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SPRAY VOLUMES FOR AGROCHEMICALS APPLIED TO SOYBEAN AND WHEAT CROPS

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Abstract
The question of the spray volume for applying agrochemicals to plants has and still demands studies to continuously search for guiding parameters for technicians due to the several variables involving application technology. This experiment aimed to determine the best spray volume for applying pesticides with a boom sprayer to soybean (*Glycine max*) and wheat (*Triticum aestivum*) crops. The experiment had a completely randomized blocks design with five treatments and five replications. In soybean (crop year 2011/12), the treatments were the control (no pesticide application) and spray volume applications of 50, 100, 150, and 200 L ha^{-1}. For wheat (crop year 2012), the treatments were the control and spray volumes of 75, 100, 125, and 150 L ha^{-1}. The variables analyzed were the yield components. The study concluded the need for applying foliar fertilizers and performing the chemical control of diseases and pests in soybean and wheat crops. The spray volumes of 50 L ha^{-1} for soybeans and 75 L ha^{-1} for wheat were satisfactory for spraying agrochemicals with a ground bar sprayer on plants.

Keywords: Boom sprayer. *Glycine max*. Pesticide application technology. *Triticum aestivum*. Yield.

1. Introduction

Application technology is defined as using all scientific knowledge to provide the correct placement of the biologically active product on the target, in the required quantity, economically, and with minimum environmental contamination (Matuo 1990). Thus, the spray volume used will always be a consequence of effective application and never a pre-established condition (Ramos et al. 2007), as it depends on factors such as the desired target, the type of spray nozzles, climatic conditions, plant characteristics, and the type of product, according to the mode of action of the products, translocation of agrochemicals in plants, climate, and the application method (Garcia et al. 2002; Matthews 2008; Swoboda and Pedersen 2009; Antuniassi and Boller 2011; Garcia et al. 2020).

In soybean, Cunha et al. (2006) did not find significant differences in the control of Asian rust (*Phakopsora pachyrhizi*) and crop productivity with spray volumes of 115 and 160 L ha^{-1}. When assessing spray solution deposition according to flow, Boschini et al. (2008) concluded that, for higher depositions, agrochemicals with spray volumes of 200 or 300 L ha^{-1} should be applied. When determining the spray volume for controlling *Piezodorus guildinii*, Maziero et al. (2009) showed increased efficiency of pest control with the increase in spray volume up to 150 L ha^{-1}.

In the wheat crop, Cooke et al. (1989) did not find significant differences in the redistribution of leaf surface deposits of pesticides and disease control caused by *Pseudocercosporella herpotrichoides* with spray volumes from 15 to 200 L ha^{-1}. When controlling wheat diseases by applying fungicides to the plants, Oliveira et al. (2015) sprayed syrup volumes from 143 to 429 L ha^{-1}, not verifying differences in productivity between the treatments. However, when testing techniques for applying fungicide to control gibberella (*Gibberella zeae*), Panisson et al. (2003) recommend a spray volume of 200 L ha^{-1}. Panisson et al. (2004) concluded that increasing the spray volume from 200 to 400 L ha^{-1} is an effective measure to increase solution deposition in wheat anthers.

The question of the spray volume for applying agrochemicals to plants has and still demands studies to continuously search for guiding parameters for technicians due to the several variables involving application technology. Thus, this study aimed to determine the best spray volume for applying agrochemicals (foliar fertilizers, fungicides, and insecticides) with a ground bar sprayer to soybean and wheat plants.

2. Material and Methods

The experiment had a randomized blocks design with five replications. The analyses were performed in plots of 10 m^2 (1.0-m long by 10.0-m wide) of useful area for evaluation. In soybean, the treatments consisted of control (without applying agrochemicals, foliar fertilizers, fungicides, and insecticides) and spray volumes of 50, 100, 150, and 200 L ha^{-1}. The wheat crop received the control treatment and spray volumes of 75, 100, 125, and 150 L ha^{-1}. Spray volumes were based on the average of the upper limit recommended by technicians from the region of Campos Gerais, PR, Brazil.

The sprayer used was the Jacto™ BK-3024 drag model, a 24-m long boom sprayer equipped with air assistance and ADI™ 110-02 spray tips spaced 0.5 meters apart. Spraying has always been performed with relative humidity above 50%, a temperature below 30 degrees Celsius, and wind speed between 3.0 and 10.0 km h^{-1}. Climatic conditions were monitored with the Kestrel 3000™ thermo-hygrometer.

The recorded values were used in the Hartley tests to verify the homoscedasticity of variations, and the Shapiro-Wilk test was used to examine data normality. These measured variables were analyzed with Fisher-Snedecor and Dunnett tests to verify differences, with a confidence level higher than 95% probability. Polynomial regression was used to determine the best spray volume for soybean and wheat plants, suppressing statistical analysis or the control treatment to define the curve only with tests using agrochemical applications.

Soybean crop

The experiment was performed at the Lagoa Grande Farm located in Carambeí, PR, Brazil, 2011/12 harvest, temperate climate, and average annual precipitation between 1,600 and 1,800 mm (Iapar 2014). The property is 980 m above sea level, cultivated with no-till, and the soil of the experimental area is classified as dystrophic Red Latosol (Embrapa 2006). The volumes of 50, 100, 150, and 200 L ha^{-1} were obtained with variations in pressure (170, 260, 390, and 320 kPa) and working speed (14.6, 8.9, 7.3, and 5.0 km h^{-1}).

The Nidera™ 5909 RR cultivar was sown on November 3, 2011, with spacings of 0.45 meters between rows, obtaining 250 thousand plants by ha^{-1} (evaluation performed 20 days after emergence). Fertilization and crop treatments followed the technical planning of the agronomist responsible for the area.

The diseases that stood out were leaf blight (*Cercospora kikuchii*), soybean rust (*Phakopsora pachyrhizi*), downy mildew (*Peronospora manshurica*), and powdery mildew (*Microsphaera diffusa*). The pests evidenced in crop management were soybean caterpillar (*Anticarsia gemmatalis*), soybean looper (*Chrysodeixis includens*), brown stinkbug (*Euschistus heros*), and small green bug (*Piezodorus guildinii*). The foliar nutritional deficiencies identified were Manganese (Mn), Cobalt (Co), and Molybdenum (Mo).

Three applications of agrochemicals were made to plants (adjuvants, foliar fertilizers, fungicides, and insecticides). The applications started on January 17, 2012 (phenological stage of soybean V6 - Ritchie et al. 1982) with 20-day intervals (phenological stages R1 and R3).

The analyzed variables were final population, pods per plant, grains per pod, thousand-grain mass, and productivity. The evaluations were performed manually. To determine the thousand-grain mass and productivity, 1.0% impurities were considered, and humidity was corrected to 14.0%, according to the standardization (Codapar 2014). Moisture was obtained with a Gehaka™ 6,600 moisture meter. The thousand-grain mass was defined with a Gehaka™ BK 6,000 digital scale.

Wheat crop

The experiment was performed at the Vó Anna Farm, 2012 harvest, located in Ventania, PR, Brazil, with coordinates of 24°18'50.4s south latitude and 50°14'2.1s west longitude, 960 meters of altitude, in a no-tillage system under straw, on a dystrophic Red-Red Latosol (Embrapa, 2006). The volumes of 75, 100, 125, and 150 L ha^{-1} deviated with variations in pressure (170, 260, 390, and 310 kPa) and working speed (9.5, 8.9, 8.7, and 6.5 km h^{-1}).

The Biotrigo Tbio Tibagi™ crop was sown on July 5, 2012, with spacings of 0.17 meters between rows, resulting in 2.4 million plants per ha^{-1} (evaluation performed 20 days after emergence). Fertilization and crop treatments followed the technical planning of the agronomist responsible for the area.

The diseases that occurred were leaf rust (*Puccinia triticina*), leaf spots (*Bipolaris sorokiniana* and *Drechslera tritici-repentis*), and powdery mildew (*Blumeria graminis f. sp. tritici*). The pests that occurred in crop management were aphids (*Metopolophium dirhodum* and *Schizaphis graminum*), wheat armyworm (*Pseudaletia sequax*), and green-bellied bug (*Dichelops furcatus*). Three agrochemical sprayings were performed on the plants (adjuvants, foliar fertilizers, fungicides, and insecticides) on August 20 and September 4 and 24, 2012 (phenological stages 08, 10.2, and 10.4 - Large 1954). The recommended foliar fertilizers aim to supply the deficiencies of Calcium (Ca) and Magnesium (Mg).

The analyzed variables were ears per ha^{-1}, grains per ear, thousand-grain mass, and productivity. All assessments were performed manually. To determine the thousand-grain mass and productivity, 1.0% of impurities and the corrected moisture to 13.0% were considered according to the standardization (Codapar 2014). Moisture was obtained with a Gehaka™ 6,600 moisture meter. The thousand-grain mass was defined with a Gehaka™ BK 6,000 digital scale.

3. Results

There was no need to transform the data to apply the Fisher and Snedecor test because the Hartley tests to verify homoscedasticity of variances and the Shapiro-Wilk test to examine data normality had not been proven. There was no significant difference for blocks (Tables 1 and 2, and Figures 1 and 2), highlighting the homogeneity of the area in which the experiment was installed.

Table 1. Soybean yield components (*Glycine max*), NIDEIRA 5909 RR™ cultivar, related to increasing spray volumes with agrochemicals reported in the plants, using a ground bar sprayer, Lagoa Grande Farm, 2011/12 harvest, Carambeí (Paraná) Brazil.

Spray volumes (L ha^{-1})	Final population (plants ha^{-1})	Pods per plant	Grains per pod	Thousand-grain mass (g)	Productivity (kg ha^{-1})
zero	206,500	43	2.3	151	3,077
50	235,250 *[1]	43 ns[2]	2.2 ns	174 *	3,918 *
100	235,500 *	45 ns	2.2 ns	176 *	4,137 *
150	235,750 *	44 ns	2.3 ns	176 *	4,141 *
200	234,250 *	45 ns	2.3 ns	177 *	4,307 *
Blocks	ns[3]	ns	ns	ns	ns
Coefficient of variation (%)	1.5	7.3	9.7	4.2	11.2

1 - Significant compared to the control treatment (zero L ha^{-1}) by the Dunnett test ($P < 0.05$); 2 - Not significant compared to the control treatment (zero L ha^{-1}) by the Dunnett test ($P > 0.05$); 3 - Not significant by the Fisher-Snedecor F-test ($P > 0.05$).

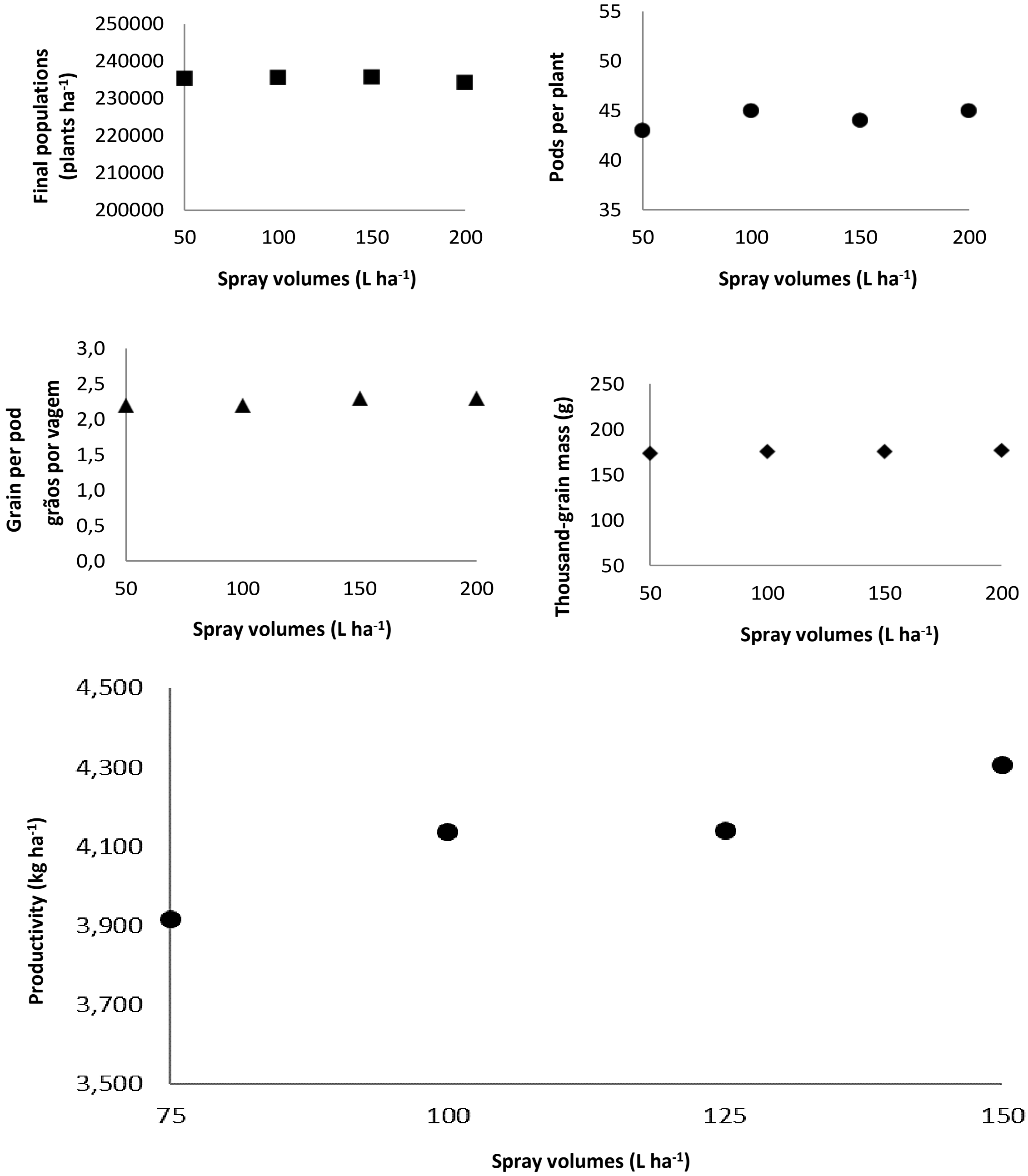

Figure 1. Soybean yield components (*Glycine max*), NIDEIRA 5909 RR™ cultivar, related to increasing spray volumes with agrochemicals reported in the plants, using a ground bar sprayer, Lagoa Grande Farm, 2011/12 harvest, (Paraná) Brazil (not significant for blocks and polynomial regression, P > 0.05).

Table 2. Wheat yield components (*Triticum aestivum*), BIOTRIGO TBIO Tibagi™ cultivar, related to increasing spray volumes with agrochemicals reported in the plants, using a ground bar sprayer, Vó Anna Farm, 2012 harvest, Ventania (Paraná) Brazil.

Spray volumes (L ha^{-1})	Final population (ear ha^{-1})	Grains per ear	Thousand-grain mass (g)	Productivity (kg ha^{-1})
zero	3,027,175	28	25	2,111
75	3,396,425 *[1]	30 ns[2]	38 *	3,842 *
100	3,490,826 *	29 ns	37 *	3,762 *
125	3,423,169 *	30 ns	38 *	3,917 *
150	3,546,691 *	29 ns	37 *	3,866 *
Blocks	ns[3]	ns	ns	ns
Coefficient of variation (%)	5.4	9.5	5.5	12.1

1 - Significant compared to the control treatment (zero L ha^{-1}) by the Dunnett test (P < 0.05); 2 - Not significant compared to the control treatment (zero L ha^{-1}) by the Dunnett test (P > 0.05); 3 - Not significant by the Fisher-Snedecor F-test (P > 0.05).

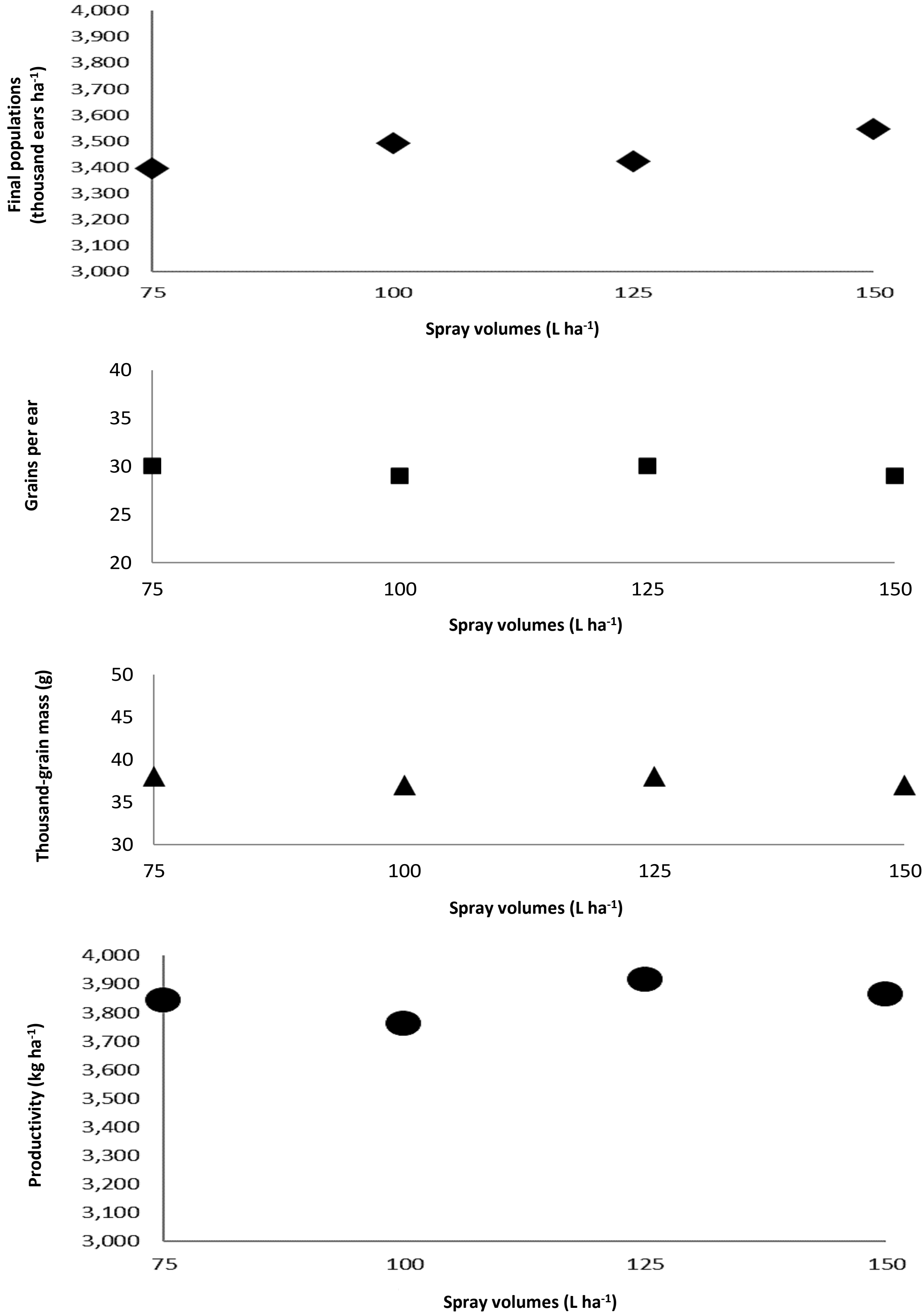

Figure 2. Wheat yield components (*Triticum aestivum*), BIOTRIGO TBIO Tibagi™ cultivar, related to increasing spray volumes with agrochemicals reported in the plants, by a terrestrial bar sprayer, Vó Anna Farm, 2012 harvest, Ventania (Paraná) Brazil (not significant for blocks and polynomial regression, $P > 0.05$).

When comparing the averages of yield components of soybean and wheat crops, there was a significant difference between the control and the other treatments for the final population, thousand-grain mass, and productivity of the variables. This shows the significance of agrochemicals sprayed on plants.

The polynomial regressions with yield components of the soybean crop in the treatments that received agrochemicals were not relevant for all the variables analyzed. Thus, the spray volume of 50 L ha^{-1} was sufficient for foliar fertilization and disease and pest control.

In wheat, the polynomial regressions with yield components of the treatments that received agrochemicals were also not relevant for all the variables analyzed. The spray volume of 75 L ha^{-1} was sufficient for foliar fertilization and disease and pest control.

4. Discussion

The result of the experiment highlighted lower values than those tested by Cunha et al. (2006) and emphasized by Boschini et al. (2008) and Maziero et al. (2009). The data analysis confirms the statements by Cooke et al. (1989) and Oliveira et al. (2015) and contradicts the recommendations of Panisson et al. (2003) and Panisson et al. (2004).

As the regressions were not significant, it was impossible to determine the adequate volume of agrochemical application to soybean and wheat crops. This corroborated the allegation by Ramos et al. (2007) that spray volume will always be a consequence of effective application and never a pre-established condition, as the function of the solvent is to contribute to the dilution and facilitate the distribution of the active ingredient.

Considering the claims by Antuniassi and Boller 2011; Garcia et al. 2002; Garcia et al. 2020; Matthews 2008; Matuo 1990; Ramos et al. 2007; and Swoboda and Pedersen 2009, experiments should be performed with agrochemical applications using ground bar sprayers, below 50 L ha^{-1} for soybeans and 75 L ha^{-1} for wheat. Therefore, there were significant differences between treatments for the variables analyzed, which were not discerned with the volumes investigated in this experiment.

5. Conclusions

Foliar fertilization and disease and pest control are recommended for soybean and wheat crops. The spray volumes of 50 L ha^{-1} for soybeans and 75 L ha^{-1} for wheat were satisfactory for spraying agrochemicals with a ground bar sprayer on plants.

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Ethics Approval: Not applicable.

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