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CONTROL OF SUGAR BEET POWDERY MILDEW WITH STROBILURIN FUNGICIDES*

ABSTRACT: *Powdery mildew*, caused by *Erysiphe betae* is a major foliar disease of sugar beet in areas with dry and relatively warm weather conditions throughout the world. In the present study, four fungicides belonging to the relatively new class of strobilurin fungicides, azoxystrobin, kresoxim-methyl, pyraclostrobin and trifloxystrobin were evaluated in three different application doses (100, 150 and 200 mg a.i. ha⁻¹) during 2003—2004 for the control of the disease. Among the four strobilurin fungicides tested, trifloxystrobin and kresoxim-methyl were the most effective with control efficiency values higher than 94% compared to the control treatment even when applied at lower application dose of 100 mg a.i. ha⁻¹. Azoxystrobin and pyraclostrobin showed a poor to modest activity against the disease even when applied at the highest application dose of 200 µg a.i. ha⁻¹. Disease severity, in terms of AUDPC values was significantly correlated to decreased root yield, while no significant correlation existed among disease severity and sugar content of the roots or sucrose yield. In addition, the efficiency of tank mixtures of four strobilurin fungicides applied at 100 µg a.i. ha⁻¹ with two sterol demethylation — inhibiting fungicides (DMIs), difenoconazole and cyproconazole applied at 62.5 and 25 mg a.i. ha⁻¹, respectively, was evaluated. The mixtures of azoxystrobin and pyraclostrobin with either difenoconazole or cyproconazole provided a better control efficiency compared to the single application of each mixture partner, while the tank mixtures of trifloxystrobin and kresoxim-methyl with either difenoconazole or cyproconazole provided a better control efficiency compared to single application of difenoconazole or cyproconazole and similar control efficiency compared to the efficiency obtained by single application of the strobilurin fungicides.

KEY WORDS: azoxystrobin, chemical control, *Erysiphe betae*, kresoxim-methyl, pyraclostrobin, trifloxystrobin

INTRODUCTION

Sugar beet powdery mildew, caused by *Erysiphe betae*, is among the most important foliar diseases of sugar beet worldwide. In the conditions of

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high disease pressure and in the absence of control measures, the reduction of root yield may exceed 22% and root sucrose content may exceed 13% (Forster, 1979). Disease development is favored by dry conditions and relatively high temperatures. The control of disease is mainly achieved by applications of broad spectrum of systemic fungicides, mainly belonging to the ergosterol biosynthesis inhibitors class (EBIs) which are also active against *Cercospora leaf spot* caused by *Cercospora beticola* or by applications of the protective fungicide sulfur which is *powdery mildew* specific (Byford, 1996). Qo inhibiting fungicides (strobilurin and strobilurin-related fungicides) constitute a relatively new fungicide class that inhibits mitochondrial respiration by binding at the Qo site of cytochrome *b*, possessing an extremely broad spectrum of activity against several fungal classes (Bartlett et al., 2002). The current study was conducted to test: i) the efficiency of four strobilurin fungicides, azoxystrobin, trifloxystrobin, pyraclostrobin and kresoxim-methyl against the pathogen in the field conditions and ii) the efficiency of tank mixtures of four strobilurin fungicides with two triazole fungicides, difenoconazole and cyproconazole.

MATERIALS AND METHODS

Fungicides: Fungicides used in the study were commercial formulations of trifloxystrobin (Flint 50 WG), pyraclostrobin (F-500 25), kresoxim-methyl (Strobby 50WG), azoxystrobin (Ortiva 25 SC) difenoconazole (Score 25 EC), cyproconazole (Caddy 10 SL) and sulfur (Thiovit 80 WG).

Plant material: Sugar beet cultivar selected for the experiment was “Rival”, a cultivar sensitive to *powdery mildew*. Field plots consisted of six 11-meter rows spaced 45 cm apart and arranged in a randomized block design with four replicates per treatment.

Time of application: Fungicides were applied preventively. Spray applications initiated before the appearance of any disease symptom on the plants, after the “closing” of rows and repeated at intervals of 15—20 days. In total, four spray applications per treatment were carried out. Fungicide solutions were applied using an AZO precision sprayer, at a volume of 0.4 L per plot and pressure 4 atm.

Disease assessment: For the assessment of *powdery mildew* severity, a six-category scale disease index suggested by Hills et al. (1980) was used. Scale categories indicated leaf area covered by fungus mycelium (R0 = 0%, R1 = 10%, R2 = 35%, R3 = 65%, R4 = 90%, R5 = 100%). Area Under Disease Progress Curve (AUDPC) was calculated for the assessment period as follows: $AUDPC = \sum_{i=1}^{n-1} [(Y_{i+1} + Y_i)/2][t_{i+1} - t_i]$ where Y_i = disease severity at the i th observation, T_i = time (days) at the i th observation and n = total number of observations.

Data on AUDPC values were subjected to an analysis of variance (ANOVA) and compared using the Fischer’s least significant difference (LSD) procedure at $p = 0.05$.

RESULTS

Control efficiency of strobilurin fungicides. During both years of the study, AUDPC values in plots treated with fungicides were significantly lower ($P < 0.05$) than in the untreated control plots. Among four strobilurin fungicides tested, kresoxim-methyl and trifloxystrobin were the most effective. AUDPC values in plots treated with kresoxim-methyl and trifloxystrobin were extremely low in all of three application rates and control efficiency had values higher than 94% during both years of the study. Pyraclostrobin showed a modest activity against *powdery mildew* since AUDPC values in plots treated with that fungicide ranged from 907 to 380 in 2003 and from 910 to 450 in 2004, significantly lower ($P < 0.05$) compared to the respective values in plots treated with the same rates of either kresoxim-methyl or trifloxystrobin. Azoxystrobin showed weaker ($P < 0.05$) activity against *powdery mildew* compared to remaining three strobilurin fungicides tested, with AUDPC values ranging from 1585 to 1075 in 2003 and 862 to 698 in 2004. Data on Area Under Disease Progress Curve (AUDPC) are summarized in Table 1. and Table 2.

Table 1. Area under the disease progress curve (AUDPC)^a of *powdery mildew* on sugar beet and control efficiency (%) in plots treated with strobilurin fungicides in 2003

Treatment	Application Dose gr a.i. ha ⁻¹	AUDPC	Control (%)
sulfur	3840	685 f ^b	72.1
azoxystrobin	100	1585 b	35.4
azoxystrobin	150	1300 c	47.0
azoxystrobin	200	1075 d	56.2
pyraclostrobin	100	907 e	63.1
pyraclostrobin	150	525 g	78.6
pyraclostrobin	200	380 h	84.6
kresoxim-methyl	100	125 i	95.0
kresoxim-methyl	150	105 i	95.8
kresoxim-methyl	200	80 i	96.8
trifloxystrobin	100	117 i	95.3
trifloxystrobin	150	85 i	96.6
trifloxystrobin	200	56 i	97.8
control	—	2452 a	—

^a AUDPC values were calculated according to Wolf and Verreet (2002).

^b Means followed by different letters in the column are significantly different according to an LSD test at $P = 0.05$.

Table 2. Area under the disease progress curve (AUDPC)^a of *powdery mildew* on sugar beet and control efficiency (%) in plots treated with strobilurin fungicides in 2004

Treatment	Application Dose gr a.i. ha ⁻¹	AUDPC	Control (%)
sulfur	3840	100 g ^b	93.3
azoxystrobin	100	862 c	41.5
azoxystrobin	150	795 d	46.0
azoxystrobin	200	698 e	47.0
pyraclostrobin	100	910 b	38.2
pyraclostrobin	150	469 f	68.2
pyraclostrobin	200	450 f	69.5
kresoxim-methyl	100	42 h	97.0
kresoxim-methyl	150	36 h	97.6
kresoxim-methyl	200	0 i	100
trifloxystrobin	100	91 g	94.0
trifloxystrobin	150	91 g	94.0
trifloxystrobin	200	36 h	97.6
control	—	1471 a	0.00

^a AUDPC values were calculated according to Wolf and Verreet (2002)

^b Means followed by different letters in the column are significantly different according to an LSD test at P = 0.05.

Control efficiency of mixtures of strobilurin and triazole fungicides. The trials were designed in order to test the control efficiency obtained by tank mixtures of four strobilurin fungicides used in the study and two DMI fungicides, difenoconazole and cyproconazole. Difenoconazole, applied alone, showed a weak to modest activity against *E. betae* during both years of the study with control efficiency values ranging from 21.1 to 55.7% in 2003 and from 40.3 to 69.9% in 2004, while cyproconazole showed a better performance particularly when applied at the dose of 50 gr a.i ha⁻¹. The addition of the DMI fungicides into the spray solution did not affect the efficacy of trifloxystrobin and kresoxim methyl significantly, since they showed extremely high control efficiency even when they were applied alone at 100 gr a.i ha⁻¹. In contrast, in plots treated with tank mixtures of azoxystrobin or pyraclostrobin and difenoconazole or cyproconazole, disease severity in terms of AUDPC values was significantly lower (P < 0,05) compared to that in plots treated with either azoxystrobin, or pyraclostrobin applied at 100 gr a.i ha⁻¹ during both 2003 and 2004. Data on Area Under Disease Progress Curve (AUDPC) are summarized in Table 3. and Table 4.

Table 3. Area under the disease progress curve (AUDPC)^a of *powdery mildew* on sugar beet and control efficiency (%) in plots treated with tank mixtures of strobilurin and DMI fungicides in 2003

Treatment	Application Dose gr a.i. ha ⁻¹	AUDPC	Control (%)
sulfur	3.840	420 h ^b	81.9
difenoconazole	62.5	1832 b	21.1
difenoconazole	150	1030 e	55.7
cyproconazole	25	1060 e	54.4
cyproconazole	50	340 h	85.4
azoxystrobin	100	1620 c	30.2
azoxystrobin + difenoconazole	100 + 62.5	1300 d	44.0
azoxystrobin + cyproconazole	100 + 25	890 f	61.7
pyraclostrobin	100	950 ef	59.1
pyraclostrobin + difenoconazole	100 + 62.5	767 g	67.0
pyraclostrobin + cyproconazole	100 + 25	695 g	70.1
kresoxim-methyl	100	80 i	96.6
kresoxim-methyl + difenoconazole	100 + 62.5	40 i	98.3
kresoxim-methyl + cyproconazole	100 + 25	40 i	98.3
trifloxystrobin	100	60 i	97.4
trifloxystrobin + difenoconazole	100 + 62.5	16 i	99.3
trifloxystrobin + cyproconazole	100 + 25	0 i	100
control	—	2320 a	0.00

^a AUDPC values were calculated according to Wolf and Verreet (2002).

^b Means followed by different letters in the column are significantly different according to an LSD test at P = 0.05.

Table 4. Area under the disease progress curve (AUDPC)^a of *powdery mildew* on sugar beet and control efficiency (%) in plots treated with tank mixtures of strobilurin and DMI fungicides in 2004

Treatment	Application Dose gr a.i. ha ⁻¹	AUDPC	Control (%)
sulfur	3.840	270 g ^b	84.4
difenoconazole	62.5	102 b	40.3
difenoconazole	150	529 e	69.3
cyproconazole	25	850 c	50.6
cyproconazole	50	170 h	90.1
azoxystrobin	100	952 b	44.7
azoxystrobin + difenoconazole	100 + 62.5	836 c	51.4
azoxystrobin + cyproconazole	100 + 25	650 d	62.3
pyraclostrobin	100	620 d	64.0
pyraclostrobin + difenoconazole	100 + 62.5	480 e	72.1
pyraclostrobin + cyproconazole	100 + 25	350 f	79.7
kresoxim-methyl	100	70 i	96.0

kresoxim-methyl + difenoconazole	100 + 62.5	45 ij	97.4
kresoxim-methyl + cyproconazole	100 + 25	0 j	100
trifloxystrobin	100	65 ij	96.3
trifloxystrobin + difenoconazole	100 + 62.5	10 ij	99.5
trifloxystrobin + cyproconazole	100 + 25	0 j	100
control	—	1720 a	0.0

^a AUDPC values were calculated according to Wolf and Verreet (2002)

^b Means followed by different letters in the column are significantly different according to an LSD test at P = 0.05.

CONCLUSIONS

- Significant reduction of *powdery mildew* incidence in all the fungicide-treated plots compared to the untreated control plots.
- Trifloxystrobin and kresoxim-methyl showed better performance compared to remaining two strobilurin fungicides, azoxystrobin and pyraclostrobin that showed a poor to modest activity against the disease, during both years of the study.
- Differences in the level of control efficiency, obtained by several strobilurin fungicide treatments can be explained by variation in the level of intrinsic activity of each fungicide against the pathogen.
- The mixtures of trifloxystrobin or kresoxim-methyl with either difenoconazole or cyproconazole had excellent performance against the disease.
- When cyproconazole or difenoconazole were applied in mixture with azoxystrobin or pyraclostrobin, a significant improvement of control efficiency was achieved compared to the control.

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СУЗБИЈАЊЕ ПЕПЕЛНИЦЕ РЕПЕ СТРОБИЛУРИНСКИМ ФУНГИЦИДИМА

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Резиме

Пепелница коју проузрокује *Erysiphe betae* је у целом свету основна болест лишћа шећерне репе, у подручјима са сувим и релативно топлим временским условима. У садашњем испитивању четири фунгицида који припадају релативно новој класи стробилуринских фунгицида, азоксистробина, кресоксим-метила, пираклостробина и трифлоскистробина, током 2003—2004, у циљу сузбијања ове болести испитане су у три различите количине примене (100, 150 и 200 μg а.и. ha^{-1}). Од четири испитана, трифлоскистробин и кресоксим-метил су били најделотворнији у сузбијању са ефикасношћу већом од 94% у поређењу са контролним третманом чак и приликом примене ниже количине од 100 μg а.и. ha^{-1} . Азоксистробин и пираклостробин били су слабо или умерено активни против ове болести чак и приликом примене највише количине од 200 μg а.и. ha^{-1} . Јачина болести, у терминима вредности АУДПЦ, била је у значајној корелацији са смањеним приносом корена, док није постојала значајна корелација између јачине обољења и садржаја шећера корена или приноса шећера. Уз то, испитана је ефикасност мешавина четири стробилуринска фунгицида примењена са 100 μg а.и. ha^{-1} са два стерол деметилацион-инхибирајућим фунгицидима (ДМИс), дифеноконазолом и цирпроконазолом примењенима са 62,5 и 25 μg а.и. ha^{-1} . Мешавине азоксистробина и пираклостробина са дифеноконазолом или цирпроконазолом обезбедиле су бољу ефикасност у сузбијању у поређењу са појединачним применама сваког фунгицида у мешавини, док су мешавине трифлоскистробина и кресоксим-метила са дифеноконазолом или цирпроконазолом показале бољу ефикасност у поређењу са појединачним применама дифеноконазола или цирпроконазола и сличну ефикасност у сузбијању у поређењу са оном постигнутом приликом појединачних примена стробилуринских фунгицида.