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Application technology with the use of different adjuvants in soybean culture

Tecnologia de aplicação com o uso de diferentes adjuvantes na cultura da soja

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ABSTRACT

The objective of this work has been to evaluate the efficiency of the effect of the addition of four types of adjuvants in the spray solution used in the soybean (*Glycine max* L.) crop. The experimental design was the randomized blocks with five treatments based on the application of adjuvants, as follows: without adjuvant (control) and with the adjuvants Blend®, Tech-Plus®, LI700®, and Protect®. For qualification, the number of droplets, relative dispersion, volume median diameter, volume applied to the target, droplet density, and percentage of coverage in the upper, middle, and lower third positions of the crop, as well as yield components, 1000-grain weight, and productivity were measured. In the upper third, the adjuvant Protect® presented the lowest relative dispersion, resulting in greater droplet spectrum homogeneity. In the middle third, the application with the adjuvant LI700® promoted greater effectiveness, and the application without adjuvants provided a greater number of droplets in the lower third of the crop. In the middle and lower position, the adjuvant Protect® presented a low-quality application, manifested by the lower number of droplets, applied volume, and droplet density. There was no significant difference in yield components resulting from the adverse weather conditions during the experiment. The addition of adjuvants showed greater application efficiency in the upper and middle third of the.
KEYWORDS: droplet spectrum; yield; spraying.

RESUMO

O objetivo deste trabalho foi avaliar a eficiência do efeito da adição de quatro tipos de adjuvantes na calda de pulverização empregada na aplicação da cultura da soja (*Glycine max* L.). O delineamento experimental foi de blocos ao acaso, com cinco tratamentos baseados na aplicação de adjuvantes, sendo: sem adjuvante (testemunha), e com adjuvantes Blend®, Tech-Plus®, LI700® e Protect®. Para qualificação foi mensurado o número de gotas, dispersão relativa, diâmetro médio volumétrico, volume aplicado no alvo, densidade de gotas e porcentagem de cobertura nas posições terço superior, médio e inferior da cultura, bem como, componentes de rendimento, massa de mil grãos e produtividade. No terço superior, o adjuvante Protect® apresentou a menor dispersão relativa, resultando em maior homogeneidade do espectro de gotas. No terço médio, aplicação com adjuvante LI700® promoveu maior efetividade na aplicação, sendo que a aplicação sem adjuvantes, proporcionou maior número de gotas no terço inferior da cultura. Na posição mediana e inferior, o adjuvante Protect® apresentou uma baixa qualidade de aplicação, manifesta pelo menor número de gotas, volume aplicado e densidade de gotas. Não houve diferença significativa nos componentes de rendimento, fato advindo das condições climáticas adversas durante o experimento. A adição de adjuvantes demonstrou maior eficiência de aplicação no terço superior e médio da cultura.
PALAVRAS-CHAVE: espectro de gotas; produtividade; pulverização.

INTRODUCTION

The use of chemical products can be considered one of the most critical steps in the soybean production chain, as this use requires a set of knowledge and techniques to ensure efficient and satisfactory control. The current increase in demand for food also results in an increased pressure to preserve the environment when using land for grain production, and this action affects the search for improvements in the techniques of application of phytosanitary products to ensure greater efficiency and environmental safety (VIEIRA et al. 2019).

In phytosanitary control, a very important term is application technology, in which adjuvants can be mentioned, which are any substance that, when added to a phytosanitary product, or placed together with the preparation of the mixture, has the function of facilitating and improving the application, in this way expanding the performance of the product of interest and reducing losses and risks in the process (ARAÚJO & RAETANO 2015).

In a study that has compared nine types of adjuvants aiming to improve the performance of fungicide application in the control of Asian soybean rust (*Phakopsora pachyrhizi*), TANIMOTO et al. (2011) have found no significant differences between adjuvants. On the other hand, the study of OLIVEIRA et al. (2015) with 33 aqueous solutions obtained from the combination of adjuvants has demonstrated that adding these products changes the physical and chemical properties of the aqueous solutions in different magnitudes depending on the concentration used. In this research, the organosilicon surfactants decreased surface tension, while the polymer-based drift-reducing adjuvants increased the viscosity and density of the solutions. In the control of drift in different spray nozzles, adding the vegetable polymer adjuvant efficiently reduced drift (MADUREIRA et al. 2015).

Adjuvants can also affect the physical structure of the droplet by increasing the volume median diameter with the use of adjuvant oils when compared to surfactant-based products (MOTA & ANTUNIASSI 2013). Every year, new products are launched on the market with variations in their chemical composition, which raises doubts in users about their real benefits; in this sense, the objective of this work has been to assess the efficiency of the effect of the addition of four types of adjuvants in the spray solution used in soybean crop (*Glycine max* L.).

MATERIAL AND METHODS

The experiment was carried out in the experimental area of the Federal Institute of Education, Science, and Technology of Rio Grande do Sul (IFRS), Campus Sertão, Brazil, in soil classified as dystrophic Red Nitosol (EMBRAPA 2018) and delimited by the geographic coordinates 28°02'48.2"S and 52°15'59.3"W. According to the Köppen climate classification, the climate is the Cfa, humid subtropical, with average temperatures of approximately 17.8 °C and an average altitude of 685 m.

The cultivar used was Brasmax® Ativa RR, with medium cycle and determined growth habit, using a density of 16 seeds linear m^{-1}, spaced at 0.45 m between rows, with a population of 355,000 $plants^{-1}$. At the time of sowing, November 19, 2019, the soil was covered by crop residues from an intercropping of tufted vetch (*Vicia Craca* L.), oilseed radish (*Raphanus sativus* L.), and oat (*Avena sativa* L.)

The experiment was carried out in a randomized block design (6) with five treatments based on the application of adjuvants in the spray solution, namely: standard application without adjuvant (control), and application with the adjuvants Blend®, Tech-Plus®, LI700®, and Protect®. The composition and technical details are described in Table 1. The experimental plots measured 4.0 x 6.0 m and the spacing between plots was 0.9 m and 0.9 m between blocks.

Table 1. Technical description of the adjuvants used in the experiment on soybean.

Adjuvants	Composition[1]	Type	Dose[2] (mL L^{-1})
Blend®	Magnesium chloride, zinc chloride	Mixed mineral fertilizer	0.5
Tech-Plus®	Urea, phosphoric acid	EDTA, emulsifier	0.6
LI700®	Propionic acid, lecithin	Surfactant and acidifying agent	0.5
Protect®	Organosilicon polyester copolymers, plant extracts	Emulsifier, tensioactive, and surfactant	0.5

[1]Composition information provided by manufacturers. [2]Dose recommended by the manufacturer.

For application of treatments, we used a backpack sprayer with a 10 L application tank (Figure 1A), eight nozzle rod (Teejet® 11001 TTPV), equipment pressure fed by a CO_2 tank, which was adjusted to 4 bar to result in an application volume of 95 L ha^{-1}.

The phytosanitary control of the area was carried out “equally” between the plots, with applications of fungicide, insecticide, mineral oil, and the respective adjuvant for each treatment. The first application was at V6, the second at R2 (full flowering, and an open flower in one of the last two stem nodes, with a fully developed leaf), when the experiment was evaluated. No additional applications were made in the area because of the climatic condition of extreme water stress. The products applied in the applications were 100 mL ha^{-1} of triflumuron (Certeiro®), 500 mL ha^{-1} of imidacloprid and beta-cyfluthrin (Connect®), and 300 mL ha^{-1} of lambda-cyhalothrin (Brutus®).

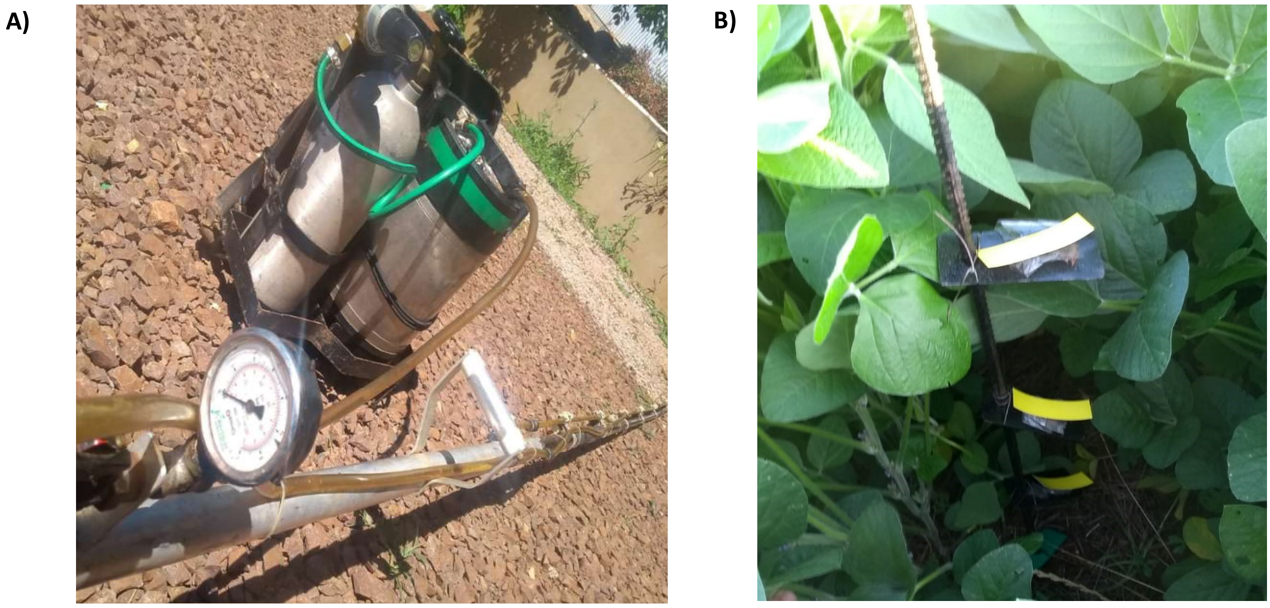

Figure 1. CO_2 pressurized backpack sprayer used in the experiment (A), and positions of the water-sensitive papers in the soybean crop (B).

To assess the quality of the application, water-sensitive papers were used by arranging them at three different heights in each plot: lower third, middle third, and upper third (Figure 1B). After application, the papers were identified, packed in newspapers to maintain their integrity, sent for scanning, then processed by the software *Sistema de Análise de Deposição de Agrotóxicos - Gotas 64 bits*.

The number of droplets, relative dispersion, volume of spray solution in liters per hectare, droplet density, volume median diameter (VMD), and percentage of coverage were assessed (EMBRAPA 2014). Based on the droplet density and volume median diameter, the application was classified according to Table 2.

Table 2. Application classification according to droplet density and volume median diameter.

Spray type[1]	Droplet density (drop cm^{-2})
Insecticide	20-30
Pre-emergence herbicide	20-30
Contact herbicide	30-40
Fungicide	50-70
Volume median diameter[2]	**Droplet size**
<60µ	Extremely Fine
61-105µm	Very Fine
106-235 µm	Fine
236-340 µm	Medium
341-403 µm	Coarse
404-502 µm	Very Coarse
503-665 µm	Extremely Coarse
>665 µm	Ultra Coarse

[1]Source: MÁRQUEZ (1997). [2]Source: ASAE (2000).

In addition, the yield and 1000-grain weight were quantified, and the plants arranged in two lines, in 2.0 linear m, were harvested after being threshed by a mechanical thresher, and corrected for 14% of humidity.

Statistical analysis consisted of normality test, analysis of variance using the F-test, and comparison of means using the Tukey test at a significance level of 5% performed using the statistical software Sisvar®. The data in the upper third and middle third position, with the exception of the dispersion, were transformed by log10; in the lower third position, the parameters of number of droplets and number of diameters were transformed by the same described method; the applied volume and droplet density used $(x+1)^{0.5}$; and, finally, coverage used (x+1). The choice of the transformation method was due to the magnitude of the values associated with the decrease in the CV of the data and their normality.

RESULTS AND DISCUSSION

The results of the application of different adjuvants in the upper, middle, and lower thirds of soybean show significant differences along the plant canopy (Table 3). In the upper position, with the exception of the relative dispersion, the other parameters were not affected by the treatments, a fact attributed to the position in the plant, which is easily reached because the leaf area imposes no barriers, and, consequently, there is greater deposit in this region regardless of the application volume (PRADO et al. 2015) or the adjuvant used (CONSTANTIN et al. 2012).

Table 3. Number of droplets (ND), relative dispersion (Dr), volume (Vol.), droplet density (Dd), coverage (Cov.), volumetric mean diameter (VMD), and classification (Class.) according to type of application and droplet size deposited by the spray in the upper, middle, and lower third of the soybean in relation to the different adjuvants.

Treatment	ND	Dr	Vol.	Dd		Cov.	VMD	
			L ha^{-1}	cm^{-2}	Class.	%	µm	Class.
			Upper third					
Blend®	1270.67 a*	1.16 b	125.99 a	29.08 a	I + Hp	16.84 a	683.82 a	uc
LI700®	1054.83 a	1.34 a	181.79 a	23.31 a	I + Hp	29.30 a	1436.27 a	uc
Protect®	981.00 a	1.02 b	93.36 a	21.66 a	I + Hp	12.84 a	621.43 a	ec
Tech-Plus®	1202.83 a	1.19 ab	161.25 a	26.76 a	I + Hp	19.77 a	862.99 a	uc
Control	963.00 a	1.07 b	76.78 a	21.20 a	I + Hp	11.34 a	565.49 a	ec
CV[1] (%)	4.66	13.54	14.97	9.44		21.25	7.57	
			Middle third					
Blend®	290.83 b	0.78 b	12.25 b	6.59 b	nsa	2.10 b	400.50 b	c
LI700®	585.96 a	1.38 a	61.58 a	13.33 a	nsa	11.40 a	952.69 a	uc
Protect®	149.50 b	0.80 b	9.04 b	3.36 b	nsa	1.46 b	377.96 b	c
Tech-Plus®	578.33 ab	0.87 b	29.42 ab	13.11 ab	nsa	4.89 ab	406.94 b	vc
Control	237.00 ab	0.79 b	9.55 ab	5.29 ab	nsa	1.75 ab	403.46 b	c
CV (%)	21.53	29.40	58.76	72.23		212.09	6.26	
			Lower third					
Blend®	129.50 b	0.70 a	4.23 a	2.68 a	nsa	0.79 a	319.15 a	m
LI700®	165.40 ab	0.63 a	4.52 a	3.74 a	nsa	0.92 a	304.83 a	m
Protect®	15.50 b	0.68 a	0.47 a	0.34 a	nsa	0.07 a	330.98 a	m
Tech-Plus®	60.20 ab	0.86 a	5.68 a	3.70 a	nsa	1.05 a	418.63 a	vc
Control	302.06 a	0.93 a	6.69 a	6.68 a	nsa	1.37 a	340.43 a	m
CV (%)	38.29	25.51	46.78	45.04		24.92	3.73	

*Means followed by the same letter in the column do not differ by Tukey test at 5% probability of error. [1]CV – Coefficient of variation. I – Insecticide, Hp – Pre-emergent herbicide, nsa – not suitable for application, m – medium, c – coarse, vc – very coarse, ec – extremely coarse, uc – ultra coarse.

The application with the adjuvant Protect® resulted in lower relative dispersion in the upper third, which means that there is a smaller difference in the size of the sprayed droplets (EMBRAPA 2014) and which is a desirable characteristic in the application; however, the numerical difference in the number of droplets, application volume, coverage, and VMD were not significant. This adjuvant presented droplets classified as extremely coarse, a fact that generates lower losses by drift and evaporation in situations of greater environmental risk (ALMEIDA et al. 2014). When there is drift, such losses cause an increase in the doses of the products in the applications by farmers, as they think that the action was inefficient by the dose used, when in fact it was due to the action of loss by drift (VIEIRA et al. 2019). The greatest dispersion in the application in the upper third occurred with LI700®, which showed the largest volume median diameter (VMD), of 1436.27 µm; however, it did not differ from the other treatments.

Regarding VMD, results corroborate those of LANDIM et al. (2020), who have found no difference in this parameter as a function of different application rates and types of adjuvants in the upper and middle thirds. This treatment, LI700®, resulted in droplets classified as ultra coarse, which has also happened with Tech-Plus® and Blend®. This type of droplet is indicated only for applications of pre-emergent insecticides and herbicides, and the type of nozzle used in this study fits the fine droplets; that is, the adjuvants drastically alter the physical structure of the spray (GIMENES et al. 2013), a fact that occurs along the entire canopy.

Differences begin to occur in the middle third of the canopy (Table 3), in which the adjuvant LI700® again demonstrates the highest relative dispersion associated with the highest number of drops that resulted in the highest VMD, again classifying the droplets as ultra coarse. In the assessment of the quality of application with four different types of nozzle, applying a solution with LI700®, GODINHO JUNIOR et al. (2018) point to a decrease in the risk of drift, thus avoiding losses to the environment. Such circumstances are related to the droplet size, the higher droplet density, and volume of deposited solution, which probably generated a higher droplet coverage rate in the leaf mass, which also corroborates the research of CUNHA & PERES (2010). This fact results in greater control efficiency, as with different volumes of solution with different spray nozzles, greater spray deposition has been found in the control of Asian soybean rust (*Phakopsora pachyrhizi*) (CUNHA et al. 2016).

The larger the diameter of the droplets sprayed in the same application volume, the greater the penetration into the plant canopy (ZAMPIROLI et al. 2019), and the use of coarse droplets is indicated by the authors as a viable alternative for the efficiency of the application in times of low relative humidity; however, care must be taken with fixed indications, as they also depend on the target to be reached. As previously mentioned, the adjuvant LI700® had ultra coarse droplets, which increased coverage by 11.4%, which is 57.1% greater than the second treatment with Tech-Plus®, and consequently, the highest volume applied. This type of droplet will be more effective in the application of pre- and post-emergent herbicides (FERGUSON et al. 2018), in which coarser droplets can provide control effectiveness or even superior control to fine droplets in some environmental situations.

The greater spread of droplets provides better coverage of the target and can lead to faster absorption of the solution containing the active ingredient (BAIO et al. 2015); however, very coarse droplets can cause runoff losses, in addition to the difficulty to reach the target when moving, thus causing heterogeneity in the droplet spectrum. In this way, in the middle third, droplets were above coarse, which requires care in the application and corroborates MOTA & ANTUNIASSI (2013), in which study the use of adjuvants increases the volume median diameter during spraying, which requires knowledge in the preparation of the solution, as droplet size and density are related to the poisoning of the plant. In greater droplets, GODINHO JUNIOR et al. (2018) have found poisoning of the plant, which requires a decrease in the dose of the product.

The addition of the adjuvant Protect® resulted in poor application quality when compared to LI700® and Tech-Plus®; however, it did not differ from the second adjuvant. Relative to LI700®, Protect® showed a decrease of 85.3, 74.8, and 87.2% in the variables of solution volume, density, and droplet coverage, respectively. Although this treatment has low relative dispersion, it was not accompanied by an increase in coverage, as it was the lowest among the treatments, with the lowest droplet density and lowest applied volume, parameters that may affect the phytosanitary control. The lowest droplet densities also occurred with the lowest solution volume in the work of ZAMPIROLI et al. (2019), however, with an adjuvant composed of orange oil.

In the lower part of the canopy (Table 3), only one variable was affected: number of droplets. The standard application without adjuvants (control) showed a greater number of droplets deposited in the lower third, and only in this treatment there was an increase in this parameter in the median position, of 27.45%. Circumstances may be related to the dripping of the solution onto the leaf surface from the interception of the leaf mass from the upper position and difficulty in deposition in the middle third, which is characterized by the "umbrella effect" (BARRÊTO 2011).

The different adjuvant applications did not significantly affect the VMD variable in the lower third. This parameter represents the distribution of droplet diameters that make up 50% of the total volume of liquid in the sample and it provides values of droplet size and classification, which are directly related to the droplet spectrum (EMBRAPA 2014). The study of NASCIMENTO et al. (2018) evaluated the effectiveness of fungicides associated with different adjuvants in the control of Asian soybean rust. The authors have not found significant differences in the VMD in the lower third, thus corroborating the results found in this study. In the classification of the size of the droplets deposited in the lower third, all were medium, except for the adjuvant Tech-Plus®, which presented very coarse droplets, a fact that also occurred in the middle third, as discussed above, and this type of droplet is indicated for pre-emergent or systemic herbicide applications.

It should be noted that there was a significant decrease in the quality of application along the crop canopy expressed by the greater volume and density of droplets in the upper third, which demonstrates how difficult it is to reach the lower third of the plant. In this sense, care must be taken, given that diseases have their initial development in the lower part (CUNHA & PERES 2010); on the other hand, insects are normally found in the middle third of the plants, hindering their chemical control because of the interception and greater leaf mass. CUNHA & PERES (2010), PRADO et al. (2015), and NASCIMENTO et al. (2018) have also found higher values for droplet density and area covered in the upper third than in the lower third. In the middle and lower position of the plant, the adjuvant Protect® presented a low quality of application, probably because of the decrease in leaf spreading and wetness, and consequently, lower rate of surface coverage on the leaf.

Adjuvants have different properties, requiring the field technician to have greater knowledge for the correct positioning of each type. It is noted that, in general, the treatments had few differences, and the main one occurred between LI700® and Protect®, but this may be related to the climatic conditions of water deficit during the experiment period. In the northern region of Rio Grande do Sul (Figure 2), where the experiment was carried out, there is variation in its distribution in addition to low rainfall. Rainfall of up to 850 mm of water is required for the proper development of soybeans (CARVALHO et al. 2013); however, in this study there was only 516 mm of rainfall during the period, and there was a lack of rainfall in the initial moments for plant emergence. The area was sown on November 19, ten days after the last rainfall event, and it took six days to rain. During flowering and grain filling, there was also a lack of rain, which affected the plant, not closing the lines and impairing its development.

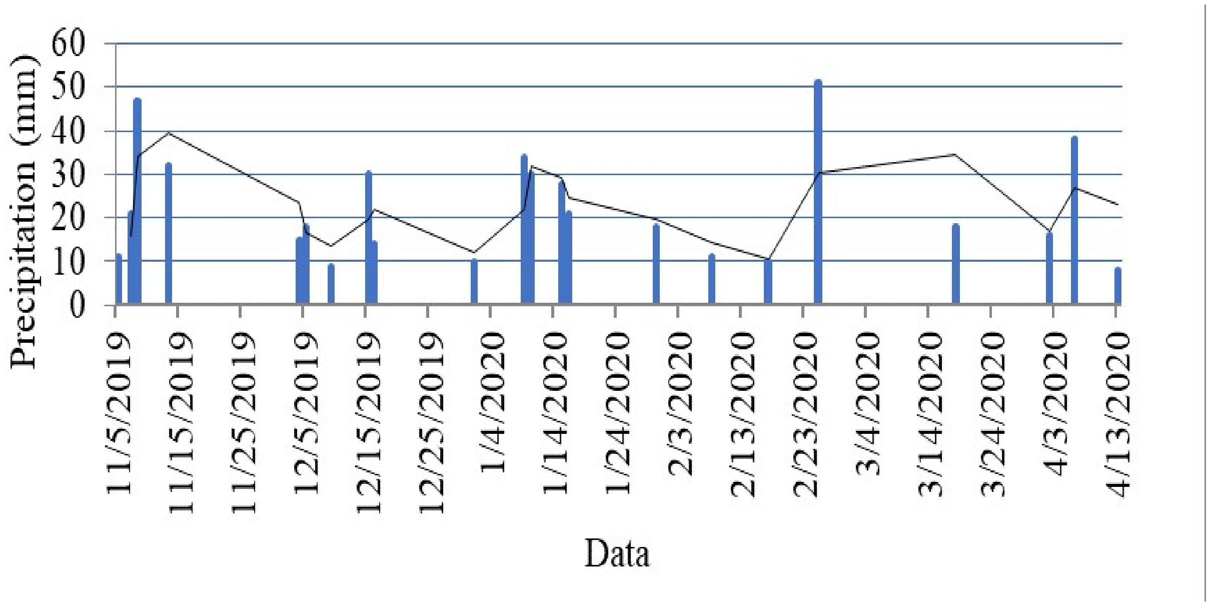

Figure 2. Precipitation in the period of the soybean development cycle in the 2019/2020 harvest, in the experiment in Sertão, RS, Brazil.

Soybean yield fluctuations in Rio Grande do Sul are correlated with accumulated rainfall, mainly between January and March (RADIN et al. 2017). In that period, in 2020, the crop was in the flowering and grain-filling stages, which are stages of greater sensitivity to water deficit (WANG & KOMATSU 2017), a fact that resulted in the reduction of yield components, as well as yield and 1000-grain weight as seen in Figure 3.

Because of the low growth and development of the crop, it was easy for the product to reach the target, as see in the control treatment, in addition to low pressure from diseases and pests, mainly from the inadequate conditions for the development of diseases and the use of highly effective products.

Overall, productivity ranged from 2416.2 to 2854.8 kg ha^{-1}, which resulted in a very low yield compared to the Brazilian national average of 3528 kg ha^{-1} (CONAB 2021).

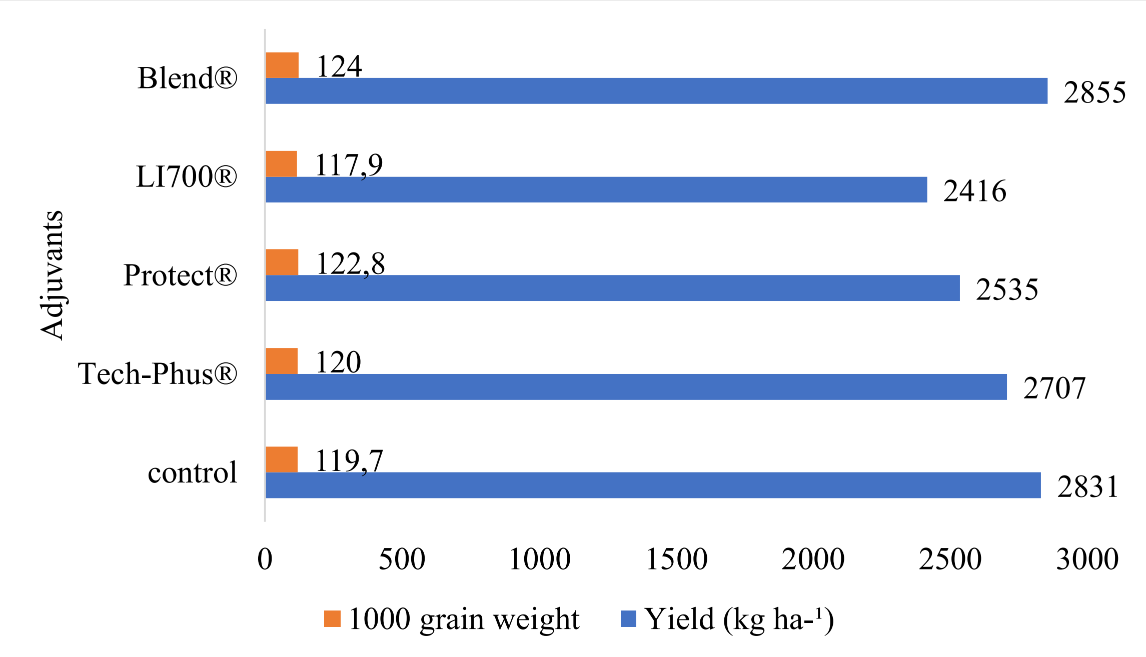

Figure 3. Yield and thousand grain weight of the soybean crop in relation to different adjuvants.

CONCLUSION

The applications of different adjuvants had different effects along the crop canopy. The adjuvant LI700® provides greater droplet density, volume reached, and coverage throughout the plant, whereas the other treatments did not differ, which points to similar conditions under study conditions. The adjuvants did not influence the yield components of the crop under the dry conditions observed in the study.

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