Performance of chlorothalonil levels and spraying intervals on Asian rust control and soybean grain yield

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ABSTRACT

Reis, E.M.; Zanatta, M.; Reis, A.C. Performance of chlorothalonil levels and spraying intervals on Asian rust control and soybean grain yield. ***Summa Phytopathologica,*** v.45, n.3, p.261-264, 2019.

In an experiment conducted in the field, during the 2017/18 growing season, with the soybean cultivar Syn 1561 IPRO, the interaction of chlorothalonil levels with application intervals was evaluated for the control of Asian soybean rust, caused by *Phakopsora pachyrhizi*. The first fungicide application was performed in V8 stage, 44 days after emergence, with 1.85% rust leaflet incidence. The experiment consisted of a factorial arrangement with five fungicide levels (1.0, 1.5, 2.0, 2.5 and 3.0 L/ha) applied at 8, 12 and 16-day intervals, using randomized block treatments and four replicates. A self-propelled sprayer with 16 bars, XR11001VS nozzles and 150 L/ha volume was employed. Leaflet rust severity in R5.4 stage and grain yield were evaluated. Data were subjected to analysis of variance, and means were compared according to Tukey's test. At eight-day intervals (six sprayings), control ranged from 75% to 93%; at 12-day intervals (four sprayings), it ranged from 35 to 63%, and at 16-day intervals (three sprayings), control ranged from 15 to 29% according to the sprayed levels. The longer the interval between applications, the lower the response of the used level for rust control and soybean grain yield. Chlorothalonil showed fungitoxicity to integrate a program of anti-resistance strategies to control soybean rust.

Keywords: chloronitrile, multisite fungicide *Glycine max, Phakopsora pachyrhizi*

RESUMO

Reis, E.M.; Zanatta, M.; Reis, A.C. Desempenho de doses e do intervalo de aplicações do clorotalonil no controle da ferrugem asiática e no rendimento de grãos da soja. ***Summa Phytopathologica,*** v.45, n.3, p.261-264, 2019.

Em experimento conduzido no campo, na safra 2017/18, com a cultivar Syn 1561 IPRO, avaliou-se a interação de doses e de intervalos entre aplicação do fungicida clorotalonil no controle da ferrugem asiática da soja, causada por *Phakopsora pachyrhizi*. A primeira aplicação do fungicida foi realizada no estádio V8, 44 dias após a emergência, com incidência foliolar da ferrugem de 1,85%. O experimento constou de um esquema fatorial de cinco doses (1,0, 1,5, 2,0, 2,5 e 3,0 L/ha) do fungicida aplicadas nos intervalos de 8, 12 e 16 dias, em tratamentos distribuídos em blocos ao acaso com quatro repetições. Utilizou-se um pulverizador autopropulsado com 16 barras, pontas XR11001VS e volume de 150 L/ha. Avaliou-se a severidade foliolar da ferrugem no estádio R5.4 e o rendimento de grãos. Os dados foram submetidos a análise da variância e comparação de médias pelo teste de Tukey. Com intervalo de oito dias (6 aplicações) o controle variou de 75 a 93%, com intervalos de 12 dias (4 aplicações) variou de 35% a 63% e com 16 dias (3 aplicações) variou de 15 a 29% em função das doses. Quanto maior o intervalo entre aplicações, menor foi a resposta de dose para o controle e para a produção de grãos. O clorotalonil tem fungitoxicidade para integrar um programa de estratégias anti-resistência no controle da ferrugem da soja.

Palavras-chave: cloronitrila, fungicida multissítio *Glycine max, Phakopsora pachyrhizi.*

Soybean [*Glycine max* (L.) Merr.] grown area in Brazil has increased every season. As a result, in the 2017/18 growing season, 35.3 million hectares were cultivated in the country (1).

Several diseases have been reported for soybean, but Asian rust (ASR), caused by a species of the Phakopsoracea family, *Phakopsora pachyrhizi* (*Pp*) Sydow & Sydow, and found in South America (Paraguay and Brazil) in the 2001/02 season by Morel (6), is the most destructive disease.

Damage caused by a plant disease is the basic tool to justify whether control is needed or not. It must be scientifically determined. For ASR, the damage can be estimated based on the functions reported by Danelli et al. (2).

ASR control measures include elimination of volunteer plants, observation of a 60–90-day soybean-free period in the off-season, cultivation of early cultivars sown at the beginning of the recommended season, and use of cultivars with partial resistance and chemical control (11). However, fungicides are still the main measure for its control.

The site-specific DMIs alone, flutriafol and tebuconazole, were the first fungicides used to control ASR. The reported reduction in *Pp* sensitivity to DMIs, after six seasons of use (9, 13), made double site-specific mixtures (DMIs + QoIs) replace them. Subsequently, from 2011/12 season, double mixtures (QoIs + SDHIs) were launched in the market and are used up to the present. In 2013/14 season, the first site-specific triple mixture (DMI+QoI+SDHI) was delivered to be used by farmers. Consequently, in the 2016/17 season, a new triple mixture was launched.

Since the beginning of fungicide use in ASR control, in 2002/03 season, there has been a constant reduction in *Pp* sensitivity towards the three modes of action of site-specific fungicides season after season.

The use of site-specific fungicides alone or in double mixtures in the entire cultivated area and with more than two sprayings/ha has resulted in reduced control efficacy, now lower than 50% (9). In the 2017/18 season, no site-specific co-formulations showed control higher than 50%, since control efficacy should be > 80% to be sustainable (10).

Reduced *Pp* sensitivity to site-specific fungicides has been shown in farms, field experiments and in the laboratory using detached soybean leaflets. Complementary studies have identified *Pp* mutations involved with cross-resistance among the three mechanisms of action: *cyp51* point mutations and overexpression to DMIs (12), F129L to QoIs (5), and I86F to SDHIs (14). Sensitivity reduction has been shown for fungicides alone or for any of their double or triple mixtures (9), thus resulting in *Pp* cross and multiple-resistance to the three site-specific MOA fungicides.

The main anti-resistance strategy of fungi to site-specific fungicides, as observed in the control of downy mildews in potato, tomato and grapevine crops, has been their mixture with multi-site chemicals such as chlorothalonil, copper oxychloride, mancozeb and tin compounds (9).

We hypothesized that chlorothalonil may have fungitoxicity against *Pp* and integrate treatment programs, added to the site-specific chemicals both in double or triple co-formulations as an anti-resistance strategy.

The objective of this study was to quantify the effects of the interactions between chlorothalonil levels and spraying intervals on ASR control and soybean grain yield.

MATERIAL AND METHODS

The study was conducted in Passo Fundo County, Rio Grande do Sul State, district of Bela Vista (28º12'18 '' latitude, 52º29'45 '' longitude and altitude 660 a.s.l.) with soybeans Syn 1561 IPRO, maturity group 5.9. Soybean was directly drilled on December 12th, 2017, in 2.5 x 6.0 m plots, in an area of soybean monoculture.

The fungicide chlorothalonil [IUPAC: 2,4,5,6 tetrachloroisophthalonitrile (Syngenta, Bravonil® **720 SC)]** was tested in a factorial design involving five levels (1.0, 1.5, 2.0, 2.5 and 3.0 L/ha commercial formulation) and three spraying intervals (8, 12 and 16 days).

Fungicide spraying was performed by using self-propelled Sider® sprayer with multi-bars, Teejet® **XR11001VS spraying** nozzles, and 150 L/ha volume.

From V5 stage, 20 leaflets of the 5th to 7th nodes were weekly removed, taken to the laboratory and searched for the presence of rust symptoms/signs under a Zeiss stereomicroscope (20 - 50x magnifications). The first spraying was performed after rust detection in the experimental area and the remaining ones at 8, 12, and 16-day intervals.

Rust severity was assessed according to the diagrammatic scale of Godoy et al. (3), and ASR control by the fungicide treatments was calculated in relation to the unsprayed plots.

Experimental design was factorial (five levels and three spraying intervals) in randomized blocks and four replicates. Severity data, rust control and grain yield were subjected to ANOVA and means were compared according to Tukey's test and regression analyses between grain yield and severity, yield and control, and control and damage.

At ripening, grains were harvested with an adapted plot combine (Massey Ferguson 220); then, grains were cleaned, humidity was adjusted to 13, and grain yield was expressed as kg/ha.

RESULTS AND DISCUSSION

ASR was detected on January 25th, 2018, at GS V8, 44 days after seedling emergence, with 1.85% leaflet incidence.

Analysis of variance showed interaction between the two tested factors.

Severity in the unsprayed plots was 87% and ranged from 6.0 to 74% in plots that received fungicide. The overall means were 12, 40 and 67% severity for 8, 12 and 16-day intervals, respectively. For 1.0, 1.5, 2.0, 2.5 and 3.0 L/ha, severity was 51, 42, 38, 34 and 33%, respectively (Table 1).

At eight-day intervals (6 sprayings), control ranged from 75 to 93%; at 12-day intervals (4 sprayings), it ranged from 35% to 63%, and at 16-day intervals (3 sprayings), control varied from 15 to 29%. Regarding levels, the control overall mean was 42, 52, 57, 60 and 62% for 1.0, 1.5, 2.0, 2.5 and 3.0 L/ha, respectively. Considering the overall means, the longer the interval between applications, the lower the control level response (Table 2).

Grain yield ranged from 2,753 kg/ha in the unsprayed plots to 4,332 kg/ha in plots treated with six sprayings (3.0 L/ha and eight-day intervals). Therefore, the damage was 1,579 kg/ha or 63.5% reduction in grain yield. In the overall mean, the yield range was 4,045, 3,696 and 3,308 kg/ha for 8, 12 and 16-day intervals, respectively. Considering levels, the yield range was 3,318, 3,517, 3,797, 3,870 and 3,912 kg/ha for 1.0 to 3.0 L/ha, respectively (Table 3).

One of the first studies that must be done in plant pathology should be damage quantification for a given disease in a given host. As a function of the disease amount and not simply of its presence, damage must be expressed as a mathematical function of the disease amount

Table 1. Effect of treatments on leaflet rust severity (%)

Interval (Days)	Chlorothalonil level (L/ha)															Mean	
		1.0			1.5			2.0			2.5			3.0			
8	A	22	c	B	14	c	C	10	c	CD	8	c	D	6	c	12	c
12	A	57	b	B	44	b	C	36	b	CD	34	b	D	32	b	40	b
16	A	74	a	B	69	a	B	68	a	CD	62	a	E	62	a	67	a
Mean	A	51		B	42		C	38		D	34		D	33			
C.V. (%)		4.52															

Means followed by the same letter are similar according to Tukey's multiple range test. Capital letters compare means in the rows and lowercase letters, in the columns. Unsprayed plots - 87% severity.

Table 2. Effect of treatments on rust control (%)

Interval (days)	Chlorothalonil level (L/ha)					Mean
	1.0	1.5	2.0	2.5	3.0	
8	75	84	89	91	93	86
12	35	50	59	61	63	54
16	15	21	22	28	29	23
Mean	42	52	57	60	62	
C.V. (%)	4.45					

Unsprayed plots - 87% severity.

Table 3. Effect of treatments on soybean grain yield (kg/ha)

Interval (Days)	Chlorothalonil level (L/ha)					Mean
	1.0	1.5	2.0	2.5	3.0	
8	C 3.610 a	BC 3.923 a	AB 4.169 a	AB 4.191 a	A 4.332 a	4.045 a
12	C 3.260 b	C 3.393 b	B 3.821 b	AB 4.002 a	AB 4.002 b	3.696 b
16	B 3.085 b	AB 3.236 b	AB 3.400 c	A 3.417 b	AB 3.403 c	3.308 c
Mean	C 3.318	B 3.517	A 3.797	A 3.870	A 3.912	
C.V. (%)	4.45					

Means followed by the same letter are similar according to Tukey's multiple range test. Capital letters compare means in the rows and lowercase letters, in the columns. Unsprayed plots - 2,753 kg/ha.

(leaflet incidence/severity) (2, 7).

In the present experiment, the relationship between grain yield (y) and ASR severity (x) was represented by the function y = 4,309.3 kg/ha – 16.01% leaflet severity (R^2 = 0.8659) (Fig. 1). Function and damage are similar to those reported by Danelli et al. (2).

The regression equation, y = 13.169x + 2,966.5 (Fig. 2), showed that for the basic yield of 2,966.5 kg/ha (unsprayed plots), each 1% control increased 13.169 kg soybean/ha.

The economic damage threshold (EDT) can be calculated by considering the total rust control cost of R$ 352.00/ha (crop kneading by a sprayer wheels, fungicide, fuel, soybean price, and labor), using Munford & Norton's (7) equation modified by Danelli et al. (2). Thus, cost of control – Cc, R$ 352.00/ha; Soybean price – Sp, R$ 70.00/60 or R$ 1,166.70/ton; Damage coefficient – Dc, 16.06 kg or 0.016061 ton (Fig. 1 equation); Control efficacy - Ce, 75% or 0.75 (Table 2). Replacing values in the equation: Economic damage threshold (EDT) = [Cc/ (Sp* Dc)] *Ce; EDT = [352.00/ha Cc/(1,166.70/t*0.016061Dc)] *0.75 Ce; EDT = [352/18.7383687] *0.75 = 15.0% leaflet severity. Thus, for our data, EDT was 15.0% leaflet severity.

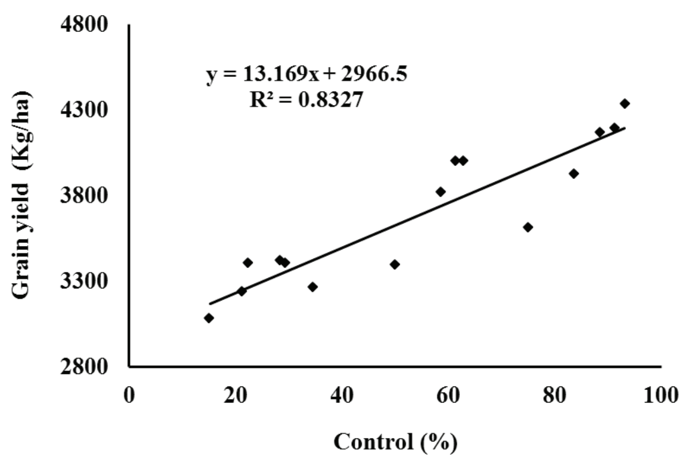

Figure 2. Relationship between soybean grain yield and Asian rust control.

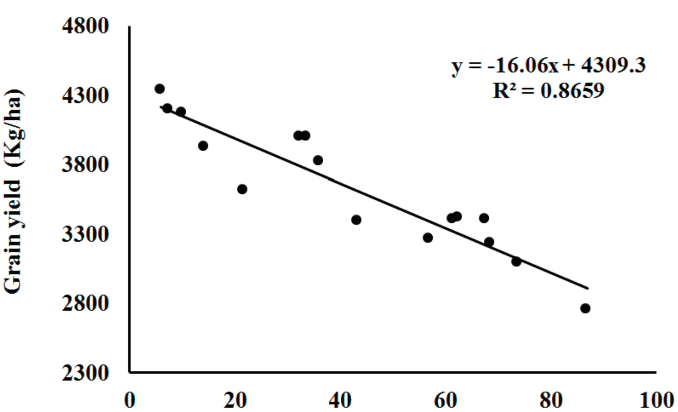

Figure 1. Relationship between soybean grain yield and Asian rust leaflet severity.

In our experiment, the control ('C') efficacy required to equalize the spraying cost can be determined by considering R$ 352.00, or 301 kg/ha soybean grains; C = 112.78 - 0.0632*d (Fig. 3); C = 112.78 - 0.0632 *301; C= 112.78 – 19.0232 = 93.7%; Therefore, C = 93.7% control equalizes R$ 352.00 control cost.

ASR was detected 44 days after sowing on December 12th. This date may be too late for seeding the crop, but this happens when soybean is seeded after wheat crop harvest.

The used methodology, weekly monitoring and examination under 20-50 x magnification, allowed rust symptoms/signs to be safely detected with < 2% LI (leaflet incidence), therefore, below the EDT

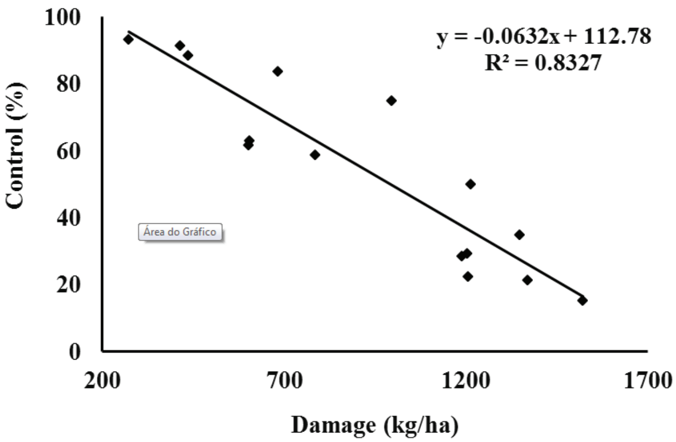

Figure 3. Relationship between Asian rust control and resulting damage to soybean crop.

of 15.0% leaflet severity.

Considering 63.5% rust damage under 87% severity in the experiment, reports of 80% damage or higher, without mentioning the methodology for its quantification, should be considered with caution.

Our data pointed out that the first application can be made before LDE is reached but should not be based on the pre-closure row spacing (4) or on a phenological stage (2). If the protection period is close to 10 days, not considering the LDE to time fungicide spraying, it may increase the number of applications which unnecessarily increase production cost, reducing the grower's profit. Our data indicate that the first application can be made before EDT (15% leaflet severity) is reached, but not based on empirical timing.

The interval between applications had greater positive effect on control and on grain yield, compared to levels. Chlorothalonil protection period of 14 days has been cited (8) but not confirmed for ASR control, considering that in the experimental site it rained 587.2mm (normal 723.3mm) during the crop cycle.

Chlorothalonil showed potential fungitoxicity to be used in ASR control. The intervals and number of applications were used as tools to gain more knowledge about the performance of this 'new' multisite fungicide for soybean in order to fight the development of Pp resistance to the three site-specific MOA's fungicides. The best and most economic rust control should be reached by adding chlorothalonil to site-specific fungicides, which show <50% rust control when applied alone.

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