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EFFECTIVENESS OF CONTROL OF TAKE-ALL IN WINTER WHEAT BY SEED DRESSING AT DIFFERENT LEVELS OF ROOT INFECTION

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Abstract: In the years 2000 and 2001 the effectiveness of control of take-all (*Gaeumannomyces graminis* var. *tritici*) in winter wheat with seed dressing fungicides at different levels of root infection was studied. Seeds were treated with siltiofam, fluquinconazole or a standard fungicide Baytan Universal 094 FS. At low level of root infection recorded at GS 75 siltiofam and fluquinconazole significantly reduced root infection as compared to untreated control by 73.5–89.9% and 65.5–89%, respectively. At a medium level of infection the respective values were 56.2 and 54.9%. No significant differences between the efficacy of the two new fungicides were stated. Standard seed treatment product showed only limited activity in the early spring. Reduction of winter wheat root infection by 1% caused the increase of grain yield by around 1%.

Key words: *Gaeumannomyces graminis,* winter wheat, take-all, effectiveness of control

INTRODUCTION

In Poland cereals are grown on nearly 60% of arable land. Nearly 1/3 of this area (over 2 million ha) is under wheat cultivation, majority of which is winter wheat (Rocznik Statystyczny 2001). In intensive wheat cropping regions of the country the proportion of wheat in rotation often exceeds 40% (Mączyńska et al. 2002), this may pose a serious threat from stem base diseases, one of which is take-all caused by *Gaeumannomyces graminis* var. *tritici*. Simplified rotation with only one-year break in cereal cropping creates suitable conditions for the development of the disease (Korbas et al. 2000; 2001). The highest threat from *G. graminis* var. *tritici* is known to occur in the third year of wheat monoculture when take-all is at its pick (Hornby et al. 1998). To assure good grain yield and reduce potential danger it is advisable to apply optimal agricultural strategies, which were in the past the only means of partial control of the disease. They include rotation, sowing date and density of plants, plant debris management and fertilisation with a special reference to nitrogen dose and form (Colbach et al. 1997). Other nutrients, such as manganese (Huber and McCay-Buis 1993) as well as soil conditions are also important factors (Hornby et al. 1998).

Early attempts of chemical control of take-all included research work on applying various active ingredients for seed treatment. The most promising results were obtained with triadimenol (Bockus 1983), which provided protection for only a short time, and this being insufficient for practical use (Hornby et al. 1998).

Recently new possibilities emerged because new seed treatment fungicides showing high effectiveness in controlling take-all have been admitted for agricultural use.

The pathogen may cause considerable losses depending on inoculum potential, earliness of primary infection and weather conditions. For example, annual loss due to *G. graminis* in the UK given by Oerke et al. (1994) was 2.5%; with moderate infections a 15% reduction and with more severe disease up to 62%.

Novel active ingredients proposed for seed treatment proved to be highly effective. These are siltiofam (MON 65500) (Shoeney and Lucas 1999; Beale et al. 1998; Spink et al. 1998), and fluquinconazole (Dowson and Bateman 2001; Metcalfe et al. 2000; Wenz et al. 1998). The latter compound was previously used for foliar treatment against *Puccinia* spp. and *Septoria* spp., however spray formulation did not provide protection against take-all because of acropetal movement in plant tissues (Wenz et al. 1998; Metcalfe et al. 2000).

The aim of this research work was to estimate the effect of seed treatment fungicides containing siltiofam and fluquinconazole in controlling take-all disease of winter wheat in conditions of Upper Silesia, and to determine its effect on grain yield.

MATERIALS AND METHODS

Experiments were performed in vegetative seasons 1999/2000 and 2000/2001 on the experimental fields of the Branch Institute of Plant Protection (IPP) in Sośnicowice, on leached brown soil, pH 5.2.

Description of experimental conditions is given in table 1. In 2000 winter wheat was grown as fourth wheat and in 2001 as second wheat crop. Experiments were laid out according to randomized block design in 4 replications measuring 20 sq.m. Sowing material was treated with fungicides using laboratory seed treatment

Table 1. Description of experimental conditions

IPP Sośnicowice 2000–2001

Experiment no.	Season	Variety of winter wheat	Previous crop			Date of sowing
			in previous year	2 years earlier	3 years earlier	
1	1999/2000	ROMA	winter wheat	winter wheat	winter wheat	13.10.1999
2		MIKON	winter wheat	winter wheat	winter wheat	10.10.1999
3	2000/2001	KOBRA	winter wheat	corn	rye	28.09.2000
4		MIKON	winter wheat	corn	rye	28.09.2000

equipment type Wencel 1. The following fungicides were used: fluquinconazole (Jockey®FS) at the dose 75.15 g a.i./100 kg seeds, siltiofam (Latitude 125 FS) at the dose 25 g a.i./100 kg seeds, and standard reference product (Baytan Universal 094 FS) at the recommended dose. The occurrence and severity of take-all in the early spring at GS 30–31 was very low on control plots in both years (0.12–1.56 of infected root system), so the results of estimation of seed treatment efficacy would not give reliable results and was not performed. A similar situation occurred in the late spring of 2000 at GS 69; however in 2001 estimation of efficacy of seed treatment at that stage was possible with root infection on control plots 5.61% and 14.19% for experiments 3 and 4 and it was performed. Final estimation of seed treatment effects was performed in both years in the early summer at GS 75–77. One hundred plants were picked at random from experimental plots for analysis. To assure reliability of visual estimation of take-all infected roots were checked under microscope and control isolations were made on agar media.

Per cent of infection of root system was recorded using standard techniques (Hornby et al. 1998). Wheat plants were harvested at the stage of technical ripeness, grain yield and 1000 grain weight were determined. Results of experiments were subjected to statistical analysis at the level of significance P=0.05.

RESULTS AND DISCUSSION

Table 2 illustrates the effect of application of seed treatment with fluquinconazole and siltiofam on severity of take-all. As indicated in the previous chapter, root infection of plants in untreated control in the early spring at GS 30–31 was very low and ranged from 0.12% in 2000 to 1.56% in 2001. Therefore the estimation of effectiveness of seed treatment could not be conclusive.

In the late spring at GS 69 it was only possible to evaluate the effectiveness of the seed treatment products in the year 2001. On control plots per cent of infection of root system in experiment 3 and 4 was low and amounted to 5.61% and 14.19%. Significant differences were obtained for both fluquinconazole and siltiofam as compared to untreated control. In experiment 3 fluquinconazole and siltiofam reduced the infection nearly by half, to 2.27% and 2.29%, respectively. In experiment 4 the infection was reduced by these fungicides from 14.19% to 6.13% and 4.37%, respectively. For both experiments no significant differences were obtained between the efficacy of the two tested preparations. In the case of Baytan Universal 094 FS its positive effect could also be seen, but it proved to be insignificant at that stage of growth.

The effect of seed treatment at GS 75 could be clearly seen in all the experiments performed in both years, although intensity of the disease on control plots was different. The level of infection in those years could be related to experimental conditions. It was much lower than in 2001 at the same stage of growth especially in relation experiment 4, where it reached the value of 39.40%. Low infection of root system in 2000 may be related to late sowing date (13 and 10 October). This may not have been the only cause of low level of infection in experiments 1 and 2 where wheat was in the fourth year of monoculture (Tab. 1), when the decline of take-all is usually observed (Hornby et al. 1998). Late sowing date was shown to be one of

Table 2. Influence of seed treatment on reduction of winter wheat roots infection by *G. graminis* var. *tritici*

IPP Sośnicowice 2000–2001

Experiment no.	Experimental objects	GS 69 root infection [%]	GS 69 % effectiveness*	GS 75 root infection [%]	GS 75 % effectiveness*	GS 75 reduction of infection root [%]
Year 2000						
1	control	**0.95**	–	**8.14 b**	–	**0.00**
	fluquinconazole	–	–	0.89 a	**89.07**	**7.25**
	siltiofam	–	–	0.82 a	**89.93**	**7.32**
	standard product	–	–	9.25 b	–	**-1.11**
LSD (0.05)				6.99		
2	control	–	–	**16.53 c**	–	**0.00**
	fluquinconazole	–	–	4.86 ab	**71.60**	**11.67**
	siltiofam	–	–	2.32 a	**85.96**	**14.21**
	standard product	–	–	12.59 b	**23.83**	**3.94**
LSD (0.05)				9.58		
Year 2001						
3	control	**5.61 b**	–	**16.49 b**	–	**0.00**
	fluquinconazole	2.27 a	**59.63**	5.77 a	**65.01**	**10.72**
	siltiofam	2.29 a	**59.18**	4.37 a	**73.50**	**12.12**
	standard product	4.54 ab	**19.07**	14.04 b	**14.85**	**2.45**
LSD (0.05)		2.65		4.71		
4	control	**14.19 b**	–	**39.40 b**	–	**0.00**
	fluquinconazole	6.13 a	**56.80**	17.74 a	**54.97**	**21.66**
	siltiofam	4.37 a	**69.20**	17.25 a	**56.22**	**22.15**
	standard product	15.57 b	–	31.25 ab	**20.68**	**8.15**
LSD (0.05)		5.32		15.79		

* Efficacy calculated using Abbott's formula
Note: means in columns followed by the same letter do not different at 5% level of significance

the most important factors negatively affecting the primary infection cycle (Colbach et al. 1997). The secondary disease cycle which is mainly related to root-to-root spread is not affected by sowing date (Hornby et al. 1998). Higher infection of roots in the year 2001 as compared to year 2000 is attributed to the fact, that wheat was grown in the second year of monoculture, condition being characterized by increasing infection potential of the pathogen (Hornby et al. 1998). Date of sowing for experiments 3 and 4 were nearly optimal for the region of Upper Silesia. In those experiments root infection at GS 75 on control plots ranged from 16.49% for cv. Kobra (experiment 3) to 39.40% for cv. Mikon (experiment 4). It is believed that the differences obtained with two different varieties were rather related to a different inoculum potential on plots than to varietal characteristics, as no commercial cultivar showing resistance or tolerance is available (Shoeney and

Lucas 1999). Seed treatment with either fluquinconazole or siltiofam was highly effective and differences were statistically significant as compared to control, and insignificant between the two fungicides. In experiment 3 fluquinconazole and siltiofam reduced the infection from 16.49% to 5.77% and 4.47%, respectively. In experiment 4 the infection was reduced by these fungicides from 39.40% to 17.74% and 17.25%. Results of seed treatment with Baytan Universal 094 FS were statistically insignificant, although a slight positive effect on the reduction of infection was noticeable. Triadimenol, which is the principal active ingredient of Baytan Universal 094 FS, has been shown to have a short-term efficacy (Bockus 1983), this was latter confirmed by other authors, and in Polish conditions by Amein (1988). According to Venz et al. (1998) fluquinconazole forms a protection zone around the seed, from which it is taken up into the roots, stems and leaves and its activity is described as long-lasting. It was also shown to be active against *Puccinia* spp. and *Septoria* spp. when used as seed treatment fungicide. This was confirmed in experiment 4 (Tab. 3) where leaf diseases were recorded at GS 32–37 and GS 69. Fluquinconazole significantly reduced the early spring leaf infection by *S. nodorum* and *P. recondita*. The same effect was observed for the reference product and *P. recondita*. Seed treatment fungicides included in experiment 4 did not show appreciable effect on leaf infection by these pathogens at GS 69. Siltiofam was shown to have a long-lasting effect in controlling take-all. Shoeney and Lucas (1999) showed on the basis of experiments conducted during 3 cropping seasons that this active ingredient used as seed treatment provided a significant reduction of severity variables during the whole epidemics, although generally in late growth stage there were as many diseased plants as in untreated plots.

The effectiveness of fungicides was compared using Abbott's formula. It can be seen from table 2 that the effectiveness of both fluquinconazole and siltiofam of controlling take-all decreased with increasing values of root infection. It was the highest in experiment 1 where infection of root system at GS 75 was on control plots only 8.14%. It ranged from 89.07% for fluquinconazole to 89.93 for siltiofam. However, in experiment 4 where the infection level on control plots reached the value of 39.40% the effectiveness was only 54.97% for fluquinconazole and 56.22% for siltiofam. Similar results were obtained by Löchel et al. (1998) and Xiulan et al. (2000).

In spite of low infection of root by *G. graminis* var. *tritici* observed in experiments 1, 2 and 3 in the years 2000 and 2001 a good negative correlation was stated between grain yield and the degree of infection (Tab. 4). The highest correlation coefficient ($r=-0.9977$) was obtained for experiment 4 in 2001 where the infection on control plots reached at GS 75 39.40%, and the lowest ($r=-0.9583$) for the experiment 1 where only 8.14% of root system was infected at that stage of growth. On plots where seeds were treated with fluquinconazole or siltiofam grain yield was always significantly higher as compared to the control (Tab. 5). Similar effects were observed for 1000 grain weight, although in the case of experiment 3 the differences for control plots and fluquinconazole treatment were the smallest. A positive but non-significant effect of seed treatment with reference product Baytan Universal 094 FS could also be seen. The decrease of root infection after seed treatment

Table 3. Influence of seed treatment on infection of winter wheat with foliar pathogens in 2001

IPP Sośnicowice 2000–2001

Experiment no.	Experimental objects	GS 32–37				GS 69							
		Septoria nodorum		*Puccinia recondita*		*Septoria nodorum*		*Puccinia recondita*		***Drechslera tritici-repentis***		*Erysiphe graminis*	
		% leaf infection	% effectiveness*	% leaf infection	% effectiveness*	% leaf infection	% effectiveness*	% leaf infection	% effectiveness*	% leaf infection	% effectiveness*	% leaf infection	% effectiveness*
4	control	**4.33 b**	–	**2.97 b**	–	**0.81 a**	–	**0.31 a**	-	**15.00 a**	–	**13.00 a**	–
	fluquinconazole	1.34 a	**69.05**	0.99 a	**66.64**	0.31 a	**61.54**	0.00 a	**100.00**	12.38 a	–	10.94 a	–
	siltiofam	3.12 ab	**27.94**	2.83 b	–	0.38 a	**53.84**	0.00 a	**100.00**	15.64 a	–	13.94 a	–
	standard product	2.23 ab	**48.56**	0.83 a	**71.86**	0.12 a	**84.62**	0.00 a	**100.00**	13.75 a	–	12.50 a	–
LSD (0.05)		2.525		1.56		**1.19**		**0.50**		**9.72**		**4.64**	

* Efficacy calculated using Abbott's formula
Note: see table 2

Table 4. Correlation coefficients for infection of roots of winter wheat at GS 75 by *G. graminis* var. *tritici* and grain yield

IPP Sośnicowice 2000–2001

Number of compared objects	Experiment 1	Experiment 2	Experiment 3	Experiment 4
4	–0.9583	–0.9852	–0.9976	–0.9977

Table 5. Influence of seed treatment on reduction of winter wheat root infection by *G. graminis* var. *tritici* and on grain yield and weight of one thousand grains

IPP Sośnicowice 2000–2001

Experiment no.	Root infection	Experimental objects	Weight of thousand grains: g	Weight of thousand grains: increase as related to control, g	Weight of thousand grains: increase as related to control, %	Yield of grain: t/ha	Yield of grain: increase as related to control, kg	Yield of grain: increase as related to control, %
Year 2000								
1	very low (0–10%)	control (untreated)	**40.02 a**	0.00	**0.00**	**4.54 a**	0	**0.00**
		fluquinconazole	41.93 b	1.91	**4.77**	4.91 b	370	**8.15**
		siltiofam	41.50 b	1.48	**3.70**	4.93 b	390	**8.59**
		standard product	40.26 a	0.24	**0.60**	4.63 a	90	**1.98**
LSD (0.05)			0.94			0.26		
2	low (11–20%)	control (untreated)	**29.40 a**	0.00	**0.00**	**6.10 a**	0	**0.00**
		fluquinconazole	30.90 b	1.50	**5.10**	6.83 c	730	**11.97**
		siltiofam	31.02 b	1.62	**5.51**	6.91 c	810	**13.28**
		standard product	30.37 ab	0.97	**3.30**	6.46 b	360	**5.90**
LSD (0.05)			1.12			0.27		
Year 2001								
3	low (11–20%)	control (untreated)	**37.45 a**	0.00	**0.00**	**4.49 a**	0	**0.00**
		fluquinconazole	38.70 ab	1.25	**3.34**	4.95 bc	460	**10.24**
		siltiofam	39.02 b	1.57	**4.19**	5.05 c	560	**12.47**
		standard product	37.87 ab	0.42	**1.12**	4.62 ab	130	**2.89**
LSD (0.05)			1.27			0.42		
4	medium (21–40%)	control (untreated)	**37.17 a**	0.00	**0.00**	**4.13 a**	0	**0.00**
		fluquinconazole	39.77 b	2.60	**6.99**	5.02 b	89	**21.55**
		siltiofam	39.50 b	2.33	**6.27**	5.07 b	94	**22.76**
		standard product	37.23 a	0.06	**0.16**	4.41 ab	28	**6.78**
LSD (0.05)			1.19			0.84		

Note: see table 2

with fluquinconazole and siltiofam caused the increase of grain yield by 8.15 to 22.70% and of 1000 grain weight by 3.34 and 6.99%. The increases of grain yield were the highest in experiment 4 where the infection on control plots reached the highest value (39.40%). Similar results were obtained by Beale et al. (1998). They also stated that increases of grain yield for seed treatment with siltiofam were higher as infection of roots increased on control plots. Literature data suggest that the decrease of grain yield caused by take-all is proportional to the percentage of infected plants and the degree of infection (Huber 1981). Correlation of root infection by *G. graminis* and grain yield was stated in the early research work (Clarkson et al. 1981) and confirmed in later trials (Hornby et al. 1998). In our experiments the reduction of root infection by 1% caused around 1% grain yield increase (Tab. 5).

CONCLUSIONS

1. Two novel seed treatment fungicides containing siltiofam and fluquinconazole significantly reduced root infection of winter wheat by *G. graminis* var. *tritici* at low and moderate levels of the disease.
2. The effectiveness in controlling take-all disease with the novel seed treatment fungicides decreased with increasing values of root infection.
3. Treatment of winter wheat seeds with siltiofam and fluquinconazole characterized by long-lasting activity enable to obtain significant increases of grain yield and one thousand grain weight, which are proportional to the decrease of root infection by *G. graminis* var. *tritici.*

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POLISH SUMMARY

EFEKTYWNOŚĆ ZWALCZANIA ZGORZELI PODSTAWY ŹDŹBŁA ZA POMOCĄ ZABIEGU ZAPRAWIANIA ZIARNA SIEWNEGO PRZY RÓŻNYCH POZIOMACH PORAŻENIA ROŚLIN

W latach 2000 i 2001 oceniano skuteczność działania zapraw nasiennych przy różnych poziomach porażenia korzeni przez grzyb *Gaeumannomyces graminis*. Ziarno pszenicy ozimej było zaprawiane fungicydami siltiofamem, fluchinconazolem oraz jedną ze standardowych zapraw dostępnych na rynku. Przy niskim poziomie porażenia korzeni siltiofam i fluchinconazol redukowały to porażenie przez grzyb *G. graminis* var. *tritici* o 73–89% i 65–89%. Przy średnim poziomie zakażania skuteczność działania zapraw wynosiła 56 i 54%. Zaprawa standardowa wykazała jedynie ograniczające działanie. Redukcja porażenia korzeni pszenicy ozimej przez grzyb *G. graminis* var. *tritici* o 1% powodowała wzrost plonu ziarna o około 1%.