EFFECT OF REDUCED FUNGICIDE DOSES ON CONTROL OF SOYBEAN ASIAN RUST AND BEAN YIELD

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SUMMARY

*One of the diseases of greatest importance for soybean [*Glycine max *(L.) Merrill] crops is the soybean Asian rust, caused by the fungus* Phakopsora pachyrhizi *Sydon & P. Sydon. One of the main methods of control is through the use of chemical fungicides. The objective of this study was to evaluate the effects of reduced doses of the fungicides azoxystrobin +ciproconazol +mineral oil and tebuconazol, with two application intervals (10 and 20 days), on two soybean cultivars [NK-412113 (V Max) and MG/BR-46 (Conquista)], for the control of soybean rust, as well as their effects on yield. A field assay was conducted during spring-summer 2006/2007. Disease severity assessment was done at 10 days intervals, before fungicide spraying, using a diagrammatic scale. For the early cultivar (NK-412113), the use of reduced fungicide doses did not change disease severity. For the semi early cycle cultivar (MG/BR-46), reduced doses were not significantly different from the recommended doses for soybean rust control. A yield increase was observed in cultivar MG/BR-46 with fungicide spraying, but not for NK-412113. When the disease affects plants at critical stages related to the formation of pods and grains, fungicide treatments azoxystrobin +ciproconazol, in their reduced doses, can also provide efficient control of the disease, with lower severity and higher yields.*

Introduction

Soybean [*Glycine max* (L.) Merrill] represents one of the strongest elements of the Brazilian economy, as it is an export commodity, it is industrialized and is used in the diet. Among the major factors limiting the maximum potential yield of soybean (>4000kg·ha^{-1}), there are several diseases caused by fungi, bacteria, nematodes and viruses reported in Brazil (Yorinori, 1996). Soybean diseases are important because they reduce the amount and quality of the grain, and increase costs due to fungicide application. One of the most important diseases affecting this crop is the soybean Asian rust, caused by the fungus *Phakopsora pachyrhizi* Sydon & P. Sydon (Carvalho Júnior and Figueiredo, 2000).

The initial rust symptoms are small dots, darker than the healthy leaf tissue, of greenish to gray-greenish color. Uredinia are observed initially in the dark dots that progressively acquire a light brown to red brown color and open in a minute pore releasing the colorless urediniospores, which become tan and accumulate around the pores (Balardin, 2002; Yorinori *et al*., 2004; Almeida *et al*., 2005). Severely infected plants present early defoliation, which can damage the formation and filling of

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EFECTO DE DOSIS REDUCIDAS DE FUNGICIDAS PARA EL CONTROL DE LA ROYA ASIÁTICA Y EL RENDIMIENTO DE LA SOJA

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RESUMEN

*Una de las enfermedades de mayor importancia de la soja [*Glycine max *(L.) Merrill] es la roya asiática causada por* Phakopsora pachyrhizi *Sydon & P. Sydon. Uno de los métodos principales de control es el uso de fungicidas. El objetivo del trabajo fue evaluar los efectos de las dosis reducidas de los fungicidas azoxystrobina +ciproconazol +aceite mineral y tebuconazol, con dos intervalos de pulverización (10 y 20 días), en dos cultivares de soja [NK-412113 (V Max) e MG/BR-46 (Conquista)], para el control de la roya y sobre su interferencia en el rendimiento de la soja. Se llevó a cabo un ensayo de campo en la primavera-verano de 2006/2007. La evaluación de la severidad de la roya fue hecha a intervalos de 10 días, antes de aplicar los fungicidas, usando escala esquemática. Para el cultivar de ciclo precoz (NK412113), el uso de dosis reducidas de fungicidas tuvo un efecto sobre la severidad. Para el cultivar de ciclo medio (MG/BR-46), las dosis reducidas no se diferenciaron de las dosis recomendadas en el control de la enfermedad. El uso de fungicidas incrementó el rendimiento en el cultivar MG/BR-46, pero el mismo efecto no fue observado en el NK-412113. Cuando la roya afecta a las plantas en etapas críticas relacionadas con la formación de vainas y granos, los tratamientos con las dosis reducidas de azoxystrobina +ciproconazol, pueden proporcionar un control eficiente de la enfermedad, con reducción de la severidad y aumento del rendimiento.*

EFEITO DE DOSES REDUZIDAS DE FUNGICIDAS NO CONTROLE DA FERRUGEM ASIÁTICA E PRODUTIVIDADE DA SOJA

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RESUMO

*Uma das doenças de maior importância para a cultura da soja [*Glycine max *(L.) Merrill] é a ferrugem asiática, causada pelo fungo* Phakopsora pachyrhizi *Sydon & P. Sydon. Um dos principais métodos de controle é o uso de fungicidas. Assim, o objetivo deste trabalho foi avaliar os efeitos de doses reduzidas dos fungicidas azoxystrobina +ciproconazol +óleo mineral e tebuconazol, com dois intervalos de aplicação (10 e 20 dias), em duas cultivares de soja [NK-412113 (V Max) e MG/BR-46 (Conquista)], no controle da ferrugem asiática e sua interferência na produtividade da soja. Um experimento de campo foi conduzido na primavera-verão de 2006/2007. A avaliação da severidade da doença foi feita em intervalos de 10 dias, antecedendo as aplicações dos fungicidas, utilizando-se escala diagramática. Para a cultivar precoce (NK-412113), o uso de doses reduzidas de fungicidas não alterou a severidade da doença. Para a cultivar de ciclo médio (MG/BR-46), as doses reduzidas não diferiram das doses recomendadas no controle da doença. O uso de fungicidas proporcionou aumento na produtividade de grãos na cultivar MG/BR-46, mas o mesmo efeito não foi observado na NK-412113. Quando a doença afeta as plantas em fases críticas relacionadas a formação de vagens e grãos, os tratamentos fungicidas com as doses reduzidas de azoxystrobina +ciproconazol, pode proporcionar controle eficiente da doença, com redução da severidade e aumento de produtividade.*

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pods and the grain final mass, resulting in yield and quality losses (Yang *et al.*, 1991; Soares *et al.*, 2004; Yorinori *et al.*, 2005).

Fungicide application is the most important control method (Soares *et al.*, 2004). However, to be effective this method must be based on a judicious scouting and knowledge of the disease occurrence in the region, the crop or both. Undue use or application at an inappropriate moment can result in production cost increase or deficient control (Yorinori *et al.*, 2004; Godoy and Canteri, 2004).

Production cost reduction could result from lesser expenses from fungicide application, such as the use of reduced doses. Therefore, considering the importance of Asian rust for soybean production, the objective of this study was to evaluate the effect of reduced fungicide doses on disease development, as well as its effects on yield.

Materials and Methods

The studies were carried out at the experimental area of the Teaching and Research Farm of the Agricultural and Veterinary Science Faculty, Jaboticabal Câmpus of UNESP, Brazil, (21°15'29"S, 48°16'47"W; average altitude 614m), on a Eutrustox, typical clay soil (Embrapa, 2006a). The climate, according to the Köppen classification system, is Cwa. Average annual climatic variables are: rainfall 1425mm, temperature 22.2°C, and relative humidity 70-80%.

Soybean sowing was performed on 11/30/2006, using cultivars NK-412113 (V Max) and MG/BR-46 (Conquista), of early and semi-early cycles, respectively. Before sowing, seeds were prepared with the fungicide carbendazim +thiram (30 + 70g a.i. 100kg^{-1} seeds) and with the insecticide thiamethoxam (0.70g a.i. 100kg^{-1} seeds), and inoculant at the recommended dose (100g 50kg^{-1} seeds). Pre-sowing fertilization was done with 0-20-20, using 300kg ha^{-1}. Herbicides trifluralin (801g a.i. ha^{-1}) and S-metolachlor (1440g a.i. ha^{-1}) were used for weed control, plus hoeing as needed.

The experimental design was completely randomized blocks with 14 treatments (combining seven fungicide doses and two application intervals) and four replications per treatments, for each cultivar. The experimental unit consisted of four rows of 4.0m spaced by 0.45m and 16 to 18 plants m^{-1}. The treatments were: 100% of the azoxystrobin +ciproconazol +0.5% mineral oil (MO) dose (60+24g a.i. ha^{-1} + 1.25l·ha^{-1}); 100% of the tebuconazol dose (100g a.i. ha^{-1}); 50% of azoxystrobin +ciproconazol +0.5% MO (30+12g a.i. ha^{-1}+1.25l·ha^{-1}); 50% tebucon-

TABLE I
SOYBEAN ASIAN RUST SEVERITY DETERMINED FOR CULTIVARS NK-412113 (V MAX) AND MG/BR-46 (CONQUISTA), SPRAYED WITH DIFFERENT DOSES OF THE FUNGICIDES AZOXYSTROBIN + CIPROCONAZOL + MINERAL OIL AND TEBUCONAZOL (TB) AT TWO APPLICATION INTERVALS

Treatment	NK-412113 (V Max)	MG/BR-46 (Conquista)			
	1st evaluation	1st evaluation	2nd evaluation	3rd evaluation	4th evaluation
Fungicide dose (F)	% diseased leaf area †				
Control	22.90	17.34	34.28 a ¶	28.02 a	31.65
100% AZ +CP +MO	19.17	15.75	18.82 b	9.78 c	21.79
100% TB	15.69	17.03	20.43 b	13.24 bc	27.67
50% AZ +CP +MO	18.25	14.90	23.14 b	10.99 bc	29.15
50% TB	21.33	15.75	27.16 ab	16.13 b	31.74
50% AZ +CP +MO / 50% TB	19.18	15.62	20.88 b	13.41 bc	29.88
25% AZ +CP +MO / 25% TB	20.38	14.99	26.46 b	15.43 bc	25.84
F Test§	4.07 *	0.41 ns	5.13 *	13.24 *	1.67 ns
LSD	4.07	5.50	7.57	6.03	8.66
Interval (I)					
10	19.22	16.11	22.51	15.28	27.88
20	19.80	15.68	24.56	14.60	28.48
F Test	0.45 ns	0.16 ns	1.40 ns	0.35 ns	0.08 ns
LSD	1.42	1.91	2.64	2.10	3.01
F x I	4.14 *	0.50 ns	0.21 ns	0.45 ns	0.46 ns
CV (%)	8.99	13.55	15.11	15.37	15.64

† Data transformed into *arcsen* $\sqrt{x/100}$ for statistical analysis. Original means are presented in the table.

¶ Means with different letter in a column are statistically different (Tukey, $p \leq 0.01$).

* Significant (F-test, $p \leq 0.01$), ns: not significant.

azol (50g a.i. ha^{-1}); 50% azoxystrobin +ciproconazol +0.5% MO and 50% tebuconazol applied alternately (30+12g a.i. ha^{-1} + 1.25l·ha^{-1} and 50g a.i. ha^{-1}); 25% azoxystrobin +ciproconazol +0.5% MO and 25% tebuconazol applied alternately (15+6g a.i. ha^{-1} + 1.25l·ha^{-1} and 25g a.i. ha^{-1}); and a control with no fungicides, at two application intervals (10 and 20 days). Two sprayings were done on NK-412113 (V Max) plants and five on the MG/BR-46 (Conquista) ones.

Fungicide (250l·ha^{-1} of the mixture) was applied with a backpack sprayer, at 1.75kgf cm^{-2} constant pressure (maintained by compressed CO_2), equipped with a bar containing four cone nozzles spaced by 0.5m. Insecticide (endosulfan; 525g a.i. ha^{-1}) was applied as needed.

Disease severity was determined by using a diagrammatic scale (Godoy *et al*., 2006), taking into account the percentage of leaf area covered by disease symptoms at four points on the central rows of each plot, and on the lower, intermediate and upper thirds of the plants. Soybean Asian rust severity evaluations were done at 10 days intervals, after the first symptoms were observed and before the spraying of the fungicides evaluated. At harvest, 10 plants of the central rows of each plot were collected to evaluate total number of pods per plant and percentage of empty pods. Yield was determined by threshing the pods of all plants in the central rows; the beans were weighed, and the data estimated to kg·ha^{-1} (13% moisture - wet basis). Four samples of 100beans were collected per plot to determine the mass of 100 beans.

The data of each experiment were submitted to variance analysis by the F test, as a 7×2 factorial (fungicide doses × application intervals), and the averages compared by the Tukey test ($p \leq 0.01$ and $p \leq 0.05$).

Results and Discussion

The culture cycle was of 104 days for cultivar NK-412113 (V Max) and 126 days for MG/BR-46 (Conquista), corresponding to the number of days between sowing and development stage R9, according to Ritchie's *et al*. (1982) phenological scale, adapted by Yorinori (1996) and published in Embrapa (2006b). The first soybean Asian rust symptoms were observed 70 days after seedling emergence, at the R6 development stage of cultivar NK-412113 (V Max) and R4 of MG/BR-46 (Conquista).

In relation to disease severity (Table I), for cultivar MG/BR-46 (Conquista), the disease affected the plants in critical stages, corresponding to pod and grain formation (R4 and R5), so the plants remained in contact with the pathogen for more time. Before the first spraying, plants presented, on average, 5.8% of infected leaf area. For this cultivar (Table I) there were no significant differences between recommended and reduced doses of both fungicides evaluated; nor were there between the application intervals, 10 and 20 days. Only the treatment with tebuconazol, tested at the dose reduced by 50% of the recommended one, presented a greater incidence of Asian rust at the second evaluation, which was not different from the control; however, it was not different from all other treatments. The fungicides controlled disease well until the leaves and pods started yellowing, when the treatments with fungicides became similar to the control, and plants defoliated.

For cultivar NK-412113 (V Max), the interaction between fungicide doses and application intervals was significant (Table I). In the detailed analysis, as presented in Table II, it can be

TABLE II
BREAKDOWN OF THE SIGNIFICANT INTERACTION OF THE ANALYSIS OF VARIANCE OF SOYBEAN ASIAN RUST SEVERITY DETERMINED FOR CULTIVAR NK-412113 (V MAX), SPRAYED WITH DIFFERENT DOSES OF FUNGICIDES AT TWO APPLICATION INTERVALS

Fungicide dose	% diseased leaf area†	
	Application intervals	
	10 days	20 days
Control	21.62 a¶	24.20 aA
100% AZ + CP + MO	21.52 a	16.92 bAB
100% TB	18.98 a	12.67 bB
50% AZ + CP + MO	16.90 a	19.63 aA
50% TB	19.50 a	23.22 aA
50% AZ + CP + MO / 50% TB	18.93 a	19.43 aA
25% AZ + CP + MO / 25% TB	17.31 b	23.62 aA
LSD (F)	5.75	
LSD (I)	3.75	

† Data transformed into *arcsen* $\sqrt{x/100}$ for statistical analysis. Original means are presented in the table.

¶ Means with different small letter in a row and capital letter in a column are statistically different (Tukey, $p \leq 0.01$).

seen that with late infection such as that which occurred in 2006/07, there was no effect of reduced fungicide doses sprayed at 10 days intervals on rust infection level. When the spraying interval was extended to 20 days, a greater control was achieved by 100% of the tebuconazol dose, and the reduced fungicide doses did not lead to an acceptable disease control. In this cultivar, the initial disease level was 8.0% of the leaf area. It can be observed also that, in general, there were no significant differences among the fungicides evaluated at different doses when applied at either 10 or 20 days intervals. Only the treatments that received 100% of the azoxystrobin +ciproconazol +MO and tebuconazol doses presented lower rust levels when applied at 20 days intervals, with special emphasis on the result obtained with tebuconazol at that interval.

The interaction between doses and application intervals was significant for number of pods per plant and weight of 100 beans for cultivar NK-412113 (V Max) (Table III). In the breakdown (Table IV), for the treatments using 100% of fungicide doses and 25% alternated fungicide doses, there were a greater number of pods per plant in the plots sprayed at 10 days. No significant differences were found for the other treatments regarding this characteristic. In relation to the mass of 100 beans, there were no differences among the treatments at 20 days interval, but all of them were different from the control, which had a lower mass. At the 10 days interval, no differences were found among treatments. It was noted that in the absence of fungicides, or with the use of 25% alternated fungicide doses, the 20 days interval presented a significant reduction in the mass of 100 beans.

There were no significant differences among the treatments for the percentage of empty pods per plant and yield, probably due to the late onset of disease in this cultivar. The late occurrence of rust, in early cycle cultivars, does not cause yield losses. In such cultivars, fungi have less time to cause yield reduction, given that plants stay a shorter time in the field in contact with the pathogen (Silva *et al*., 2007).

There were no significant differences among the treatments for the number of pods per plant for cultivar MG/BR-46 (Conquista). However, significant differences were found among the fungicide treatments for the percentage of empty pods of this cultivar (Table V). The treatments were not different among them, except for the control, which presented a greater percentage of empty pods per plant than all other treatments (54 to 90%). Soybean Asian rust presents great damage potential to this crop, since it can cause early and quick yellowing and leaf senescence, hampering the complete formation of the beans (Soares *et al*., 2004). Early occurrence of disease contributed to greater formation of empty pods on the plants that did not receive fungicide treatment.

There was significant interaction between fungicides and application intervals for the mass of 100 beans and yield (Table V), and its breakdown can be seen in Table VI. In general, the treatment with the mixture of strobilurin +triazol gave a significant increase in the mass of 100 grains and yield compared to the triazol-only application. Those results may be related to the combina-

TABLE III
NUMBER OF PODS PER PLANT, PERCENTAGE OF EMPTY PODS PER PLANT, MASS OF 100 BEANS AND YIELD OF BEANS IN SOYBEAN CULTIVAR NK-412113 (V MAX), SPRAYED WITH DIFFERENT DOSES OF THE FUNGICIDES AZOXYSTROBIN + CIPROCONAZOL + MINERAL OIL AND TEBUCONAZOL AT TWO APPLICATION INTERVALS

Treatment	Number of pods/plant	% empty pods/plant†	Mass of 100 beans (g)	Yield ($kg \cdot ha^{-1}$)
Fungicide dose (F)				
Control	29.85	1.21	13.94	2,795
100% AZ + CP + MO	29.45	0.48	14.80	2,961
100% TB	30.36	0.76	14.69	3,002
50% AZ + CP + MO	30.65	0.77	15.03	3,168
50% TB	31.92	0.99	14.71	3,041
50% AZ + CP + MO / 50% TB	31.91	1.03	14.80	2,959
25% AZ + CP + MO / 25% TB	32.15	0.56	14.94	3,198
F Test¶	1.03 ns	0.95 ns	3.42 **	1.81 ns
LSD	4.75	4.19	0.85	446.63
Interval (I)				
10	32.01	0.79	14.83	3,069
20	29.78	0.84	14.56	2,966
F Test	7.47 **	0.06 ns	3.47 ns	1.81 ns
LSD	1.65	1.46	0.30	155.47
F × I	2.35 *	0.79 ns	2.79 *	1.32 ns
CV (%)	9.89	46.92	3.71	9.52

† Data transformed into *arcsen* $\sqrt{x/100}$ for statistical analysis. Original means are presented in the table.

¶ Significant (F-test, ** $p \leq 0.01$; * $p \leq 0.05$). ns: not significant.

TABLE IV
BREAKDOWN OF THE SIGNIFICANT INTERACTION OF THE ANALYSIS OF VARIANCE OF NUMBER OF PODS PER PLANT AND MASS OF 100 BEANS IN SOYBEAN CULTIVAR NK-412113 (V MAX), SPRAYED WITH DIFFERENT DOSES OF FUNGICIDES AT TWO APPLICATION INTERVALS

Fungicide dose	Number of pods $plant^{-1}$		Mass of 100 beans (g)	
	Application interval			
	10 days	20 days	10 days	20 days
Control	29.65 a†	30.05 a	14.61 a	13.27 bB
100% AZ + CP + MO	31.68 a	27.23 b	14.85 a	14.75 aA
100% TB	33.15 a	27.58 b	14.67 a	14.69 aA
50% AZ + CP + MO	31.50 a	29.80 a	14.73 a	15.33 aA
50% TB	32.80 a	31.04 a	14.93 a	14.49 aA
50% AZ + CP + MO / 50% TB	30.30 a	33.53 a	14.72 a	14.88 aA
25% AZ + CP + MO / 25% TB	35.03 a	29.28 b	15.34 a	14.54 bA
LSD (F)	6.71		1.20	
LSD (I)	4.37		0.78	

† Means with different small letter in a row and capital letter in a column are statistically different (Tukey, $p \leq 0.05$)

TABLE V
NUMBER OF PODS PER PLANT, PERCENTAGE OF EMPTY PODS PER PLANT, MASS OF 100 BEANS AND YIELD OF BEANS IN SOYBEAN CULTIVAR MG/BR-46 (CONQUISTA), SPRAYED WITH DIFFERENT DOSES OF THE FUNGICIDES AZOXYSTROBIN + CIPROCONAZOL + MINERAL OIL (AZ+CP+MO) AND TEBUCONAZOL (TB) AT TWO APPLICATION INTERVALS

Treatment	Number of pods/plant^{-1}	% empty pods/ plant†	Mass of 100 beans (g)	Yield (kg·ha^{-1})
Fungicide dose (F)				
Control	33.85	15.32 A¶	9.00	1,472
100% AZ +CP +MO	42.95	4.61 B	12.95	3,304
100% TB	37.90	5.54 B	11.43	2,858
50% AZ +CP +MO	36.50	4.40 B	12.40	3,064
50% TB	39.36	6.65 B	11.21	2,427
50% AZ +CP +MO / 50% TB	35.45	5.39 B	12.32	3,104
25% AZ +CP +MO / 25% TB	38.84	5.93 B	11.97	2,739
F Test§	1.58 ns	18.68 **	50.07**	38.49 **
LSD	10.39	4.24	0.80	435.79
Interval (I)				
10	37.54	6.44	11.64	2,654
20	38.13	6.62	11.58	2,765
F Test	0.11 ns	0.09 ns	0.23 ns	2.20 ns
LSD	3.62	1.48	0.28	151.69
F × I	1.05 ns	1.44 ns	5.22 **	3.88 **
CV (%)	17.67	16.60	4.46	10.35

† Data transformed into *arcsen* $\sqrt{x/100}$ for statistical analysis. Original means are presented in the table.
¶ Means with different letter in a column are statistically different (Tukey, p≤0.01).
* Significant (F-test, p≤0.01). ns: not significant.

TABLE VI
BREAKDOWN OF THE SIGNIFICANT INTERACTION OF THE ANALYSIS OF VARIANCE OF MASS OF 100 BEANS AND YIELD IN SOYBEAN CULTIVAR MG/BR-46 (CONQUISTA), SPRAYED WITH DIFFERENT DOSES OF FUNGICIDES AT TWO APPLICATION INTERVALS

Fungicide dose	Mass of 100 beans (g)		Yield (kg·ha^{1})	
	Application interval			
	10 days	20 days	10 days	20 days
Control	9.11 aE†	8.89 aB	1,534 aC	1,409 aC
100% AZ +CP +MO	12.57 aA	12.34 bA	3,281 aA	3,327 aA
100% TB	10.63 bD	12.22 aA	2,411 bB	3,304 aA
50% AZ +CP +MO	12.53 aAB	12.26 aA	3,255 aA	2,873 aAB
50% TB	11.20 aCD	11.22 aA	2,374 aB	2,481 aB
50% AZ +CP +MO / 50% TB	12.43 aAB	12.21 aA	3,049 aA	3,158 aA
25% AZ +CP +MO / 25% TB	12.04 aBC	11.91 aA	2,675 aAB	2,804 aAB
LSD (F)	1.14		6.16	
LSD (I)	0.74		4.01	

† Means with different small letter in a row and capital letter in a column are statistically different (Tukey, p≤0.01).

tion of protective and curative effects of this mixture and of their greater residual effect (Silva Jr *et al*., 2009).

The mass of 100 beans was a characteristic affected by the different fungicides and doses at both intervals. All treatments were significantly different from the control in both intervals, presenting a greater mass of 100 beans. The treatment 100% azoxystrobin +ciproconazol +MO was the best for the 10 days interval, resulting in 37.9% greater mass than the control. In contrast, the treatment 100% tebuconazol was the least effective, although its mass accumulation was 16.6% greater than the control. There were no significant differences among the fungicide treatments, within the 20 days interval. It was observed that the mass of 100 beans was greater with 100% azoxystrobin +ciproconazol +MO at the 10 days interval, or when 100% tebuconazol was sprayed at the 20 days interval. Since there were no differences between application intervals with lower doses, these could be used every 20 days without loss for the mass of 100 beans.

Fungicides affected bean yield at both application intervals (Table VI). When the products were applied at 10 days intervals, the treatments with 100% and 50% azoxystrobin +ciproconazol +MO, and 50% azoxystrobin +ciproconazol +MO alternated with 50% tebuconazol resulted in greater yield, with an average of 3195kg·ha^{-1}, about 1660kg·ha^{-1} more than the control. At the 20 days interval, the treatments that presented greater yield were 100% fungicide doses and 50% alternated fungicide doses, which were, on average, 1850kg·ha^{-1} better than the untreated control. At both application intervals, all fungicides were significantly different from the control and presented greater yield. Only the treatment 100% tebuconazol was significantly different for both application intervals, with a bean yield 37% greater at the 20 days interval than on the 10 days one.

The treatment with 50% azoxystrobin +ciproconazol +MO alternated with 50% tebuconazol did not differ from the best treatments for bean yield, at both spraying intervals, indicating that, for intermediate cycle cultivars, and with the occurrence of infection still in early reproductive stages, the fungicide doses could be reduced without losses in control efficacy. Also, the importance of alternating products to reduce the risk of selecting resistant populations of the pathogen should be highlighted. The treatment with 50% tebuconazol, which was not as effective for rust control, was significantly different from the control in relation to yield; however, it was not equivalent to the best treatments.

The linear correlation coefficient is more indicated to measure the degree of relationship between independent variables (Peixoto *et al*., 2000). For cultivar NK-412113 (V Max) significant and positive linear correlations were observed just between the mass of 100 beans and yield (Table VII). However, rust disease level did not present significant correlations with the variables analyzed, which may be explained by the late disease onset on this cultivar.

Disease level in cultivar MG/BR-46 (Conquista) was negatively correlated to the mass of 100 beans and yield. Disease level also presented significant but positive correlations with the percentage of empty pods per plant. Also, positive and significant corre-

TABLE VII
SIMPLE LINEAR CORRELATION COEFFICIENTS (R) [†] BETWEEN RUST LEVEL, NUMBER OF PODS PER PLANT, PERCENTAGE OF EMPTY PODS PER PLANT, MASS OF 100 BEANS AND BEAN YIELD, FOR CULTIVAR NK-412113 (V MAX) AND MG/BR-46 (CONQUISTA)

	NK-412113 (V Max)			
	RL	NPP	PEPP	MHB
NPP	0.09 ns[¶]	-	-	-
PEPP	0.36 ns	0.11 ns	-	-
MHB	- 0.48 ns	0.30 ns	- 0.26 ns	-
Y	- 0.28 ns	0.36 ns	- 0.33 ns	0.88 **[§]
	MG/BR-46 (Conquista)			
	RL	NPP	PEPP	MHB
NPP	- 0.43 ns[NS]	-	-	-
PEPP	0.95 **[Þ]	- 0.48 ns	-	-
MHB	- 0.92 **[¤]	0.49 ns	- 0.93 **[††]	-
Y	- 0.94 **[¶¶]	0.58 *[§§]	- 0.93 **[ÞÞ]	0.95 **[¤¤]

[†]Number of pairs used for the correlation was equal to 14. [¶]Significant (F-test, ** p≤0.01; * p≤0.05). [§] y= -1835.30 +330.17x. [Þ] y= -2.75 +0.59x. [¤] y= 14.80 -0.17x. [††] y= 13.90 -0.28x. [¶¶] y= 328.12 +0.43x. [§§] y= --929.02 +95.23x. [ÞÞ] y= 3769.99 -132.07x. [¤¤] y= -2520.08 +448.78x.

lations between the number of pods per plant and yield and between the mass of 100 beans and yield were found. The percentage of empty pods per plant had a negative correlation between the mass of 100 beans and yield, highlighting the effect of rust severity (Table VII).

Soybean Asian rust severity and the losses caused by it have been variable since its detection in 2001, depending on the region and the agricultural year, and especially on favorable weather conditions. Thus, this research could aid the farmer to reach safer decisions to guarantee greater stability.

Conclusions

Reduced doses of fungicides do not differ from recommended ones for the control of soybean Asian rust in either cultivar. There was a greater disease effect on bean yield in cultivar MG/BR-46 (Conquista). Treatments using reduced doses of fungicides provide similar bean yields to the treatment using the recommended dose of azoxystrobin +ciproconazol +MO.

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