean seedlings submitted to different seed treatments. Mineiros, GO, UNIFIMES, Brazil, 2019.

| Cultivars | -------------Seed treatments------------- | | | | |
|---|---|---|---|---|---|
| | Water | Cruiser | Fipronil Alta | Fortenza | Standak Top |
| | Stem diameter SDI (cm) | | | | |
| BKS7830 | 0.16 bB[1] | 0.19 bA | 0.18 aB | 0.17 bB | 0.16 bB |
| Bônus | 0.20 aA | 0.19 bA | 0.19 aA | 0.18 bA | 0.20 aA |
| Extra | 0.19 aA | 0.17 bA | 0.18 aA | 0.19 aA | 0.18 bA |
| Ultra | 0.17 bB | 0.21 aA | 0.18 aB | 0.19 aA | 0.20 aA |
| // | Hypocotyl height HHE (cm) | | | | |
| BKS7830 | 3.87 aB | 4.34 bA | 4.12 aA | 4.26 bA | 4.36 aA |
| Bônus | 3.53 bC | 3.61 cC | 3.78 bC | 4.54 aA | 4.09 bB |
| Extra | 4.08 aA | 3.82 cB | 3.42 cC | 3.78 cB | 3.47 cC |
| Ultra | 4.02 aB | 4.69 aA | 3.82 bB | 4.57 aA | 3.60 cC |
| // | Epicotyl height EHE (cm) | | | | |
| BKS7830 | 3.41 aA | 3.47 bA | 3.29 bA | 2.91 bC | 3.17 bB |
| Bônus | 3.08 bC | 3.00 cC | 3.67 aA | 3.48 aA | 3.29 bB |
| Extra | 3.50 aD | 4.00 aB | 3.77 aC | 3.60 aD | 4.22 aA |
| Ultra | 3.63 aA | 3.64 bA | 3.74 aA | 3.58 aA | 3.25 bB |
| // | Seedling height SHE (cm) | | | | |
| BKS7830 | 7.28 bB | 7.81 bA | 7.42 aB | 7.17 bB | 7.53 aA |
| Bônus | 6.61 cC | 6.61 cC | 7.46 aB | 8.02 aA | 7.38 aB |
| Extra | 7,58 aA | 7.83 bA | 7.19 aB | 7.39 bB | 7.70 aA |
| Ultra | 7.65 aB | 8.33 aA | 7.56 aB | 8.15 aA | 6.86 bC |

[1]Means followed by the same lower case letter vertically and upper case horizontally do not differ from each other by the Scott-Knott test at 5% probability.

Regarding the seedling height (SHE), it was verified that, among the cultivars, cv. Ultra obtained the highest mean (8.33 cm) in ST Cruiser, and it stood out among the other seed treatments (Table 4). In similar studies Moraes Dan et al. (2012) also found differences between the analyzed seed treatments. As reported by Silva et al. (2017) where he obtained in all STs elevation in SHE, thus differing from ST water. Some factors such as genotype, vitality, longevity, viability, maturity and physiological potential of seeds can influence seedling germination and growth (Ferreira & Borghetti, 2004).

By analyzing Table 5 it was possible to identify that the root length (RLE) in cv. Extra was reduced when submitted to ST Water. The ST Water was the one that presented the lowest means among the other seed treatments for the RLE. Results obtained by Moraes Dan et al. (2012), observed that the RLE in the ST Cruiser did not differ from the control ST, but, it reached a higher mean than the other STs.

However, the work of Cunha et al. (2015), demonstrated that the RLE was not altered by the different STs analyzed.

**Table 5.** Breakdown of interaction (Cultivar x seed treatment) for root length (RLE), shoot fresh mass (SFM) and root fresh mass (RFM) of soybean cultivars submitted to different seed treatments. Mineiros, GO, UNIFIMES, Brazil, 2019.

| Cultivars | -------------Seed treatments------------- | | | | |
|---|---|---|---|---|---|
| | Water | Cruiser | Fipronil Alta | Fortenza | Standak Top |
| | Root length RLE (cm) | | | | |
| BKS7830 | 6.60 aC[1] | 7.06 aB | 7.90 aA | 5.65 cD | 7.79 bA |
| Bônus | 6.43 aC | 6.02 bC | 7.35 aB | 7.25 bB | 9.03 aA |
| Extra | 5.86 bC | 7.11 aB | 6.66 bB | 7.67 bA | 7.08 cB |
| Ultra | 6.77 aC | 7.38 aB | 6.73 bC | 8.45 aA | 6.32 dC |
| // | Shoot fresh mass SFM (g) | | | | |
| BKS7830 | 21.50 aB | 26.25 aA | 19.00 aC | 17.75 bC | 15.75 bD |
| Bônus | 14.75 bB | 23.00 bA | 16.25 bB | 16.62 bB | 21.12 aA |
| Extra | 19.75 aB | 12.25 dD | 16.50 bC | 22.00 aA | 15.75 bC |
| Ultra | 13.75 bC | 18.25 cB | 15.25 bC | 17.75 bB | 20.75 aA |
| // | Root fresh mass RFM (g) | | | | |
| BKS7830 | 4.75 aA | 5.25 aA | 4.75 aA | 3.50 bB | 3.75 bB |
| Bônus | 3.25 bB | 3.75 bB | 3.25 bB | 3.25 bB | 4.95 aA |
| Extra | 4.50 aB | 4.25 bB | 4.50 aB | 5.75 aA | 5.25 aA |
| Ultra | 2.75 bA | 3.50 bA | 3.25 bA | 3.25 bA | 3.50 bA |

[1]Means followed by the same lower case letter vertically and upper case horizontally do not differ from each other by the Scott-Knott test at 5% probability.

In shoot fresh matter (SFM) it can be observed that cv BKS7830 had its SFM inferior to the others. Reduction in SFM was also observed in ST Fipronil Alta. The highest mean in root fresh mass (RFM) was noted in cv. Extra and among the STs on Standak Top (Table 5). In work conducted by it was possible to observe that SFM and RFM that the chemical STs differed from the control ST, concluding that the treatments with mixtures of active ingredients and separated according to the combination have positive action for the seed treatment in the plant development.

The simple linear correlation matrix revealed the positive pairs (HHExSHE), (HHExRLE), (EHExSHE), (EHExRFM), (SHExRLE), (RLExRFM) and (SFMxRFM) and negative pairs only in (EHExSFM) (Table 6). The association between agronomic characteristics is important because it allows to verify the degree of interference of one trait on another of economic interest, as well as to practice indirect selection (Zuffo et al., 2016). In this context, Pearson's correlation coefficient is used to express the degree of association between two numerical variables.

The correlation network showed positive interaction only among the variables hypocotyl height (HHE) and seedling height (SHE), but the other correlations were not significant (Figure 1). According, to interpret the correlations, one must consider three factors: magnitude, direction and significance. Carvalho et al. (2016), in a study with corn, concluded that the adoption of seed treatment changes the magnitude of associations between characters related to the physiological quality of corn. By analyzing the dendrogram representative of dissimilarity for the variables, it can be noted that four distinct groups were formed, highlighting the individual groups Extra_Cruiser and BKS7830_Cruiser (Figure 2).

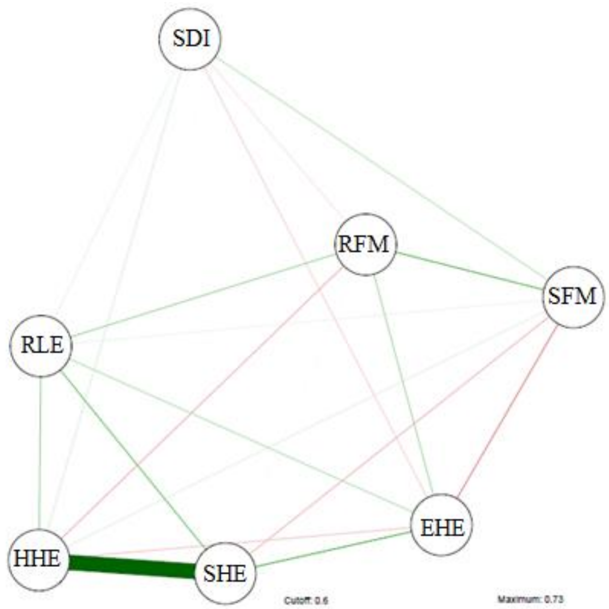


**Figure 1.** Correlation network applied for stem diameter (SDI), hypocotyl height (HHE), epicotyl height (EHE), seedling height (SHE), root length (RLE), shoot fresh mass (SFM) and root fresh mass (RFM) of soybean cultivars submitted to different seed treatments. Mineiros, GO, UNIFIMES, Brazil, 2019.

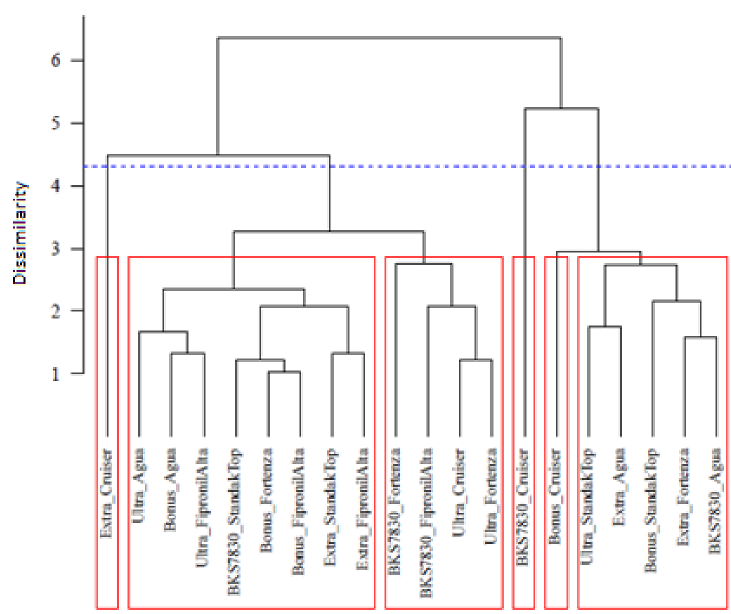


**Figure 2.** Dendrogram representing dissimilarity for stem diameter (SDI), hypocotyl height (HHE), epicotyl height (EHE), seedling height, (SHE) root length (RLE), shoot fresh mass (SFM) and root fresh mass (RFM) of soybean cultivars submitted to different seed treatments. Mineiros, GO, UNIFIMES, Brazil, 2019.

**Table 6.** Simple phenotypic correlation matrix for stem diameter, (SDI) hypocotyl height (HHE), epicotyl height (EHE), seedling height (SHE), root length (RLE), shoot fresh mass (SFM) and root fresh mass (RFM) of soybean cultivars subjected to different seed treatments. Mineiros, GO, UNIFIMES, Brazil, 2019.

| Variables | SDI | HHE | EHE | SHE | RLE | SFM | RFM |
|---|---|---|---|---|---|---|---|
| SDI | 1 | | | | | | |
| HHE | 0.08 | 1 | | | | | |
| EHE | -0.1 | -0.15 | 1 | | | | |
| SHE | 0 | 0.73** | 0.57** | 1 | | | |
| RLE | 0.05 | 0.30** | 0.19 | 0.38** | 1 | | |
| SFM | 0.17 | 0.07 | -0.32** | -0.17 | 0.05 | 1 | |
| RFM | -0.06 | -0.18 | 0.24* | 0.01 | 0.26* | 0.51** | 1 |

Significance: * 5% probability; ** 1 probability.

According to, the use of correlation networks may increase the effectiveness of selection in soybean breeding, since it allows us to quickly identify the pairs of traits that present the highest correlations, determining which groups of variables influence more expressively the most important characters for the breeding program and identify the groups of correlated variables. For this, the canonical correlation was used, which assumes that the characters do not only present a linear trend in pairs, and it is possible that not only a single trait influences the main attributes of this species, but two or more determining characters (Vergara et al., 2021). Silva, Rêgo, Pessoa and Rêgo (2016) also observed the potentiality of the use of correlation networks to improve pepper (*Capsicum* spp.).

The canonical axes add up to an explanation total equivalent to 76.07% of the total data variation. The variables SFM, RFM and SDI showed similarities, where cultivar BKS7830 with ST Cruiser presented the highest SFM and cultivar Extra in ST Fortenza for SDI and RFM. Cultivar Ultra in ST Fortenza corresponded to the highest RLE and SHE (Figure 3).

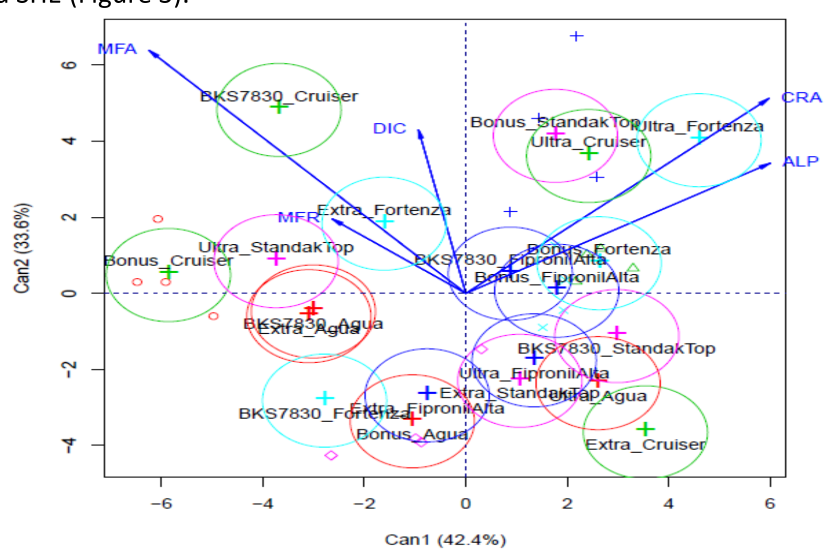


**Figure 3.** Analysis of canonical variables for stem diameter (SDI), hypocotyl height (HHE), epicotyl height (EHE), seedling height (SHE), root length (RLE), shoot fresh mass (SFM) and root fresh mass (RFM) of soybean cultivars submitted to different seed treatments. Mineiros, GO, UNIFIMES, Brazil, 2019.

Silva et al. (2015) state that multivariate analysis techniques are efficient to verify similarities or differences in yield variability based on chemical and physical soil attributes in the studied area. Also being added the influence of soybean genetic variability and seed treatment on the initial seedling performance of their seedlings.

## CONCLUSIONS

The interaction of soybean cultivars and types of seed treatments showed variations in all analysis evaluated in soybean seedlings.

Hypocotyl height and root fresh matter have high correlations with the other variables.

The best performances were verified among the cultivars BKS7830 which expressed the largest shoot fresh matter when submitted to Cruiser seed treatment, while the largest root length was expressed in the Ultra cultivar in the Fortenza seed treatment.

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