SPRAY NOZZLE AND ADJUVANT EFFECTS ON FUNGICIDAL CONTROL OF SOYBEAN ASIAN RUST

João Paulo Arantes Rodrigues da Cunha, Lísias Coelho and Renato Geraldo Corsino Araújo

SUMMARY

This study evaluated the efficacy of fungicidal control of Asian rust and deposition of fungicide applied on soybean as affected by different adjuvants and types of spray nozzles. Four compositions of tank mixture (with or without three commercial adjuvants), two types of spray nozzles (flat-fan and air induction flat-fan) and an untreated control were evaluated. Spray deposition of azoxystrobin + ciproconazole fungicide on the crop canopy was evaluated after application, using a tracer for spectrophotometric quantification. Other observations included Asian rust severity, 1000-grain mass and yield. Spray deposition on soybean upper and lower canopies and yield were not affected by the adjuvants or the spray nozzle. Fungicide deposition on soybean in the conditions evaluated was 65% greater on the upper canopy than on the lower canopy. The addition of adjuvants reduced rust severity in comparison with the fungicide alone.

EFECTOS DE ADYUVANTES Y BOQUILLAS DE ASPERSIón EN EL CONTROL QUÍMICO DE LA ROYA ASIÁTICA DE LA SOYA

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RESUMEN

Se evaluó la eficacia de diferentes adyuvantes y tipos de boquilla de aspersión en el control químico de la roya asiática de la soya y en la deposición de fungicida aplicado. Se evaluaron tanques con cuatro mezclas (con tres adyuvantes comerciales o ninguno), dos tipos de boquillas (abanico plano y abanico plano por aire inducido) y un control. La deposición del fungicida azoxystrobin + ciproconazole en el dosel del cultivo fue evaluada tras la aplicación, utilizando un marcador para su cuantificación espectrofotométrica. Otras observaciones incluyeron la severidad de la roya asiática, la masa de 1000 granos y el rendimiento. La deposición por aspersión en los doseles superior e inferior de la soya, así como el rendimiento, no se vieron afectados por lo adyuvantes o las boquillas utilizadas. La deposición de fungicida en la soya bajo las condiciones evaluadas fue 65% mayor en el dosel superior que en el inferior. La adición de adyuvantes redujo la severidad de la roya en comparación con el fungicida solo.

Introduction

Pesticide use on soybean (*Glycine max* (L.) Merrill) is intense, especially because it is cultivated in extensive areas and its yield is limited by weeds, insects and plant pathogens. The diseases occurring on soybean limit the crop yield, which is worsened due to the lack of appropriate pesticide application technology.

Asian rust (*Phakopsora pachyrhizi* H. Sydow & Sydow) dissemination and the lack of resistant cultivars to control this disease have increased demand for fungicide use (Yorinori *et al*., 2005). When plants reach their maximum vegetative growth, with complete soil coverage and a large leaf area, fungicides applied to control the disease need maximum leaf penetration and coverage, even when systemic fungicides are applied (Antuniassi *et al*., 2004; Derksen *et al*., 2008).

One technique to obtain good deposition on biological targets is to use the correct spray nozzles and fungicide application technique, as well as the crop stage at application. In most cases, great importance is given to fungicide selection and too little concern to application technique (Guler *et al*., 2007).

Pesticide efficacy often is affected by tank mixture components. Adjuvants may improve pesticide's performance. Adjuvants act differently from each other and can improve wetting, adherence, spreading, foam reduction, or dispersal of the fungicide mixture (Mendon-

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ADJUVANTES E PONTAS DE PULVERIZAÇÃO NO CONTROLE QUÍMICO DA FERRUGEM ASIÁTICA DA SOJA

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RESUMO

O presente trabalho teve como objetivo avaliar o controle químico da ferrugem asiática e a deposição da calda fungicida aplicada na cultura da soja, em função de diferentes adjuvantes e tipos de pontas de pulverização. Quatro composições de calda (calda sem e com três adjuvantes comerciais), dois tipos de ponta de pulverização (jato plano e jato plano com indução de ar) e um tratamento adicional que não recebeu fungicida foram avaliados. Foram analisados, após a aplicação do fungicida azoxystrobin + ciproconazole com um traçador para quantificação por espectrofotometria, a deposição de calda no dossel da cultura, a severidade da ferrugem, a massa de 1000 grãos e a produtividade. Concluiu-se que deposição da calda fungicida nas partes superior e inferior da cultura da soja e a produtividade não foram influenciadas pela adição de adjuvante à calda e pelas pontas de pulverização. A deposição proporcionada na parte superior do dossel foi superior à obtida na posição inferior. O emprego dos adjuvantes reduziu a severidade da ferrugem em comparação à testemunha.

ça *et al*., 2007; Montório *et al*., 2004). Currently, several adjuvants are available to farmers, making appropriate selection difficult. The effect of adjuvants used in applications is complex, involving many physical, chemical and physiological aspects (Chow, 1993).

This study evaluated fungicidal control of Asian rust and fungicide deposition on soybean as affected by different adjuvants and types of spray nozzles.

Materials and Methods

This work was carried out at the experimental area of Uberlândia Federal University, Minas Gerais, Brazil. The soybean cultivar Valiosa RR (intermediate cycle) was sown in a no-till field, with 0.45m between rows and 11 plants per linear meter. A randomized complete-block design with five replications was used. Treatments were in a factorial scheme (4×2) + 1, with four tank mixture compositions (tank mixture alone or with three commercial adjuvants); two spray nozzles (flat-fan and air-induction flat-fan); and an untreated control (no fungicide or adjuvant).

The systemic fungicide (Priori Xtra®, Syngenta) used was a commercial mixture of azoxystrobin (60g ha^{-1}) and cyproconazole (24g·ha^{-1}). Treatments were applied with a CO_2-pressurized backpack sprayer with a boom of four nozzles spaced 0.5m apart and boom height of 0.5m. The pressure of 200kPa and travel speed of 4km·h^{-1} were used to obtain a spray volume of 200l·ha^{-1}. The first treatment was applied when the disease was first detected and the number of re-applications was determined by the product residual period.

The fungicide was applied three times at intervals of ~21 days. The first treatment was applied on stage R1 (51 days after seedling emergence; DAE), when soybean leaves covered 90% of the area. At this stage, soybean Asian rust severity was 2% on the lower third of the canopy and was not visible on the upper third of the canopy. The second application was done at the R3 stage and the third application at the R6 stage; the soybean canopy covering the soil completely at these times.

The commercial adjuvant tested, selected arbitrarily, were dodecyl benzene with N at 172.5g·l^{-1} and P_2O_5 at 46.0g·l^{-1} (Imantic®, Bac Science) at 50ml per 100 liters, phosphatidilcoline propionic acid (LI700®, De Sangosse) at 200ml per 100 liters, and nonyl phenol ethoxylate (Anti-deriva®, Inquima) at 100ml per 100 liters of water. The products are listed as quality and efficiency improvers on application and were applied according to manufacturers' recommendations. Their effects on physico-chemical characteristics of solutions are described by Cunha and Alves (2009).

Two types of hydraulic spray nozzles were used at 200kPa, an air-induction flat-fan (ULD120-02, Hypro) that produces coarse droplets, and a standard flat-fan (VP110-02, Hypro) that produces fine droplets. Both of them presented equivalent nominal flow rates.

Evaluation of treatments' effectiveness for soybean Asian rust control was achieved by comparing disease severity and soybean 1000-grain mass and yield in fungicide-treated and non-treated (control) treatments. Asian rust severity evaluations were made at 68 (stage R3), 80 (stage R4), and 95 DAE (stage R6). The diagrammatic scale by Godoy *et al*. (2006) was used for all evaluations. Ten plants were arbitrarily marked in each plot, and three leaves per plant were selected, one each from the lower, intermediate, and upper canopies. The average of these evaluations formed the disease severity average. The disease progress curve was made with the severity data of all three dates of evaluation, and the area under the progress curve (AUPC) was estimated.

Soybean was harvested at 122 DAE. Yield and 1000-grain mass, corrected to 13% moisture, were evaluated from an experimental area of 9.0m^2 (5.0×1.8m), consisting of four 5m-long rows.

Spray deposition was evaluated on plots that received fungicide in conjunction with the third fungicide application (plant height of 1.2m). A blue food coloring (azul brilhante, Duas Rodas Industry, catalogued as FD&C Blue n.1) was used as a deposition tracer, which was detected spectrophotometrically. The dye at 1500mg·l^{-1}concentration was used in the tank mixture and applied at 200l·ha^{-1}.

Ten plants were arbitrarily marked after crop spraying in each plot, and two leaves per plant were collected, one each from the upper (1m height) and lower (0.3m height) canopies. Leaves were bulked according to their position on the plant, placed in plastic bags containing 100ml of distilled water, and shaken for 30s. Dye concentration was quantified (Digital Spectrophotometer, 325-1000ηm, model SP22, Biospectro) by reading absorbance at 630ηm (Palladini *et al*., 2005). The leaf area was determined by the image analysis program "Image Tool" (UTHSCSA Image Tool, version 3.0, University of Texas Health Science Center, San Antonio, TX, USA) with space resolution of 600dpi non-interpolated, with 24-bit color.

The absorbance data were transformed using calibration curves into dye volume per leaf area (μl·cm^{-2}), for the upper and lower canopies. Also, the ratio between volumes retained in the upper and lower canopies was calculated according to Cunha *et al*. (2006) as

$$\text{Canopy ratio} = \frac{\text{Average upper deposition}}{\text{Average lower deposition}}$$

Air temperature, relative humidity and wind speed conditions were monitored during fungicide application. Deposition data were submitted to analysis of variance and averages were compared by the Tukey test at 5% probability. Rust severity and soybean 1000-grain mass and yield data were also submitted to analysis of variance, and averages of fungicide treatments were compared among themselves using the Tukey test at 5% probability, and with the control using the Dunnett test at 5% probability.

TABLE I
SUMMARY OF THE ANALYSIS OF VARIANCE FOR SOYBEAN AUPC* OF ASIAN RUST, 1000-GRAIN MASS AND YIELD, DUE TO FUNGICIDE APPLIED WITH DIFFERENT ADJUVANTS AND SPRAY NOZZLES

Variation Source	DF	Mean-square significance of AUPC of Asian rust*	Mean-square significance of 1000 - grain mass*	Mean-square significance of yield*
Nozzle	1	Significant	Non-significant	Non-significant
Adjuvant	3	Significant	Non-significant	Non-significant
Nozzle x adjuvant	3	Significant	Non-significant	Non-significant
Factorial x control	1	Significant	Significant	Significant

AUPC: area under the progress curve. * Significant at 5% probability by the F test.

Results and Discussion

Temperature, relative humidity and wind speed were favorable during fungicide application. Temperature was <29°C, relative humidity >62%, and wind speed 3-7km·h^{-1}.

There were no differences between nozzles and adjuvants for 1000-grain mass and soybean yield (Table I). The only significant differences observed were between the treated and non-treated plots for 1000-grain mass and yield (Table II). All treatments that received the fungicide outperformed the control, indicating that disease control was effectively achieved by the product. The AUPC was affected by the nozzles and adjuvants.

Cunha *et al*. (2008) also evaluated the effect of spray nozzles (turbo twin flat-fan, drift guard twin flat-fan, standard hollow cone and air-induction hollow cone) on fungicidal control of soybean Asian rust, and found no differences between the spray nozzles on the fungicide application in soybean yield. A systemic fungicide applied under favorable weather conditions certainly contributed to disease control.

TABLE II
EFFECT OF THE SPRAY NOZZLE AND ADJUVANT ADDED TO THE TANK MIXTURE USED IN THE FUNGICIDE APPLICATION ON SOYBEAN, IN THE AUPC OF ASIAN RUST, 1000-GRAIN MASS AND YIELD

Treatment		AUPC	1000-grain mass (g)	Yield (kg·ha^{-1})
Adjuvant	Nozzle			
Dodecyl benzene	Standard	1111*	146*	2513*
Phosphatidilcoline propionic acid	Standard	815*	146*	2836*
Nonyl phenol ethoxylate	Standard	1263*	144*	2469*
Without adjuvant	Standard	848*	148*	2711*
Dodecyl benzene	Low-drift	1046*	152*	2887*
Phosphatidilcoline propionic acid	Low-drift	1160*	154*	3124*
Nonyl phenol ethoxylate	Low-drift	1183*	152*	2736*
Without adjuvant	Low-drift	1975*	145*	2553*
Control		2359	115	712

AUPC: area under the progress curve.
* The averages followed by an asterisk differ significantly from the control by the Dunnett test at 5% probability.

Asian rust severity was lower in all fungicide-treated plots than in the control (Table II). Crop spraying reduced the disease progress in all plots, showing that Asian rust control was necessary, regardless of adjuvant use and nozzle type. Disease control with fungicide resulted in a visible greater green leaf area remaining, with the consequent maintenance of the productive potential.

There was a significant interaction between nozzles and adjuvants for the AUPC in the fungicide-treated plots, indicating dependency between these two factors (Table III). No differences were found between the two nozzles in plots where the adjuvant was added to the tank mixture. However, in treatments without the adjuvant, the standard flat-fan nozzle, which produces a fine droplet spectrum, provided better Asian rust control than the air-induction flat-fan. When the standard flat-fan was used, no differences were found between the adjuvants and the treatment without adjuvant. In contrast, when the air induction flat-fan was used, the addition of any of the three adjuvants was effective for reducing the AUPC.

The physical properties of the sprayed liquid can interact with the type of

TABLE III
AUPC OF ASIAN RUST AFTER FUNGICIDE APPLICATIONS WITH ADDITION OF DIFFERENT ADJUVANTS AND TWO SPRAY NOZZLES

Adjuvant	AUPC		
	Flat fan nozzle		Average
	Standard	Low-drift	
Dodecyl benzene	1111 aA*	1046 aA	1078
Phosphatidilcoline propionic acid	815 aA	1160 aA	988
Nonyl phenol ethoxylate	1263 aA	1183 aA	1223
Without adjuvant	848 aA	1975 bB	1411
Average	1009	1341	

AUPC: area under the progress curve.
* Averages followed by different capitalized letters in each line and non-capitalized in each column, differ significantly from each other at 5% by the Tukey test.

TABLE IV
SPRAY VOLUME RETAINED ON SOYBEAN CROP FOLIAGE (µl cm^{-2} OF LEAF) ON THE UPPER AND LOWER PARTS OF THE CANOPY, AFTER FUNGICIDE APPLICATION WITH DIFFERENT ADJUVANTS AND TWO SPRAY NOZZLES

Adjuvant	Upper canopy			Lower canopy			Canopy ratio
	Flat fan nozzle		Average	Flat fan nozzle		Average	
	Standard	Low-drift		Standard	Low-drift		U/lit
Dodecyl benzene	0.65	0.51	0.58 a*	0.31	0.15	0.23a	2.5
Phosphatidilcoline propionic acid	1.13	0.84	0.99 a	0.57	0.28	0.43a	2.3
Nonyl phenol ethoxylate	0.55	0.86	0.71 a	0.18	0.34	0.26a	2.7
Without adjuvant	1.00	0.73	0.87 a	0.22	0.17	0.20a	4.4
Average	0.83 A	0.74 A		0.32 A	0.24 A		

* Averages followed by different capital letters in each line and non-capitalized in each column, differ significantly from each other at 5% by the Tukey test.

nozzle used, forming a unique spray in each situation (Stainier *et al*., 2006). This may explain the existence of different results between the nozzles with the use of adjuvants.

There was no interaction between nozzles and adjuvants, indicating independence of the two factors (Table IV). Within both the upper and lower canopies, the average spray volume retained on the foliage was similar with the different adjuvants, showing no differences in deposition between them. Also, deposition by the two spray nozzle designs was similar in the two canopy positions analyzed.

Martins *et al*. (2005) evaluated spray deposit on *Pistia stratiotes* leaves, using the adjuvant Aterbane and found that it did not promote greater deposition in quantitative terms. However, Carbonari *et al*. (2005), studying the effect of surfactants in spray deposition in *Cynodon dactylon*, concluded that deposition on leaves was lower when no surfactant was added, regardless of the spray nozzle used. The differences between these results can probably be explained by the different plant canopy sizes and structures.

The difference in the volume retained between the upper and lower positions of the canopy indicates uniformity of deposition. Large differences show uneven distribution. Even with the use of adjuvants and different nozzles, the spray process was unable to cross the barrier imposed by the leaves, which would allow a similar deposition of the product between the lower and upper canopies. Lan *et al*. (2007) mentioned that adding adjuvants may alter application performance; however, the effect on pesticide deposition may be either positive or negative.

Deposition and control of Asian rust were evaluated under adequate application conditions, including air temperature, humidity and wind speed, but when weather conditions are not completely favorable for spraying, the use of adjuvants may positively impact disease control.

Conclusion

Spray deposition on soybean upper and lower canopies and yield were not affected by the addition of adjuvants to the tank mixture or by the spray nozzles used. The deposition on the soybean upper canopy was greater than that obtained on the lower canopy, indicating unevenness of spray. Strategies to enhance fungicide deposition on the lower canopy must be found. The use of the evaluated adjuvants reduced Asian rust severity in comparison to the treatment with fungicide alone, associated with the air induction flat-fan nozzle; however, this difference was not sufficient to affect soybean yield.

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