Addition of mancozeb to the fungicide mixtures DMI + QoI and SDHI + QoI on the control of wheat leaf blights

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ABSTRACT

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Wheat leaf blights caused by *Drechslera siccans, D. tritici-repentis*, especially *D. tritici-repentis*, are difficult to be controlled by site-specific fungicide mixtures. Due to development of resistance, the use of double site-specific mixtures has shown control inferior to 50%. In an experiment conducted in the field with the wheat cultivar Jadeite 11, in 3 x 6 m plots and four replicates, the effect of a muli-site fungicide added to fungicide mixtures on the control of leaf blights was evaluated. The effect of the following mixtures was evaluated: picoxystrobin + cyproconazole, kresoxim-methyl + epoxiconazole, azoxystrobin + cyproconazole, pyraclostrobin + epoxiconazole, pyraclostrobin + fluxapyroxad, trifloxystrobin + prothioconazole and azoxystrobin + propiconazole, added of five mancozeb levels, 0; 1.5; 2.0; 2.5 and 3.0 kg/ha. The first application occurred after 30% leaf incidence, and the remaining two occurred at 15 and 18-day intervals. The fungicides were applied with a backpack sprayer pressurized by CO_2, delivering 180 L/ha. Leaf blights severity was quantified, control was calculated, the percentage of chlorophyll in flag leaves was determined, and grain yield was assessed. The mean control of leaf blights by the mixtures without addition of the multi-site fungicide was 44%. The disease severity reduced as a function of the addition of mancozeb levels for all treatments. Control superior to 80% was obtained with the mixtures kresoxim methyl + epoxiconazole and pyraclostrobin + epoxiconazole, both added at least 2.0 kg/ha mancozeb. There was a positive reflex on the increase in wheat grain yield as a function of control, varying from 3005 kg/ha for the best treatment to 2026 kg/ha for control.

Keywords: *Drechslera siccans, D. tritici-repentis,* manganese ethylene–bis-dithiocarbamate, triazoles, strobilurins, carboxamides.

RESUMO

Reis, E. M.; Zanatta, M.; Forcelini, C.A. Adição de mancozebe às misturas de fungicidas IDMs + IQes e IQes + ISDHs no controle das manchas foliares do trigo. ***Summa Phytopathologica,*** v.45, n.1, p.23-27, 2019.

As manchas foliares do trigo causadas por *Drechslera siccans* e, principalmente, *D. tritici-repentis* são de difícil controle pelas misturas de fungicidas sítio específicos. Devido ao desenvolvimento da resistência, o uso das misturas duplas de sítio específicos apresenta controle inferior a 50%. Em experimento conduzido no campo com a cultivar de trigo Jadeíte 11, parcelas de 3 x 6 m, com quatro repetições, avaliou-se o efeito da adição de fungicida multi sítio às misturas de fungicidas no controle das manchas foliares. Foi avaliado o efeito das misturas picoxistrobina + ciproconazol, cresoxim metílico + epoxiconazol, azoxistrobina + ciproconazol, piraclostrobina + epoxiconazol, piraclostrobina + fluxapiroxada, trifloxistrobina + protioconazol e azoxistrobina + propiconazol adicionadas de cinco doses de mancozebe, 0; 1,5; 2,0; 2,5 e 3,0 kg/ha. A primeira aplicação foi feita após o afilhamento com 30% de incidência foliar e as outras duas com intervalos de 15 a 18 dias. Os fungicidas foram aplicados com pulverizador costal e pressão gerada por CO_2 e vazão de 180 L/ha. Foi quantificada a severidade foliar das manchas, calculado o controle, determinado o percentual de clorofila nas folhas-bandeiras e o rendimento de grãos. A média do controle das manchas foliares pelas misturas sem adição do fungicida multi sítio foi de 44%. A severidade da doença foi reduzida em função da adição de doses do mancozebe em todos os tratamentos. Controle superior a 80% foi obtido com as misturas de cresoxim metílico + epoxiconazol e piraclostrobina + epoxiconazol, ambas adicionadas de no mínimo 2,0 kg/ha de mancozebe. Houve reflexo positivo no aumento do rendimento de grãos do trigo em função do controle, variando de 3005 kg/ha no melhor tratamento e 2026 kg/ha na testemunha.

Palavras-chave: *Drechslera siccans, D. tritici-repentis*, etilenobisditiocarbamato de manganês, falha de controle, triazóis, estrobilurinas, carboxamidas.

The annual consumption of wheat (*Triticum aestivum* L.) in Brazil is estimated at 11 million tons. According to Conab (1), the national production of wheat in 2015 growing season was 5,971 million tons. The difference between consumption and demand is supplied by imports.

The most common diseases caused by fungi in wheat are powdery mildew, leaf rust, leaf blights, fusarium head blight, and blast (6).

Leaf blights are caused by the necrotrophic fungi *Bipolaris sorokiniana* (Ito & Kurib.) Drechsler ex Dastur, *Drechslera siccans* (Died.) Schoem., *D. tritici-repentis* (Died.) Schoem, while *Stagonospora nodorum* (Berk) Berk. *Drechslera* spp. are predominant in southern Brazil (6, 9, 11).

Yellow spot symptoms begin with a dark brown spot of approximately 1 mm in diameter, which then evolve presenting a prominent yellow halo of elliptical shape that increases in size reaching up to 1.0 cm in length. The dark brown central spot scarcely evolves in size and remains distinct until the senescence of leaves. When the green leaf area is completely killed by the disease, the dark spots, which marked the infection site, are still identifiable. In plants with all dead leaves, the symptoms of dark central point in the center of the spot and yellowish yellow halo are visible in the still green leaf sheaths.

The causal agents of leaf blights have as common characteristic the transmission by seeds and, saprophytically survive in crops residues after harvests. In southern Brazil, complete wheat residue decomposition takes place in 18 months (7).

Damage due to leaf blights caused by *Drechslera* spp. can reach up to 45% and can be assessed by y = 1000 - 6.5 LI function, where 'y' is the grain yield normalized to 1,000 kg/ha and LI is the leaf incidence (8).

Control measures against leaf blights include seed production in fields under crop rotation, seed treatment with fungicides and efficient levels of fungicides applied to aerial organs. The time for the first application is defined based on the economic damage threshold and the remaining applications should occur at 15 days intervals (8).

From 2004 season, farmers and farm advisers have complained about the difficulty in controlling wheat leaf blights by using fungicides. Some authors (11, 12) have shown that the reduced sensitivity of *Drechsler*a spp. to strobilurins and triazoles, except for pyraclostrobin, may explain the control failure.

Mean control of wheat leaf blights has been less than 50%. Such low efficiency indicates that the fungicide application cost is not covered and has a negative effect on wheat grain yield (10).

We hypothesized that, due to the reduced sensitivity of the fungus to site-specific fungicides, addition of a non-penetrating, multi-site, protectant fungicide can improve the control of wheat leaf blights, which nowadays is only 50%.

This study aimed to quantify the effects of the addition of a protectant/multisite fungicide to the co-formulations currently used to control wheat leaf blights.

MATERIAL AND METODS

The present study was conducted in the experimental field of the Faculty of Agronomy of University of Passo Fundo (latitude 28º13'S, longitude 52º23'W and altitude 687 m a.s.l.) from June to December 2015.

The wheat cultivar Jadeite 11, susceptible to leaf spot, was grown in no-tillage and under crop rotation with black oats (*Avenas trigosa* Schreb.) cultivated in the previous winter and seeded on June 29, 2015.

Seeds were treated with the insecticides imidacloprid (Gaucho) and fipronil + pyraclostrobin (Standak Top) 0.1 L + 0.2 L for 100 kg seeds, respectively.

Modus, a plant growth regulator, 200 mL/ha, was applied at growth stage GS 32 (13). The other cultural treatments were applied according to the technical recommendations (8).

Fertilization: 300 kg/ha of the formulated fertilizer 05-20-20 (N-P_2O_5-K_2O) was applied in the sowing furrows. Nitrogen application was carried out by using Super N, 350 kg/ha (33% N and 22% S), at the first visible node, GS 31 (13).

The following fungicides were assessed in the field: epoxiconazole (16%) + pyraclostrobin (26%) (Abacus SC – 300 mL/ha), cyproconazole (8%) + picoxystrobin (20%) (Aproach Prima – 300 mL/ha), azoxystrobin (30%) + benzovindiflupyr (15%) (Elatus – 200 mL/ha), prothioconazole (17.5%) + trifloxystrobin (15%) (Fox SC - 500 mL/ha), epoxiconazole (12.5%) + kresoxim methyl (12.5%) (GuapoSC – 600 mL/ha), fluxapyroxad (16.7%) + pyraclostrobin (33.3%) (Orkestra SC – 300 mL/ha), cyproconazole (8%) + azoxystrobin (20%) (Priori Xtra SC 300 mL/ha), azoxystrobin (25%) + propiconazole (25%) (Priori + Tino – 500 mL/ha), added of mancozeb at 0, 1.5, 2.0, 2.3, and 3.0 kg/ha) (Unizeb Gold 75 WG).

Three applications were programmed: the first one was at the stem elongation stage (GS 33: third node visible); the second application was at the booting stage (GS 41: flag leaf sheath expanding), and the third application was at anthesis (GS 61: anthesis beginning). The interval between applications was 17 days between the first and the second application, 14 days between the second and the third application and 21 days between the third and the fourth application.

Sprayings were carried out by using a precision backpack sprayer with constant pressure by CO_2 gas. The boom was equipped with four DG TeeJet® 110015 nozzles spaced 0.5 m apart. The applied water volume was 180 L/ha. For the spraying, the boom was positioned at 40 cm above the plant canopy for complete and uniform foliar coverage

Experimental design was factorial, considering five mancozeb levels x eight co-formulation (DMI, QoI, and SDHI) mixtures in a completely randomized block design (DBC), plots of 2.21 x 6.0 m and four replicates.

Leaves containing lesions were collected and taken to the laboratory, where a humid chamber of leaf segments was prepared. Such material was kept in acrylic boxes (11 x 11 x 2.5 cm in height) containing, at the bottom, a 5-mm nylon foam layer covered with Whatman filter paper no. 4, and maintained at 25ºC and 12h photoperiod. One hundred lesions were analyzed under a stereoscopic microscope (60x magnitude) after 48-hour incubation.

Three leaves from the top of the main stem of 10 plants /plot were collected and, in the laboratory, severity (0 to 100%) was assessed.

The relative chlorophyll content was measured by using a chlorophyll meter (SPAD-502, Minolta, and Osaka, Japan) (4), which estimates the percentage of chlorophyll in the leaf blade. Readings were made on 20 flag leaves per plot.

Grain yield was obtained by harvesting with a Wintersteiger plot machine, 8.2 m^2, on November 23.

Data underwent analysis of variance and treatment means were compared according to Tukey's test at 5% for severity and according to Duncan's test at 5% for grain yield. The relationship between grain yield and mancozeb rates was determined.

RESULTS AND DISCUSSION

In the experimental area, leaf blights occurred naturally. Plots that were not sprayed (control) with fungicide showed 72% severity. The incidence of fungi causing leaf blight was 60% *D. tritici-repentis* and 4% *B. sorokiniana.*

Leaf blight severity after treatments. Plots treated with the mixtures, without addition of mancozeb, showed severity of 18% for epoxiconazole + pyraclostrobin, 26% for fluxapyroxad + pyraclostrobin, 28% for epoxiconazole + kresoxim methyl, 34% for prothioconazole + trifloxystrobin, 34 % for azoxystrobin + propiconazole, 39% for cyproconazole + picoxystrobin, and 62% for azoxystrobin + benzovindiflupyr (Table 1). The high severity after treatments, without addition of the protectant, evidences the difficulty in controlling leaf blights with these mixtures (10, 12). This shows the reduction in sensitivity of *D. tritici-repentis* to DMIs + QoIs, and QoI + SDHI.

On the other hand, considering the overall means for mancozeb effect, the severity reduced when the protectant was added to all mixtures. The average severity using the mixtures was 36, 28, 25, 22 and 21% for 0.0, 1.5, 2.0, 2, 2 and 3 kg/ha mancozeb, respectively (Table 1).

Wheat plots treated with epoxiconazole + pyraclostrobin added by 2.5 and 3.0 kg/ha mancozeb showed the lowest leaf spot severity: 5 and 4%, respectively (Table 1).

The overall control mean was 50, 61, 65, 69 and 70% for mancozeb added at the levels 0, 1.5, 2.0, 2.5 and 3.0 kg/ha, respectively (Table 2). The control mean by the co-formulations alone was 50%. This is considered very low and does not equalize the fungicide application cost.

Control greater than 80% was obtained by adding 1.5, 2.0, 2.5 and 3.0 kg/ha mancozeb to epoxiconazole + pyraclostrobin, 2.0, 2.5 to 3.0 kg/ha mancozeb to epoxiconazole + methyl kresoxim and 2.5 to 3.0 kg/ha mancozeb to prothioconazole (17.5%) + trifloxystrobin (15%) (Table 2).

The mixtures with the least response to mancozeb addition were cyproconazole (8%) + azoxystrobin (20%), showing maximum control of 53%, and azoxystrobin + benzovindiflupyr with control of 51% (Table 2).

An important tool against the development of fungal resistance is the addition of multi-site protectant fungicides, such as mancozeb, as reported by Gisi et al. (3) and confirmed in our study.

It has often been observed that the application of some fungicides such as pyraclostrobin and mancozeb results in a more intense green leaves color of treated plants (2). Reis & Floss (8) showed that the effect of fungicides (maneb and mancozeb) on increasing green color in wheat was due to manganese uptake by the wheat leaves.

The lowest chlorophyll content was shown by the mixtures applied without addition of mancozeb, i.e. cyproconazole (8%) + azoxystrobin (20%) and with 30% the highest for epoxiconazole + pyraclostrobin with 45%. On the other hand, the mixture that showed the highest response of the addition of mancozeb in increasing the chlorophyll content was kresoxim methyl + epoxiconazole with 48, 48, 49 and 50% of chlorophyll at 1.5, 2 , 0, 2.5 and 3.0 kg/ha of mancozeb, respectively (Table 3).

Table 1. Effect of the addition of mancozeb to triazole, strobilurin and carboxamid mixtures on leaf blight severity. Jadeíte 11 wheat cultivar. Passo Fundo, 2015.

Treatments	Severity (%)															Means
	Addition of mancozeb(kg/ha)															
		0.0			1.5			2.0			2.5			3.0		
Mancozeb	A	72*	A	B	59	a	BC	55	a	C	50	a	D	41	a	55
Picoxy+cypro	A	39	C	B	23	b	B	19	cd	B	17	b	B	17	bc	23
Cresoxy+epoxy	A	28	De	B	16	bc	BC	12	de	BC	8	cd	C	9	cd	15
Azoxy+cypro	A	53	B	B	44	a	C	34	b	C	34	a	C	37	a	41
Pyra+epoxy	A	18	E	B	12	c	C	8	e	C	5	d	C	4	d	9
Pyra+fluxa	A	26	De	AB	19	bc	B	17	cd	B	16	bc	B	15	bc	19
Azoxy+benzo	A	62	B	B	42	a	B	40	ab	B	37	a	B	35	a	43
Triflo+prothio	A	26	De	B	15	bc	B	15	cde	B	13	bc	B	14	bc	17
Azoxy+propi	A	34	Cd	B	23	b	B	23	c	B	22	b	B	20	b	24
Means		36			28			25			22			21		27
C.V.(%) 12.36																

Means followed by the same letter do not differ from each other according to Tukey's test at 5% significance. Lowercase letters compare means in the columns and uppercase letters compare means in the lines.* Control without fungicide application.

Table 2. Effect of mancozeb added to triazole, strobilurin and carboxamidmixtures on leaf blight control. Jadeíte 11 wheat cultivar. Passo Fundo, 2015

Treatments	Control (%)					Means
	Addition of mancozeb(kg/ha)					
	0	1.5	2.0	2.5	3.0	
Mancozeb	-	18	23	39	43	24
Pycox+cypro	56	68	52	76	76	68
Kresoxi+epo	66	78	86	89	88	79
Azoxy+cypro	26	39	52	53	49	43
Pyra+epoxy	75	83	89	93	94	88
Pyra+fluxa	64	73	76	78	79	74
Azox+benzo	14	41	44	48	51	40
Triflo+prothi	64	79	79	82	81	76
Azox+propi	53	68	68	69	72	67
Means	50	61	65	69	70	

Control without fungicide application, 72% severity.

Table 3. Effect of mancozeb on the chlorophyll content in wheat leaves. Wheat Jadeite 11 cultivar. Passo Fundo, 2015

Treatments	Chlorophyll (%)					Means	
	Addition of mancozeb (kg/ha)						
	0	1.5	2.0	2.5	3.0		
Mancozeb	33	35	36	34	38	35	d
Picox+cypro	35	40	40	40	42	39	bc
Kresoxi+epoxy	44	48	48	49	50	47	a
Azoxy+cypro	30	38	38	41	40	37	cd
Pyra+epoxy	45	47	49	47	47	47	a
Pyra+fluxa	43	44	46	48	48	45	a
Azoxy+benzo	33	36	42	40	39	38	cd
Triflo+prothio	40	41	43	42	43	41	b
Azoxy+propi	39	40	41	44	44	41	b
Means	C 38	B 41	AB 43	AB 43	AB 43		
C.V. (%) 6.8							

Means of four replications, determined in 20 leaves per plot. Means followed by the same lowercase letter in the column and upper case in the line, do not differ by the Tukey's test at 5%.

Table 4. Response of mancozeb addition to fungicide mixtures in wheat grain yield. Jadeíte 11, wheat cultivar. Passo Fundo, 2015

Treatments	Grain yield (Kg/ha)															Means	
	Addition of mancozebe (kg/ha)																
		0.0			1.5			2.0			2.5			3.0			
Mancozeb	B	2026	c	A	2431	C	A	2472	d	A	2441	d	A	2409	d	2342	f
Pycox+cypro	A	2493	ab	A	2483	Bc	A	2499	cd	A	2647	cd	A	2620	cd	2530	e
Kresoxi+epo	C	2723	a	BC	2796	A	AB	2946	a	AB	2943	a	A	3005	a	2852	a
Azoxy+cypro	A	2492	b	A	2639	abc	A	2629	bcd	A	2636	cd	A	2629	cd	2599	de
Pyra+epoxy	B	2700	ab	AB	2788	A	AB	2805	ab	A	2918	ab	A	2940	ab	2803	ab
Pyra+fluxa	A	2613	ab	A	2601	abc	A	2721	abc	A	2706	bc	A	2751	bc	2660	cd
Azoxy+benzo	A	2570	ab	A	2552	Bc	A	2604	bcd	A	2607	cd	A	2723	bc	2584	de
Trifl+prothio	B	2691	ab	AB	2701	Ab	AB	2765	ab	AB	2756	abc	A	2897	ab	2728	bc
Azoxy+propi	A	2635	ab	A	2621	abc	A	2723	abc	A	2681	c	A	2760	bc	2665	cd
Means	C	2549		BC	2624		AB	2685		A	2704		A	2748			
C.V. (%):		**3.33**															

Means of four replications, followed by the same lowercase letter in the column and upper case in the row, do not differ by the Tukey test at 5%.

Comparing the chlorophyll content in the treatment with cyproconazole + azoxystrobin (without mancozeb) 30% and epoxiconazole + methyl kresoxim (3.0 kg / ha mancozeb) 50%, there was a 20% increase in chlorophyll content (Table 3).

Some mixtures containing strobilurins, and without mancozeb, such as methyl kresoxim (44%) or pyraclostrobin (43%), increased the chlorophyll content in wheat leaves (Table 3).The increase in chlorophyll content may influence grain yield regardless of fungicide control.

Analyzing the overall mean effect for mancozeb doses, grain yield was 2,549, 2,624, 2,685, 2,704, and 2,748 kg/ha for 0, 1.5, 2.0, 2.5, and 3.0 kg/ha, respectively. Regarding the fungicides, the lowest yield was obtained with the application of mancozeb alone with 2,342 kg/ha and the highest with the application of epoxiconazole + kresoxim methyl 3,005 kg/ha (Table 4). Comparing the grain yield in the control with that of kresoxim methyl + epoxiconazole the increase was 48.3%.

Each 0.5 kg of mancozeb resulted in 44.079 kg/ha grain yield increase (y = 44.079x + 2,568, **R^2 = 0.98, where y** = grain yield and x mancozeb kg/ha).

Rainfall was uneven distributed with an excess in July, when the crop was sown and a deficit in August, preventing the correct application of the second dose of nitrogen cover (Fig. 1). Rainfall accumulated during the wheat cycle (sowing on June 29 and harvest on November 23, 2015) was 1,050 mm. Considering the leaf blights control (94%),

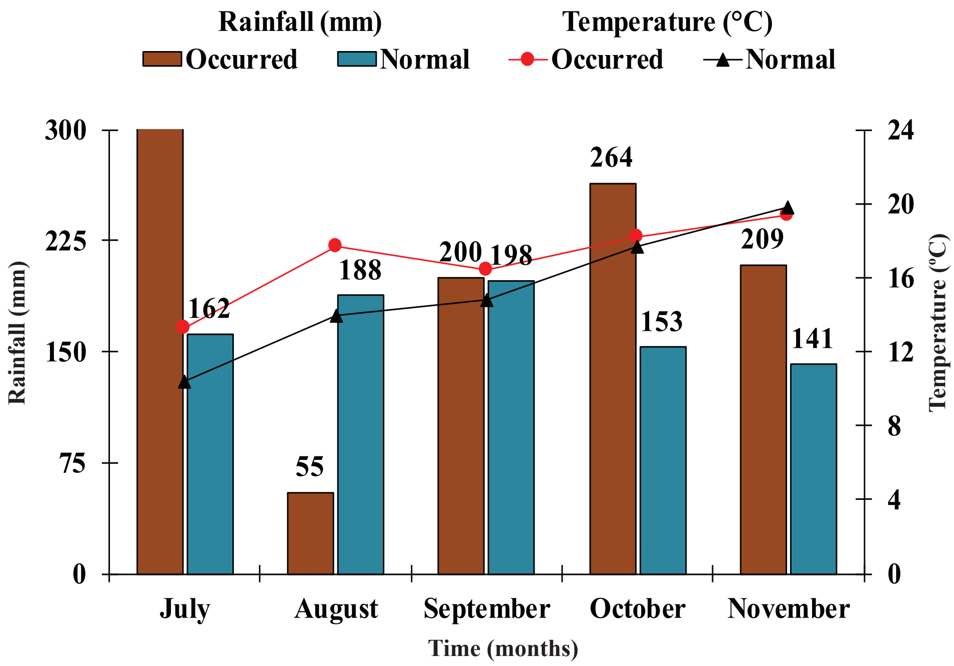

Figure 1. Rain and temperature fluctuation during the wheat cycle. Passo Fundo, 2015

it may be inferred that with this rain amount the protectant fungicide showed rain fastness.

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