Use of isolated fungicides for the control of *Phakopsora pachyrhizi* in soybean

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ABSTRACT

The occurrence of diseases in soybean crop has negatively affected its development and caused significant losses in productivity. Among the diseases, Asian rust caused by the fungus Phakopsora pachyrhizi Sydow stands out because of its high severity. As a way of controlling, chemical fungicides is a tool used to mitigate the damage. The objective of this work was to evaluate the efficiency of different isolated fungicides in the control of Asian rust. The experiment was carried out in the experimental area of the University of Cruz Alta in the state of Rio Grande do Sul with a randomized block design and four replications. The cultivar used was BMX Ativa, and the fungicide applications occurred before the interline closure and later with 15 days of interval between applications. The fungicides tested in the experiment were: metominostrobin + tebuconazole, piraclostrobin + fluxpyroxade, picoxystrobin + cyproconazole, Azoxystrobin + benzovindiflupir, picoxystrobin + benzovindiflupir, Trifloxystrobin + protioconazole, Pyraclostrobin + epoxiconazole + fluxpyroxade, Bixafen + protioconazole + Trifloxystrobin, Mancozebe + picoxystrobin + tebuconazole and control. The variables analyzed were yield kg ha^{-1}, weight of one thousand seeds and disease severity. The fungicides Mancozebe + picoxystrobin + tebuconazole and bixafen + protioconazole + trifloxystrobin showed the highest yield, one thousand grain weight and lower severity of Asian soybean rust.

Keywords: Asian rust; *Glycine max*, production.

INTRODUCTION

The edaphoclimatic conditions found in Brazil promotes the most diverse farming activities. The country stands out as the world's second largest producer of soybeans, falling behind only the USA. According to CONAB (2019) in the 2018/19 harvest, this legume grew by 1.9% in relation to the previous harvest, corresponding to the planting of 35.8 million hectares.

Among the main factors that compromise soybean yield are the diseases, which, depending on their level of severity, can reduce the total crop productivity by 15% to 20% annually, in addition to contributing to the raise in production costs (TECNOLOGIAS, 2010). Among the main soybean diseases, Asian soybean rust (*Phakopsora pachyrhizi* Sydow) stands out due to its high severity.

The first report of the disease in commercial soybean crops was in the 2000/01 harvest (YORINORI et al., 2002). The symptoms are particularly evident in the leaves, evolving from isolated uredias to areas with pronounced coalescence when it causes yellowing and premature leaf abscission (NAVARINI, 2007). The damage caused to the leaves of the plants reduces the photosynthetic area and spreads rapidly, starting in the lower third of the plant and moving upwards in the final stages of the crop.

Some conductions are indicated for the control of this disease, among them, choice of cultivars with early cycle, use of cultivars less susceptible to disease, management of plants in the off-season, crop rotation and the main and most used currently by producers is the chemical management by means of fungicides (AMORIM *et al*, 2016).

Although there are a large number of commercial products registered to control Asian rust in Brazil, they belong to only three mechanisms of action (DUHATSCHEK, 2017). Multisite or protective fungicides have contact action, whereas those with preventive action are systemic, carboxamides and strubirulins are the main examples of these, yet there are curative action fungicides represented by triazoles and morpholines, which are responsible for controlling diseases and maintaining plant productivity.

The fungus has already shown resistance to the main existing actives for several harvests, so it is essential to study the control efficiency of the main fungicides used in isolate manner to identify possible deficiencies in the control and selection of molecules, which will be able to formulate further mixtures. The objective of this work was to evaluate the efficiency of fungicides used separately to control *Phakopsora pachyrhizi* in soybeans.

MATERIAL AND METHODS

The experiment was carried out in the Experimental Area of the University of Cruz Alta – UNICRUZ, Cruz Alta/RS. The climate in the region is humid subtropical (Cfa), according to the Köppen's classification. It has an average annual precipitation of 1300mm and an average annual temperature of 20ºC. The experiment area is classified at Distrofic Red Latosol, clay texture (EMBRAPA, 2018).

The experimental design used was randomized blocks, totaling 10 treatments with four repetitions of each treatment, using plots of five lines of 0.45 m by 3 meters in length, consisting of corridors spaced by 0.5 m between plots.

The experiment consisted of a single soybean cultivar, BMX-Ativa® which was sown on December 7, 2018. This cultivar has high susceptibility to the fungus. Fertilization, pest and weed control was carried out according to the recommendation for the crop. Fungicides applied isolate were tested for disease control. The first application occurred in the pre-closing of the between-line and the others with an interval of 15 days, totaling three applications. The sprays were performed using a CO_2-based backpack with a spray volume of 150 L ha^{-1} (Table 1).

Table 1 – Active ingredient (a.i.), commercial product (c.p.) and dose of fungicides in treatments to control Asian soybean rust, 2018/19 harvest

Active ingredient (a.i,)	Dose g a.i. ha^{-1}	Dose L or kg c.p. ha^{-1}
Control	-	-
Metominostrobin + tebuconazole[5]	79.75 + 119.63	0.725
Pyraclostrobin + fluxpyroxade[6]	116.55 + 58.45	0.35
Picoxystrobin + cyproconazole[2]	60 + 24	0.3
Azoxystrobin + benzovindiflupir[1]	60 + 30	0.2
Picoxystrobin + benzovindiflupir	60 + 30	0.6

Trifloxystrobin + protioconazole[3]	60 + 70	0.4
Pyraclostrobin + epoxiconazole + fluxpyroxade[6]	65 + 40 + 40	0.8
Bixafen + protioconazole + trifloxystrobin[3]	62.5 + 87.5 + 75	0.5
Mancozebe + picoxystrobin + tebuconazole [4]	1000 + 66.5 + 83.33	2.5

Source: Author, 2019.
1Added Nimbus 0.6 L ha-1; [2]Added Nimbus 0.75 L ha^{-1}; [3]Added Áureo 0.25% v/v; [4] Added Rumba 0.5 L ha^{-1}; [5] Added iharol gold 0.25% v/v; [6]Added Assist 0.5L ha^{-1}.

Evaluations of the severity of *Phakopsora pachyrhizi* (leaf area covered with symptoms) were performed using a diagrammatic scale (Figure 1) (GODOY et al., 2006). Such assessments were performed at 7 days after the application of the fungicides (7DAA), on the respective days 73 days after sowing (DAS), 90 (DAS) and 120 (DAS) and after averaging the severities.

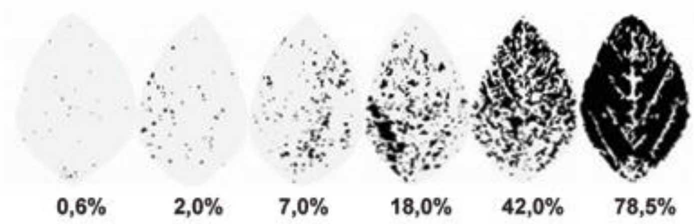

Figure 1-Diagrammatic Scale for Assessment of Soybean (*Glycine max*) Rust Severity, (Godoy et al, 2006).

The area was subsequently harvested to determine productivity, where the useful area of each plot consisted of 3 lines of 0.45m by 2.5m in length totaling 3.375m², the results obtained were extrapolated to kg ha^{-1} and 13% moisture adjustments were made for each sample with the aid of the formula:

= ((100 – moisture of the plot) x sample weight /87).

The variable a thousand seed weight (TSW) was obtained by counting a thousand soybean seeds for each treatment, which were then weighed with the aid of a precision scale to determine the weight in grams.

The data obtained in this work were subjected to analysis of variance and the means of the treatment were compared through the Scott-Knott test at 5% error probability, using the Assistat software.

RESULTS AND DISCUSSION

Regarding productivity, a statistical difference occurred between the variables analyzed in here, and greater productivity was observed for the treatments mancozebe + picoxystrobin + tebuconazole (4878.24 kg ha^{-1}) and bixafen + protioconazole + trifloxystrobin (4269.40 kg ha^{-1}). On the other hand, the lowest yields were obtained in the control (2192.00kg ha^{-1}) (Table 2).

Table 2. Productivity in kg/ hectare and weight of one Thousand seed in different active principle (grams).

Treatment	Productivity kg ha^{-1}	Weight of one thousand seeds (g) (PMS)
Mancozebe + picoxystrobin + tebuconazole	4878.24 a	185.41 a
Bixafen + protioconazole + trifloxystrobin[3]	4269.40 a	175.38 a
Pyraclostrobin + epoxiconazole + fluxpyroxade[6]	3705.01 b	164.31 b
Trifloxystrobin + protioconazole[3]	3693.54 b	156.38 b
Picoxystrobin + benzovindiflupir	3569.58 b	144.00 c
Azoxystrobin + benzovindiflupir[1]	3434.90 b	143.81 c
Picoxystrobin + cyproconazole[2]	3374.36 b	142.81 c
Pyraclostrobin + fluxpyroxade[6]	3330.78 b	142.75 c
Pyraclostrobin + fluxpyroxade[5]	3308.14 b	141.38 c
Control	2192.00 c	115.63 d
CV (%)	**18.48**	**3.92**

Means followed by the same letter are not different from each other by the test of Scott-Knott at 5% probability.

The highest productivities of these fungicides can be associated with the triple mixture of actives and the presence of a multisite in its composition, as is the case of the fungicide mancozebe + picoxystrobin + tebuconazole, which, in a way, results in a plant with greater protection and better effectiveness in controlling the fungus. Multisites affect different metabolic points of the fungus and show a low risk of resistance, showing an important role in the anti-resistance management for site-specific fungicides (MCGRATH, 2004).

Similar but superior results were found by Guterres (2019) where the treatments of picoxystrobin + tebuconazole + mancozebe used separately totaled 94 bags ha $^{-1}$ approximately 5640 kg ha^{-1}. Soares, 2004 states that the use of fungicides provides an increase in the productivity of soybeans.

For the variable a thousand seed weight (TSW), the highest results were observed in the treatments bixafen + protioconazole + trifloxystrobin and mancozebe + picoxystrobin + tebuconazole, 185.41 and 175.38 grams respectively, followed by the fungicides trifloxystrobin + protioconazole + pyraclostrobin + epoxiconicon fluxpyroxade. Such fact demonstrated superiority when compared to the treatment without fungicides, which showed the lowest result for TSW of 115.63 grams (Table 2). In this sense, some studies were carried out explaining that among the yield components of the plant, one of the most affected by rust is the seed size (COSTAMILAN et al., 2002). A work carried out by Pinto *et al*, 2011 demonstrated that the high severity of Asian rust in soybean plants negatively affected the thousand seed weight, as it was seen in treatments 1 (control) and 2 (Flutriafol + methyl thiophanate (triazole), which presented the lowest averages totaling 91.6 and 100.7 grams, respectively.

In the first assessment of rust severity, the symptoms were not evident in the leaves, which resulted in low means of severity. The lowest severities were obtained in the treatments: piraclostrobin +

fluxpyroxade, trifloxystrobin + protioconazole, azoxystrobin + benzovindiflupir, bixafen + protioconazole + trifloxystrobin, picoxystrobin + benzovindiflupir, metominostrobin + tebuconazole, mannobonazole, mannoboxazone. The highest mean of severity was observed in the control treatment, totaling 40.48% (Table 3).

Table 3. Severity of Asian soybean rust evaluated at 7 days after each application of different fungicides 07/20, 03/06 and 04/01 2019.

Treatment	Mean of the severities	Control efficiency %
Mancozebe + picoxystrobin + tebuconazole	11.77 a	70.92%
Bixafen + protioconazole + trifloxystrobin[3]	14.74 a	63.58%
Pyraclostrobin + epoxiconazole + fluxpyroxade[6]	19.99 b	50.61%
Metominostrobin + tebuconazole[5]	18.90 b	53.31%
Trifloxystrobin + protioconazole[3]	18.27 b	54.86%
Picoxystrobin + benzovindiflupir	23.48 c	41.99%
Picoxystrobin + cyproconazole [2]	21.34 c	47.28%
Azoxystrobin + benzovindiflupir [1]	36.28 d	10.37%
Pyraclostrobin + fluxpyroxade [6]	35.70 d	11.80%
Control	40.48 e	0%
CV (%)	8.46	

*Means followed by the same letter are not different from each other by the test of Scott-Knott at 5% probability.

For treatments mancozebe + picoxystrobin + tebuconazole, bixafen + protioconazole + trifloxystrobin where the severities were lower, also showed the best fungus control efficiencies, totaling 70.92% and 63.58% respectively (Table 3). Similar results were found by Embrapa (2014), where the lowest severities were observed in isolated fungicide treatments with the active ingredients azoxystrobin + benzovindiflupir, followed by the treatment bixafen + protioconazole + trifloxystrobin, and trifloxystrobin + protioconazole. The same study conducted by EMBRAPA in the 2017/2018 harvest obtained control efficiencies in fungicides isolated in the mancozebe + picoxystrobin + tebuconazole treatments of 71%, and bixafen + protioconazole + trifloxystrobin of 72%. However, use them separately is not a recommended practice due to the selection of resistant individuals. For the management of the disease, anti-resistance strategies must be followed, which include not using more than two applications of the same product in sequence and a maximum of two applications of the products must be used (EMBRAPA, 2018). The combination of active ingredients, as long as the application stage is correctly positioned, makes it vital for an effective control of the disease (NAVARINI, 2007).

Fungicides based on azoxystrobin + benzovindiflupir and pyraclostrobin + fluxpyroxade, picoxystrobin + cyproconazole showed low control efficiency totaling 10.37% and 11.80% respectively. Those were also the treatments that presented greater severities when compared to the others.

CONCLUSION

The fungicides mancozebe + picoxystrobin + tebuconazole and bixafen + protioconazole + trifloxystrobin show higher productivity, greater a thousand seed weight o and less severity of *Phakopsora pachyrhizi*.

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