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The efficiency of triazole fungicides in sugar beet protection against *Cercospora beticola* Sacc. depending on the plant infection at the time of the protective treatment

Skuteczność fungicydów triazolowych w ochronie buraka cukrowego przed chwościkiem (*Cercospora beticola* Sacc.) w zależności od porażenia roślin w momencie wykonywania zabiegu ochronnego

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Summary

The objective of a series of strict 19 field experiments conducted in 2007–2010 was to evaluate the efficiency of triazole fungicides depending on the degree of sugar beet leaf infection by *Cercospora beticola* Sacc. at the time of the application. The delayed treatment resulted in a significant decrease of the effectiveness of the used fungicides. The increase of infection degree by 1.0% at the time of treatment decreased effectiveness of fungicide on average by 3.0%. The infection of plants by *C. beticola* had a significant effect on the root and sugar yield.

Key words: sugar beet; *Cercospora beticola*; infection level; triazole fungicides; protection effectiveness

Streszczenie

Serię 19 doświadczeń polowych, których celem było określenie skuteczności fungicydów triazolowych w zależności od stopnia porażenia buraka cukrowego przez chwościka (*Cercospora beticola* Sacc.) w momencie wykonywania zabiegu ochronnego, przeprowadzono w latach 2007–2010. Opóźnienie zabiegów skutkowało istotnym obniżeniem skuteczności fungicydów. Wzrost stopnia porażenia roślin o 1% powodował spadek skuteczności ochronnej stosowanych fungicydów o 3%. Porażenie roślin przez chwościk miało istotny wpływ na plon korzeni i cukru.

Słowa kluczowe: burak cukrowy; *Cercospora beticola*; stopień porażenia; fungicydy triazolowe; skuteczność ochronna

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Wstęp / Introduction

The increase of the threat from *Cercospora beticola* Sacc. on sugar beet in Poland has been observed since the 1990s. This is due to the introduction of sugar beet varieties with a low resistance to this pathogen to the polish market (Nowakowska *et al.* 1997; Wójtowicz and Jakubowska 2000). The changes in technology of harvesting and leaving leafs in the soil as a green manure, and reducing the use of silages leafs as fodder for cattle was also very important (Schäufele and Wevers 1996).

Currently *C. beticola* is the most devastating fungal disease of sugar beet leafs in Poland. The disease occurs annually throughout the sugar beet crop and the plant requires chemical protection. *C. beticola* under favorable conditions with hot and humid weather, may contribute to loss in yield of roots up to 50% (Bleiholder and Weltzien 1972) and significant losses in yield of sugar (Shane and Teng 1992; Rossi *et al.* 2000).

In practice, the observed efficiency of the fungicides is often not satisfactory. It may be due to the prevalence of resistance to fungicides fungus (Piszczek 2004; Piszczek and Czekalska 2006) but also a decrease in the effectiveness of treatment as a result of its late application (Ayala and Bermejo 2003).

The evaluation of the effectiveness of selected fungicides in controlled *C. beticola* field experiments, depending on the degree of infection of plants at the time of their application, was the aim of study.

Materiały i metody / Materials and methods

In 2007–2010, in 10 villages in the Kuyavian-Pomeranian, a series of 19 field experiments took place which examined the effectiveness of the selected triazole fungicides in controlling cercospora leaf spot, with varying degrees of leaf infection at the time of the first protective application. The study was done on ten varieties of sugar beet with a similar susceptibility to *C. beticola* (Boryna, Bruno, Carlos, Griffin, Kujawska, Leopard, Lupus, Soplica, Zawisza, Zosia).

In every experiment a control variant (without chemical protection) and a protected variant (two protective sprayings) were established.

The following fungicides: Duett 250 SC (carbendazim – 125 g/l and epoxiconazole – 125 g/l), Horizon 250 EW (tebuconazole – 250 g/l), Orius 250 EW (tebuconazole – 250 g/l) Rubric 125 SC (epoxiconazole – 125 g/l) and Soprano 125 SC (epoxiconazole – 125 g/l) were used for protection. The location of experiments, a variety of fungicides and doses are presented in Tables 1 and 2.

Assessment of the plant infection by *C. beticola* was carried out in accordance with European and Mediterranean Plant Protection Organization standard (EPPO 2002). The degree of leaf infection (%) was assessed at 5 randomly selected points of the plot by making an assessment of at least 5 adjacent plants along the row (at least 25 plants per plot in all) in 9 degrees scale. Evaluation was done on the first treatment (BBCH 39), and before harvest roots (BBCH 49).

Infection index (IP) was calculated according to the formula:

$$IP\% = \frac{\Sigma(P \times W)}{n}$$

wherein: $\Sigma(P \times W)$ – the sum of the ratios of the number of plants infested to a certain extent – (P) by the corresponding value of the infection degree – (W), n – total number of assessed plants.

The effectiveness of fungicides (Sk) was calculated according to the formula Henderson-Tilton:

$$Sk\% = \left(1 - \frac{Ta}{Tb} \times \frac{Cb}{Ca}\right) \times 100$$

where: Cb – infection index in control before spraying, Ca – an infection index in the control after spraying, Ta – an infection index in the variant protected after application, Tb – infection index in the protected variant prior to protection application.

The root yield was determined in four randomly assigned plots of 10 m^2 (four rows along the length of 5.6 m), and the controlled and protected variant, and converted to root mass containing 16% sugar. The sugar content of the roots was determined on an automatic Venema line.

The results of the infection index and root yield were statistically analyzed using one-way ANOVA. The significance of differences between the combinations was rated in accordance with the procedure Newman-Keuls test at the significance level $\alpha = 0.05$. The relation between the index of infected plants by *C. beticola* and fungicide effectiveness, root yield and sugar content in the roots, were expressed using linear regression equations. The significance of equations was tested at $p = 0.05$. The entire calculation was performed in Excel 2010, ARM 9 (Agriculture Research Manager) and STATISTICA v. 10.

Wyniki i dyskusja / Results and discussion

Chemical protection of sugar beet, regardless of the year, the place and variations led to a significant decrease of leaf infection by *C. beticola* (Tab. 1). Results of 19 experiments showed that, on average, the use of fungicides reduced the leaf infection index by the pathogen by 18.3%.

Furthermore, regression analysis showed that the efficiency of the fungicide was significantly correlated with the degree of leaf infection by *C. beticola* on the day of application. On the basis of the derived regression equation (Fig. 1) it was found that the delay in protective application led to a significant increase of plant infection by *C. beticola*, and thus to a significant decrease in the effectiveness of fungicides. The increase of leaf infection by *C. beticola* caused a decrease in effectiveness of the fungicides by 3.0%. Moreover, application at the time when the level of infection was close to zero provided effectiveness of the fungicides to a level of 76.8%, and in the initial infection of 10%, protective effectiveness decreased to 46.7%.

Tabela 1. Wpływ porażenia przez *Cercospora beticola* w dniu zabiegu na skuteczność fungicydu
Table 1. Effect of plant infection by *Cercospora beticola* at the day of application on efficacy of fungicide

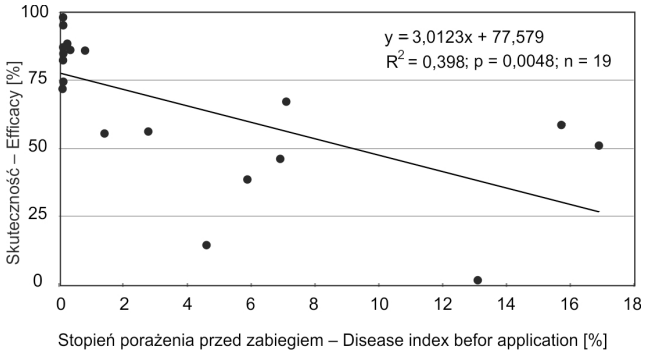
Rok Year	Miejscowość Location	Odmiana Variety	Preparat Treatment	Dawka Dose [l/ha]	Indeks porażenia – Disease index		Skuteczność Efficacy [%]
					przy aplikacji at application [%]	przy zbiorze at harvest [%]	
2007	Piwnice	Kujawska	kontrola – control	–	2,7 a	19,4 a	–
			Duett 250 SC	1,00	2,8 a	8,8 b	55,5
	Sierzchowo	Zawisza	kontrola – control	–	17,8 a	45,5 a	–
			Orius 250 EW	0,80	13,1 a	34,5 b	–3,0
	Kryńsk	Boryna	kontrola – control	–	16,4 a	55,1 a	–
			Soprano 125 SC	1,00	16,9 a	27,6 b	51,6
	Falęcin	Lupus	kontrola – control	–	6,1 a	29,3 a	–
			Duett 250 SC	1,00	6,9 a	17,9 b	45,6
	Koniczynka	Zawisza	kontrola – control	–	1,1 a	25,4 a	–
			Duett 250 SC	1,00	1,4 a	14,4 b	53,6
2008	Sierzchowo	Kujawska	kontrola – control	–	6,3 a	22,6 a	–
			Duett 250 SC	1,00	5,9 a	13,0 b	38,7
	Grzybno	Gryf	kontrola – control	–	5,3 a	33,9 a	–
			Orius 250 EW	0,80	4,6 a	25,3 b	15,4
	Kryńsk	Zawisza	kontrola – control	–	15,8 a	55,9 a	–
			Duett 250 SC	1,00	15,8 a	23,0 b	58,8
	Koniczynka	Lupus	kontrola – control	–	6,5 a	34,4 a	–
			Duett 250 SC	1,00	7,1 a	12,4 b	67,2
	Jeleniec	Leopard	kontrola – control	–	0,3 a	44,8 a	–
			Rubric 125 SC	1,00	0,1 b	0,3 b	98,3
2009	Koniczynka	Soplica	kontrola – control	–	0,2 a	26,5 a	–
			Horizon 250 EW	0,80	0,1 a	6,0 b	75,5
	Tylice	Zosia	kontrola – control	–	0,1 a	13,6 a	–
			Horizon 250 EW	0,80	0,1 a	3,5 b	68,2
	Tytlewo	Bruno	kontrola – control	–	0,1 a	10,4 a	–
			Horizon 250 EW	0,80	0,1 a	0,5 b	95,1
	Piwnice	Carlos	kontrola – control	–	0,1 a	12,4 a	–
			Horizon 250 EW	0,80	0,0 a	1,1 b	83,4
	Lipniczki	Boryna	kontrola – control	–	0,4 a	17,9 a	–
			Horizon 250 EW	0,80	0,8 a	5,0 b	85,7
2010	Koniczynka	Soplica	kontrola – control	–	0,2 a	27,8 a	–
			Horizon 250 EW	0,80	0,2 a	3,3 b	89,7
	Tylice	Zosia	kontrola – control	–	0,1 a	26,5 a	–
			Horizon 250 EW	0,80	0,0 b	3,7 b	71,6
	Tytlewo	Bruno	kontrola – control	–	0,1 a	7,9 a	–
			Horizon 250 EW	0,80	0,1 a	1,0 b	90,0
	Jeleniec	Leopard	kontrola – control	–	0,3 a	45,0 a	–
			Soprano 125 SC	1,00	0,3 a	6,0 b	88,8
2007–2010	–	–	kontrola – control	–	4,2	29,2	–
	–	–	ochrona – protection	–	4,0	10,9	64,7

Średnie wartości dla preparatów w miejscowościach oznaczone tą samą literą nie różnią się istotnie zgodnie z regułą Fishera przy $p < 0,05$
Means for treatments in locations marked by the same letter do not differ significantly according to Fisher's test at $p < 0.05$

Tabela 2. Wpływ fungicydu na plon korzeni i zawartość cukru w korzeniach
Table 2. Effect of fungicide on the root yield and sugar content in the roots

Rok Year	Miejscowość Location	Odmiana Variety	Preparat Treatment	Dawka Dose [l/ha]	Plon korzeni Root yield		Zawartość cukru Sugar content	
					[t/ha]	[%]*	[%]	[%]**
2007	Piwnice	Kujawska	kontrola – control	–	71,5 a	–	16,56	
			Duett 250 SC	1,00	71,0 a	99,3	16,47	–0,09
	Sierzchowo	Zawisza	kontrola – control	–	73,5 b	–	15,81	
			Orius 250 EW	0,80	80,2 a	109,1	16,74	0,93
	Kryńsk	Boryna	kontrola – control	–	74,4 a	–	16,74	
			Soprano 125 SC	1,00	83,2 a	111,9	17,89	1,15
	Falęcin	Lupus	kontrola – control	–	79,7 b	–	16,59	
			Duett 250 SC	1,00	94,4 a	118,5	17,47	0,88
	Koniczynka	Zawisza	kontrola – control	–	84,6 a	–	17,17	
			Duett 250 SC	1,00	91,5 a	108,2	16,58	–0,59
2008	Sierzchowo	Kujawska	kontrola – control	–	78,0 a	–	16,55	
			Duett 250 SC	1,00	77,6 a	99,4	16,61	0,06
	Grzybno	Gryf	kontrola – control	–	88,0 a	–	17,99	
			Orius 250 EW	0,80	95,5 a	108,5	18,36	0,37
	Kryńsk	Zawisza	kontrola – control	–	77,0 a	–	16,13	
			Duett 250 SC	1,00	83,8 a	108,9	16,51	0,38
	Koniczynka	Lupus	kontrola – control	–	86,6 b	–	18,27	
			Duett 250 SC	1,00	95,3 a	110,1	19,21	0,94
	Jeleniec	Leopard	kontrola – control	–	66,1 b	–	16,99	
			Rubric 125 SC	1,00	78,2 a	118,3	17,16	0,17
2009	Koniczynka	Soplica	kontrola – control	–	78,4 a	–	17,05	
			Horizon 250 EW	0,80	79,5 a	101,4	17,37	0,32
	Tylice	Zosia	kontrola – control	–	79,3 b	–	17,20	
			Horizon 250 EW	0,80	89,9 a	113,3	18,17	0,97
	Tytlewo	Bruno	kontrola – control	–	92,2 a	–	19,82	
			Horizon 250 EW	0,80	96,0 a	104,1	20,26	0,44
	Piwnice	Carlos	kontrola – control	–	88,7 a	–	17,50	
			Horizon 250 EW	0,80	96,8 a	109,2	17,81	0,31
	Lipniczki	Boryna	kontrola – control	–	90,5 a	–	16,59	
			Horizon 250 EW	0,80	91,6 a	101,2	16,42	–0,17
2010	Koniczynka	Soplica	kontrola – control	–	76,2 a	–	17,02	
			Horizon 250 EW	0,80	78,8 a	103,4	17,70	0,68
	Tylice	Zosia	kontrola – control	–	85,9 a	–	17,76	
			Horizon 250 EW	0,80	89,3 a	104,0	17,08	–0,68
	Tytlewo	Bruno	kontrola – control	–	102,7 a	–	19,84	
			Horizon 250 EW	0,80	104,0 a	101,3	19,58	–0,26
	Jeleniec	Leopard	kontrola – control	–	61,5 b	–	16,26	
			Soprano 125 SC	1,00	75,9 a	123,4	17,31	1,05
2007–2010	–	–	kontrola – control	–	80,8	–	17,29	
	–	–	ochrona – protection	–	87,0	107,8	17,62	0,33

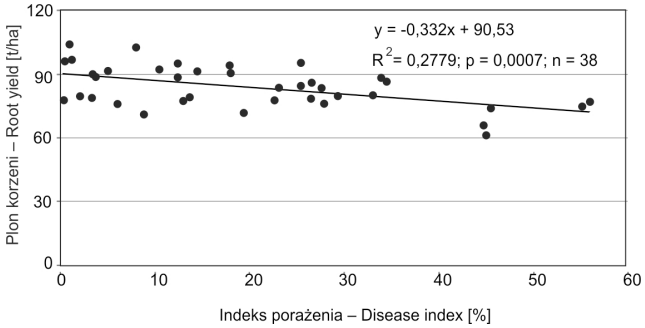
*plon korzeni w stosunku do kontroli = 100% – root yield relative to control = 100%
**wzrost zawartości cukru w punktach procentowych w stosunku do kontroli – increase of sugar content in percentage points in the root relative to control
Średnie dla zabiegów w danych lokalizacjach oznaczone tą samą literą wskazują na brak różnic istotnych pomiędzy obiektami wyliczone zgodnie z regułą Fishera przy $p < 0,05$
Means for treatments in locations marked by the same letter do not differ significantly according to Fisher's test at $p < 0.05$



Rys. 1. Wpływ porażenia roślin przez *Cercospora beticola* w dniu wykonania zabiegu na skuteczność fungicydów
Fig. 1. Effect of plant infection by *Cercospora beticola* at the day of application on efficiency of fungicide

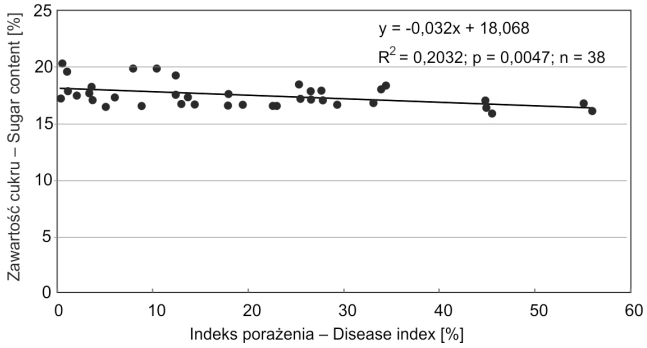
Chemical protection against *C. beticola*, when the degree of leaf infection by the pathogen was reduced, had positive impact on the growth of root yield and the sugar content in them. At the same time, a significant increase, compared to the unprotected variant, was found in 6 of the 19 conducted experiments (Tab. 2). Taking the average of all results, chemical protection against *C. beticola*, had an impact on the increase in root yield of 7.7%, while the sugar content increased by 0.36%.

In the regression equations derived (Fig. 2, 3), that the delay of application against *C. beticola* resulted in a significant decrease in sugar beet root yield and the content of sugar in them. With the increase in the leaf infection index for every 10% root yield had drop an average of 3.3 t/ha and sugar content of 0.3%.



Rys. 2. Wpływ porażenia roślin przez *Cercospora beticola* na plon korzeni
Fig. 2. Effect of plant infection by *Cercospora beticola* on the root yield

The obtained results in this study correlate with the results of other authors (Anesiadis *et al.* 2003; Piszczek 2010). According to these studies, the highest fungicide effectiveness was obtained when chemical application was carried out just before, or within 24–48 hours post leave infection by the pathogen. Harveson and Blehm (2003) achieved a significant increase in root yield, as compared to two weeks delayed application, using chemical



Rys. 3. Wpływ porażenia roślin przez *Cercospora beticola* na zawartość cukru w korzeniach
Fig. 3. Effect of plant infection by *Cercospora beticola* on sugar content in the roots

protection prior to the onset of the first symptoms of the disease. However, they obtained such results only with very strong disease pressure. In addition, Ayala and Bermejo (2003) compared the effectiveness of fungicides applied on sugar beet, affected to varying degrees by *C. beticola*, at the time of application. They found a decrease in the effectiveness of applications with leafs infested by the pathogen to a higher degree, compared to healthy one. The delay of application also had an impact on the resulting yield of sugar. Reaction to the application of protection depended on the used fungicide and beet variety. Merrigi *et al.* (2003) underline the necessity to make protective application on varieties susceptible to *C. beticola* when the first symptoms appear on leafs. Only in this case protection will be effective. The achieved results fully confirm these results. The results clearly show that, in the case of crops of varieties susceptible to *C. beticola*, with increasing leaf infection by the fungus, the efficiency of the fungicides containing the active substance from the group of triazoles declines.

Wnioski / Conclusions

1. Delayed sugar beet treatment against cercospora leaf spot resulted in a significant decrease of the effectiveness of the used fungicides.
2. The degree of infection of plants by cercospora leaf spot had a significant effect on root and sugar yield.

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