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ADJUVANTS IN FUNGICIDE SPRAYING IN WHEAT AND SOYBEAN CROPS

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ABSTRACT: The objective of this study was to determine whether the combination of adjuvants to fungicides significantly alters the spray physicochemical characteristics, and potentiates the chemical control of foliar diseases, in that it may affect yield components in wheat (*Triticum aestivum*) and soybean (*Glycine max*). The experimental design was completely randomized for the spray physicochemical characteristics, and randomized blocks for the culture variables analyzed, with four treatments and five replications. Treatments consisted of control (no fungicide spraying in the shoot), with fungicides only in plant shoots, fungicides + 0.25% of the spray with adjuvant of methyl ester base of soybean oil, and fungicides + 0.05% of the spray with adjuvant lauryl ether sodium sulfate base. Treatments were applied with land boom sprayer in wheat (season 2012) and soybean (season 2013). The variables evaluated were spray physicochemical characteristics, incidence and severity of diseases and yield components. Adjuvants altered the spray surface tension. Adding lauryl ether sodium sulfate to spray significantly reduced the disease severity in wheat, and incidence in soybean cultivation. The addition of adjuvants to spray fungicide did not affect yield components in both cultures.

KEYWORDS: disease, *Glycine max*, application technology, *Triticum aestivum*.

INTRODUCTION

Wheat (*Triticum aestivum*) and soybean (*Glycine max*) are among the main crops in Brazil. Diseases are among the factors that restrict yield (OLIVEIRA et al., 2015; WEIRICH NETO, 2013). Their incidence and severity vary each season depending on the cultivar, crop rotation, weather conditions and source of pathogens inoculum. One of the control strategies in the integrated management of diseases is chemical control (ITO, 2013; TORMEN et al., 2013).

Once the need for chemical control is determined, it is important to emphasize the process quality recommended by application technology, defined as the use of all scientific knowledge that provides proper placement of sufficient biologically active product on target, cost effectively, and with minimal environmental contamination (MORGAN & MATTHEWS, 2012).

The addition of adjuvants to spray may be a way to enhance the chemical activity or the application characteristics (AGUIAR JÚNIOR et al., 2011). These substances are designed to act as spreaders, wetting agents, adhesives, emulsifiers, dispersants, detergents, antievaporant, thickeners, buffers, chelation, antifoams and/or solar filters (XU et al., 2010).

After testing the physicochemical characteristics of aqueous solutions with adjuvant adhesive spreader nonylphenol ethoxylate, BUENO et al. (2013) stated that the hydrogen potential (pH) was the only factor not modified by adjuvants, from all characteristics analyzed: pH, density, viscosity, surface tension and solution stability. By studying the variability of surface tension break of the drop by mixing ester soybean oil methyl (Aureo -Bayer©) in water collection sites, SILVA-MATTE et al. (2014) emphasized that water values fell from 69 to 32 mN m^{-1} with the addition of this adjuvant. When evaluating aqueous solutions with adjuvants for agricultural use at 25 °C, CUNHA et al. (2010) concluded that the same adjuvant kept the spray stable, altered its pH, and reduced water surface tension from 71 to 33 mN m^{-1}. When checking the water physicochemical properties with and without adjuvants, BAIO et al. (2015) emphasize that water surface tension was reduced

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from 73 to 57 mN m^{-1} with the addition of adjuvant ester soybean oil methyl (Bayer©); which significantly differed from 30 mN m^{-1}, which was obtained with adjuvant lauryl ether sodium sulfate base (TA35- Inquima©).

SOUZA et al. (2014) examined a combination of fungicides and adjuvants soyal phospholipids plus propionic acid (LI 700- Fortgreen©) and orange essential oil (Orobor -Oroagri©) in wheat crop. These authors observed a significant reduction on severity of leaf spot (*Drechslera tritici-repentis* and *Bipolaris sorokiniana*, Shoemaker), oidium (*Blumeria graminis* f. sp. *tritici*, Marchal) and gibberella (*Gibberella zeae*, Schwabe), increasing the number of kernels per ear, yield and economic return. Verifying the effect of adjuvants mineral oil (Assist-Basf©) and orange essential oil (Orobor -Oroagri©) associated with fungicides to control wheat leaf diseases, CORADINI et al. (2016) asserted that adjuvants did not change yield components, nor the control of the diseases analyzed.

When testing fungicides combined with eight adjuvants in soybean crops, TANIMOTO et al. (2011) reported less severity and symptoms of rust (*Phakospsora pachyrhizi*); however, it did not affect yield components. NASCIMENTO et al. (2012), on the other hand, pointed out that the addition of seven different adjuvants to fungicide spray altered the incidence of soybean rust and thousand-grain weight, keeping similar severity and yield. When researching the same topic, AGUIAR JÚNIOR et al. (2011) asserted that the use of adjuvants nonylphenol ethoxylated (Antideriva -Inquima©) and a trisiloxane ethoxylate base (Silwet L-77 -FMC©) associated with fungicides significantly affected yield components, and also the incidence and severity of Asian soybean rust disease.

The aim of this study was to verify if the association of adjuvant to fungicide significantly alters the spray physicochemical characteristics and potentiates the chemical control of foliar diseases to the extent that it may affect yield components in wheat and soybean crops.

MATERIAL AND METHODS

The experiments were performed in no-tillage system in the crop seasons 2012 and 2013. In 2012, the experiment was conducted in wheat crop, at Paiquerê farm, in the Pirai do Sulcity - PR (24°21’11” S e 50°06’12’’ O), with 950 m up sea level and Red Dystrophic Latosol (Oxisol). In 2013, the experiment was conducted with soybean, at Mutuca farm, in the town of Arapoti - PR (24°16’27’’ S e 50°6’13’’ O), with 970 m up sea level and Red-Yellow Dystrophic Latosol (Oxisol). The climate is classified as *Cfb* with agro-meteorological data that favored crops during the experiments.

The experimental design was completely randomized for the spray physicochemical characteristics, and randomized blocks for the culture variables analyzed. There were four treatments and five replications. Treatments consisted of control (no spraying of fungicide in the shoot), fungicides only in crop shoots, fungicides + 0.25% of spray with adjuvant based on a methyl ester of soybean oil (Aureo - Bayer©), and fungicides + 0.05% of spray with adjuvant lauryl ether sodium sulfate base (TA35 - Inquima©). Field blocks had evaluation area of 20 m^2.

Sowing of wheat cultivar Abalone (Biotrigo) took place on May 22, 2012, with spacing of 0.17 m between rows and initial population evaluated at 15 days after emergence (DAE) in 2.8 million plants ha^{-1}. All farming and phytosanitary practices were performed accorging to region’s cultivation recommendations (EMBRAPA, 2011).

Under the wheat crop experimental conditions, the diseases that stood out were leaf rust (*Puccinia triticina*) and tan spot (*Drechslera tritici-repentis*), controlled by spraying fungicide trifloxystrobin + prothioconazole (Fox -Bayer©) at 0.5 L ha^{-1}. Applications occurred on June 26, July 19, August 01 and 21 of 2012.

All applications in wheat were conducted by a John Deereground sprayer, model 4630, 24 m of sprayboom, Hypro, with air induction flat fan nozzles, model ULD 110 02, spaced at 0.5 m, pressure of 210 kPa, speed 8.0 km h^{-1}, and application rate of 100 L ha^{-1}. The tip and pressure chosen generated large drops, because the wind speed in the region pushed the application technology recommended to the limit, and wheat has reduced restriction to the penetration of droplets into the canopy, and the target were the upper leaves. Water pH in the spray mixture was 6.3.

Sowing of soybean Potência (Brasmax), took place on February 12, 2013, with spacing of 0.35 m between rows and initial population evaluated at 15 days after emergence (DAE) in 270,000 plants ha^{-1}. All farming and phytosanitary practices were performed according to crop recommendations for the region (EMBRAPA, 2012).

Foliar soybean diseases requiring control were leaf blight (*Cercospora kikuchii*), Asian soybean rust (*Phakopsora pachyrhizi*), and oidium (*Microsphaera diffusa*). The diseases were controlled by spraying the fungicide trifloxystrobin + prothioconazole (Fox -Bayer©) at 0.4 L ha^{-1} on March 28 and April 18, 2013, and carbendazim (Carbomax -Nufarm©) at 0.4 L ha^{-1}) with cyproconazole + picoxystrobin (Approach Prima -Du Pont©) at 0.3 L ha^{-1} on May 3 and 21, 2013.

A self-propelled spray Jacto, model Uniport 3000, equipped with 24-m boom, hollow cone spray nozzle spacing of 0.5 m, tip Jacto, model JA3, speed of 13 km h^{-1}, working pressure at 1034 kPa, fine droplets and application rate of 125 L ha^{-1} was used. The water used in the spray preparation had pH 7.8, which came to 4.2 after the addition of pH reducer Nutriplant, Compact Zinc (0.10% of the spray mixture).

Sprayings were always carried out with relative humidity above 55%, temperature below 30 °C and wind speed between 3.0 and 10.0 km h^{-1} (SOUZA et al., 2014). Environmental conditions were monitored by anemo-thermo-hygrometer 3,000 (Kestrel, Chester, USA).

The following physicochemical characteristics of the three spray mixtures were analyzed (15 minutes after mixing): foam height, stability, pH and surface tension. Foaming formation occurred by measuring it on the spray, using a scale graduated in millimeters. Stability was evaluated by visual acuity in granule formation. The spray pH was measured with manual pH meter Phtek, model 100-B. Surface tension was determined in laboratory based on NBR 13241 (ABNT, 1994).

The culture variables evaluated were incidence and severity of diseases and yield components. Disease incidence and severity were evaluated in wheat plants following the guidelines of EMBRAPA (2011), and for soybeans, it was used those described in EMBRAPA (2012). Evaluations were performed five days after the last spraying.

Wheat harvest took place on October 15, 2012, and soybean harvest on June 12, 2013. Yield components were determined manually. Mass calculations of thousand grains and yield had 1.0% of impurities, with moisture corrected to 13.0% for wheat, and 1.0% impurities and 14.0% moisture for soybeans. Grain moisture was assessed by weighting on a precision analytical balance (G800, Gehaka, São Paulo, Brazil). And the thousand-grain weight was determined by a Diamonddigital scale 0.1 to 500 g. Yield assessment occurred with the aid of a Ramud digital scale, with a capacity of 50 kg.

The Hartley test was used to verify the homoscedasticity of data variance. The variables measured were subjected to the F and Duncan tests, with a degree of confidence higher than 95% probability.

RESULTS AND DISCUSSION

The Hartley test showed homoscedasticity of variance for all variables. Therefore, there was no need for transformation of the means for applying the analysis of variance.

When assessing some of the spray physicochemical characteristics, the formation of foam in the mixture of fungicides and adjuvants was not observed (Table 1). There was no visual identification of granule formation, emphasizing spray stability within evaluation time. These results corroborate the findings of CUNHA et al. (2010) when studying Aureo adjuvant (Bayer©).

The addition of fungicides and adjuvants to the solvent did not significantly alter the mixture pH in solvent with and without adding pH reducer to the spray. The results corroborate BUENO et al. (2013), who state that pH was the only variable not affected by adjuvants, among the spray physicochemical characteristics analyzed. They are contrary to the findings of CUNHA et al. (2010), however, on the susceptibility of pH to the addition of Aureo (Bayer), in that the adjuvant was not indicated as a pH regulator by these authors.

Surface tension did not change with fungicide addition to spray, but it is significantly reduced by the addition of adjuvants, which did not differ. The figures confirm the statements of AGUIAR JÚNIOR et al. (2011), BUENO et al. (2013), CUNHA et al. (2010), SILVA-MATTE et al. (2014) and XU et al. (2010). They are contrary to the findings of BAIO et al. (2015), however, which highlighted significant differences in surface tension of adjuvants Aureo (Bayer©) and TA35 (Inquima©); with lower values for Aureo at the same dose, and similar to TA35 adjuvant , at a ten times higher dose.

TABLE 1. Physicochemical characteristics of spray solution containing fungicides with and without adjuvant, after 15 minutes of mixture.

Treatments	Foam height (cm)	Stability	pH	Surface tension (mN m^{-1})
---------- Fox (0.32% of spray) ----------				
Water	0.0	Yes	6.3 a[1]	73.4 a
Fungicide	0.0	Yes	6.1 a	69.0 a
Fungicide + Aureo (0.25% of spray)	0.0	Yes	6.0 a	35.7 b
Fungicide + TA35 (0.05% or spray)	0.0	Yes	6.0 a	31.0 b
CV (%)	//	//	4.6	7.8
---------- Fox (0.50% of spray) [2] ----------				
Water	Zero	yes	7.8 a	73.4 a
Fungicide	Zero	yes	4.2 a	68.8 a
Fungicide + Aureo(0.25% of spray)	Zero	yes	4.3 a	35.9 b
Fungicide + TA35(0.05% of spray)	Zero	yes	4.4 a	31.4 b
CV (%)	//	//	4.4	7.3
---------- Carbomax (0.32% of spray) +Aproach Prima (0.24% of spray)[2] ----------				
Water	Zero	yes	7.8 a	73.4 a
Fungicides	Zero	yes	4.3 a	67.9 a
Fungicides + Aureo (0.25% of spray)	Zero	yes	4.3 a	35.3 b
Fungicides + TA35 (0.05% of spray)	Zero	yes	4.2 a	30.9 b
CV (%)	//	//	6.4	8.8

1 - Means followed by the same letter in the column do not differ by the Duncan test (P> 0.05).
2 – Due to the high solvent pH, from artesian well, pH reducer Compact Zinc (0.10% of the spray) was used.

With regard to the incidence and severity of disease, there were no significant differences for blocks (Table 2), indicating the homogeneity of the development of plant pathogens between treatment replications.

TABLE 2. Percentage of disease severity and incidence in wheat crop (*Triticum aestivum*) and soybean (*Glycine max*) controlled by spraying fungicides with and without adjuvants[1].

Treatments[2]	Wheat (harvest 2012)		Soybean (harvest 2013)	
	Incidence (%)	Severity (%)	Incidence (%)	Severity (%)
Control[3]	10.8 a[4]	87.5 a	98.2a	2.0 a
Fungicides	6.4 b	72.5 b	90.0 a	1.3 b
Fungicides + Aureo	6.3 b	77.5 b	83.7 a	1.0 b
Fungicides + TA35	6.2 b	55.0 c	64.5 b	0.8 b
CV (%)	34.6	9.7	13.2	12.9

1 - Evaluations were performed five days after the last spraying.
2 – Non-significant for blocks in all variables by the F test (P> 0.05).
3 - No application of fungicides in crop leaves.
4 - Means followed by the same letter in the column do not differ by the Duncan test (P> 0.05).

The incidence and severity of foliar diseases in wheat were affected by fungicide application. Adding TA35 (Inquima©) to the spray potentiated fungicide action, significantly reducing disease severity, through product characteristics not identified in the spray physicochemical evaluations, because they were not significantly different from those of Aureo (Bayer©). Results corroborate SOUZA et al. (2014), but contradict CORADINI et al. (2016), who ensured that adjuvants do not alter the control of the wheat diseases analyzed.

In soybean, incidence was only reduced significantly in the blocks sprayed with fungicides associated with adjuvant TA35 (Inquima©). Therefore, the claims of AGUIAR JÚNIOR et al. (2011) and NASCIMENTO et al. (2012) are confirmed, and the variety of adjuvants used in the work should be considered.

When evaluating the variable of disease severity in soybeans, the use of disease chemical control stood out. The addition of adjuvants to fungicide spray did not affect the percentage of disease severity compared to the blocks without adjuvants.

As there was significant changes in the surface tension of the sprays analyzed with the addition of adjuvants, the differences highlighted by studying the incidence and severity of diseases in crops can be attributed to the factor mentioned, and to the characteristics of each product.

Surveys of yield components did not show significant differences among blocks, indicating homogeneity of experimental conditions for these variables (Table 3). With a degree of confidence higher than 95% probability, it is possible to state that chemical control significantly affected all yield components in wheat, and thousand-grain weight and yield in soybean.

The reduction potential of crop yield capacity by the occurrence of diseases is therefore confirmed, as described by OLIVEIRA et al. (2015) and WEIRICH NETO (2013) on the conclusions of their work.

The differences highlighted in the physicochemical analysis, disease incidence and severity - with the addition of adjuvants to spray – did not reflect in the yield components. This can be attributed to the fact that all cultural practices were carried out at the times agronomically recommended, resulting in low disease incidence in wheat crop, and reduced severity in soybean. The results corroborate those obtained by CORADINI et al. (2016), NASCIMENTO et al. (2012) and TANIMOTO et al. (2011).

TABLE 3. Yield Components of wheat (*Triticum aestivum*) and soybean (*Glycine max*) sprayed with fungicides with and without adjuvants[1].

Treatments	Ears (ha)	Kernels per ear		Thousand-grain weight (g)	Yield (kg ha^{-1})
------------- Wheat cultivar Abalone, season 2012, Paiquerê Farm (Piraí do Sul - PR) ------------					
Control[2]	2.721.667 b[3]	28.0 b		29.1 b	2.236 b
Fungicide	3.654.317 a	33.2 a		31.0 a	3.758 a
Fungicide + Aureo	3.563.083 a	32.7 a		31.8 a	3.701 a
Fungicide + TA35	3.577.458 a	32.9 a		32.4 a	3.808 a
CV (%)	7.5	4.1		3.9	8.3
----------------- Soy cultivar Potência season 2013.Mutuca Farm (Arapoti - PR) ---------------					
Control	256.025 a	23 a	2.3 a	95 b	1.266 b
Fungicides	229.555 a	27 a	2.4 a	118 a	1.708 a
Fungicides + Aureo	246.348 a	24 a	2.4 a	120 a	1.718 a
Fungicides + TA35	245.102 a	25 a	2.4 a	116 a	1.732 a
CV (%)	6.2	12.9	8.7	2.9	16.8

1 – Non-significant for blocks in all variables by the F test (P>0.05).
2 - No application of fungicides in crop leaves.
3 - Means followed by the same letter in the column do not differ by the Duncan test (P> 0.05).

CONCLUSIONS

The addition of adjuvants to fungicide spray affected stability and pH, and did not generate foam. The physicochemical characteristic significantly reduced was surface tension.

The chemical control of foliar diseases interferes with the incidence and severity of foliar diseases in wheat and severity in the soybean culture. The addition of the adjuvant lauryl ether sodium sulfate base to fungicide spray significantly reduced the severity of disease in wheat and incidence in soybean cultivation.

The mixture of adjuvants to fungicide spray did not affect yield components in both cultures.

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