

COBERTURA DAS FOLHAS DE SOJA UTILIZANDO PONTAS DE PULVERIZAÇÃO COM DIFERENTES FORMATOS DOS JATOS*

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RESUMO: O objetivo dessa pesquisa foi avaliar a interação entre os formatos dos jatos de pulverização e os volumes de calda, na cobertura nas folhas de soja. Os tratamentos foram compostos por três pontas de pulverização com diferentes formatos dos jatos (jato plano, jato plano duplo e jato plano angulado) e dois volumes de caldas (100 e 200 L ha⁻¹). A análise de cobertura foi realizada através da avaliação visual, comparando cada folha com uma escala de notas, em sala escura com iluminação fluorescente. No extrato superior, ocorreu 27,59% a mais de cobertura no volume de calda de 200 L ha⁻¹, comparado com 100 L ha⁻¹ e entre os formatos dos jatos, não houve diferença significativa. No extrato médio/inferior, ocorreu 52,32% a mais de cobertura no volume de calda de 200 L ha⁻¹, comparado com o 100 L ha⁻¹ e entre os formatos dos jatos não houve diferença significativa. Em aplicação de fungicidas no início do florescimento da soja, o formato do jato de pulverização não alterou a cobertura do alvo e o aumento do volume de calda de 100 para 200 L ha⁻¹ aumentou a cobertura do alvo, para ambos os extratos analisados.

Palavras-chaves: tecnologia de aplicação, gotas médias, fungicida.

COVERAGE IN SOYBEAN LEAVES WITH DIFFERENT SPRAY NOZZLES

ABSTRACT: The aim of this research was to evaluate interaction between the spray nozzles shape and the application volume rate, in the coverage in soybean leaves. The treatments consisted of three spray nozzles (pre-orifice low drift flat fan, pre-orifice low drift double flat fan and angled flat fan) and two application volumes rates (100 and 200 L ha⁻¹). The analysis of coverage was performed through the visual evaluation, comparing each leaf with a scale of grades, in a dark room with fluorescent lighting. In the upper portion of canopy had 27.59% more coverage in the 200 L ha⁻¹ than 100 L ha⁻¹. There were no significant difference between the nozzles, in the upper portion. In the medium/lower portion of canopy, the application volumes rates of 200 L ha⁻¹ had 52.32% more coverage than 100 L ha⁻¹ and there were no significant difference between the nozzles. When applying fungicides at the beginning of soybean flowering, the shape of spray nozzles does not change the leaf coverage in any canopy portion. The change in application volume rates from 100 to 200 L ha⁻¹ increased the leaf coverage, for both portions of the canopy analyzed.

Keywords: application technology, medium droplets, fungicide.

1 INTRODUCTION

Spray nozzles are among the components that influence the quality and

efficiency of an application and are responsible for the fragmentation of the liquid into droplets, the shape of the jet, and the flow rate of the

spray mixture (CUNHA, REIS, SANTOS, 2006).

There are several spray nozzle models with specific characteristics for different spraying purposes, such as air-induction nozzles or preorifice nozzles (FERGUSON *et al.*, 2015). These spray nozzle models can reduce the risk of drift due to the increased droplet size generated by the nozzles (CUNHA *et al.*, 2008; FERGUSON *et al.*, 2019). However, in spraying aimed at obtaining better target coverage and droplet penetration into the crop canopy, it is common to use spray nozzles that produce smaller droplet sizes, such as wide-band flat fan nozzles, cone nozzles, and twin-flat fan nozzles (CARVALHO *et al.*, 2017; CHECHI *et al.*, 2020).

In the current scenario, there are new models and brands of spray nozzles, covering different types of applications, such as angled jet nozzles (3D). This nozzle model has a three-dimensional jet shape and allows the use of "medium" class droplets, depending on the pressure and flow rate used. Despite the diversity of nozzle models on the market, with different characteristics and purposes, in Brazil, it is still common to use a single model for all applications on a property, such as flat fan and cone jet nozzles (CHECHETTO *et al.*, 2014).

As a crop develops during its cycle, leaf mass and branches increase, making it necessary to alter spraying characteristics, such as the spray nozzle model, droplet spectrum, and spray volume (CUNHA *et al.*, 2008). Furthermore, the type of pesticide used influences the most suitable spray nozzle model. In the spraying of agricultural pesticides, the droplet spectrum and spray volume are parameters that primarily define the efficiency of target coverage and the quality of the spraying (FERGUSON *et al.*, 2016; ROEHRIG *et al.*, 2018). According to Nansen *et al.* (2015), droplet coverage during spraying can be determined as the area covered by spray solution droplets on a desired target, such as leaves, insects, or soil.

Increasing the spray volume (L ha⁻¹) and reducing the droplet size improved target coverage and droplet penetration into the crop canopy (ANTUNIASSI *et al.*, 2004). On the other hand, the use of "Very Fine" and "Fine"

droplet classes can lead to greater potential for drift, resulting in a loss of application quality, as well as reaching nontarget areas (CUNHA, REIS, SANTOS, 2006; FERGUSON *et al.*, 2015).

The need to obtain good target coverage must also consider the type and characteristics of the pesticide used and the type of target (CUNHA *et al.*, 2010). In applications with systemic pesticides that have good mobility on the target, coverage may be lower, as in the case of the herbicides 2,4-D, glyphosate, and dicamba (MONIZ *et al.*, 2020). This is different from applications with contact pesticides that have lower mobility on the target, where greater coverage is recommended, such as with protective fungicides.

There are several types of targets for pesticide spraying (OLIVEIRA *et al.*, 2012), such as insect pests, leaves, branches, and soil, which have different requirements regarding target coverage. Asian soybean rust (*Phakopsora*) is one example. *Pachyrhizi*, one of the main diseases of soybean crops, initially develops in the lower layer of the crop canopy. For effective control of this disease, good target coverage and droplet penetration into the crop canopy at the time of pesticide application must be achieved (ANTUNIASSI *et al.*, 2004).

Notably, during crop development, there is an increase in the mass and branching of the leaves of plants. This makes it more difficult for the target to be covered and for the droplets to penetrate the crop canopy, especially in the lower layers of the plants (CUNHA *et al.*, 2008).

The objective of this research was to evaluate the interaction between spray jet shapes, with similar droplet spectra and spray volumes, and covering soybean leaves.

2. MATERIALS AND METHODS

Droplet spectrum and leaf coverage analyses were performed at the Spraying Machinery Laboratory of the Agricultural and Forestry Machinery and Tire Testing Center (NEMPA), at the Faculty of Agronomic Sciences (UNESP), Botucatu, SP. The field experiment was installed at Fazenda Nova Fiorelli, which is located in the municipality of

Tejupá, SP, where the application and leaf collection were carried out.

Droplet spectrum analysis was performed as a preliminary test to verify whether the droplet spectra of the spray nozzles used in the experiment were similar, aiming to isolate the effect of droplet size on leaf coverage analysis. Analyzing the results according to the ASABE S572.2 standard (ASABE, 2018), it was determined that the three nozzles presented spectra within the "medium" droplet class for spraying with the solutions prepared for this test (it should be noted that the droplet classes presented in the catalogs refer to spraying with water).

Leaf coverage was evaluated via two 3x2 factorial designs (three spray nozzles × two spray volumes), one using leaves from the upper stratum of the plant and the other using leaves from the middle/lower stratum of the plant. The experimental design was a randomized block design with five replications.

The spray nozzle models used were the reduced drift flat fan (LD11002 - Lurmark), the double reduced drift flat fan (DGTJ60-11002 - TeeJet), and the angled flat fan (3D 10002 - Hypro). The spray volumes used were 100 and 200 L ha⁻¹, and the working pressure was 200 kPa.

The spray solutions were prepared considering spray volumes of 100 and 200 L ha⁻¹ and a mixture of the fungicide Sphere Max® (trifloxystrobin + cyproconazole) at a dose of 0.2 L ha⁻¹, the adjuvant Aureo® (methylated soybean oil) at a dose of 0.25% vv⁻¹, and the dye Luxcor LRM 100 at a concentration of 0.15% (ANTUNIASSI *et al.*, 2004). The dye is intended to allow for subsequent visual assessment of the percentage of coverage in a dark room with fluorescent lighting.

The soybean variety used in the experiment was NS6700 IPRO. Planting was carried out on November 7, 2019, with a spacing of 0.5 m between rows and fertilization of 360 kg ha⁻¹ of 04--30--10 (NPK) fertilizer.

The treatments were replicated and divided into plots measuring 10 × 20 m in width and length. To avoid contamination between plots, a 10-meter space was delimited between each plot. Leaf collection for droplet coverage evaluation was carried out on January 6, 2020,

at the R1 reproductive stage of soybean (beginning flowering), with an average plot stand of 11 plants per meter and a plant height of 0.62 m.

The application was carried out via a Columbia AD18 sprayer (Jacto). The spray nozzles were placed on the sprayer boom with a spacing of 0.5 m between the nozzles, and the application was carried out at a height of 0.5 m above the crop. The sprayer travel speeds were 7.8 and 3.9 km h⁻¹ for spray volumes of 100 and 200 L ha⁻¹.

The applications were carried out on two consecutive days because it was impossible to perform several applications on the same day under the same weather conditions. For this reason, the start time (11:00 am) and end time (1:30 pm) were determined for the applications; this interval was determined on the basis of the dew at the beginning of the day (waiting for the leaves to dry) and the occurrence of increased temperature and reduced relative humidity after 1:30 pm. In addition, the wind speed on both days of the experiment and the position of the leaves (leaf epinasty) were taken into consideration.

In all the applications, the weather conditions were monitored and recorded, with wind speeds ranging from 3.1--10.8 km⁻¹, relative humidities ranging from 44--72%, and temperatures ranging from 28.1--32.1°C.

At the end of the application to each plot, the leaves were allowed to dry for 20 min, and 10 leaves were collected from two positions on the plants (upper stratum and middle/lower stratum). The upper stratum was defined as the collection of exposed leaves at the top of the plant, and the middle/lower stratum was defined as the collection of unexposed leaves within the plant canopy.

Each leaf was placed in an individual paper bag and properly identified; in this way, the leaf was allowed to dry, facilitating evaluation. The 20 paper bags from each replicate were subsequently stored in an identified paper envelope.

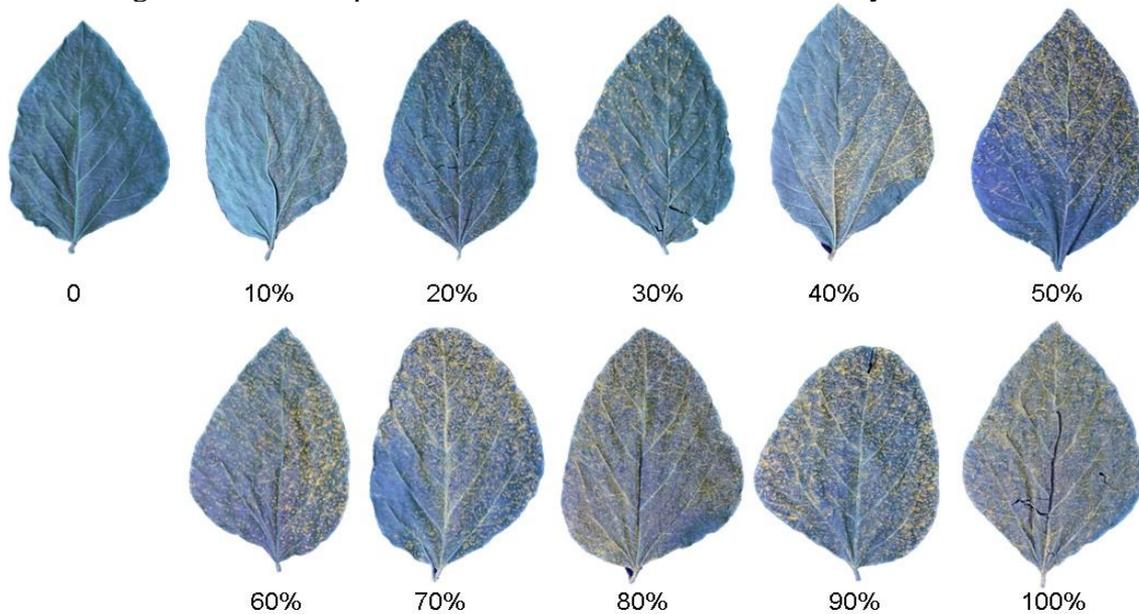
The evaluation of leaf coverage was carried out 48 hours after application and leaf collection to allow time for the leaves to dry. To visualize the dye used in the preparation of the solution on the leaves, a dark room with

fluorescent lighting was used, which contained four lamps (OurLux® Black Light 20 W 127 V).

According to Antuniassi *et al.* (2004), the analysis of the percentage of leaf coverage was performed on the upper surface of the leaves, as it is easier for spray deposition to occur there than on the lower surface.

Coverage was determined through visual assessment by three evaluators, who compared the leaves with a rating scale used as a parameter (Figure 1), adapted from Bullock, Brooks and Whitney (1968), with values of 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100%.

Figure 1. Rating scale used as a parameter in the visual assessment of soybean leaf cover.



3. RESULTS AND DISCUSSION

According to Table 1, in the analysis of variance of leaf coverage in soybean plants in

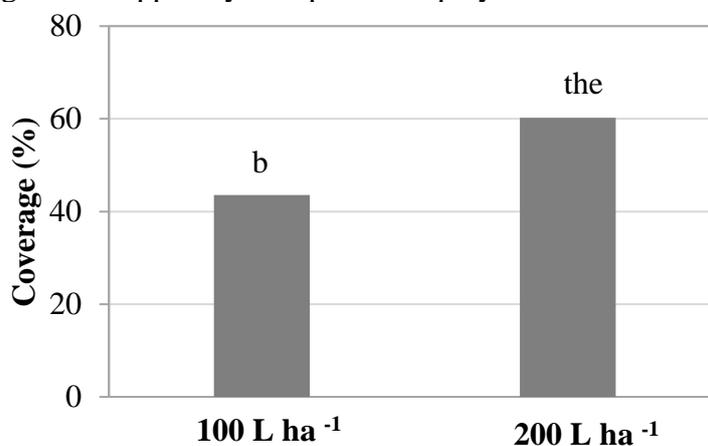
both evaluated strata (upper and middle/lower), there were no interactions between the spray nozzle models and the spray volume ($p > 0.05$).

Table 1. Analysis of variance (ANOVA) of leaf cover in soybean plants in the upper and middle/lower strata.

	GL	SQ	QM	F calc .	P value
Top extract					
Block	4	1240.00	309.99	2.02	0.1297
Tip	2	755.40	377.70	2.47	0.1103
Syrup	1	2067.80	2067.80	13.50	<0.05
Tip*Tail	2	280.20	140.12	0.91	0.4167
Residue	20	3063.20	153.16		
Total	29	7406.60			
CV: 23.85%					
Middle/lower extract					
Block	4	165.51	41.38	1.37	0.2845
Tip	2	225,38	112,69	3,69	0,0432
Calda	1	1205,20	1205,20	39,48	<0,05
Ponta*Calda	2	119,68	59,84	1,96	0,1669
Resíduo	20	610,50	30,53		
Total	29	2326,20			
CV: 30,88%					

In the upper layer of the soybean plants, a greater percentage of leaf coverage occurred with a spray volume of 200 L ha⁻¹ (60.19%)

than with a spray volume of 100 L ha⁻¹ (43.59%) (Figure 2).

Figure 2. Leaf coverage in the upper layer of plants at spray volumes of 100 and 200 L ha⁻¹.

* Different lowercase letters indicate statistically significant differences according to Tukey's test (p<0.05).

Cunha, Reis and Santos (2006), evaluating the deposition of spray solution applied to soybean crops as a function of different application volumes and spray nozzle models, reported that higher spray volumes resulted in greater deposition on the target, which is consistent with the present work. Increasing the spray volume leads to greater product distribution, which is particularly

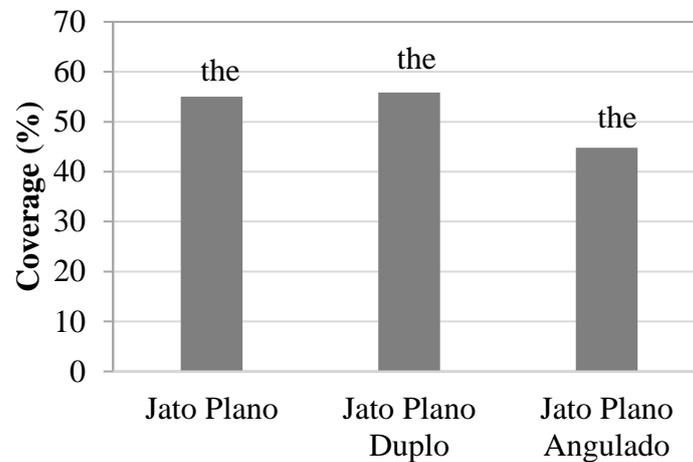
desirable in applications of protective fungicides.

Roehrig (2017), evaluating the coverage and deposition of droplets on soybean leaves in applications with different spray volumes (40, 70, 100, 130 and 160 L ha⁻¹) and using "medium" droplets, reported that as the spray volume increased, droplet deposition increased, as per the results of this research.

When the leaf coverage in the upper layer was analyzed for the different spray patterns (Figure 3), the values were 44.81%,

55.00%, and 55.85% for the angled flat jet, flat jet, and double flat jet, respectively, with no significant difference between them.

Figure 3. Leaf coverage in the upper layer of plants in the form of flat jets, double flat jets, and angled flat jets.



* Different lowercase letters indicate statistically significant differences according to Tukey's test ($p < 0.05$).

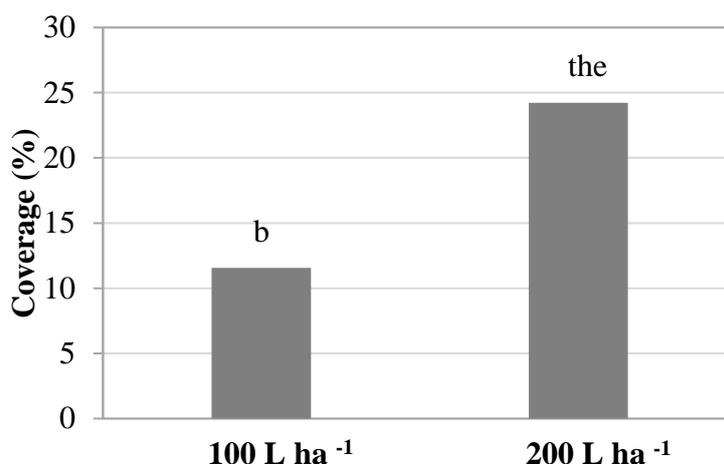
Cunha, Reis, and Santos (2006) evaluated the deposition of spray solution applied to soybean crops as a function of different application volumes and spray nozzle models. They used flat fan nozzles, preorifice flat fan nozzles, double flat fan nozzles with air induction, and flat fan nozzles with air induction, all with the same spray pattern but different droplet sizes. The authors reported that, compared with other nozzle models, the flat fan nozzle resulted in a more homogeneous distribution of the spray solution on the plants. This can be explained by the "fine" droplet size, unlike the other nozzle models, which had larger droplet sizes ("medium" and "very coarse").

Negrisoni *et al.* (2019) studied the performance of angled flat fan nozzles in relation to spray deposition and Asian soybean

rust control. The experiment used three spray nozzle models with different nozzle shapes (flat fan, double flat fan, and angled flat fan). The authors reported that in the upper stratum, there was no difference in spray deposition between the nozzle shapes, which is consistent with the present study. Disease control was achieved in all the applications, regardless of the nozzle model; however, there was no increase in control when the angled flat fan nozzle model was used compared with the other nozzle shapes.

In the middle/lower layer of the soybean plants, the highest percentage of leaf coverage occurred with a spray volume of 200 L ha⁻¹ (24.23%), compared with 100 L ha⁻¹ (11.55%), with a difference of 52.32% between the spray volumes applied (Figure 4).

Figure 4. Leaf coverage in the middle/lower layers of plants at spray volumes of 100 and 200 L ha⁻¹.



* Different lowercase letters indicate statistically significant differences according to Tukey's test ($p < 0.05$).

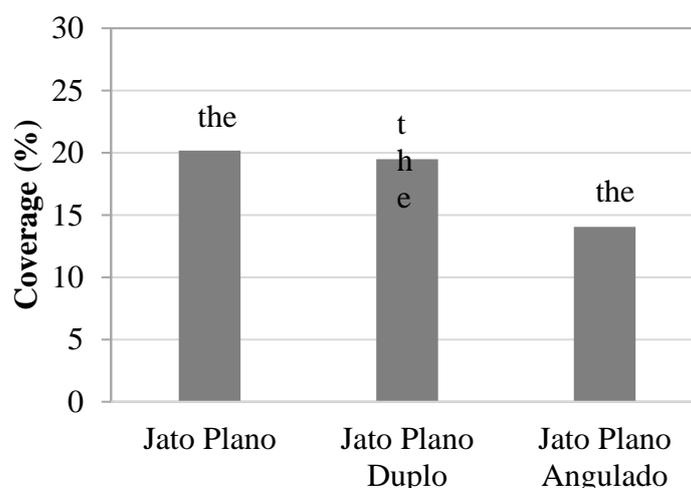
In a study conducted by Negrisoli *et al.* (2019), which analyzed spray solution deposits with the same jet shapes as those used in the present work (flat jet, double flat jet and angled flat jet), in the middle/lower layer, there was also a reduction in deposition when the spray volume decreased, which is in agreement with the results of this research.

Roehrig (2017), evaluating the coverage and deposition of droplets on soybean leaves in applications with different spray volumes, reported that there was an increase in droplet deposition in all the plant layers (upper, middle, and lower), similar to the results of the present

work. In one of the experiments evaluated by the author, increasing the spray volume from 60 to 100 L ha⁻¹ resulted in a 67.3% increase in coverage in the upper layer. In the middle/lower layer, there was a 2.15-fold increase in coverage at a spray volume of 100 L ha⁻¹, compared with 60 L ha⁻¹.

In the analysis of leaf coverage in the middle/lower layer for each spray pattern (Figure 5), the values were 14.04%, 19.47%, and 20.17%, respectively, for the angled flat jet, double flat jet, and flat jet, with no significant difference between them.

Figure 5. Leaf coverage in the middle/lower stratum of plants in the form of flat jets, double flat jets and angled flat jets.



* Different lowercase letters indicate statistically significant differences according to Tukey's test ($p < 0.05$).

The nonsignificant difference in leaf coverage percentages between the different spray patterns, especially for the middle/lower stratum, can be explained by the plant stands not being completely closed, having spaces between the planting rows that facilitated the entry of droplets into the crop canopy.

In addition to studies of leaf coverage and spray deposition, which compare different nozzle models and droplet sizes, several authors have correlated plant extracts (upper, middle, and lower), unlike this assay. Antuniassi *et al.* (2004) evaluated soybean leaf coverage in applications using three spray nozzle models with three droplet classes (“Very Fine”, “Fine”, and “Very Coarse”). The authors reported that “very fine” and “fine” droplets resulted in greater coverage in the middle and lower layers of the plants. In general, reducing droplet size during spraying increases target coverage; conversely, using finer droplets also increases the risk of drift (FERGUSON *et al.*, 2015).

Cunha *et al.* (2008) analyzed the effects of four spray nozzles (hollow cone jet with air induction, hollow cone jet, double flat deflector jet, and double flat jet with preorifice) on the

4 CONCLUSIONS

In the analysis of variance, there was no interaction effect between the spray jet shape and the spray volume.

The different spray patterns did not significantly affect the coverage of soybean leaves at the beginning of flowering (R1) in the upper, middle, or lower layers.

In the analysis of spray volume, there was a significant difference in soybean leaf coverage between the two extracts. Increasing the spray volume from 100 to 200 L ha⁻¹ increased leaf coverage.

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6 REFERENCES

chemical control of Asian soybean rust. The authors reported that in applications at soybean stages R3 and R5, the percentage of leaf coverage did not differ significantly for the four nozzle models or for the two plant positions evaluated (upper and lower), which is in agreement with the present work.

In addition to research evaluating the performance of spray nozzles in fungicide applications in soybean crops, other crops, such as beans, are also highly important. Cunha, Teixeira and Vieira (2005) reported that the use of different nozzle models (flat fan, anti-drift flat fan and cone fan) did not influence the control of anthracnose, angular leaf spot or rust in beans, as did this research.

In the situation where the soybean was at the time of application (R1 stage), the different spray jet shapes did not significantly affect soybean leaf coverage. A different scenario was observed for the two spray volumes analyzed, with greater coverage of the soybean leaves when the spray volume was increased from 100 to 200 L ha⁻¹.

ANTUNIASSI, UR; CAMARGO, TV; VELINI, ED; CAVENAGHI, AL; FIGUEIREDO, ZN; BONELLI, MAO.

Control of soybean rust through aerial and ground applications. *In* : INTERNATIONAL SYMPOSIUM ON PESTICIDE APPLICATION TECHNOLOGY, 3, 2004, Botucatu. **Proceedings** [...]. Botucatu : UNESP, 2004. p. 48-51.

ASABE. **Spray Nozzle Classification by Droplet Spectra** . St. Joseph: ASABE, 2018.

BULLOCK, RC; BROOKS, RF; WHITNEY, JD. A method for evaluating pesticide application equipment for Florida citrus. **Journal of Economic Entomology** , Lanham , v. 61, n. 6, p. 1511-1514, 1968. Available at: <https://academic.oup.com/jee/article-abstract/61/6/1511/972606?redirectedFrom=fulltext>. Accessed On : January 1 , 2020.

CARVALHO, FK; ANTUNIASSI, UR; CHECHETTO, RG; MOTA, AAB; JESUS,

MG; CARVALHO, LR Viscosity, surface tension and droplet size of sprays of different formulations of insecticides and fungicide. **crop Protection**, Guildford, v. 101, p. 24-28, 2017. DOI: <https://doi.org/10.1016/j.cropro.2017.07.014>. Available at: <https://www.sciencedirect.com/science/article/pii/S0261219417302077>. Accessed on: May 25, 2023.

CHECHETTO, RG; MOTA, AAB; ANTUNIASSI, UR; CARVALHO, FK; VILELA, CM; SILVA, ACA. Characterization of the application rate and spray nozzles used in the Cerrado Grosso state. **Magistra**, Cruz das Almas, v. 26, n. 1, p. 89-97, 2014. Available at: <https://www3.ufrb.edu.br/magistra/index.php/magistra/article/view/442>. Accessed [date]. in : May 23, 2023.

CHECHI, A.; ROEHRIG, R.; PITON, B.; LUZ, M. R.; DEUNER, C. C.; FORCELINI, C. A.; BOLLER, W. The combined use of spray volumes and droplet sizes in the chemical control of Asian soybean rust in cultivars with different leaf area indices. **Crop protection**, Guildford, v. 136, p. 105212, 2020. DOI: <https://doi.org/10.1016/j.cropro.2020.105212>. Disponível em: <https://www.sciencedirect.com/science/article/pii/S0261219420301459>. Acesso em: 23 maio 2023.

CUNHA, JPAR; MOURA, EAC; SILVA JÚNIOR, JL; ZAGO, FA; JULIATTI, FC. Effect of spray nozzles on the chemical control of Asian soybean rust. **Engenharia Agrícola**, Jaboticabal, v. 28, n. 2, p. 283-291, 2008. DOI: <https://doi.org/10.1590/S0100-69162008000200009>. Available at: <https://www.scielo.br/j/eagri/a/cRGbftqdJrbmDcLPJbtrfnn/?lang=pt&format=html>. Accessed on: May 23, 2023.

CUNHA, JPAR; REIS, EF; SANTOS RO. Chemical control of Asian soybean rust as a function of spray nozzle and spray volume. **Ciência Rural**, Santa Maria, v. 36, n. 5, p.

1360-1366, 2006. DOI: <http://dx.doi.org/10.1590/S0103-84782006000500003>. Available at: <https://www.scielo.br/j/cr/a/D4TsMGq73h99Y9PhSSmNBQb/abstract/?lang=pt>. Accessed on: May 23, 2023.

CUNHA, JPAR; SILVA, LL; BOLLER, W.; RODRIGUES, JF. Aerial and terrestrial application of fungicide for the control of corn diseases. **Revista Ciência Agronômica**, Fortaleza, v. 41, n. 3, p. 366-372, 2010. Available at: <https://www.scielo.br/j/rca/a/Br6kwydsVrNGB5p3FTrgTSp/abstract/?lang=pt>. Accessed on: May 23, 2023.

CUNHA, JPAR; TEIXEIRA, MM; VIEIRA, RF. Evaluation of hydraulic spray nozzles in fungicide application in common bean. **Ciência Rural**, Santa Maria, v. 35, n. 5, p. 1069-1074, 2005. DOI: <https://doi.org/10.1590/S0103-84782005000500013>. Available at: <https://www.scielo.br/j/cr/a/zkk3BqTMLCYXvLWjhVHHgHM/abstract/?lang=pt>. Accessed Date : May 23, 2023.

FERGUSON, J. C.; CHECHETTO, R. G.; O'DONNELL, C. C.; DORR, G. J.; MOORE, J. H.; BAKER, G. J.; POWIS, K. J.; HEWITT, A. J. Droplet-size effects on control of *Chloris spp.* with six post herbicides. **Weed Technology**, Cambridge, v. 33, n. 1, p. 153-158, 2019. DOI: <http://dx.doi.org/10.1017/wet.2018.99>. Disponível em: <https://www.cambridge.org/core/journals/weed-technology/article/abs/dropletsize-effects-on-control-of-chloris-spp-with-six-postherbicides/992A44076A72DAD2BAADB0C42EF1E12C>. Acesso em: 23 maio 2023.

FERGUSON, J. C.; CHECHETTO, R. G.; O'DONNELL, C. C.; FRITZ, B. K.; HOFFMANN, W. C.; COLEMAN, C. E.; CHAUHAN, B. S.; ADKINS, S. W.; KRUGER, G. R.; HEWITT, A. J. Assessing a novel smartphone application - SnapCard, compared to five imaging systems to quantify droplet deposition on artificial collectors.

Computers and Electronics in Agriculture, Nova Iorque, v. 128, p. 193-198, 2016. DOI: <http://dx.doi.org/10.1016/j.compag.2016.08.022>. Disponível em: <https://www.sciencedirect.com/science/article/pii/S016816991630182X>. Acesso em: 23 maio 2023.

FERGUSON, JC; O'DONNELL, CC; CHAUHAN, BS; ADKINS, SW; KRUGER, GR; WANG, R.; URACH FERREIRA, PH; HEWITT, AJ. Determining droplet size uniformity and consistency through drift spray reduction puzzles in a wind tunnel. **Crop Protection**, Guildford, v. 76, n. 1, p. 6, 2015. DOI: <https://doi.org/10.1016/j.cropro.2015.06.008>. Available at: <https://www.sciencedirect.com/science/article/pii/S026121941530048X>. Accessed on: May 23, 2023.

MONIZ, A.; CARVALHO, FK; CHECHETTO, RG; MOTA, AAB; ANTUNIASSI, UR Technologies against drift. **Cultivar Máquinas Magazine**, Pelotas, year 18, no. 204, pp. 22-28, 2020.

NANSEN, C.; FERGUSON, JC; MOORE, J.; GROVES, L.; EMERY, R.; GAREL, N.; HEWITT, A. Optimizing pesticide spray coverage using a new web and smartphone tool, SnapCard. **Agronomy for Sustainable Development**, Paris, v. 35, p. 1075-1085. 2015. DOI: <https://doi.org/10.1007/s13593-015-0309-y>. Available at: <https://link.springer.com/article/10.1007/s13593-015-0309-y>. Accessed Date : May 23, 2023.

NEGRISOLI, M. M.; RAETANO, C. G.; SOUZA, D. M.; SOUZA, F. M. S.;

BERNARDES, L. M.; BEM JUNIOR L. D.; RODRIGUES D. M.; SARTORI, M. M. P. Performance of new flat fan nozzle design in spray deposition, penetration and control of soybean rust. **European Journal of Plant Pathology**, Dordrecht, v. 155, p. 755-767, 2019. DOI: <https://doi.org/10.1007/s10658-019-01803-1>. Disponível em: <https://link.springer.com/article/10.1007/s10658-019-01803-1>. Acesso em: 23 mai0 2023.

OLIVEIRA, GM; BALAN, MG; FONSECA, ICB; SAAB, OJGA. Application directions and spray nozzles in the percentage of coverage on artificial targets, for different target orientation and wind situations. **Ciência Rural**, Santa Maria, v. 42, n. 4, p. 581-586, 2012. DOI: <https://doi.org/10.1590/S0103-84782012000400001>. Available at: <https://www.scielo.br/j/cr/a/hFVmkJ3hGQCZfyDcxDnWMvJ/abstract/?lang=pt>. Accessed on: May 23, 2023.

ROEHRIG, R. **Behavior of Asian soybean rust in response to leaf surface coverage and fungicide deposition in the plant canopy**. 2017. Thesis (Doctorate in Agronomy) – Faculty of Agronomy and Veterinary Medicine, University of Passo Fundo, Passo Fundo, 2017.

ROEHRIG, R.; BOLLER, W.; FORCELINI, CA; CHECHI, A. Use of surfactant with different volumes of fungicide application in soybean culture. **Engenharia Agrícola**, Jaboticabal, v. 38, n. 4, p. 577-589, 2018. DOI: <https://doi.org/10.1590/1809-4430-eng.agric.v38n4p577-589/2018>. Available at: <https://www.scielo.br/j/eagri/a/LC5XTWtH6FbDZBLZCjdCcPm/>. Accessed on: May 23, 2023.