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Soybean cultivar performance in the presence of soybean Asian rust, in relation to chemical control programs

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Abstract Soybean rust is caused by an obligate parasite (*Phakopsora pachyrhizi*) which has spread in Brazil in each new season since 2001 and, despite the efforts to control the disease, losses have occurred every year. Its control demands several tactics amongst which chemical control with fungicides is the main method and remains indispensable. Control strategies such as the use of cultivars with partial resistance are desirable, but are not yet commercially available. The present study analyzed the existing differences in the reactions of short, medium and long cycle soybean cultivars against Asian rust and their responses to fungicide sprays. The experiment was conducted at Uberlândia-MG, Brazil, under field conditions from December 2007 to May 2008, in the Syngenta Seeds Experimental Station. The high pressure of the disease in the experiment simulated the natural pressure that the disease often reaches in Brazil. The studied variables were: visual severity (percentage of infected leaf area), percentage defoliation and productivity (kg ha^{-1}). Disease severity was expressed as AUDPC (area under disease progress curve). Variance analysis and comparison of means by the Tukey test (5% significance) were done for all variables studied. Significant differences were observed between cultivar effects and chemical control programs. The results obtained here indicate that the cultivars M-Soy 8199RR and Emgopa 315RR were less susceptible to disease, and that a control program termed "monitoring" (in which the appearance of new pustules of the pathogen were monitored to make the decision at each fungicide spray) was the most effective.

Keywords Glycine max · Leaf disease · Phakopsora pachyrhizi

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Introduction

The greatest constraint for soybean production currently is the fungus *Phakopsora pachyrhizi* H. Sydow & Sydow, the causal agent of Asian soybean rust. The disease is highly aggressive and has shown destructive results in all countries where found.

The pathogen forms intercellular mycelium, attacks plant tissues by forming haustorium and shows host selectivity (Putzek and Putzek 1998). The disease is favoured by well-distributed rain pattern and a long moisture period. The urediniospores are easily transported by the wind to both nearby crop fields and those further away. This appears to be the only dissemination mode as the disease cannot be transmitted by seed (Yorinori 2002).

The symptoms start on the lower leaves of the plant as tiny, dark coloured spots. Above the dark spot, a region that progressively turns tan or brown with an ostiole, or small hole, where urediniospores emerge can be observed (Yorinori 2004). A greater number of uredinia can be found on the abaxial and, subsequently, on the adaxial surface of the leaf (Reis et al. 2006). Severely infected plants show premature leaf loss, that compromises pod filling and the final weight of the grains (Yorinori 2002).

Disease control demands the combination of several tactics in order to reduce losses. Some of the recommended strategies are: sowing of short cycle cultivars; avoiding a lengthening of the planting period; periodically monitoring the field (Juliatti et al. 2005); eliminating volunteer soybean plants and secondary hosts (Reis et al. 2006); as well as chemical control with fungicides, and genetic control which is still limited.

On soybean, four genes have been identified as conferring resistance against soybean rust: Rpp1, Rpp2, Rpp3 and Rpp4. (Bromfield and Hartwig 1980; McLean and Byth 1980; Hartwig and Bromfield 1983; Hartwig 1986). However, Rpp1 and Rpp3 have been broken by the pathogen, leaving only Rpp2 and Rpp4 conferring resistance against the physiological races present in Brazil (Arias 2004). Resistance genes were also reported in native species of the genera *Glycine*, which show variability in the reaction to *Phakopsora pachyrhizi* (Burdon and Marshall 1981a). According to Burdon and Marshall (1981b), four Australia native species of *Glycine* (*G. canescens*, *G. clandestina*, *G. tabacina* and *G. tomentella*) presented qualitative resistance against soybean Asian rust.

Even though several sources of resistance are known, none of these genes have been used in commercial cultivars, due to the occurrence of races of *P. pachyrhizi*. According to Hartman et al. (1997), there is a predominance of complex races of Asian rust, and these races hold multiple virulence factors that confer compatibility with most soybean lines. Moreover, it has been reported that at least one race, originating in Taiwan, has three different virulence genes (Bromfield and Melching 1982).

Therefore, the exploitation of partial resistance seems to be the best option for the management of soybean Asian rust (Tschanz 1984). Genotypes that show lower disease severity, longer latent period and lesser sporulation capacity of the pathogen, can result in reduced defoliation. Cultivars showing these characteristics would be of great value, making possible a reduction in the number of fungicide sprays during the growing season (Hartman et al. 2005).

In this context, the present study analyzed the reaction of six different soybean cultivars of short, medium and long cycles against *Phakopsora pachyrhizi* in combination with fungicide control programs, in order to identify differences related to susceptibility to Asian rust among the genotypes.

Material and methods

Localization

The experiment was conducted at Syngenta's Crop Protection Experimental Station, at Uberlândia-MG, Brazil, located at 18º 55′ 62″ S, 48 º 10′ 47″ W and 935 m above sea level.

Sowing, cultural practices and inoculation

Sowing occurred on 26 November 2007, by conventional tillage, using a Seedmatic sowing machine. The cultivars were sown in 3×6 m plots and 22 seeds per linear metre. The fertilization applied was 350 kg ha^{-1} of 2-20-20 (N-P-K). The area received an herbicide treatment (2.5 l ha^{-1} of gliphosate (480 g l^{-1})) before sowing.

The experiment was designed as a split plot with 4 replications per treatment. Each subplot corresponded to an area of 18 m^2, with 6 m long soybean lines. Fungicide sprays on the chemical control programs started when the first rust pustule was detected in the experimental area. The inoculum consisted of a suspension of 80,000 spores of *Phakopsora pachyrhizi* per ml, collected from soybean plants cultivated in a green house at Fazenda Capim Branco, Univerisidade Federal de Uberlândia, Brazil. Inoculation was done once only on 30 January 2008, when the crop was at stage V6, at the end of a high relative humidity day, for all treatments including the untreated control.

Treatments

The cultivars used in the experiment were: short cycle M-Soy 8045RR and M-Soy 8199RR (120 to 123 days); medium cycle Emgopa 315RR and Luziânia (128 to 134 days); and long cycle M-Soy 9350 and M-Soy 9144RR (150 to 164 days). Each cultivar was subjected to two chemical control programs, in which the mixture of fungicides azoxystrobin + cyproconazole (Priori Xtra ® at 0.3 l ha^{-1} plus Nimbus) was used, and an untreated control. The first control program (Calendar) consisted of three pre-scheduled sprays, in which the first was applied when the first rust pustule was detected and the other two at 14 day intervals. The second control program was termed 'Monitoring', and the applications were made each time new pustules were detected in the plots. Thus, the number of sprays could vary according to cultivar capacity to inhibit pathogen development.

The emergence of new pustules was monitored at 7 day intervals. Trefoils taken from the lower canopy of the plants from each plot were brought to the laboratory and observed under a stereomicroscope in the Laboratório de Micologia e Proteção de Plantas (LAMIP), of the Instituto de Ciências Agrárias – UFU.

A CO_2 propelled backpack sprayer was used for fungicide application, at a flow rate of 150 l ha^{-1}, supplied by a 3 m boom with 6 extended range XR11002 nozzles. The dates and phenological stages of the applications in both chemical control programs, for all cultivars, are listed on Tables 1 and 2.

Assessments and statistical analysis

The experiment was designed as randomized split plot blocks with four subplots. The cultivars were randomized in the blocks and the chemical control programs were randomized within the cultivars, representing the subplots.

The mean severities of soybean rust (*Phakopsora pachyrhizi*) were calculated after the collection and assessment of leaves from the lower and middle canopies of the plants from each plot, using the diagrammatic scale proposed by Godoy et al. (2006) was used. The assessments were done every week, starting at the moment when the symptoms were first detected in the area, on February 16th and 25th, March 3rd, 11th, 18th, 24th and 31st and April 9th and 16th of 2008.

Plant defoliation on each plot was assessed rating intensity from 0% to 100%, based on the scale presented on Fig. 1. The assessments started approximately at stage R6.

Harvesting was done manually on the central 8 m^2 of each subplot. The samples were weighed on a 5 kg capacity digital scale with humidity measured by portable automatic equipment. Humidity was then adjusted to 13%, to estimate yield in kg per hectare.

The values of disease severity were used to obtain the AUDPC (area under the disease progress curve), which takes into account the disease severity and progress over time (Campbell and Madden 1990).

The variables AUDPC, defoliation and yield were analyzed for each cycle of soybean cultivars separately: short, medium and long. Differences among subplots, treatments and cultivars were determined by analysis of variance. No transformation of data was required to normalize the data. ANOVA was done using the program SISVAR (Ferreira 2000).

Results and discussion

Short cycle cultivars

Artificial inoculation resulted in homogeneous infection of soybean rust in the whole experimental area, reaching 100% severity on untreated control plots at stage R6. This is a situation that can occur in practical soybean production in Brazil. According to Yorinori et al. (2005),

Table 1 Application dates and phenological stages for the chemical control program "Monitoring" in six soybean cultivars. Uberlândia, 2008

Application date	M-Soy 8045RR Stage	M-Soy 8199RR Stage	Emgopa 315RR Stage	LuziâniaRR Stage	M-Soy 9350 Stage	M-Soy 9144RR Stage
16 Feb	V9	V9	V9	V9	V8	V8
3 Mar	R2	R2	R2	R2	V11	V11
13 Mar	R5.1	R5.1	R5.1	R5.1	R3	R3
19 Mar	R5.5	R5.5	R5.3	R5.3	R4	R4
3 Apr	R6.1	R6.1	R5.7	R5.7	R5.1	R5.1
10 Apr	–	–	R6.1	R6.1	R5.5	R5.5

Table 2 Application dates and phenological stages for the chemical control program "Calendar" in six soybean cultivars. Uberlândia, 2008

Application date	M-Soy 8045RR Stage	M-Soy 8199RR Stage	Emgopa 315RR Stage	LuziâniaRR Stage	M-Soy 9350 Stage	M-Soy 9144RR Stage
16 Feb	V_9	V_9	V_9	V_9	V_8	V_8
3 Mar	R_2	R_2	R_2	R_2	V_{11}	V_{11}
19 Mar	$R_{5.5}$	$R_{5.5}$	$R_{5.3}$	$R_{5.3}$	R_4	R_4

the damage caused by the disease has reached 90% in the various regions where it has been reported.

The first symptoms of the disease were detected on 11 February, when soybean was around stages V7 up to V8, 12 days after the artificial inoculation. During this period, there were suitable conditions for pathogen development.

Values of AUDPC on lower and middle canopies, respectively, are shown in Tables 3 and 4. In both cases, the interaction between cultivars and chemical control programs was significant. For the "Monitoring" program, spray application with the mixture of fungicides was done five times on the cultivars M-Soy 8199RR and M-Soy 8045RR; whereas with the calendar program three sprays were done, always on pre-defined dates.

For the cultivars in question, the values of AUDPC rust severity for the control programs did not differ, although both differed from the untreated plots. In contrast, for the middle canopy (Table 4) and considering the cultivar M-Soy 8045RR, there were differences in the severities of the two control programs, which also differed from the untreated plots. It is suggested that this difference is due to the smaller response shown by the lower plant canopy to the fungicide sprays, due to the lesser deposition of the product on this area of canopy. According to McNichol et al. (1997), the efficacy of treatment depends not only on the amount of material deposited on the vegetation, but also on the uniformity of coverage of the target. Studies of spray deposition patterns indicate great variability on the deposition of agrochemicals along the tracks of application, decreasing the efficacy of the treatments (Gupta and Duc 1996; Pergher et al. 1997).

For the cultivar M-Soy 8199RR, only the untreated plots differed in AUDPC values, while the effects of the control programs were statistically similar.

From Table 3, it is also noticeable that on the lower canopy there were differences between the effects of the cultivars within the control programs, with the cultivar M-Soy 8199RR presenting the lower values of AUDPC (58.6% lower in monitoring and 57.7% lower in calendar). In the untreated plots, however, this difference was not observed.

In contrast to these data, on the middle canopy of the plants (Table 4) there were differences between the cultivars in the untreated plots, where M-Soy 8199RR presented again lower values of AUDPC (11.5% lower), while the effects of the cultivars for both control programs, were similar. It is believed that these data reinforce the suggestion that the lower canopy receives lower fungicide deposition, thus maintaining a greater level of disease on the treated sub-plots, which could explain the observed differences in cultivar effects Asian rust. Moreover, according to Reis et al. (2006), the first rust lesions in general emerge on the lower leaves, close to the ground, when the plants are

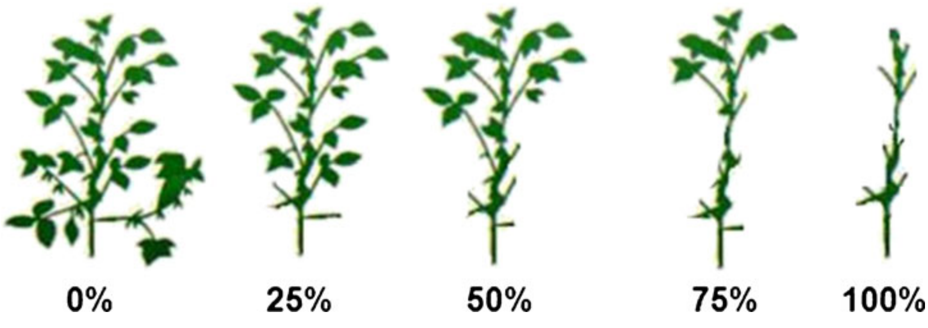

Fig. 1 Diagrammatic scale for soybean defoliation assessment. Uberlândia, 2008

Table 3 Area under the disease progress curve (AUDPC) for visual severity of Asian rust on the lower canopy of soybean plants. Uberlândia, 2008

Short cycle cultivars	Chemical control programs		
	Monitoring	Calendar	Untreated control
MS8199RR	18.75 Aa	19.25 Aa	603.50 Ab
MS8045RR	45.25 Aa	45.50 Aa	579.25 Ab
CV 1 (%)	5.92		
CV 2 (%)	8.21		

Data followed by the same letter are not statistically different ($P<0.05$)

reaching the flowering stage. Since the epidemic starts earlier on the lower canopy, the untreated plots in this case kept very high disease levels, evening out the effects of the genotypes.

The middle canopy responded more efficiently to the fungicide sprays due to greater deposition, and kept lower levels of rust on the sub-plots of the disease control programs that were insufficient to show differences between the cultivars. The untreated plots, having a slower development of disease on the middle canopy than on the lower one, were able to show the existing cultivar differences.

These results are due to the effective control of Asian rust shown by the commercial fungicide mix used in the experiment. The active ingredients of the triazole group have curative effects, interfering with ergosterol biosynthesis in the fungal membrane and being absorbed by leaf tissues (Tsuda et al. 2004). According to Koehle et al. (2002), the fungicides of the strobilurin group interfere with spore germination and on the development of the germ tube and, like the triazols, move in a translaminar way. Habe et al. (2003), studying the efficacy of fungicides on rust control, concluded that triazoles tested in mixtures with strobilurins blocked the development of disease progress, keeping the foliar area green, even under high disease pressure. Tables 5 and 6 present mean values for yield (kg ha^{-1}) and defoliation (%), in which no interaction between the factors (cultivars and chemical control programs) was found. There were significant differences between the yields of the cultivars and also between the yields of the control programs. Cultivar M-Soy 8199RR showed the greatest yield, following the tendency of the other variables analyzed in which it was less susceptible to *Phakopsora pachyrhizi* than cultivar M-Soy 8045RR.

Among the chemical control programs and the untreated plots, monitoring provided the greatest yield, followed by the calendar program and, last, the untreated plots. Considering the monitoring program as representing the productive potential of the genotypes, a yield loss of 17.2% can be estimated for the calendar program and 70.2% for the untreated control plots.

Juliatti et al. (2005) testing active ingredients for the control of *P. pachyrhizi*, under green house and field conditions, obtained better yield stability after two and three applications in a 20 day interval, with

Table 4 Area under the disease progress curve (AUDPC) for visual severity of Asian rust on the middle canopy of soybean plants. Uberlândia, 2008

Short cycle cultivars	Chemical control programs		
	Monitoring	Calendar	Untreated control
MS8199RR	18.25 Aa	77.50 Aa	1046.00 Ab
MS8045RR	29.25 Aa	120.25 Ab	1182.50 Bc
CV 1(%)	8.55		
CV 2 (%)	8.94		

Data followed by the same letter are not statistically different ($P<0.05$)

Table 5 Yield (kg ha^{-1}) of soybean cultivars under the influence of *Phakopsora pachyrhizi*. Uberlândia, 2008

Short cycle cultivars	Chemical control programs			
	Monitoring	Calendar	Untreated control	Mean
MS8199RR	3907.91	3136.46	1233.44	2759.27 B
MS8045RR	3477.61	2979.44	968.22	2475.09 A
Mean	3692.76 c	3057.95 b	1100.83 a	
CV 1 (%)	17.43			
CV 2 (%)	9.8			

Data followed by the same letter are not statistically different ($P<0.05$)

the mixture of azoxystrobin and cyproconazole at a dose of 300 ml of the commercial product per hectare. Oliveira et al. (2005), assessing yield of soybean cultivars with and without fungicide sprays in the west of Bahia, found decreases that varied from 10% to 39%, although the greatest severity of the Asian rust observed on this trial had been low (30.5%).

Estimates of the damage caused by Asian rust in the untreated control plots of each cultivar, in comparison to the best chemical control program, indicates losses of 68.4% for M-Soy 8199RR, and 72.2% for M-Soy 8045RR. Hartman et al. (1991) observed yield reductions of 62% for cultivars which were susceptible to *P. pachyrhizi*, and 22% for the resistant ones.

The cultivars assessed were significantly different for percentage of defoliation (Table 6) with M-Soy 8199RR having the smallest values, followed by M-Soy 8045RR. These data also indicate M-Soy 8199RR as being less susceptible to Asian rust than M-Soy 8045RR. The defoliation was shown to be significantly correlated to the number of pustules per trefoil, by Bromfield (1984). Yang et al. (1990) also demonstrated a significant correlation between rust severity and leaf loss in soybean plants, but they found high variability in the results especially at low values of severity (up to 25%). According to those authors, the environment plays an important role on the defoliation caused by *P. pachyrhizi*, especially wind intensity when associated with rain.

Table 6 Percentage of defoliation of soybean cultivars by *Phakopsora pachyrhizi*. Uberlândia, 2008

Short cycle cultivars	Defoliation (%)
MS8199RR	82.00 a
MS8045RR	89.58 b
CV (%)	7.40
Chemical control programs and untreated control	
Monitoring	72.62 a
Calendar	84.75 b
Untreated control	100.00 c
CV (%)	5.41

Data followed by the same letter are not statistically different ($P<0.05$)

Medium cycle cultivars

The interaction between factors (cultivars and chemical control programs) was not significant for the area under the disease progress curve (AUDPC), on the lower and middle canopies, for the medium cycle cultivars. The mean values obtained for this variable are presented in Table 7. In the middle canopy of the soybean plants, there were differences between the cultivars, in which Emgopa 315RR presented the smallest AUDPC values. Oliveira et al. (2005), assessing the reaction of soybean cultivars to Asian rust in the west of Bahia, tested the cultivar Emgopa 315 and found significant differences among the mean

Table 7 Area under the disease progress curve (AUDPC) for visual severity of Asian rust on soybean plants. Uberlândia, 2008

Medium cycle cultivars	Lower canopy	Middle canopy
Emgopa315RR	122.87 a	335.98 a
LuziâniaRR	160.95 b	338.21 a
CV (%)	26.18	8.96
Chemical control programs and untreated control		
Monitoring	36.15 a	32.59 a
Calendar	36.14 a	96.81 b
Untreated control	353.43 b	881.88 c
CV (%)	22.43	8.71

Data followed by the same letter are not statistically different ($P<0.05$)

severities of the studied cultivars. In that study, Emgopa 315 was classified in the group that had the smallest disease severity.

Among the chemical control programs and untreated control plots, monitoring (six fungicide sprays with the mixture azoxystrobin and cyproconazole on medium cycle cultivars) differed from the other treatments in the lower canopy and had the smallest AUDPC values, followed by the calendar treatment and lastly the untreated plots. In the lower canopy, the untreated control plots differed from the control programs and had the greatest AUDPC values. The chemical control programs, in turn, were similar, which again suggests that the lower canopy showed a less clear response to the successive fungicide sprays.

Considering the variables yield (kg ha^{-1}) and defoliation (%), there were no interactions between factors, as shown in Tables 8 and 9. No significant differences were found between the yields of the two cultivars. There were differences, however, among the chemical control programs and untreated control plots, and the greatest values were obtained in the monitoring program, followed by calendar and lastly by the untreated plots.

The average yield increase obtained with the monitoring program, compared to the calendar and untreated plots, was 17.5% and 64.7%, respectively.

Considering the yield increase obtained with the monitoring program for each cultivar separately, for Emgopa 315RR it was 19.2% greater than calendar and 64.4% greater than the untreated plots. For the cultivar LuziâniaRR, it was 15.8% greater than calendar and 65.1% greater than the untreated plots. The difference in yield increase between the monitoring and calendar programs for the two cultivars can be explained as existing variation among the genotypes regarding the physiological capacity to respond to chemical control according to Navarini et al. (2007). These authors reported that, even with fungicide curative sprays upon the cultivar RS10, the increase obtained was greater than with the cultivar BRS 154, and concluded that this result characterizes variety responsiveness associated with fungicide sprays. de Azevedo (2005) and Silva (2007) also reported the occurrence of variation in the cultivar response to fungicide treatment.

Table 9 Percentage of defoliation of soybean cultivars under the influence of *Phakopsora pachyrhizi*. Uberlândia, 2008

Medium cycle cultivars	Defoliation (%)
Engopa 315RR	84.50 b
LuziâniaRR	80.67 a
CV (%)	8.12
Chemical control programs and untreated control	
Monitoring	65.50 a
Calendar	84.00 b
Untreated control	98.25 c
CV (%)	4.36

Data followed by the same letter are not statistically different ($P<0.05$)

Significant differences in defoliation (%) occurred among the cultivars and also among the chemical control programs and untreated control plots (Table 9). The monitoring program was always best averages for the variable yield, followed by calendar and lastly the untreated plots. For the cultivars, Emgopa 315RR presented the best results, followed by LuziâniaRR.

Long cycle cultivars

No interactions were found between cultivars and chemical control program for the area under the disease progress curve (AUDPC) (Table 10). No significant differences on either the lower or middle canopies of soybean plants were found for mean AUDPC). This

Table 8 Yield (kg ha^{-1}) of soybean cultivars under the influence of *Phakopsora pachyrhizi*. Uberlândia, 2008

Medium cycle cultivars	Chemical control programs			
	Monitoring	Calendar	Untreated control	Mean
Engopa 315RR	3680.45	2972.85	1310.18	2654.49 A
LuziâniaRR	3548.90	2987.46	1238.10	2591.49 A
Mean	3614.68 c	2980.16 b	1274.14 a	
CV 1 (%)	14.48			
CV 2 (%)	11.44			

Data followed by the same letter are not statistically different ($P<0.05$)

Table 10 Area under the disease progress curve (AUDPC) for visual severity of Asian rust on soybean plants. Uberlândia, 2008

Long cycle cultivars	Lower canopy	Middle canopy
MS9144RR	155.91 a	466.82 a
MS9350	174.00 a	450.53 a
CV (%)	26.76	11.40
Chemical control programs and untreated control		
Monitoring	16.30 a	25.86 a
Calendar	17.66 a	125.50 b
Untreated control	460.91 b	1224.65 c
CV (%)	39.06	12.41

Data followed by the same letter are not statistically different ($P<0.05$)

Table 12 Percentage of defoliation of soybean cultivars under the influence of *Phakopsora pachyrhizi*. Uberlândia, 2008

Long cycle cultivars	Defoliation (%)
MS 9144RR	70.58 a
MS 9350	69.67 a
CV (%)	8.22
Chemical control programs and untreated control	
Monitoring	50.62 a
Calendar	66.62 b
Untreated control	93.12 c
CV (%)	3.59

Data followed by the same letter are not statistically different ($P<0.05$)

means that, among longer cycles cultivars, it is harder to detect differences in disease susceptibility because of the longer exposure period in the field, which leads to a greater disease pressure and tends to equalize the effect of treatments.

The chemical control programs and untreated control plots, in contrast, presented significant differences on both lower and middle canopies. As observed for short and medium cycle cultivars, the untreated plots differed statistically from the other programs with the greatest AUDPC. Between the monitoring and calendar programs on the lower canopy, however, no significant differences were observed. As expected for the middle canopy, because of the possible better fungicide coverage, all treatments differed, with the monitoring program (six fungicide applications) presenting the smallest mean AUDPC, followed by calendar and lastly the untreated plots.

No significant interaction between the factors cultivars and chemical control programs was found for yield (kg ha^{-1}) (Table 11). The monitoring program gave the greatest increases, followed by calendar and lastly the untreated plots. The average increase in the monitoring program compared with the calendar was 28% and compared with the untreated control plots, 75.6%.

Oliveira et al. (2005) had already observed that, among the cultivars studied in Bahia, the yield decreases were always greater on the longer cycle cultivars, in comparison to middle cycle, because of the longer period of exposure to the pathogen.

For M-Soy 9350, the calendar program gave a yield decrease of 245% compared with monitoring, while the untreated control plots gave a decrease of 76.5%, also in comparison with the monitoring program. M-Soy 9144RR, in turn, gave a decrease of 31.1% and 74.8%, respectively, for the same comparisons. These data again demonstrate that cultivars respond differently to the same active ingredients and number of applications, some expressing a greater yield increase then others. The mean yield for the two cultivars, however, did not differ significantly.

Although there were differences in defoliation (%) between the chemical control programs and the untreated plots, no significant differences between the long cycle cultivars were observed (Table 12). The monitoring

Table 11 Yield (kg ha^{-1}) of soybean cultivars under the influence of *Phakopsora pachyrhizi*. Uberlândia, 2008

Long cycle cultivars	Chemical control programs			
	Monitoring	Calendar	Untreated control	Mean
MS 9144RR	3857.96	2658.28	971.77	2496.00 A
MS 9350	3443.74	2601.70	810.77	2285.40 A
Mean	3650.85 c	2629.99 b	891.27 a	
CV 1 (%)	8.85			
CV 2 (%)	9.70			

Data followed by the same letter are not statistically different ($P<0.05$)

program gave the smallest percentage of leaf loss, followed by calendar and lastly by the untreated plots.

It can be concluded that there were statistically significant differences among the genotypes of the six cultivars studied in relation to the susceptibility to Asian rust, although levels of partial resistance, which would permit a reduction on the number of fungicide sprays, have not yet been reported. The cultivars M-Soy 8199RR and Emgopa 315RR were less susceptible to Asian rust than M-Soy 8045RR and LuziâniaRR, respectively. Variations in disease progress rate and in the incubation period of the fungus were observed by Dall'Agnol et al. (2004), while testing the reaction of 60 soybean cultivars to an isolate of *Phakopsora pachyrhizi*, suggesting that this behavior is related to the variation in partial resistance in each cultivar. However, among the long cycle cultivars, the differences are less evident. Therefore, in the present study, significant susceptibility differences could not be found between the cultivars M-Soy 9144RR and M-Soy 9350.

Disease severity assessments made on the lower canopy demonstrated that the efficacy of the fungicide sprays on this area of the plant is less than in the middle canopy, due to erratic fungicide deposition. For this reason, these assessments did not seem to be adequate for the comparison between active ingredients, under the conditions observed in this study; although they were important for the evaluation of susceptibility to Asian rust between the genotypes, especially in the presence of fungicides.

The data presented demonstrate that the soybean Asian rust affected significantly the yield of the cultivars, with reductions varying from 65.1% to 76.5% in the untreated plots, in comparison to the best chemical control program (monitoring). The longer period of protection to the plant obtained with the monitoring program, resulted in the greater yield increases. This result was expected and indicates that a fungicide treatment more adjusted to the disease epidemic will lead to a better control of the disease. In accordance with this, Oliveira (2004), observed a yield increase of 100% in preventive disease control, which ensured better performance of the fungicides (Forcelini 2003; Juliatti et al. 2004). The actual fungicide application strategy in practice in soybean production, by contrast, is based on calendar application set in advance of the crop/disease season and which, frequently, does not correspond to the disease dynamics at each year.

The response of the long cycle cultivars to the increase in the number of fungicide sprays was greater than that of the other cycles, and also yield losses were greater when untreated. Hartman et al. (2005) used the expression "yield stability" and suggested that the yield equivalence between plots with and without fungicide sprays, for genotypes identified in Africa (Tschanz and Wang 1987), can be related to partial resistance. However, in the present study, it was observed that the cultivars responded differently to the fungicide sprays, as has been reported by Silva et al. (2007) and de Azevedo (2005).

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