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Trailing Boom on Fungicides Application on Wheat, Bean and Soybean

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***Abstract*— *This study aimed to determine the influence of air-assisted and trailing boom technologies on fungicide applications to control diseases incidence and severity on wheat, bean and soybean. The experiments were conducted in three different sites in the Campos Gerais (PR) region in a completely randomized blocks design. In the wheat crop season of 2011, the treatments were: i) control (no fungicide application on the plants); fungicide spray with ii) nozzles in conventional ground boom sprayer; iii) nozzles in trailing boom; and iv) nozzles in conventional boom sprayer + trailing boom simultaneously. In the bean and soybean crop season of 2011-12, we added an extra treatment of boom with air-assisted sprayer, since the farmers had this technology available. We conclude that at the area under the disease progress curve (AUDPC), the diseases controlled with fungicides presented lower severity and incidence compared with the control treatment for all the crops evaluated. The fungicide spraying technology aggregated to air-assisted and trailing boom did not differ from the conventional boom sprayer for disease control and yield components of wheat, beans and soybeans.*

Keywords*— *application technology; Glycine max; Phaseolus vulgaris; Triticum aestivum.

I. INTRODUCTION

With the constant population growth, the necessity of food production becomes each year more important. In Brazil, bean, soybean and wheat crops account for approximately 56% of the total grains produced in 2015/16. In this crop season, wheat reached a mean crop yield of 2.941 kg ha^{-1}in the 2.1 million ha cultivated. In the same way, bean cropwas cultivated in 2.8 million ha achieving a mean productivity of 907 kg ha^{-1}while soybean was cultivated in 33.3 million ha with mean yield of 2.870 kg ha^{-1} (CONAB, 2016).

The use of appropriate management techniques together with good genetic materials can lead to higher crop yields. However, the occurrence and incidence of diseases stands out as one of the main limiting factors for crop productivity. In the integrated pathogens management, the use of appropriate techniques to place the pesticides in the targeted pathogen is crucial for an effective disease control (Garcia et al., 2002; Souza et al., 2014; Garcia et al. 2016).

Once the need for chemical control is determined, the success of a phytosanitary treatment program in agriculture depends fundamentally on the use of a product with proven efficacy and a technology developed for its application (Vieira et al., 2012; Cunha et al., 2014; Tackenberg et al., 2016).

Pesticide application technology is defined as the use of all scientific knowledge in order to provide the correct placement of the biologically active product in the target. This must be conducted with the appropriate amount of product, with maximum economy and with minimum environmental damage (Matthews, 2014).

Since the movement of most of the fungicides is via xylem and the initial development of most of the diseases occurs on the plant base, it is intended that the spray reach the lower third of the plants. Due to theirlocal systemic action, some fungicides are translocated only in small distances on the plant leaf. Therefore, a good coverage is needed in order to obtain a maximum control efficiency (Cunha et al., 2011; Lehoczki-Krsjak et al., 2013; Liu et al., 2014).

Application of phytosanitary products with ground boom sprayers in association with air assistance technology are a recognized strategy to facilitate the target coverage and reduce the weather conditions influence (Matthews, 2004; Garcia et al., 2004; Guedes et al., 2012). Testing the technology in bean crop, Baesso et al. (2011) found that air assistance on the boom sprayer significantly increased the crop yields. In soybean, Aguiar Júnior et al. (2011) concluded that air-assisted spraying contributed for the control of Asian rust (*Phakopsora pachyrhizi*Syd. & Syd.), increasing in this way the crop productivity.

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Another promising spraying technology is the trailing boom, commercially called "kit alvo®". The principle of the application technique is to couple to the conventional boom sprayer, a rod with hydraulic circuit and application nozzles to be entrained on the crop rows (Figure 1). With the plants movement by the trailing boom, it is expected to achieve a greater penetration of the droplets into the crop canopy, better coverage by the product and reduction of the weather conditions influence (Bueno et al., 2014).

In the experiment carried out by Alves and Cunha (2011), the authors verified better leaf coverage of the plants upper third and mass of thousand grains due to the use of auxiliary boom. The coverage of the bottom leaves; the droplet density and crop yield were not influenced by the use of the auxiliary boom. In soybeans, Weirich Neto et al. (2013) concluded that trailing boom spraying did not significantly affect yield components compared to the conventional boom.Also in soybean, Ozkan et al (2006) tested several spraying equipment for fungicide application and concluded that the air-assisted boom and crown opener presented better coverage and deposition in comparison to conventional boom. The objective of this study was to evaluate if the spraying of fungicides with ground boom sprayer with the aggregated technologies of air assistance and trailing boom affect the incidence and severity of diseases and yield components in wheat, soybeans and soybean crops.

II. MATERIALS AND METHODS

2.1 Wheat crop(*Triticum aestivum*L.)

The experiment was carried out in the crop season of 2011 at the farm "Paiquerê", located in the municipality of Piraí do Sul – PR (Brazil), with geographical coordinates 24°21'15"S, 50°6'8"W, Cfb climate, 910 m of altitude, with wheat cultivation conducted in no-tillage system, on a dystrophic Yellow Red Latosol (EMBRAPA, 2013).

The experimental completely randomized block design, with four treatments and five replicates. The treatments consisted of: i) control (no fungicide spraying); chemical control of leaves and spike of diseases with ii) nozzles in conventional ground boom sprayer; iii) nozzles in trailing boom; and iv) nozzles in conventional boom sprayer + trailing boom simultaneously.

The seeding of Abalone® wheat cultivar occurred on July 8, 2011, with an initial population of 2,300,000 ha^{-1} plants at 15 days after emergence (15 DAE). The cultivar is susceptible to leaf rust (*Puccinia triticina* Eriks.). The following diseases occurred: yellow spot (*Drechslera tritici-repentis*Died.), leaf rust and giberela (*Gibberella zeae*Schw.), which were controlled by the five fungicides spraying treatments.

The first fungicide application was performed at the tillering stage (Large, 1954) using 0.3 L ha^{-1} of Priori Xtra® (200 g L^{-1} of Azoxistrobina and 80 g L^{-1} of Ciproconazol), 0.7 L ha^{-1} of Propiconazole Nortox® (250 g L^{-1} of propiconazol), 0,03 L ha^{-1} of the surfactant Aller Biw® and 0,3 L ha^{-1} of mineral oil Nimbus®.

The second spraying operation was carried out at the stage of stem elongation (Large, 1954) with 0.3 L ha^{-1} of Priori Xtra®, 0.03 L ha^{-1} de Aller Biw® and 0.3 L ha^{-1} de Nimbus®. The third spraying was performed at the stage of earing (Large, 1954) using 0.8 L ha^{-1} of Opera® (50 gL^{-1} of Epoxiconazol and 133 gL^{-1} of Pyraclostrobin), 0.8 L ha^{-1} of Tilt® (250 g L^{-1} of propiconazol) and 0.03 L ha^{-1} of Aller Biw®. The fourth spraying was applied at the stage of flowering (Large, 1954) using 0.8 L ha^{-1} of opera®, 0.4 L ha^{-1} of Odin 430 sc® (430 g L^{-1} of tebuconazol, sistemic) e 0.3 L ha^{-1} de Aller biw®. Finally, the fifth spraying was carried out at the stage of maturation using 0.8 L ha^{-1} of Tilt® and 0.03 L ha^{-1} of Aller Biw®.

The sprayer used was a self-propelled John Deere 4630®, with 24-m non air-assisted spray bar, nozzles spaced in 0.5 m and spray tips LD 110 02-Hypro®. In the trailing boom, the tip that accompanied the equipment was the MDP 0.5 - Magno Jet® (130º), spaced in 0.5 m.

The speed variations were automatically corrected by the on-board computer, adjusted to maintain - in all treatments –a spraying carrier flow rate of 100 L ha^{-1}. The spray calibration for conventional treatment occurred with an average speed of 6.0 km h^{-1}, a pressure of 120 kPa and a large droplet size. When the trailing boom was used, we utilized an average displacement velocity of 4.0 km h^{-1}, working pressure 200 kPa and fine droplet size. For the conventional boom, we used an average speed of 8.5 km h^{-1}, working pressure 100 kPa, coarse drop size for spraynozzleLD 11002 (volume of the spraying carrier at 65 L ha^{-1}) and mean droplet for MDP 0.5 nozzle (35 L ha^{-1}spraying carrier volume).

Harvesting, threshing, counting of grains per pod, mass of one thousand grains and productivity were performed manually. The determination of the mass of a thousand grains and the productivity occurred with 1.0% of impurities and with corrected humidity to 13.0% humid based.

2.2 Bean (*Phaseolus vulgaris*L.)

The experiment was carried out at the farm "Vó Anna" located in the municipality of Ventania – PR (Brazil), 2011/12 crop, coordinates 24°14 S, 50°14'W, Cfb climate, 1013 m altitude, no-tillage system , in dystrophic Dark Red Latosol soil(EMBRAPA, 2013).

A completely randomized block design with five treatments and four replicates was used. The treatments consisted of: i) control (no fungicide spraying in the

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plants); fungicide application through nozzles in boom sprayer ii) with and iii) without air assistance; iv) spraying with nozzles in trailing boom; and v) nozzles in boom sprayer (not air-assisted) + trailing boom simultaneously. We added a treatment with air-assisted boom because this technology was already used at the farm routine.

The seeding of the cultivar Pérola® occurred on December 05, 2011, with about 196,000 plants ha^{-1} (15 DAE). We conducted three applications of fungicides for the chemical control of anthracnose disease (*Colletotrichum lindemuthianum*Sacc. & Magn.), disease to which the cultivar is susceptible. We applied 0.5 l ha-1 of the fungicide Mertin® (400 g L^{-1} of Fentina hydroxide) in all the spraying operations. The phenological stages during the spraying operations were V3, R2, and R5 (Fernandez et al., 1982).

The sprayer used was the BK 3024 Vortex (Jacto®), provided with 24 m air assist spray boom, 0.5 m spaced nozzles and ADI 11002 spray tips (Jacto®). In the trailing, the spray tip used was the MDP 0.5 (Magno Jet®), which accompanied the equipment.

The speed variations were corrected automatically by the on-board computer, adjusted to maintain a spraying carrier flow rate of 150 L ha^{-1} in all treatments. The spraying operations for the treatments with and without air assistance in the boom occurred with average speed of 6.0 km h^{-1} and pressure of 260 kPa (medium drop for ADI tip 11002). For the trailing boom, we used an average speed of 3.0 km h^{-1} and 320 kPa pressure (fine drop for the tip MDP 0.5 130°). For the conventional treatment + trailing boom, we used an average speed of 7.5 km h^{-1}, working pressure 200 kPa and medium droplet size ADI 11002 (volume of the spraying carrier in 100 L ha^{-1}) and fine droplet for MDP 0.5 tip (volume of the spraying carrier 50 L ha^{-1}).

Harvesting, threshing, counting of grains per pod, mass of one thousand grains and productivity were performed manually. The harvest was given on March 10, 2012. The determination of the mass of a thousand grains and the productivity occurred with 1.0% impurities and with moisture corrected to 14.0% wet basis.

2.3 Soybean(*Glycine maxL.*)

The experiment was carried out at the farm "Lagoa Grande", located in the municipality of Carambeí – PR (Brazil), 2011/12 crop, coordinates 24° 49 'S and 50 ° 12' W, Cfb climate, 980 m altitude, no-till system, in an Eutrophic Dark Red Latosol (EMBRAPA, 2013).

A completely randomized block design with five treatments and four replicates was used. The treatments consisted of: i) control (nofungicide spraying in the plants), spraying of fungicide with nozzles in boom sprayer ii) with and iii) without air-assistance, iv) spraying with nozzles intrailing boom; and v) nozzles in boom sprayer (not air-assisted) + trailing boom simultaneously.

The sowing of Nidera® 5909 RR cultivar occurred on November 03, 2011, with about 250 thousand plants ha^{-1} (15 DAE). The cultivar is susceptible to Asian Rust (*Phakopsora pachyrhizi*Syd. & Syd). We performed three pesticides applications for the chemical control of the following diseases: mildew (*Peronospora manshurica*Naum.)Asian rust and white mold (*Sclerotinia sclerotiorum*Lib.).The phenological stages during the spraying operations were V5, R2 and R5 (Fehr and Cavibess, 1977; Ritchie et al., 1982).

At the first spraying, we used 0.5 L ha^{-1} of Carbomax 500 SC® (500 g L^{-1} deccarbendazim), 0.5 L ha^{-1} of Opera® (133 g L^{-1} of Piraclostobine + 50 g L^{-1} of epoxiconazol) e 0.5 L ha^{-1} of Alterne® (200 g L^{-1} of Tebuconazol). The products used at the second spraying operation were 0.3 L ha^{-1} of Priori Xtra® (200 g L^{-1} of cazoxistrobine + 80 g L^{-1} of ciproconazol) and 0.5 L ha^{-1} of mineral oil Nimbus®. The third application was performed with 0.3 L ha^{-1} of the fungicide Aproach Prima® (200 g L^{-1} of picoxystrobin + 80 g L^{-1} of ciproconazol), 0.3 L ha^{-1} of Ninbus® and 0.1 L ha^{-1} of the adjuvant LI700® (surfactant lecithin and propionic acid based).

The sprayer used was BK 3024 Vortex (Jacto®), spray bar with 24 m air assist, nozzles spaced 0.5 m and spray tips ADI 11002 (Jacto®). In the trailing boom, the tip used was MDP 0.5 (Magno Jet®). With the same model of spray, we used the same spray tips, spraying carrier volume and calibration described in the bean experiment.

Harvesting, threshing, counting of grains per pod, mass of one thousand grains and productivity were performed manually. The harvest took place on March 30, 2012. The determination of the mass of a thousand grains and the productivity occurred with 1.0% impurities and with moisture corrected to 14.0% wet basis.

2.4 General characteristics

Agro-climatic conditions favored all crops. All crop treatments and phytosanitary practices were carried out in accordance with the recommendations of wheat cultivation for the region.The dimensions of the plots were 5.0 m length x by 4.0 m width, with an evaluation area of 20 m^2. Each plot was delimited in the center by half boom spray lenght in a distiance of 30 m (12 x 30 = 360 m^2).

We standardized the use of the flat jet tip 11002 in the conventional spraying boom, due to the higher use of this type in the region for fungicide applications. In the Trawl boom, we maintained the tip that the factory sends with the equipment. The spraying carrier volume for each crop followed the average of fungicide applications at the farms in which the experiments were installed. The air-assisted boom has an average air speed of 38 kg h^{-1}, measured by the Kestrel 3000® anemone thermo-hygrometer.

Spraying operations were always performed with relative air humidity above 55%, temperature below 30ºC and wind speed between 3.0 and 10.0 km h^{-1}. Climatic conditions were monitored by the Kestrel 3000®anemo thermo-hygrometer.

The variables evaluated were as follow: spraying carrier deposition andarea under the disease progress curve (AUDPC) for incidence, severity and yield components. The spraying carrier deposition on the sprayed plants were measured with hydro sensitive cards.

The values of incidence were obtained from the percentage of sick plants. The severity was determined based in diagrammatic scales recommended for each crop. On wheat it was applied the James (1971) and Stack and McMullen (1995) scale; in beans Dalla Pria et al (2003), in soybeans Kowata et al., (2008), Godoy et al., (2006) and Napoleão et al (2005). The AUDPC was calculated for wheat bases in the evaluations performed in the phenological stages of tillering, flowering and milky grain (Large, 1954); on beans at the stages V4, R3 and R6 (Fernandez et al., (1982); and on soybeans at the stages V6, R3 and R6 (Fehr and Cavibess., 1977 and Ritchie et al., 1982). We used the entire plant for the evaluations of AUDPC and foliar diseases.

Humidity was measured using a moisture meter (G800 Gehaka®). The mass of one thousand grains was defined by means of a digital scale 0.1 to 500 g Diamond®. Productivity measurement was carried out using a Ramud® digital scale, with a capacity of 50 kg.

The values recorded were analyzed by the Hartley test to verify the homoscedasticity of the variances, and Shapiro-Wilk to examine the normality of the data. The measured variables were submitted to analysis of variance by the Fisher-Snedecor test and the mean values compared by the Duncan test ($p < 0.05$).

III. RESULTS AND DISCUSSION

The attempts to measure the spraying carrier deposition on the sprayed plants with hydro sensitive cards were affected by the air-assisted boom technology, which moved the cards out of the plants. Therefore, we could not measure this variable.

The Hartley test pointed to the variances homoscedasticity and the Shapiro-Wilk confirmed the data normality for all variables studied. Therefore, there was no need to transform the values for the analysis of variance. There were no differences for blocks for all the analyzed variables, which demonstrates the uniformity of the experimental conditions (Tables 1, 2 and 3).

The control plots presented significantly higher values of AUDPC disease incidence and severity for all crops evaluated when compared with the fungicides treatments. Therefore, we confirm the importance of the chemical control (Vieira et al., 2012; Cunha et al., 2014; Tackenberg, et al., 2016).

When analyzing the AUDPC of diseases incidence and severity controlled by fungicide application - with nozzles in boom and in addition to the technologies of air assistance in the boom and trailing - no significant differences were found between the treatments for wheat and soybean. Thus, the technologies added to the conventional process did not stand out in the experimental conditions.

Our results do not agree with Aguiar Júnior et al. (2011), regarding the affirmation that the air-assistance in the spraying operations can contribute for the control of Asian rust (*Phakopsora pachyrhizi* Syd. & Syd.) in soybean. In this experiment, the difference was only visible between treatments that received or not fungicide spraying.

In this way, although the air-assistance in the boom minimizes the weather influence (Guedes et al., 2012; Garcia et al, 2004) and the trailing boom improves the spray tip positioning in relation to the target (Bueno et al., 2014), they did not increase the fungicide efficiency in comparison to the conventional boom sprayer. This fact may have occurred because the ideal spray conditions were respected in the experiment for the three evaluated crops.

Regarding the wheat yield components, the significantly affected variables by the diseases were number of ears ha^{-1}, mass of thousand grains and crop yield (Table 4). In the plots that did not receive phytosanitary treatment, the diseases reduced the productive potential by 34%.

The trailing boom aggregated to the ground boom sprayer, applying fungicides isolated or in combination, did not differ from conventional technology. With a confidence degree more than 95% of probability, in the experimental conditions of the wheat crop, we do not recommend the use of trailing boom.

On bean crop, comparing the plots with and without fungicides application, we verified that the anthracnose reduced the crop yield potential by 43% (Table 5).The variables that differed significantly were grains per pod, pods per plant and productivity. Thus, we confirm the importance of chemical control, within the integrated management of diseases (Garcia et al, 2002; Vieira et al., 2012; Cunha et al., 2014; Souza et al, 2014; Garcia et al., 2016; Tackenberg, et al., 2016).

The application of fungicide with ground boom sprayer, air-assisted boom, trailing boom alone and in conjunction with the conventional boom did not significantly differ from each other for the yield components of the bean crop. The results do not confirm the conclusions of Baesso et al. (2011), who observed increases in bean productions in response to the use of air-assisted boom.

The analysis of soybean yield components showed significant differences for final population, one thousand grain mass and crop yield (Table 6). The diseases reduced the productive potential of soybean by 25%. The results highlight the efficiency of fungicide application using appropriate technology. Therefore, we confirm the statements of Garcia et al. (2002), Vieira et al. (2012), Cunha et al. (2014), Matthews (2014), Souza et al. (2014), Garcia et al. (2016) andTackenberg, et al. (2016).

The use of air-assisted boom aiming to facilitate the product conduction to the target and reduce the climatic influence, as observed by Garcia et al. (2004) and Guedes et al. (2012), did not result in increases of soybean yield components. The experimental data do not corroborate with the conclusions of Aguiar Júnior et al. (2011) who stated that the air assistance spraying contributed to better control of Asian rust (*Phakopsora pachyrhizi* Syd. & Syd.) increasing in this way the crop yields.

The proposal of the trailing to move the leaf canopy, to spray the spraying carrier near the target and reduce the influence of the climate (Bueno et al., 2014) did not differ significantly from the conventional system without and with air assistance, either alone or in combination. The results agree with the conclusions of Weirich Neto et al., (2013) regarding the soybean yield components and with Alves and Cunha (2011) regarding the crop yield. The superior performance of the air-assisted boom and the canopy opener highlighted by Ozkan et al (2006) in the comparison with the conventional systems for fungicide application were not observed in this experiment.

The results were similar even in different crops, properties, crop seasons, sprayers, pressures, spraying carrier volumes, spraying tips and droplets size. Therefore, the use of trailing boom did not present advantages in this experiment.

The authors observed that the angle of distribution of the baffle tip, adopted by the trailing manufacturer, was greatly affected by the trailing boom movement during spraying. Thus, evaluations with tips that generate jets with other characteristics are recommended.

Because the high investment on the crop cultivation, mainly regarding the number of fungicide sprays in crops, the yields of the properties under study were 1.3, 3.7 and 1.4 times higher than the national average for wheat, beans and soybeans, respectively (CONAB, 2016). Therefore, with appropriate crop management strategies, it is possible to reduce the influence of pesticide application technologies.

IV. CONCLUSIONS

We conclude that at the area under the disease progress curve (AUDPC), the diseases controlled with fungicides presented lower severity and incidence compared with the control treatment for all the crops evaluated.

The fungicide spraying with the technologies of air-assisted boom and trailing boom did not differ from the conventional sprayer for disease control and yield components of wheat, soybean and beans.

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Fig.1: Trailing boom (kit alvo®) coupled to a traditional sprayer (Image: Willy Schnepper Junior).

Table.1: Area under the disease progress curve (AUDPC) for incidence (I) and severity (S) yellow spot (Drechslera tritici-repentis Died.), leaf rust (Puccinia triticina Eriks.) and head scab (Gibberella zeae Schw.) on wheat crop (Triticum aestivum L.) - in the phenological stages of tillering, flowering and milky grain[1] - with different application techniques, cultivate Abalone®, crop 2011, farm "Paiquerê" (Pirai do Sul – PR, Brazil).

Treatments[2]	Yellow spot[1]		Leaf rust		Head scab	
	I	S	I	S	I (%)[3]	S (%)
Control[4]	4,248 a[5]	868 a	2.341a	699 a	53 a	31 a
Nozzles in boom sprayer	2,328 b	359 b	915 b	298 b	22 b	07 b
Nozzles in trailing boom	2,298 b	376 b	898 b	286 b	20 b	06 b
Nozzles in boom sprayer + trailing boom	2,322 b	395 b	869 b	278 b	22 b	06 b
Coefficient Variation(%)	3.7	9.5	2.9	11.6	50.6	28.7

(1) Phenological stages proposed by Large (1954).

(2) In all analyzed variables there were no significant differences for blocks by the Fisher-Snedecor test (P> 0.05).

(3) Since it was only possible to carry out an evaluation in the spikes, the AUDPC can not be calculated.

(4) No fungicide spraying in the plants.

(5) Means followed by the same letter in the column did not differ significantly by Duncan's test (P> 0.05).

Table.2: Area under the disease progress curve (AUDPC) for incidence (I) and severity (S) of leaf anthracnose (Colletotrichum lindemuthianum Sacc. & Magn.) on bean (Phaseolus vulgaris L.) - in the phenological stages V4, R3 and R6[1] - with different application techniques, cultivate Pérola®, crop 2011- 12, Farm Vó Anna (Ventania – PR, Brazil).

Treatments[2]	Leaf anthracnose	
	I	S
Control[3]	2,380 a[4]	1,342 a
Nozzles in boom sprayer	838 b	601 b
Nozzles in boom with air-assisted sprayer	849 b	597 b

Nozzles in trailing boom	857 b	609 b
Nozzles in boom sprayer + trailing boom	835 b	589 b
Coefficient Variation (%)	13.6	16.8

(1) Phenological stages proposed by Fernandez et al. (1982).
(2) In all analyzed variables there were no significant differences for blocks by the Fisher-Snedecor test (P> 0.05).
(3) No fungicide spraying in the plants.
(4) Means followed by the same letter in the column did not differ significantly by Duncan's test (P> 0.05).

Table.3: Area under the disease progress curve (AUDPC) for incidence (I) and severity (S) of downy mildew (Peronospora manshurica Naum.), asian rust (Phakopsora pachyrhizi Syd. & Syd.) and white mold (Sclerotinia sclerotiorum Lib.) on soybean (Glycine max L.) - in the phenological stages V6, R3 and R6[1] - with different application techniques, cultivar NIDEIRA 5909 RR®, crop 2011-12, farm "Lagoa Grande" (Carambeí – PR, Brazil).

Treatments[2]	Downymildew		Asian rust		White mold	
	I	S	I	S	I	S
Control[3]	198a[4]	148a	328a	91 a	87 a	77 a
Nozzles in boom sprayer	118b	64b	222b	55 b	41 b	39 b
Nozzlesinboomwithair-assistedsprayer	115b	66b	213b	51 b	40 b	39 b
Nozzles in trailing boom	125b	68b	226b	57 b	45 b	40 b
Nozzles in boom sprayer + trailing boom	112b	60b	211b	49 b	39 b	38 b
Coefficient Variation (%)	14	19	10	26	29	30

(1) Phenological stages proposed by Fehr & Cavibess (1977) e Ritchie et al. (1982).
(2) In all analyzed variables there were no significant differences for blocks by the Fisher-Snedecor test (P> 0.05).
(3) No fungicide spraying in the plants.
(4)Means followed by the same letter in the column did not differ significantly by Duncan's test (P> 0.05).

Table.4: Yield components of the wheat (Triticum aestivum L.) with different application techniques, cultivate Abalone®, crop 2011, Farm Paiquerê (Pirai do Sul - PR).

Treatments[1]	Earsha^{-1}	Grainspe rear	Thousandgrainsmass (g)	Crop yield (kgha^{-1})
Control[2]	4,584,043b[3]	20 a	28 b	2,687 b
Nozzles in boom sprayer	5,725,351 a	22 a	31 a	3,986 a
Nozzles in trailing boom	5,473,482 a	23 a	32 a	4,124 a
Nozzlesinboomsprayer+trailingboom	5,593,795 a	23 a	32 a	4,125 a
Coefficient Variation (%)	6.1	7.7	4.1	8.6

(1)In all analyzed variables there were no significant differences for blocks by the Fisher-Snedecor test (P> 0.05).
(2)No fungicide spraying.
(3) Means followed by the same letter in the column did not differ significantly by Duncan's test (P> 0.05).

Table.5: Yield components of the bean (Phaseolus vulgaris L.), with different application techniques, cultivate Pérola®, crop 2011-12, Farm Vó Anna (Ventania - PR).

Treatments[1]	Final population (plants ha^{-1})	Pods per plants	Grains per pod	Thousand grains mass (g)	Crop yield (kg ha^{-1})
Control[2]	163,000 a[3]	11 b	4.4 b	269 a	2,075 b
Nozzles in boom sprayer	162,250 a	15 a	5.9 a	251 a	3,628 a
Nozzlesinboomwithair-assistedsprayer	156,750 a	15 a	5.9 a	261a	3,537 a
Nozzles in trailing boom	162,750 a	15 a	5.8 a	264 a	3,482 a
Nozzles in boom sprayer + trailing boom	169,000 a	15 a	5.9 a	265 a	3,912 a
Coefficient Variation (%)	7.6	5.1	5.9	6.7	13.9

(1) In all analyzed variables there were no significant differences for blocks by the Fisher-Snedecor test (P> 0.05).
(2)No fungicide spraying.
(3) Means followed by the same letter in the column did not differ significantly by Duncan's test (P> 0.05).

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Table.6: Yield components of the soybean (Glycine max L.), with different application techniques, cultivate NIDEIRA 5909 RR®, crop 2011-12, Farm Lagoa Grande (Carambeí - PR).

Treatments[1]	Final population (plants ha^{-1})	Pods per plants	Grains per pod	Thousand grains mass (g)	Crop yield (kg ha^{-1})
Control[2]	206,500 b[3]	43 a	2,3 a	151 b	3,077 b
Nozzles in boom sprayer	236,132 a	44 a	2,3 a	174 a	4,137 a
Nozzles in boom with air-assisted sprayer	235,512 a	45 a	2,2 a	176 a	3,948 a
Nozzles in trailing boom	234,750 a	45 a	2,3 a	177 a	4,082 a
Nozzles in boom sprayer + trailing boom	235,089 a	45 a	2,3 a	175 a	4,208 a
Coefficient Variation (%)	2.3	7.1	9.9	4.2	11.2

(1) In all analyzed variables there were no significant differences for blocks by the Fisher-Snedecor test (P> 0.05).

(2)No fungicide spraying.

(3) Means followed by the same letter in the column did not differ significantly by Duncan's test (P> 0.05).