Asian soybean rust control efficacy calculated with AUDPC and with final severity data

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ABSTRACT

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Data from experiments conducted in the field during four growing seasons aiming at the chemical control of soybean rust caused by Phakopsora pachyrhizi, the control values calculated for the area under the disease progress curve (AUDPC) were compared with those of the final severity. Data were analyzed according to a factorial experiment: (i) treatments with fungicides and (ii) rust control. Out of 70 treatments, the control was always lower when calculated with the AUDPC than with the final severity. In the general means for four growing seasons, the AUDPC control was of 48.5 (range 36 to 65%) and for calculation with the final severity 43.25% (range 29 to 66%). It can be concluded that, in the case of soybean rust, the control calculation shows advantage when performed with final severity data.

.**Keywords**: *Glycine max,* disease quantification, plant pathometric methods, *Phakopsora pachyrhizi*

RESUMO

Reis, E.M.; Zanatta, M.; Silva, L.H.C.P.; Reis, A. Estimativas da eficácia de fungicidas para controle da ferrugem asiática da soja com base em dados da AACPD ou da severidade final da doença. ***Summa Phytopathologica,*** v.48, n.1, p.28-31, 2022.

Com dados de experimentos conduzidos no campo durante quatro safras visando ao controle químico da ferrugem da soja, causada por *Phakopsora pachyrhizi*, foram comparados os níveis de controle com base na área abaixo da curva de progresso da doença (AACPD) com os da severidade final. Os dados foram analisados segundo um experimento fatorial com dois fatores: (i) tratamentos com fungicidas e (ii) método para calcular eficácia. Dos 70 tratamentos, as estimativas de eficácia de controle foram maiores quando calculadas com dados de AUDPC do que com a severidade final da doença em três das quatro safras. No entanto, considerando a média das quatro safras de cultivo, a estimativa da eficácia do controle dos fungicidas com base no AUDPC foi de 48,5 ± 11,2% (variando de 36 a 65%), semelhante à estimativa baseada na severidade final da doença (43,3 ± 14,0%, variando de 29 a 66%). Portanto, para simplificar e reduzir custos experimentais, a eficácia do fungicida para o manejo da ferrugem da soja pode ser estimada com base na severidade final da doença.

Palavras-chave: *Glycine max***,** quantificação de doenças, métodos patométricos, *Phakopsora pachyrhizi.*

Asian soybean rust (ASR), caused by the basidiomycete fungus *Phakopsora pachyrhizi* Sydow. & Sydow (6) in soybean plants [*Glycine max* (L.) Merr.], was first reported in South America in the 2001 growing season (5).

Experiments conducted to identify the most efficacious fungicide treatments or treatment programs that result in economic ASR control have proposed several methods to estimate control levels and consequently determine the efficacy of fungicides. Each of those studies adopt multiple methods to quantify ASR severity and its effects on the host, which makes the collection of disease severity data time-consuming and laborious, poorly contributing to interpretation. As a common feature, most of those studies have included estimates of the area under the disease progress curve (7).

Asian soybean rust quantification demands considerable time and human resources. To determine the AUDPC, rust intensity (incidence or severity) on the leaves is measured in sequential evaluations at various soybean development stages. Some of the above-mentioned studies used only AUDPC values corresponding to each treatment, not reporting the control efficacy levels. Fungicide trials with the aim of identifying economic treatment programs require that control efficacy values are estimated for comparison.

In the current study, we hypothesize that control values estimated based on the AUDPC are similar to those obtained with the final disease severity level.

The analyzed data were obtained from a national cooperative fungicide trial conducted in Rio Verde, Goiás State, in the 2013/14, 2014/15, 2015/16 and 2016/17 growing seasons. Asian soybean rust severity was assessed at four phenological stages, and the AUDPC was calculated. On average, in each season, 16 different fungicides were tested for their effects on rust severity. Ten central trifoliate leaves were removed from the main stem of the plant and used for severity assessment. The AUDPC was calculated based on four periods, and final severity data underwent statistical analysis to compare the control efficacy estimated based on AUDPC with that obtained based on final severity. Fungicide efficacy, determined by ASR control level, was calculated as [1-(disease severity for the corresponding treatment/ disease severity for the unsprayed control)*100].

For the 2013/14 growing season, final severity ranged from 10%

Table 1. Asian soybean rust control levels calculated based on final disease severity and AUDPC data from 2013/14 season.

Treatment	Final severity		AUDPC		Mean (%)	
	(%)	Fungicide control efficacy*	Value	Fungicide control efficacy		
Untreated (control)	59	-	1398	-	-	-
Tebuconazole	50	16	1005	28	22	ij
Cyproconazole	48	19	931	33	26	gh
Azoxystrobin	47	20	1015	27	24	hi
Azox + cypr	41	31	906	35	33	ef
Pyra + epox	43	26	936	33	30	fg
Picox + cypr	28	53	661	53	53	c
Trif + prot	18	69	421	70	70	b
Cypr + dife	28	53	609	56	55	c
Azox + flut[y]	52	12	1055	25	18	k
Pyra + metc	50	15	1097	22	18	jk
Tetraconazole	46	23	1025	27	25	hi
Pyra + flux	41	31	876	37	34	e
Prothi	48	19	1015	27	23	hi
Azox + tebuc	49	17	1018	27	22	i
Azox + flut[y]	54	9	1128	19	14	l
Metom + tebuc	31	47	686	51	49	d
Flux + oxyc	30	49	638	54	52	cd
Bixa + prot + trif	16	73	408	71	72	b
Azox + benz	10	82	309	78	80	a
Mean		35 B		41 A		

Tebuconazole (200 EC), 0.4 L/ha, demethylation inhibitor (DMI); cyproconazole (200 EC), 0.4 L/ha, DMI; azoxystrobin (100 EC), 0.2 L/ha, quinone outside inhibitor (QoI); azoxystrobin + cyproconazole (200 + 80 SC), 0.2 L/ha, QoI + DMI; picoxystrobin + cyproconazole (200 + 80 SC), 0.3 L/ha, DMI + QoI; trifloxystrobin + prothioconazole (150 + 175 SC), 0.4 L/ha, QoI + DMI; cyproconazole + difenoconazole (150 + 250), 0. 5L/ha, DMI + DMI; azoxystrobin + flutriafol (125 + 225 SC), 0.6 L/ha, QoI + DM; pyraclostrobin + metconazole (130 + 80 EC), 0.5 L/ha, QoI + DMI; tetraconazole (100 EC), 0.5 L/ha, DMI; pyraclostrobin + fluxapyroxad (333 + 167 SC), 0.3 L/ha, QoI + succinate dehydrogenase inhibitor (SDHI); prothioconazole (250 EC), 0.3 L/ha, DMI; azoxystrobin + tebuconazole (72 + 96), 0.3 L/ha, QoI + DMI; metominostrobin + tebuconazole (1100 + 165), 0.6 L/ha, SDHI + DMI; fluxapyroxad + copper oxychloride (50 + 420 SC), 0.8 L/ha, SDHI + copper oxychloride; bixafen + prothioconazole + trifloxystrobin (125 + 175 +150 SC), 0.5 L/ha, SDHI + DMI + QoI; azoxystrobin + benzovindiflupyr (60 + 30 WG), 0.2 kg/ha, QoI + SDHI.

* The control efficacy of fungicides was calculated as [1-(disease severity for the unsprayed control – disease severity for the corresponding treatment)*100]. Means followed by the same lowercase letters to compare means in the column and uppercase letters on the line are similar, according to Tukey's multiple range test at 0.05.

to 59% (unsprayed) and control efficacy varied from 9% to 82%. The AUDPC ranged from 309 to 1398 (unsprayed) units, resulting in fungicide control efficacy of 19% to 78%. The general means of fungicide efficacy level were 35% based on final disease severity and 41% based on AUDPC, which were statistically different at $p \leq 0.05$ (Table 1).

Regarding the 2014/15 growing season, final ASR severity ranged from 5% to 75% (unsprayed) and control levels varied from 33% to 94%. The AUDPC ranged from 43 to 532 (unsprayed) units and control efficacy varied from 33% to 92%. The general means of fungicide control level were 66% based on final disease severity and 65% based on AUDPC, which were not significantly different at $p \leq 0.05$ (Table 2).

For the 2015/16 soybean growing season, final ASR severity ranged from 40% to 100% (unsprayed) and fungicide control levels varied from zero to 60%. The AUDPC ranged from 576 to 1591 (unsprayed) units and control varied from 15% to 64%. The mean fungicide efficacy level based on final severity was 29% and that based on AUDPC was 36%, which were statistically different at $p \leq 0.05$ (Table 3).

Considering the 2016/17 growing season, final severity ranged from 30% to 93% (unsprayed) and control efficacy varied from 6% to 68%, while the AUDPC ranged from 462 to 1425 (unsprayed) units and fungicide control levels varied from 33% to 68%. The mean fungicide efficacy level based on final severity was 43% and that based on AUDPC was 52%, which were statistically different at $p \leq 0.05$ (Table 4).

According to the overall analysis of the four seasons, fungicide efficacy (control efficacy) calculated based on the final severity ranged from 29% to 66%, presenting an overall mean of 43.25(±14.04)%. Similarly, fungicide control levels obtained with the AUDPC ranged from 36% to 65%, showing an overall mean of 48.5(±11.15)%. Thus, considering the data from the four growing seasons, fungicide efficacy values estimated based on the final disease severity were similar to those calculated with the AUDPC.

The AUDPC has been recommended especially to: (i) determine the damage caused by plant diseases (5); (ii) assess the reaction of cultivars

Table 2. Asian soybean rust control efficacy calculated based on final disease severity and AUDPC data from 2014/15 season.

Treatment	Final severity (%)	Fungicide control efficacy * (%)	AUDPC	Fungicide control efficacy (%)	Mean (%)
Unsprayed (control)	**75**	-	532	-	-
Tebuconazole	50	33	353	34	k
Cyproconazole	32	57	253	52	g
Azoxystrobin	41	45	290	45	i
Azox + cyp	26	66	183	66	ef
Pico + cypr	18	76	134	75	d
Trif + prot	7	90	71	87	b
Pico + tebu	10	87	86	84	c
Pyr + flux	10	86	83	84	c
Azox + benz	5	94	43	92	a
Chlorothalonil	39	48	276	48	h
Azox + tebu	50	34	323	39	j
Azox + flut	57	25	358	33	l
Pyra + epox + flux	11	85	88	84	c
Bix + ptz + trif	7	90	70	87	b
Azox + tebu	24	69	175	67	e
Azox + benzo	27	64	181	66	f
Mean		66 A		65 A	

Tebuconazole (200 EC), 0.4 L/ha, demethylation inhibitor (DMI); cyproconazole (200 EC), 0.4 L/ha, DMI; azoxystrobin (100 EC), 0.2 L/ha, quinone outside inhibitor (QoI); azoxystrobin + cyproconazole (200 + 80 SC), 0.2 L/ha, QoI + DMI; azoxystrobin (100 EC), 0.2 L/ha, quinone outside inhibitor (QoI); azoxystrobin + cyproconazole (200 + 80 SC), 0.2 L/ha, QoI + DMI; picoxystrobin + cyproconazole (200 + 80 SC), 0.3 L/ha, DMI + QoI; trifloxystrobin + prothioconazole (150 + 175 SC), 0.4 L/ha, QoI + DMI; picoxystrobin + tebuconazole (120 + 200 EC), 0.5 L/ha, QoI + DMI; pyraclostrobin + fluxapyroxad (333 + 167 SC), 0.3 L/ha, QoI + succinate dehydrogenase inhibitor (SDHI); azoxystrobin + cyproconazole (200 + 80 SC), 0.2 L/ha, QoI + DMI; chlorothalonil (40 SC), 1.0 L/ha, chloronitrile, multisite; azoxystrobin + tebuconazole (75 + 144 SC), 0.75 L/ha, QoI + DMI; bixafen + prothioconazole + trifloxystrobin (125 + 175 +150 SC), 0.5 L/ha, SDHI + DMI + QoI; azoxystrobin + tebuconazole (75 + 144 SC), 0.75 L/ha, QoI + DMI; azoxystrobin + benzovindiflupyr (60 + 30 WG), 0.2 kg/ha, QoI + SDHI.
* The control efficacy of was calculated as [1-(disease severity for the unsprayed control – disease severity for the corresponding treatment)*100]. Means followed by the same lowercase letters to compare means in the column and uppercase letters on the line are similar, according to Tukey's multiple range test at 0.05.

Table 3. Asian soybean rust control calculated for final severity and AUDPC data from 2015/16 season.

Treatment	Final severity (%)	Fungicide control efficacy (%)	AUDPC	Fungicide control efficacy (%)	Mean (%)
Unsprayed (control)	100	-	1591	-	-
Tebuconazole	100	0	1299	18	e
Cyproconazole	100	0	1298	18	e
Azoxystrobin	100	0	1360	15	e
Azo + cyp	95	5	1238	22	e
Pico + cyp	77	23	1078	32	d
Trif + cypr	74	26	1054	34	d
Trif + prot	59	41	881	45	b
Pico + tebu	60	40	871	45	bc
Pyra + flux	60	40	862	46	b
Azox + benz	45	55	654	59	a
Chlorothalonil	100	1	1309	18	e
Azox + tebuco	56	45	883	44	b
Azox + tebu + manc[y]	70	31	1107	30	d
Azox + tebu + manc[z]	64	36	1042	34	cd
Pyra + epox + flux	58	42	871	45	b
Bix + prot + trif	55	45	922	42	bc
Picox + benzo	40	60	576	64	**a**
Mean		B 29		A 36	

Tebuconazole (200 EC), 0.4 L/ha, demethylation inhibitor (DMI); cyproconazole (200 EC), 0.4 L/ha, DMI; azoxystrobin (100 EC), 0.2 L/ha, quinone outside inhibitor (QoI); azoxystrobin + cyproconazole (200 + 80 SC), 0.2 L/ha, QoI + DMI; picoxystrobin + cyproconazole (200 + 80 SC), 0.3 L/ha, DMI + QoI; trifloxystrobin + prothioconazole (150 + 175 SC), 0.4 L/ha, QoI + DMI; picoxystrobin (120) + tebuconazole (200 EC), 0.5 L/ha, QoI + DMI; pyraclostrobin + fluxapyroxad (333 + 167 SC), 0.3 L/ha, QoI + succinate dehydrogenase inhibitor (SDHI); azoxystrobin + benzovindiflupyr (60 + 30 WG), 0.2 kg/ha, QoI + SDHI; chlorothalonil (40 SC), 1.0 L/ha, chloronitrile, multisite; azoxystrobin + tebuconazole (75 +144 SC), 0.75 L/ha, QoI + DMI; azoxystrobin + tebuconazole (47 + 597), WG, 1.5 L/ha[y]; azoxystrobin + tebuconazole (47 + 597 WG), 2 L/ha[z]; pyraclostrobin + fluxapyroxad (333 + 167 SC), 0.3 L/ha, QoI + SDHI; bixafen + prothioconazole + trifloxystrobin (125 + 175 +150 SC), 0.5 L/ha, SDHI + DMI + QoI; picoxystrobin + benzovindiflupyr (100 + 50 EC), 0.6 L/ha, QoI + SDHI.
* The control efficacy of fungicides was calculated as [1-(disease severity for the unsprayed control – disease severity for the corresponding treatment)*100]. Means followed by the same lowercase letters to compare means in the column and uppercase letters on the line are similar, according to Tukey's multiple range test at 0.05.

Table 4. Asian soybean rust control levels calculated based on final disease severity and AUDPC data from 2016/17 season.

Treatment	Final severity (%)	Fungicide control efficacy (%)	AUDPC	Fungicide control efficacy (%)	Mean (%)
Unsprayed (control)	**93**	-	1425	-	-
Tebuconazole	81	12	955	33	f
Cyproconazole	82	11	880	38	f
Azoxystrobin	87	6	903	37	f
Azo + cypo	82	11	886	38	f
Pico + cypr	64	30	770	46	e
Trif + cypr	60	35	823	42	e
Trif + prot	48	48	555	61	bc
Pico + epox	53	43	729	49	d
Pyra + epox	45	51	607	57	bc
Azox + benz	31	66	509	64	a
BAS 702	40	57	603	58	b
MILF0675-13	43	54	658	54	bc
UPL 2000	48	48	716	50	cd
BIX+PTZ+TF	46	51	547	62	b
A19487	31	67	473	67	a
DPX-R0G79	30	68	474	67	a
S-2399T 260	32	65	462	68	a
Mean		43 B		52 A	

* The control level of fungicides was calculated as [1-(disease severity for the unsprayed control – disease severity for the corresponding treatment)*100]. Means followed by the same lowercase letters to compare means in the column and uppercase letters on the line are similar, according to Tukey's multiple range test at 0.05.

(3, 4), and (iii) compare data obtained in several years and places or with different disease management strategies. Data on the AUDPC, if not expressed as control efficacy levels, are more difficult to interpret.

It must be considered that >80% control efficacy is required for matching the fungicide spraying costs in soybean crops. Another important outcome from our long-term study is that the majority of the tested fungicides and co-formulations did not control ASR (63 out of 70 tested fungicide treatments, approximately 90%, showed low ASR control efficacy). This is a very serious scenario for ASR management in Brazil, indicating that spraying of fungicides with these actives should not be recommended by extension plant pathologists.

Therefore, in the current case study on ASR, control efficacy calculated based on the final severity (one single evaluation) can be considered similar to that obtained with the AUDPC (four evaluations in a season). Thus, to simplify and reduce experimental costs, there is no need for estimating the AUDPC in studies involving fungicide efficacy trials for the management of soybean rust.

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