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Efficiency loss of recorded fungicides for the control of asian soybean rust in Central region of Brazil

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ABSTRACT

Due to grower allege of low efficiency of triazole fungicides in recent years in Central Brazil on the control of Asian soybean rust (*Phakopsora pachyrhizi*), this study was undertaken to demonstrate the efficiency loss of products registered for rust and applied alone and to evaluate the efficiency of fungicides mixtures. The trials were carried out in five locations in Brazil, in the 2009/10 growing season. The experimental design was completely randomized blocks with four replications. Ten mixtures of triazole + strobilurin and two applications of pure triazoles were evaluated and the control without application. The application of fungicides started in the R1/R2 stage or in any vegetative stage if infections occurred early. The mixtures of fungicides were effective in controlling Asian soybean rust. Application of sole triazole fungicides was less effective in controlling the rust than the mixtures of triazoles + strobilurins. The use of commercial mixtures of triazole with strobilurin for rust control is recommended.

Key words: *Phakopsora pachyrhizi*, triazole, strobilurin.

Perda de eficiência de fungicidas registrados para controle de ferrugem asiática da soja na região Central do Brasil

RESUMO

Devido à alegação de produtores que os fungicidas triazóis tem apresentado menor eficiência no controle da ferrugem asiática da soja (*Phakopsora pachyrhizi*) nas últimas safras, este trabalho objetivou demonstrar a perda de eficiência de produtos do grupo dos triazois registrados para ferrugem da soja e aplicados isoladamente e avaliar a eficiência de misturas de fungicidas. Os ensaios foram realizados em cinco regiões produtoras, na safra 2009/10. O delineamento experimental foi de blocos ao acaso com quatro repetições. Foram avaliadas dez misturas de triazóis + estrobilurinas e dois triazóis isoladamente, além do controle sem aplicação. As aplicações dos fungicidas foram iniciadas no estádio R1/R2 ou no período vegetativo, quando observados sintomas nessa fase. As misturas de fungicidas são eficientes no controle da ferrugem asiática da soja, enquanto os fungicidas triazóis são significativamente menos eficientes no controle do que as misturas de triazóis + estrobirulinas.

Palavras-chave: *Phakopsora pachyrhizi*, triazol, estrobilurina.

1. Introduction

Soybean (*Glycine max* (L.) Merr.), one of the major crops in the world, has high levels of oil and protein (approximately 20% and 40%, respectively). In 2013/14 the consumed in the word of oil corresponded the 44.209 thousand tons (HIRAKURI; LAZZAROTTO, 2014). Diseases are one of the main factors that limit high yields of soybean crops. About 40 soybean diseases caused by fungi, bacteria, nematodes, and viruses have been identified in Brazil. The acreage devoted to soybeans is increasing as the crop expands into new areas and as a result of monoculture. The economic importance of each disease varies from year to year and from region to region, depending on the weather conditions in each growing season. Annual yield losses due to diseases are estimated at about 15% to 20%; however, some diseases can lead to losses of almost 100% (EMBRAPA, 2010). Asian soybean rust (*Phakopsora pachyrhizi* Syd.), for example, is one of the most serious soybean diseases in the world. This fungus can cause severe losses in crop yield ranging from 10% to 50%, reaching up to 80% in humid tropical and subtropical regions (AGRIOS, 2005). Asian soybean rust is favored by frequent rainfalls and long periods of wetness. The optimum temperature for infections ranges from 18 ºC to 26.5 ºC (EMBRAPA, 2010). As it is easily spread by the wind, it occurs in practically all soybean producing regions in Brazil, leading to reductions of up to 75% in productivity (ALMEIDA et at., 2005). In addition to infecting many plant species (AGRIOS, 2005), the existence of physiological races hinder control by race-specific resistance, so chemical control is currently the most viable tool to prevent losses caused by soybean rust in Brazil. Fungicides must be applied preventively or shortly after the first symptoms of the disease, in the lower third of the plants (EMBRAPA, 2003). Reis et al. (2007) concluded that the earlier the identification of the disease in the crop, the more efficiently it can be controlled.

The number of applications required is determined by the stage at which the disease is first identified in the crop, the residual effect of the fungicides and the weather conditions EMBRAPA, 2010). Navarini et al. (2007) evaluated the effectiveness of different rates of fungicide application in controlling soybean rust applied at different phenological stages of the crop, and showed that the number of rust pustules cm^{-2} was significantly affected by the number of sprays. For example, a single application of azoxystrobin at stage R3 resulted in a reduced average number of rust pustules of 5.58 cm^{-2}, while programs that included two applications reduced the number to 1.91 to 3.06 rust pustules cm^{-2}, resulting in higher yields.

Fungicides in the triazole and strobilurin groups are effective in controlling Asian soybean rust (ALMEIDA et at., 2005). However, in the 2007/08 growing season, some populations of P. pachyrhizi tolerant to triazoles may have arisen in regions in the states of Mato Grosso, Mato Grosso do Sul, and Goiás, since growers observed decreases in disease control with the triazole fungicide group. Therefore, the goal of this study was to demonstrate the efficiency loss of products registered for rust and applied alone and to evaluate the efficiency of fungicides mixtures.

2. Material and Methods

The trials were carried out in three states in the Central Region of Brazil, namely Goiás State – GO (two locations), Mato Grosso State – MT (one location), and Mato Grosso do Sul State – MS (two locations) during the 2009/10 growing season, at different institutions. The treatments, experimental design, and evaluations were defined according to a single protocol to facilitate joint summarization of the test results, and to standardize its evaluations and recommendations for fungicide application for soybean (REIS et al., 2007 & SILVA JÚNIOR et al., 2009). The research was conducted at five locations in Brazil (Table 2).

Ten mixtures of triazole + strobilurin fungicides and two specific triazoles were evaluated (Table 1). The triazoles tebuconazole at 100 g i.a. ha^{-1} and cyproconazole at 30 g i.a. ha^{-1} were included in the tests to evaluate the possible loss in efficacy of these products in the different regions. The experimental design was arranged in completely randomized blocks with four repetitions, with each repetition consisting of plots with at least six rows five meters in length.

Table 1. Active ingredients and doses of fungicides used to control Asian soybean rust (*Phakopsora pachyrhizi*) in the 2009/2010 growing season in Brazil

	Active ingredients	Rate (g i.a. ha^{-1})
1	Control	-
2	Tebuconazole	100
3	Cyproconazole	30
4	azoxystrobin + cyproconazole[1]	60 + 24
5	pyraclostrobin + epoxiconazole[2]	66.5 + 25
6	trifloxystrobin + tebuconazole[3]	50 + 100
7	picoxystrobin + cyproconazole[4]	60 + 24
8	trifloxystrobin + cyproconazole [3]	56.25 + 24
9	azoxystrobin + tetraconazole[5]	50 + 50
10	trifloxystrobin + prothioconazole[6]	45 + 52.5
11	pyraclostrobin + metconazole	65 + 40
12	pyraclostrobin + epoxiconazole[7]	65 + 40
13	pyraclostrobin + epoxiconazole[8]	51 + 37.5

Mineral oil brands: [1]Added Nimbus 0.5% v/v; [2]Added Assist 0.5 L ha^{-1}; [3]Added Aureo 0.5 L ha^{-1}; [4]Added Nimbus 0.5 L ha^{-1}; [5]Added Nimbus 0.6 L ha^{-1}; [6]Added Aureo 0.6 L ha^{-1}; [7]Added Dash HC 0.3 L ha^{-1}; [8]Added Lanzar 0.25 %.

Table 2. Locations, cultivar and number of applications of fungicides

Locations in Brazil	Cultivar	Applications of fungicide
Jataí – GO (17°53' S and 52°43' W with an average altitude 670m)	NA 7334	47th day after planting (d.a.p.) and 60th d.a.p.
Senador Canedo – GO (16°43'27" S and 49°7'18" W with an average altitude 7730 m)	Valiosa	52th and 72th d.a.p.
Diamantino – MT (S 14º11'36" and W 57º33'22")	Monsoy 8757	51st, 65th and 82nd d.a.p.
Chapadão do Sul – MS (Location one) (18º 46'24"S and 52º38'58,5"W with an average altitude 810 m)	8001 RR	53rd and 74th d.a.p.
Chapadão do Sul – MS (Location two) (18º 46'11"S and 52º39'01"W with an average altitude 823 m)	P98Y11	49th, 70th and 85th d.a.p.

d.a.p. - days after planting.

The procedure used the most sown medium cycle cultivars in each region. Spraying of the fungicides started at the R1/R2 growing stage of the plants (flowering/full flowering) or at the end of the vegetative stage, when the first symptoms were observed. The number of sprays was determined by the timing of the appearance of the first symptoms of the disease. The number of applications was higher in trials in which symptoms first appeared in the late vegetative stage. A backpack sprayer was used to apply the products, pressurized with CO_2 with an application volume of 150 L ha^{-1}, except Senador Canedo that used to flow 120 L ha^{-1}.

Evaluations of rust severity were performed every week after the second application of the fungicides in Chapadão do Sul (localities 1 and 2) and Jataí. Statistical analysis was carried out using the Sisvar statistic program (Ferreira, 2000) and the treatment means were compared using the Scott Knott test at 5% significance.

At Senador Canedo and Diamantino, rust ratings were carried out one day before fungicide application and every week or every other week after fungicide applications, with the aid of a diagrammatic scale (GODOY et al., 2006) to minimize the variation in the estimates among the localities. The severity of the disease over time was used to determine the area under the disease progression curve. The extent of defoliation was evaluated when plants in the control plots were approximately 80% defoliated. Yield was determined by harvesting the central 5 m^2 area of each plot.

3. Results and Discussion

In the county of Jataí, GO, the largest area under the disease progression curve (AUDPC) was observed in the control treatment (Figure 1). Among the fungicides, tebuconazole and cyproconazole had the highest AUDPC followed by the fungicide mixtures, which did not differ among themselves but all of which significantly reduced the severity of the disease. The separate application of triazoles and the mixture of trifloxystrobin + tebuconazole (T6) produced yields lower than those of the other mixtures and they were only higher than the control. The mixtures of azoxystrobin + cyproconazole (T4), and pyraclostrobin + epoxiconazole (T5) had higher yields than the other treatments and produced yield increases of 760 kg ha^{-1} and 816 kg ha^{-1} in productivity, respectively, compared to the control. The superiority of the mixtures of triazoles with strobilurins in relation to triazoles alone has been confirmed by other researchers (SCHERM et al., 2009; SILVA et al., 2007). Scherm et al. (2009) demonstrated that combinations of triazoles with strobilurin, especially using the triazole cyproconazole, are better for the control of the disease and reducing yield losses compared with separate application of the active ingredients.

In the county of Senador Canedo (GO), the highest yields were observed with the picoxystrobin + cyproconazole (T7) and trifloxystrobin + prothioconazole (T10) mixtures, which also had the lowest AUDPC values. Among the fungicide triazoles, tebuconazole (T2) and cyproconazole (T3), along with the mixture tetraconazole + azoxystrobin (T9), had the highest AUDPC and also the lowest productivity (Figure 1 and 2).

The AUDPC values of the triazoles tebuconazole, and cyproconazole, along with the mixture tetraconazole + azoxystrobin (T9), were only lower than the control, which showed the highest percentage of defoliation and lowest yield compared to any of the treatments (Figure 2). That supports the recommendation from the soy research meeting in the central region of Brazil in 2009 to use a mixture of triazol + strobilurin in regions where the populations of fungus are less sensitive to fungicides in the triazole group (REIS et al., 2007; SILVA JÚNIOR et al., 2009).

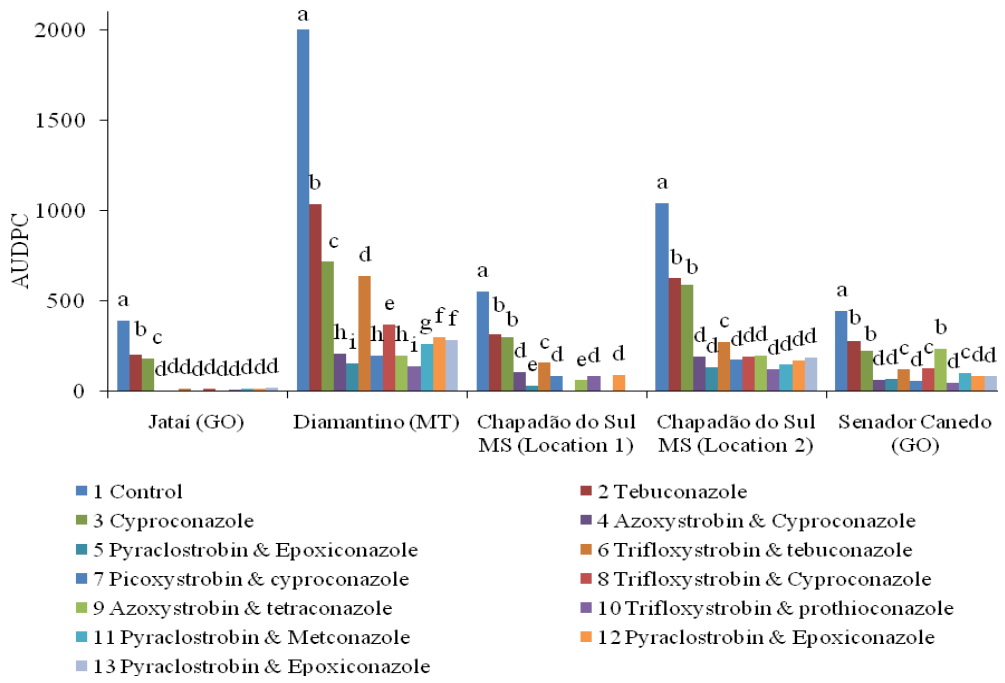

Figure 1. Area under the disease progression curve (AUDPC) of soybean rust (*Phakopsora pachyrhizi*) in function of application of mixtures of triazoles and strobilurins and sole applications of triazoles in the central region of Brazil, 2009/10.

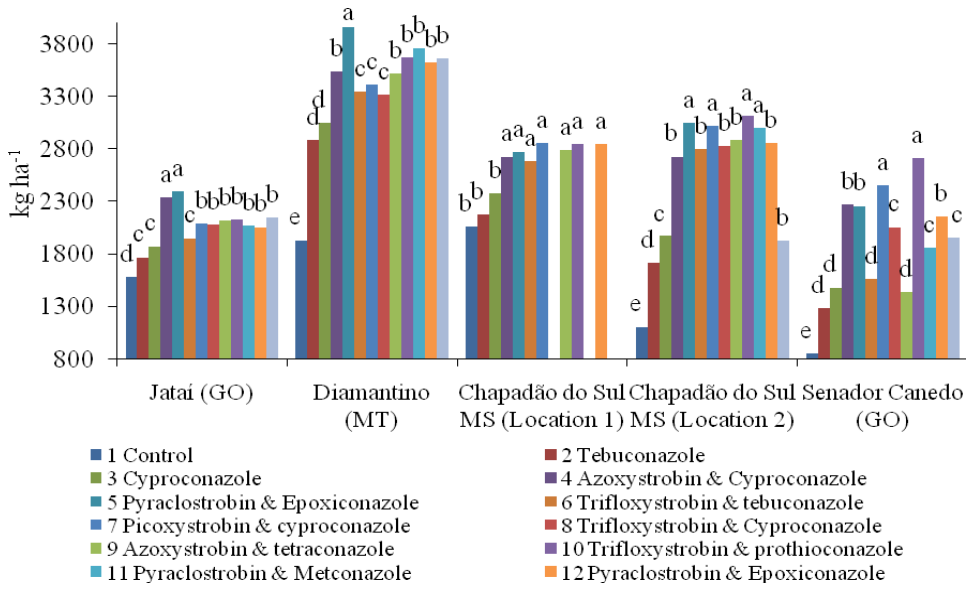

Figure 2. Effect of mixtures of triazoles and strobilurins and separate applications of triazoles on soybean yield (kg ha^{-1}) in the central region of Brazil, 2009/10**.**

In the county of Diamantino (MT), the lowest AUDPC values were observed in the mixtures epoxiconazole + pyraclostrobin (T5) and trifloxystrobin + prothioconazole (T10), while T10 had the lowest percentage of defoliation, but its productivity did not differ from the other mixtures. Pyraclostrobin + epoxiconazole (T5) showed the highest yield (3,964 kg ha^{-1}), with an increase of 2,036 kg compared to the control, which had the highest AUDPC (Figure 1 and 2). The better average yields and greater efficacy in controlling Asian rust by the mixture of epoxiconazole + pyraclostrobin (T5) was reported by Silva Júnior et al. (2009) and Reis et al. (2007).

Among the mixtures, the lowest yields occurred for trifloxystrobin + tebuconazole (T6), picoxystrobin + cyproconazole (T7), and trifloxystrobin + cyproconazole (T8). The separate applications of tebuconazole and cyproconazole triazoles produced lower AUDPC values

and higher yields than the control, but did not differ in the percentage of defoliation.

In the county of Chapadão do Sul, MS (location one), the control plots had the highest AUDPC, followed by the separate applications of tebuconazole and cyproconazole, which did not differ among themselves or the control in terms of the percentage of defoliation or yield (Figure 2 and 3), demonstrating the loss of sensitivity in the rust population to some products in the triazole group, which did not show the same efficacy as previous crop seasons (REIS et al., 2007; SILVA JÚNIOR et al., 2009). Although the mixtures differed regarding their AUDPC values, they still significantly reduced the severity of the disease but there were no statistical differences among them regarding yield. The loss of sensitivity to some products in the triazole group by the rust population has also been observed by Meneghetti et al. (2010) in which there was a reduction of 29% in the control of soybean rust by application of triazole compared to a strobilurin and triazole mixture. Likewise, Miles et al. (2007) reported lower levels of severity and defoliation by rust when triazoles and strobilurins were applied jointly compared to the use of triazoles alone.

In the county of Chapadão do Sul, MS, location two, although the triazoles did not differ from the control in terms of percentage defoliation, they had lower AUDPC values which resulted in higher yields (Figure 1, 2 and 3). Regarding the mixtures, only the trifloxystrobin + tebuconazole (T6) showed a higher AUDPC value in relation to the other mixtures, which did not differ among themselves. However, for yield the best mixtures were the pyraclostrobin + epoxiconazole (T5), picoxystrobin + cyproconazole (T7), trifloxystrobin + prothioconazole (T10) and pyraclostrobin + metconazole (T11), which produced from 1,895 to 2,007 kg ha^{-1} more than the control.

Analyzing the separate applications of the triazoles and mixtures of triazole + strobilurins in the five counties, the mixtures had lower AUDPC values (Figure 1) and consequently higher yields (Figure 2). In the counties of Jataí, Chapadão do Sul (location one), and Senador Candedo, the inoculum pressure was low, while in Chapadão do Sul (location two) it was intermediate and highest in Diamantino. Despite the differences in inoculum pressure among the regions, the performance of the separate fungicide applications or the mixtures did not change.

Among the mixtures, trifloxystrobin + tebuconazole (T6) consistently showed the highest AUDPC, regardless of the region, except for pyraclostrobin + epoxiconazole (T3) in the county of Jataí and azoxystrobin + tetraconazole (T9) in the county of Senador Canedo (Figure 1). However, it should be taken into account that tebuconazole + trifloxystrobin (T6) is a product that, according to the producers, has shown efficacy at certain sites, such as Diamantino, a location with high inoculum pressure, where its performance was closer to separate application of cyproconazole. On the other hand, trifloxystrobin + prothioconazole (T10) showed the lowest AUDPC, except for location one in Chapadão do Sul, as epoxiconazole + pyraclostrobin (T5) and azoxystrobin + tetraconazole (T9) were shown to be more effective in controlling the disease.

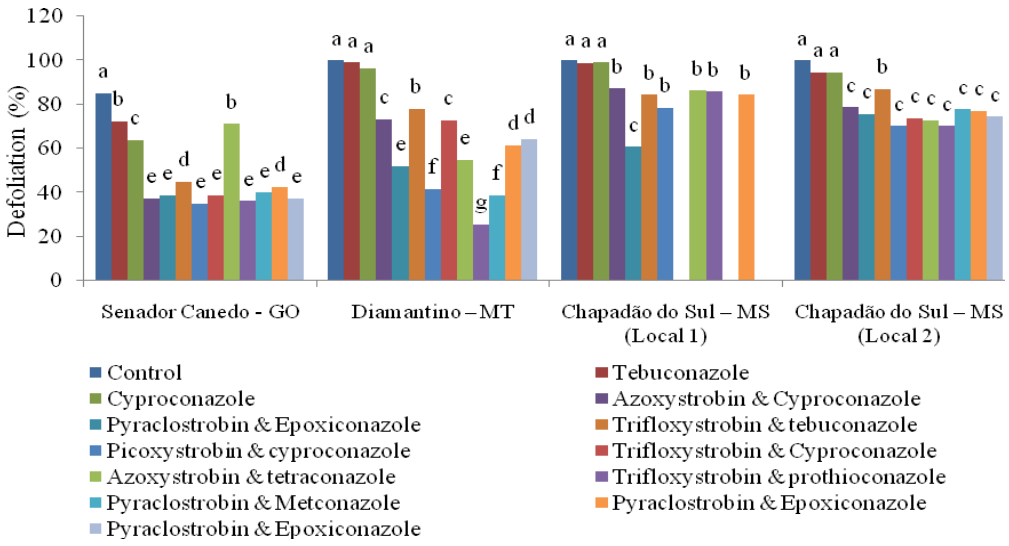

Figure 3. Decrease in defoliation due to spraying mixtures of triazoles and strobilurins or sole applications of triazoles for control of soybean rust in the central region of Brazil, 2009/10.

These differences in the sensitivity of the rust population to the fungicides resulted from the frequent use of the same active ingredient. Controlling Asian soybean rust with the use of triazoles alone is difficult, as they are systemic fungicides that affect sterol synthesis (BERGAMIN FILHO et al., 1995), so the use of triazole mixtures with strobilurins becomes quite necessary.

The strobilurins are fungicides that interfere with cellular respiration, that is, with energy production in the fungal cell (AZEVEDO, 2003), acting as a complement to triazoles. The strobilurins are fungicides that act at a specific genetic site and so are subject to selection of isolates that are insensitive to the fungicide, which leads to the development of populations of pathogens also resistant to fungicides (AGRIOS, 2005).

Despite the efficacy of triazoles on other pathosystems, for example, tebuconazole and difenoconazole for controlling target spot (*Corynespora* spp.) on cucumber (TERAMOTO et al., 2011) or triadimenol, tebuconazole and difenoconazole to control poplar rust (*Melampsora larici-populina*), reducing the number of pustules on the leaves and the percentage of defoliation, resulting in gains in the final yields of these plants (MIO; RUARO, 2008), the findings from the current study show that triazole fungicides when used alone are losing their effective ness in controlling soybean rust on farms in the central part of Brazil. These observations support grower complaints and suggest that the some genetic change must have occurred in the populations of *P. pachyrhizi* that should be further investigated.

4. Conclusões

Mixture of fungicides (triazole + strobilurins) are very effective in controlling Asian soybean rust and should be recommended.

The triazole fungicides (tebuconazole and cyproconazole) are less efficient in controlling Asian rust than the mixtures of triazole + strobilurins.

The use of commercial mixtures of triazole with strobilurin for rust control should be preferred.

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