FUNGICIDE SPRAY COVERAGE AND DEPOSITION IN SOYBEAN ASIAN RUST MANAGEMENT

COBERTURA E DEPÓSITO DE CALDA FUNGICIDA NO MANEJO DA FERRUGEM ASIÁTICA EM SOJA

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ABSTRACT: At maximum vegetative growth, sprays with fungicide to control Asian rust (*Phakopsora pachyrhizi* Sydow and P. Sydow) should reach high canopy penetration and plant coverage. Therefore, the central objective of this study was to determine leaf area, spray deposition, and plant coverage by fungicides sprayed on soybeans as a function of sowing seasons and plant population densities with reduced doses of tebuconazole and azoxystrobin + cyproconazole. Field experiments were conducted in the 2009/2010 and 2010/2011 crop years, using a medium-cycle soybean cultivar MG/BR–46 (Conquista) under a natural infestation of Asian soybean rust. Leaf area (LA) and leaf area index (LAI) were measured at three developmental stages (V8, R2, and R4). Spray deposition and coverage were evaluated during the first fungicide spraying. As results, LAI decreased as plant population decreased. Despite the lower LAIs, smaller plant populations had no effect on spray deposition and plant coverage. Both fungicides presented similar depositions on all thirds when plants had lower development.

KEYWORDS: Chemical control. Sowing season. Leaf area index. *Phakopsora pachyrhizi* Sydow and P. Sydow. Plant population.

INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is worldwide characterized as an agricultural product of great economic importance. The production of these beans has faced several challenges to reach high quality and productivity such as attaining an effective control of pests and mainly leaf diseases caused by fungi, which normally require two or three fungicide applications (CUNHA et al., 2011).

Asian soybean rust is a highly aggressive disease caused by the fungus *Phakopsora pachyrhizi* (Sydow & P. Sydow); it has been one of the major soybean problems since first recorded in Brazil during 2000/2001 crop year (EMBRAPA, 2013). For the control, joint measures have been undertaken, however, still making use of chemicals (LANGENBACH et al., 2016).

According to Santos et al. (2007) and Seixas et al. (2006), Asian soybean rust is mainly controlled by fungicide spraying. However, for Raetano (2007), despite the efficiency, fungicide use is not always satisfactory. Given its location, reaching a biological target directly is usually difficult. Asian rust symptoms begin in the lower third of plants; therefore, fungicide applications must cross the barrier imposed by leaves and thus promote good coverage inside plant canopies (ZHU et al., 2008).

The control strategies for Asian soybean rust are based on how systemic fungicides move in the plants after being applied and absorbed. Hence, the transport of active ingredient through plant canopy is a basic condition for an effective control.

Pesticide spray technology aims at depositing crop protection products at the desired target in proper amounts, avoiding losses, and environmental contamination (MATTHEWS, 2002). The efficiency of the droplets generated by a spray tip in reach the lower layers of the plant canopy depends on the architectural characteristics of the cultivar used. Cultivars that have a larger leaf area and a greater number of lateral branches allow faster closure of lines, which causes difficulty in transporting the droplets to the lower layers of the canopy (TORMEN et al., 2012). The penetration of the active ingredient into the canopy is an essential condition for effective disease control and, as the crop grows, reaching the lower layers becomes increasingly difficult (DEBORTOLI et al., 2012; TORMEN et al., 2012). During spraying, if any amount of chemical does not reach the target surface, application effectiveness will be void and will constitute a form of loss (MATUO,

http://dx.doi.org/10.14393/BJ-v35n5a2019-42323
Received: 15/05/18
Accepted: 05/12/18

1990).

Nevertheless, treatment effectiveness depends not only on the amount of material deposited but also on its coverage uniformity on the target (MCNICHOL et al. 1997). In general, spray deposition is lower in the lower and inner parts of crop canopy; for fungicides, this lack of uniformity provides a low effectiveness in disease control.

To determine the percentage of coverage and spray deposition on the leaves or other plant parts, it is essential to collect, evaluate and measure the penetration of the canopy drops.

In light of the above, this study aimed to determine spray deposition and coverage on soybeans grown in different sowing seasons, plant populations, and sprayed with different concentrations of active ingredient.

MATERIAL AND METHODS

The study was carried out at an experimental field of the São Paulo State University (UNESP), Campus in Jaboticabal - São Paulo State, Brazil. It is located at the geographical coordinates 21°15′29″ S and 48°16′47″ W, at an average altitude of 614 m. The experiment was conducted during the 2009/2010 and 2010/2011 crop years. The local soil is classified by Embrapa (2006) as a clayey eutroferric Red Latosol (Oxisol). According to Köppen (1948), the climate is a *Cwa* type, which stands for a humid subtropical region with dry winters. Annual rainfall, temperature, and relative air humidity averages are 1425 mm, 22.2 °C, and 70–80%, respectively.

The used soybean cultivar was MG/BR–46 (Conquista), which has a medium cycle and determinate growth habit. Sowing was performed mechanically in areas under conventional soil tillage. Seeds were previously treated with carbendazim + thiram (Protreat®) at a dose of 30 + 70 g ai/100 kg seed, and a peat-based inoculant at a dose of 100 g/50 kg seed.

Weeds were controlled with post-emergence herbicides, as recommended for soybeans, in addition to handpicking and hoeing when necessary. The area was monitored, and the main pests were controlled by insecticide spraying as crop recommendations.

Thirty treatments were tested by combining three plant population densities, two sowing seasons, and four fungicide treatments, as follows: **Plant populations** – plots were thinned about 20 days after sowing, at V3 stage, to adjust plant stands to 160,000, 280,000, and 400,000 plants ha^{-1}. **Sowing seasons** – soybeans were sown during the second fortnight of October and November in the 2009/2010 and 2010/2011 crop years. **Fungicides and doses** – the following spray mixtures were studied at both recommended and reduced doses: 50% azoxystrobin + cyproconazole (Priori Xtra®) + 0.5% mineral oil (Nimbus® 0.5% v/v) (30 + 12 g ai ha^{-1} + 1.25 L ha^{-1}); 100% azoxystrobin + cyproconazole (Priori Xtra®) + 0.5% mineral oil (Nimbus® 0.5% v/v) (60 + 24 g ai ha^{-1} + 1.25 L ha^{-1}); 50% tebuconazole (Folicur 200 EC®) (50 g ai ha^{-1}); and 100% tebuconazole (Folicur 200 EC®) (100 g ai ha^{-1}). Spraying was applied at 15- to 20-day intervals after the onset of the first Asian soybean rust symptoms.

The experimental design was a randomized block with four replications. Each experimental unit consisted of six 6-m long rows spaced 0.45 m apart, using as floor area the four central rows of each plot. The experiment was carried out under natural pathogen infestation and the ending rows of plots were maintained without fungicide spraying, aiming to standardize the inoculum of *P. pachyrhizi*.

Fungicides were sprayed by a CO_2 backpack sprayer, at a constant pressure of 3.0 kgf cm^{-2} and spray consumption of 250 L ha^{-1}; the sprayer was equipped with four twin flat-jet nozzles (TJ 60 11002 model) spaced at 0.45 m. During spraying, wind speed, temperature, and air relative humidity were monitored by an anemometer-thermo-hygrometer (Kestrel, model 3000), which registered values between 3.0 and 9.0 km h^{-1}, 29 to 34 °C, and 58 to 68%, respectively.

Leaf area (LA) and leaf area index (LAI) were estimated at V8, R2, and R4 stages of soybean cycle (RITCHIE et al. 1982). For that, twenty leaflets were randomly collected from three plants from each plot, being then measured by an image analysis Delta system (Delta Devices LTD, Cambridge. England/WD–R3–110). Afterwards, these leaves and leaflets were dried in a forced air circulation oven at 60–70 °C until constant weight, and weighed for total LA calculations (BENINCASA, 1988). Yet the LAI was calculated as the ratio between total LA of one plant and the soil area occupied by it.

Fungicide spray deposition was assessed during the first spraying by adding to copper oxychloride (Cuprogarb 500®) at 252 g ai ha^{-1} as a marker. This assessment was made by randomly collecting three leaves from three different points in the central rows of each plot. Each leaf was sampled from the lower, middle, and upper third of soybean plants, totaling nine leaflets per plant third per plot. Then, these leaves were placed into identified plastic bags and taken to the laboratory; there, 250 mL of 0.2 N HCl solution was added and left stand for about 2 hours (MACHADO NETO; MATUO, 1989). Thereafter, the solutions were filtrated, and the obtained extracts were read in an atomic absorption spectrophotometer for analysis of copper concentration. The leaflets maintained in HCl solution were washed and determined for leaf area, using a Delta-T image analysis system. Copper concentrations read in spectrophotometer were correlated with LA measures, and the results were expressed in µg copper cm^{-2}.

Spray coverage was also evaluated during the first spraying. Before application, hydro-sensitive paper cards were stapled in two plants in the central row of each plot, in the lower, middle, and upper thirds of soybean plants. Immediately after sprayed foliage dried, these papers were removed, placed into paper bags, and taken to the laboratory for scanning on a 300-dpi resolution scanner and subsequently analyzed by QUANT software v.1.0.0.22 (FERNANDES FILHO et al., 2002) to quantify spray coverage on treated surfaces.

Data from each experiment underwent analysis of variance by F test, and means were compared by Tukey's test ($p \leq 0.05$). For LA and LAI, only plant populations and sowing seasons were assessed.

RESULTS AND DISCUSSION

In both crop years, leaf areas (LAs) at R2 and R4 reproductive stages were larger in the smaller plant densities. Conversely, LAI decreased as plant population reduced when considering the same stages and V8 (Table 1).

Plants from the first sowing season reached higher LA and LAI values if compared to those from the second; these outcomes were observed at R2 and R4 for the first crop year and at R2 for the second. At V8, plants sown in November presented a greater development. According to Daroish et al. (2005), an LAI enough to enhance light interceptions is acquired late in plants from earlier sowings due to lower temperatures.

For the significant interactions within the same V8 plant population during the first year, higher LAI was measured in plants sown in November. At R4, LA and LAI were higher in plants from the first sowing season for all population densities. An LA reduction and LAI increase were observed in plants sown in October as plant population increased. Likewise, Heiffig et al. (2006) also obtained lower LAI when low plant populations were used.

For Müller (1981), soybean LAI variations are very high and usually range from 2.5 to 9.0. At flowering, this index could range between 4.0 and 8.0, exceeding the critical values, which corresponds to 95% absorption of the incident light (from 2.7 to 3.2). The faster the plants reach the critical LAI, and the longer they remain with the same index, the higher the crop growth, and productivity. In the second crop year, LAI values were lower, and it took longer to reach the critical LAI. In the same year, temperatures and rainfall records were slightly lower than those in the first crop year were, and possibly slowed plant development.

The first symptoms of Asian soybean rust were observed at R4 and R3, around 70 days after seedling emergence for plants sown in October, in the first and second crop years, respectively. On the other hand, for the second sowing season, the initial symptoms appeared at 60 days after emergence at R3 in the 2009/2010 crop year, and at 50 days in 2010/2011, with plants still at R2.

In the first crop year (2009/2010), fungicide treatments with azoxystrobin + cyproconazole (AZ + CP), in which the addition of mineral oil is recommended by the manufacturer, presented a higher deposition on the upper third of plants. Yet the treatment with tebuconazole (TB) showed the lowest spray deposition on the upper and middle thirds (Table 2). In this crop year, LA and LAI values were high, indicating a poor deposition when spraying tebuconazole onto a large leaf mass.

For all treatments, deposition was higher in the upper third than in the lower. When assessing the effects of spray nozzles on Asian soybean rust chemical control, using conventional sprayers (without air assistance), chemical control, Cunha et al. (2008) also observed a higher deposition at the plant top compared to the bottom parts. These authors attributed such result to canopy closure; they also stated that disease control might not be effective when pathogen grows initially in the lower plant parts, thereby compromising fungicide performance. Therefore, droplets reaching the outer leaves of the upper canopy will not control the diseases in the lower parts.

Table 1. Leaf area (LA) and leaf area index (LAI) of soybean cultivar MG/BR–46 (Conquista) grown at different plant populations and two sowing seasons. Jaboticabal, SP, Brazil.

Treatment	Leaf area (dm^2 $plant^{-1}$)			LAI		
	V8	R2	R4	V8	R2	R4
	2009/2010					
Population (plants ha^{-1}) (P)						
160,000	12.48	26.86 a †	35.52 a	2.09 c	4.45 b	5.82 b
280,000	12.56	24.79 ab	28.73 b	3.28 b	6.26 a	6.91 b
400,000	11.75	21.44 b	26.80 b	3.87 a	6.93 a	8.38 a
F test ‡	1.11 ns	7.06 **	8.33 **	40.05 **	19.99 **	9.55 **
LSD §	1.44	3.48	5.35	0.48	0.97	1.40
Sowing season (S)						
October	9.36 b	27.52 a	52.73 a	2.20 b	6.35 a	12.09 a
November	15.17 a	21.20 b	7.98 b	3.96 a	5.40 b	1.99 b
F test ‡	139.20 **	28.18 **	597.06 **	113.35 **	8.25 **	443.15 **
LSD §	0.98	2.37	3.64	0.33	0.66	0.95
P × S	2.44 ns	0.12 ns	3.69 *	5.55 **	0.36 ns	6.33 **
CV (%) ¶	21.98	26.76	33.05	29.51	30.85	37.33
	2010/2011					
Population (plants ha^{-1}) (P)						
160,000	3.42	9.00 a	12.26 a	0.56 b	1.43 b	1.98 b
280,000	3.67	8.37 a	8.95 b	0.90 b	2.01 a	2.16 ab
400,000	3.24	6.84 b	7.95 b	0.96 a	2.00 a	2.36 a
F test ‡	2.37 ns	8.36 **	41.85 **	39.13 **	14.45 **	5.26 **
LSD §	0.48	1.30	1.17	0.12	0.29	0.28
Sowing season (S)						
October	3.39	9.37 a	9.74	0.73 b	1.95 a	2.00 b
November	3.49	6.76 b	9.70	0.88 a	1.67 b	2.34 a
F test ‡	0.38 ns	34.61 **	0.01 ns	14.85 **	7.65 **	13.36 **
LSD §	0.33	0.88	0.80	0.08	0.20	0.19
P × S	1.04 ns	0.11 ns	0.22 ns	1.02 ns	2.00 ns	0.47 ns
CV (%) ¶	26.10	30.14	22.65	27.39	30.34	24.05

† Means followed by the same letter in the column do not differ statistically ($p \leq 0.05$, Tukey's test). ‡ By the F test; ** significant at 1% probability; * significant at 5% probability; ns non-significant. § Least significant difference. ¶ Coefficient of variation.

Table 2. Fungicide spray deposition and coverage on the upper, middle, and lower thirds of soybean plants cultivar MG/BR–46 (Conquista) sprayed with two doses of azoxystrobin + cyproconazole + mineral oil (AZ + CP) and tebuconazole (TB), for plants grown in different plant populations and two sowing seasons, in the 2009/2010 crop year. Jaboticabal, SP, Brazil.

Treatment	Deposition			Coverage		
	Cu concentration (μg cm^{-2})			Covered hydro-sensitive paper area (%)		
	Upper third	Middle third	Lower third	Upper third	Middle third	Lower third
Population (plants ha^{-1}) (P)						
160,000	1.30	0.30	0.07	66.60	46.50	31.78
280,000	1.04	0.29	0.08	62.20	47.16	30.17
400,000	1.08	0.31	0.11	65.14	46.52	29.59
F test ‡	1.26 ns	0.02 ns	1.49 ns	0.33 ns	0.01 ns	0.12 ns
LSD §	0.42	0.20	0.05	13.22	10.79	10.90
Fungicide (F)						
50% AZ + CP	1.50 a †	0.40 ab	0.10	62.48	34.11 c	22.50 bc
100% AZ + CP	1.75 a	0.46 a	0.11	60.85	48.73 ab	34.41 ab
50% TB	0.76 b	0.19 b	0.06	69.23	61.02 a	46.40 a
100% TB	0.56 b	0.15 b	0.07	66.04	43.06 bc	18.75 c
F test ‡	16.28 **	5.00 **	2.18 ns	0.69 ns	9.38 **	11.35 **
LSD §	0.53	0.25	0.06	16.78	13.70	13.84
Sowing season (S)						
October	1.41 a	0.32	0.13 a	62.33	58.94 a	44.95 a
November	0.87 b	0.28	0.05 b	66.97	34.51 b	16.07 b
F test ‡	14.21 **	0.39 ns	23.51 **	1.06 ns	44.09 **	60.40 **
LSD §	0.28	0.14	0.03	8.99	7.33	7.41
P × F	1.41 ns	0.43 ns	0.50 ns	2.11 ns	0.74 ns	0.18 *
P × S	2.84 ns	0.38 ns	1.03 ns	3.26 *	0.32 ns	0.40 ns
F × S	0.91 ns	1.18 ns	2.28 ns	2.59 ns	0.52 ns	7.92 **
P × F × S	1.19 ns	1.44 ns	1.09 ns	1.01 ns	0.95 ns	0.91 ns
CV (%) ¶	60.99	110.30	89.08	34.16	38.56	59.67

† Means followed by the same letter in the column do not differ statistically ($p \leq 0.05$, Tukey's test). ‡ By the F test; ** significant at 1% probability; * significant at 5% probability; ns non-significant. § Least significant difference. ¶ Coefficient of variation.

Even with smaller LAIs, less dense plant populations had no effect on spray deposition and coverage on soybeans. For Costa et al. (2002), narrow crop spacing speed up canopy closure, increasing humidity and worsening the disease course. In addition, Balardin (2002) reiterated the difficulty of disease control in this plant portion.

In the bottom parts, larger areas were covered by fungicides in plants sown in October, in the 2009/2010 crop year; this was observed for the reduced dose of TB and the recommended dose of AZ + CP. In contrast, these treatments showed lesser covering in the second sowing season. For all plant populations, the treatment applying the recommended dose of TB promoted a coverage below that from the reduced dose.

The recommended and reduced doses of TB, in which mineral oil addition is not recommended by the manufacturer, showed similar deposition as that from treatments with AZ + CP in all thirds of soybean plants, in the 2010/2011 crop year (Table 3). In this year, LA and LAI low values were recorded; the lower leaf mass might not have influenced deposition on the treatments as well. For Roehrig (2017), the coverage of the leaf surface in soybean is influenced using adjuvants and the spray volume, which impacts deposition, relating directly to the severity of Asian rust, impacting on the IAF and productivity, justified by the characteristic of low mobility of fungicides used in the management of this disease. For the upper and middle thirds, higher depositions were reached in plants sown in the second season. For significant interactions, higher depositions were observed in the lower thirds of soybean plants from plots sown in November and with a population of 160,000 plants ha^{-1}.

By analyzing droplet deposition, Lenz et al. (2011) observed no effect from the used fungicides (azoxystrobin + cyproconazole and azoxystrobin), neither the active ingredient nor adjuvant addition influenced spraying pattern as well.

In general, the second crop year presented a lower deposition on the lower third when compared to the middle and upper parts. This outcome might have occurred because leaves located in the lower third of soybean plants are perhaps the most difficult to be reached by sprays. According to Souza et al. (2007), leaf overlapping in the way of droplets, smaller drop losses by evaporation or drift under adverse environmental conditions and long-distance travel may decrease droplets reaching the target, generating uneven deposited volumes. Thus, the treatments used here promoted a poor deposition on the lower part of plants. For Tormen et al. (2012), the fungicide coverage of leaves of the plant is extremely dependent on the LAI and the cultivar architecture at the time of application since the leaves at the top of the canopy intercept much of the spray droplets and prevent leaves from the lower third receive the same amount of active ingredient. Each cultivar has specific characteristics with respect to its architecture and they vary according to the sowing season, environmental conditions and crop development stage.

The fungicide distribution gradient in the plant, in addition to the direct impacts on the control of soybean Asian rust, has impacts on the *P. pachyrhizi* fungus population. In fungicide applications, most of the product remains in the upper part of the plant, while the smallest reaches the lower portion of the plant, causing super and sub dosage respectively, being this one of ways to select different populations of the pathogen (GODOY et al., 2016; ROEHRIG, 2017).

When considering the significant interactions, treatments with recommended fungicide doses presented the highest spray coverage on the upper third of soybean plants sown in October at the lowest plant populations. On the other hand, when reduced fungicide doses were used, the covered area rate was higher in the second sowing season.

In both sowing seasons and plant populations, fungicide treatments with AZ + CP and TB presented a similar coverage on the middle third. In the lower third of soybean plants sown in October, the reduced dose of AZ + CP promoted a lower coverage if compared to the other treatments. In the second sowing season, the lower coverage rates were measured with the reduced dose of TB. For these plant thirds, the treatments with TB provided a greater coverage on the sowing performed in October.

There was a great coverage unevenness along the thirds of soybean plants, being higher in the upper plant and lower in the bottom. For diseases with early growth in the lower plant parts, e.g. Asian soybean rust, surface spraying may not be efficient, thereby compromising crop development. Similarly, Boschini et al. (2008) asserted a significantly lower spray deposition on the lower third of soybeans cultivar CD 202 when compared to the upper third, regardless of nozzle or flow rate used.

Table 3. Fungicide spray deposition and coverage on the upper, middle, and lower thirds of soybean plants cultivar MG/BR–46 (Conquista) sprayed with two doses of azoxystrobin + cyproconazole + mineral oil (AZ + CP) and tebuconazole (TB), for plants grown in different plant populations and two sowing seasons in the 2010/2011 crop year. Jaboticabal, SP, Brazil.

Treatment	Deposition			Coverage		
	Cu concentration ($\mu g\ cm^{-2}$)			Covered hydro-sensitive paper area (%)		
	Upper third	Middle third	Upper third	Middle third	Upper third	Middle third
Population (plants ha^{-1}) (P)						
160,000	1.66	0.54	0.13	68.01 a [†]	34.75	15.06
280,000	1.37	0.54	0.11	58.65 b	31.10	13.88
400,000	1.58	0.54	0.11	58.99 b	38.25	12.32
F test [‡]	0.90 [ns]	0.00 [ns]	0.42 [ns]	4.52 *	2.03 [ns]	1.29 [ns]
LSD [§]	0.54	0.31	0.06	8.46	8.50	4.09
Fungicide (F)						
50% AZ + CP	1.69	0.71	0.16	46.80 c	36.06	11.18
100% AZ + CP	1.67	0.50	0.13	68.45 ab	33.58	16.14
50% TB	1.53	0.62	0.10	60.28 b	34.31	12.32
100% TB	1.25	0.34	0.08	71.99 a	34.84	15.36
F test [‡]	1.20 [ns]	2.29 [ns]	2.60 [ns]	15.05 **	0.13 [ns]	2.91 [ns]
LSD [§]	0.69	0.40	0.08	10.74	10.79	5.20
Sowing season (S)						
October	1.29 b	0.39 b	0.09 b	59.42	39.15 a	15.78 a
November	1.79 a	0.69 a	0.14 a	64.34	30.25 b	11.73 b
F test [‡]	7.15 **	8.12 **	4.22 *	2.90 [ns]	9.43 **	8.40 **
LSD [§]	0.37	0.21	0.04	5.75	5.78	2.78
P × F	1.46 [ns]	1.05 [ns]	0.41 [ns]	2.38 *	2.31 *	1.57 [ns]
P × S	1.36 [ns]	2.23 [ns]	4.28 *	0.62 [ns]	1.68 [ns]	1.71 [ns]
F × S	1.95 [ns]	0.94 [ns]	1.54 [ns]	6.77 **	4.32 **	11.94 **
P × F × S	1.28 [ns]	0.68 [ns]	1.32 [ns]	3.78 **	0.75 [ns]	2.33 *
CV (%) [¶]	59.12	95.36	87.97	22.84	40.92	49.72

[†] Means followed by the same letter in the column do not differ statistically ($p \leq 0.05$, Tukey's test). [‡] By the F test; ** significant at 1% probability; * significant at 5% probability; [ns] non-significant. [§] Least significant difference. [¶] Coefficient of variation.

Given the direct relationship between depositions in the lower and upper parts, each treatment could be analyzed regarding its spray penetration through leaf mass. In the second crop year, depositions in the lower parts were proportionally similar for all plant populations, sowing seasons, and fungicide treatments. In the 2009/2010 crop year, depositions in the lower parts were proportionally higher as plant population increased. However, these differences were not observed among populations when analyzing the thirds individually. Regarding the sowing dates, plants sowed in October had proportionally higher deposition rates in the lower third, confirming the results of deposits in the upper and lower thirds. Despite the lower LAI, depositions and coverages of both sprayed fungicides did not increase as plant population reduced.

CONCLUSIONS

Even though the leaf area index of soybean plants cultivar MG/BR-46 (Conquista) was reduced in smaller population densities, at V8, R2, and R4 stages, fungicide spray deposition and coverage had no increase.

Among the three plant thirds, there was a great coverage unevenness, where deposits on the upper third were larger than were those on the lower third, for all treatments and in both crop years.

The lowest deposits in the upper third were recorded in plants treated with tebuconazole in the 2009/2010 crop year when LA and LAI values were also high. The presence of vegetable oil influences the spray coverage and deposition on the leaf surface when higher leaf area index is observed. In the 2010/2011 crop year, both tebuconazole and azoxystrobin + cyproconazole showed similar results for deposition on all plant thirds, when plants showed less development.

ACKNOWLEDGMENTS

The authors thank the State of São Paulo Research Foundation (FAPESP) for the doctoral scholarship granted to the first author (Process # 08/54225–5) and for the financial support to this research (Process # 08/54224–9).

RESUMO: Para o controle da ferrugem asiática (*Phakopsora pachyrhizi* Sydow & P. Sydow), quando as plantas atingem o máximo de desenvolvimento vegetativo, as pulverizações com fungicidas necessitam de alta capacidade de penetração e cobertura. O objetivo deste trabalho foi determinar a área foliar, o depósito e a cobertura de calda fungicida em soja em função de épocas de semeadura, populações de plantas e doses reduzidas de fungicidas. Experimentos de campo foram conduzidos nos anos agrícolas 2009/2010 e de 2010/2011, com a cultivar de ciclo médio MG/BR-46 (Conquista), sob infestação natural da ferrugem asiática. Nos estádios V8, R2 e R4 de desenvolvimento da cultura foram determinados a área foliar e o índice de área foliar (IAF) das plantas. As avaliações de depósito e cobertura foram realizadas no momento da primeira pulverização com os tratamentos fungicidas. Com a redução da população de plantas houve redução no IAF. Os depósitos e coberturas da calda aplicada não apresentaram aumento com a redução da população de plantas, apesar dos menores IAF. Os tratamentos fungicidas com tebuconazol e com azoxystrobina + ciproconazol apresentaram deposições semelhantes em todos os terços das plantas quando as plantas apresentaram menor desenvolvimento.

PALAVRAS-CHAVES: Controle químico. Época de semeadura. Índice de área foliar. *Phakopsora pachyrhizi* Sydow & P. Sydow. População de plantas.

REFERENCES

BALARDIN, R. S. **Doenças da soja**. Santa Maria: Ed. Autor, 2002. 100p.

BENINCASA, M. M. P. **Análise de crescimento de plantas (noções básicas)**. Jaboticabal: Funep, 1988. 41p.

BOSCHINI, L.; CONTIERO, R. L.; MACEDO JÚNIOR, E. K.; GUIMARÃES, V. F. Avaliação da deposição da calda de pulverização em função da vazão e do tipo de bico hidráulico na cultura da soja. **Acta Scientiarum. Agronomy**, v. 30, n. 2, p. 171-175, 2008. http://dx.doi.org/10.4025/actasciagron.v30i2.1789

COSTA, J. A.; PIRES, J. L. F., RAMBO, L.; THOMAS, A. L. Redução no espaçamento entrelinhas e potencial de rendimento da soja. **Revista Plantio Direto**, v. 68, n. 2, p. 22-28, 2002.

CUNHA, J. P. A. R.; FARNESE, A. C.; OLIVET, J. J.; VILLALBA, J. Deposição de calda pulverizada na cultura da soja promovida pela aplicação aérea e terrestre. **Engenharia Agrícola**, v. 31, n. 2, p. 343-351, 2011. http://dx.doi.org/10.1590/S0100-69162011000200014

CUNHA, J. P. A. R.; MOURA, E. A. C.; SILVA JR., J. L.; ZAGO, F. A.; JULIATTI, F. C. Efeito de pontas de pulverização no controle químico da ferrugem da soja. **Engenharia Agrícola**, v. 28, n. 2, p. 283-291, 2008. http://dx.doi.org/10.1590/S0100-69162008000200009

DAROISH, M.; HASSAN, Z.; AHAD, M. Influence of planting dates and plant densities on photosynthesis capacity, grain and biological yield of soybean [*Glycine max* (L.) Merrill] in Karaj, Iran. **Journal of Agronomy**, v. 4, n. 3, p. 230-237, 2005. http://dx.doi.org/10.3923/ja.2005.230.237

DEBORTOLI, M. P.; TORMEN, N. R.; BALARDIN, R. S.; FAVERA, D. D.; STEFANELLO, M. T.; PINTO, F. F.; UEBEL, J. D. Espectro de gotas de pulverização e controle da ferrugem-asiática-da-soja em cultivares com diferentes arquiteturas de planta. **Pesquisa Agropecuária Brasileira**, v. 47, n. 7, p.920-927, 2012. https://dx.doi.org/10.1590/S0100-204X2012000700007

EMBRAPA - EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. **Tecnologias de produção de soja – região central do Brasil – 2014**. 1. ed. Londrina, PR: Embrapa Soja, 2013. 265p.

EMBRAPA - EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA. **Sistema brasileiro de classificação de solos**. 2 ed. Rio de Janeiro, RJ: Embrapa Solos, 2006. 306p.

FERNANDES FILHO, E. I.; VALE, F. X. R.; LIBERATO, J. R. **QUANT v.1.0.0.22: quantificação de doenças de plantas**. Viçosa: editora, 1 CD-ROM, 2002.

GODOY, C. V.; SEIXAS, C. D. S.; SOARES, R. M.; MARCELINO-GUIMARÃES, F. C.; MEYER, M. C.; COSTAMILAN, L. M. Asian soybean rust in Brazil: past, present, and future. **Pesquisa Agropecuária Brasileira**, v. 51, n. 5, p.407-421, 2016. https://dx.doi.org/10.1590/S0100-204X2016000500002

HEIFFIG, L. S.; CÂMARA, G. M. S.; MARQUES, L. A.; PEDROSO, D. B.; PIEDADE, S. M. S. Fechamento e índice de área foliar da cultura da soja em diferentes arranjos espaciais. **Bragantia**, v. 65, n. 2, p. 285-295, 2006. http://dx.doi.org/10.1590/S0006-87052006000200010

KÖPPEN, W. **Climatologia: con un estudio de los climas de la tierra**. México: Fondo de Cultura Económica, 1948. 478p.

LANGENBACH, C.; CAMPE, R.; BEYER, S. F.; MUELLER, A. N.; CONRATH, U. Fighting Asian Soybean Rust. **Plant Science**, v. 7, n. 979, p.1-14, 2016. https://doi.org/10.3389/fpls.2016.00797

LENZ, G.; BALARDIN, R. S.; MINUZZI, S. G.; TORMEN, N. R.; MARQUES, L. N. Espectro de gotas e idade de trifólios na taxa de absorção e efeito residual de fungicidas em soja. **Ciência Rural**, v. 41, n. 10, p. 1702-1708, 2011. http://dx.doi.org/10.1590/S0103-84782011005000127

MACHADO NETO, J. G.; MATUO, T. Avaliação de um amostrador para estudo da exposição dérmica de aplicadores de defensivos agrícolas. **Ciência Agronômica**, v. 4, n. 2, p. 21-22, 1989.

MATTHEWS, G. A. The application of chemicals for plant disease control. In: WALLER, J. M.; LENNÉ, J. M.; WALLER, S. J. **Plant pathologist's pocketbook.** London: CAB, 2002. p.345-353. https://doi.org/10.1079/9780851994581.0345

MATUO, T. **Técnicas de aplicação de defensivos agrícolas**. Jaboticabal: Funep, 1990. 139p.

MCNICHOL, A. Z.; TESKE, M. E.; BARRY, J. W. A technique to characterize spray deposit in orchard and tree canopies. **Transactions of the ASAE**, v. 40, n. 6, p. 1529-1536, 1997. https://doi.org/10.13031/2013.21410

MÜLLER, L. Fisiologia: fotossíntese. In: MIYASAKA, S.; MEDINA, J. C. (Eds.). **A soja no Brasil**. Campinas: ITAL, 1981. p.109-129.

RAETANO, C. G. Assistência de ar e outros métodos de aplicação a baixo volume em culturas de baixo fuste: a soja como modelo**. Summa Phytopathologica**, v. 33, supl., p. 105-106, 2007.

RITCHIE, S.; HANWAY, J. J.; THOMPSON, H. E. **How a soybean plant develops**. Ames: Iowa State University of Science and Technology, Cooperative Extension Service (Special Report, 53), 1982. 20p.

ROEHRIG, Rafael. **Comportamento da ferrugem asiática da soja frente a cobertura da superfície foliar e a deposição de fungicida no dossel da planta.** 2017. 137 f. Dissertação (Mestrado em Agronomia) - Universidade de Passo Fundo, Passo Fundo, 2017.

SANTOS, J. A.; JULIATTI, F. C.; SANTOS, V. A.; POLIZEL, A. C.; JULIATTI, F. C.; HAMAWAKI, O. T. Caracteres epidemiológicos e uso da análise de agrupamento para resistência parcial à ferrugem da soja. **Pesquisa Agropecuária Brasileira**, v. 42, n. 3, p. 443-447, 2007. http://dx.doi.org/10.1590/S0100-204X2007000300019

SEIXAS, C. D. S.; GODOY, C. V.; FERREIRA, L. P.; YORINORI, J. T.; HENNING, A. A.; ALMEIDA, A. M. R. Manejo das doenças da soja nas regiões Sul e Sudeste. **Fitopatologia Brasileira**, v. 31, supl., p. 60-61, 2006.

SOUZA, R. T.; CASTRO, R. D.; PALLADINI, L. A. Depósito de pulverização com diferentes padrões de gotas em aplicações na cultura do algodoeiro. **Engenharia Agrícola**, v. 27, n. esp., p. 75-82, 2007. http://dx.doi.org/10.1590/S0100-69162007000200011

TORMEN, N. R.; SILVA, F. D. L.; DEBORTOLI, M. P.; UEBEL, J. D.; FÁVERA, D. D.; BALARDIN, R. Deposição de gotas no dossel e controle químico de *Phakopsora pachyrhizi* na soja. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 16, n. 7, p. 802-808, 2012. http://dx.doi.org/10.1590/S1415-43662012000700015

ZHU, H.; DERKSEN, R. C.; OZKAN, H. E.; REDING, M. E.; KRAUSE, C. R. Development of a canopy opener to improve spray deposition and coverage inside soybean canopies. 2. Opener design with field experiments. **Transactions of the ASABE**, v. 51, n. 6, p. 1913-1922, 2008. http://dx.doi.org/10.13031/2013.25390