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VIRULENCE FREQUENCY OF *BLUMERIA GRAMINIS* F. SP. *HORDEI* AND THE OCCURRENCE OF POWDERY MILDEW ON FOUR WINTER BARLEY CULTIVARS

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Abstract: Powdery mildew caused by *Blumeria graminis* f. sp. *hordei* is one of the most important diseases of barley in Poland. *B. graminis* is a genetically diverse pathogen with different special forms and races. The aim of the two-years' experiment was to assess of *B. gramins* f. sp. *hordei* virulence frequency and powdery mildew occurrence on four winter barley cultivars. Virulence frequency of the pathogen depended on place and term of exposition. The occurrence of powdery mildew on four winter barley cultivars depended on virulence frequency of the pathogen and weather conditions.

Key words: *B. graminis* f. sp. *hordei*, winter barley

INTRODUCTION

Barley, after wheat, rye and triticale is one of the important cereal crops grown in Poland (about 12% of total cereal growing area). Spring barley is more popular however winter barley thanks to its advantages like short vegetation period and feeding value is also common, especially in small farms.

Except unfavourable meteorological or soil conditions in many cases yield losses are caused by fungal diseases and pests. Powdery mildew caused by *Blumeria graminis* f. sp. *hordei* is one of the most important disease of barley in Poland. Usually winter barley is more seriously affected than spring barley. *B. graminis* is a genetically diverse pathogen with different special forms and races. Within *B. gramins* f. sp. *hordei* many races can be distingushed. Some of them disappear for instance as a consequence of resistant barley cultivars' introduction and other races appear which are able to infect new barley cultivars (Czembor and Czembor 1998, 1999, 2001, 2005; Gacek et al. 2004).

In the countries where powdery mildew is a problem, including Poland, yield losses may exceed 50%, although average losses are smaller and can reach about

10–20%. Yield reduction is due to loss of functional green leaf area, reduced kernel weight, smaller numbers of kernels per ear and tillers per plant. Reduction in quality characteristics is important for malting barley. There are several ways of controlling the disease. The primary one is the use of genetically mildew-resistant varieties. This is cheap and environmentally safe method. Powdery mildew can be also controlled with fungicides but these are ecologically undesirable and on the other hand their frequent use may speed up the evolution towards resistance to fungicides. In agricultural practice, integrated control is often applied – cultivation of several more or less resistant cultivars, sometimes in mixtures, and supplemented by fungicides as required. The efficacy of using of resistant cultivars depends on pathogen virulence (Helms Jørgensen 1994; Czembor and Czembor 2005; Gacek et al. 2004).

The aim of the research work was assessing of *B. gramins* f. sp. *hordei* virulence frequency and the powdery mildew occurrence on four winter barley cultivars.

MATERIALS AND METHODS

In the growing seasons 2003/2004–2004/2005, experiments in two places (Bąków and Słupia Wlk.) on evaluation of *B. graminis* f. sp. *hordei* virulence frequency were done. In the experiment 25 near-isogenic lines of the spring barley cultivar Pallas (Table 2) were used as test plants for virulence frequency studies. One- to two- leaf seedlings of near-isogenic lines were exposed to infection for about one week in the field near by plots where four winter barley cultivars (Bombay, Gil, Gregor, Bażant) were grown (Table 1). After incubation for 10 days mildew colonies were counted on the seedlings. The number of colonies per plant was expressed as per cent on the standard (Pallas). During every vegetation season four expositions (terms 1–4) were done (September/October 2003, end of April 2004, April/May 2004, end of May 2004, October 2004, end of April 2005, beginning of May 2005, end of May 2005). Powdery mildew incidence on four winter barley varieties was evaluated using 1–9 scale (where 9 – fully resistant, 1 – fully susceptible). These scores were transformed to percentage of whole plant infection data then the area under the disease progress curve (AUDPC) was calculated (Finckh et al. 1999; Finckh and Wolfe 1997; Shaner and Finney 1977; Woźniak-Strzembicka and Nadziak 2001).

Table 1. Characteristics of winter barley cultivarss (Najewski 2005)

Cultivar	Resistance against *B. graminis*			Corresponding virulence of *B. graminis*
	level[1]	source of resistance	genes	
Bombay	7.7	Ar+Ra	*Mla12* + *Mlra*	Va12, Vra
Gil	7.3	Ru+La	*Mla13* + *Mla*(*La*)	Va13, V(La)
Gregor	8.0	Bo+un	*Ml*(*Bw*) +?	V(Bw)
Bażant	8.1	Hetero-genic	*Ml*(*Bw*) +?	V(Bw)

[1] data from Research Centre for Cultivar Testing Słupia Wlk. using 1–9 scale (1 – fully susceptible, 9 – fully resistant)

Table 2. Resistance characteristics of near-isogenic Pallas lines (Brown i Helms Jørgensen 1991; Helms Jørgensen 1994)

No.	Near-isogenic line Pallas	Resistance genes	Resistance	Corresponding virulence of *B. graminis*
1.	P 01	*Mla1*	Al (Algierian)	Va1
2.	P 02	*Mla3*	Ri (Ricardo)	Va3
3.	P 03	*Mla6, Mla14*	Sp (Spontaneum)	Va6+Va14
4.	P 04A	*Mla7, Mlk, +?*	Ly (Lyallpur), Kw (Kwan)	Va7+Vk
5.	P 04B	*Mla7, +?*	Ly (Lyallpur)	Va7
6.	P 06	*Mla7, Ml(LG2)*	Ly (Lyallpur), LG (Long Glumes)/Iso 26R	Va7+VLG2
7.	P 07	*Mla9, Mlk*	MC (Monte Christo), Kw (Kwan)	Va9+Vk
8.	P 08A	*Mla9, Mlk*	MC (Monte Christo), Kw (Kwan)	Va9+Vk
9.	P 08B	*Mla9*	MC (Monte Christo)	Va9
10.	P 09	*Mla10, Ml(Du2)*	Du (Durani)	Va10+VDu2
11.	P 10	*Mla12*	Ar (Arabische)	Va12
12.	P 11	*Mla13, Ml(Ru3)*	Ru (Rupee)	Va13+VRu3
13.	P 12	*Mla22*	HOR 1657	Va22
14.	P 13	*Mla23*	HOR 1402	Va23
15.	P 14	*Mlra*	Ra (Ragusa)	Vra
16.	P 15	*Ml(Ru2)*	Ru (Rupee)	Va13
17.	P 17	*Mlk*	Kw (Kwan)	Vk
18.	P 18	*Mlnn*	Nigrinudum	Vnn
19.	P 19	*Mlp*	Psaknon	Vp
20.	P 20	*Mlat*	Atlas	Vat
21.	P 21	*Mlg, Ml(CP)*	Goldfoil, We (Weihenstephan)	Vg+VCP
22.	P 22	*mlo5*	Mlo	Vo
23.	P 23	*Ml(La)*	La (Laevigatum)	V(La)
24.	P 24	*Mlh*	Hanna	Vh
25.	Pallas-standard	*Mla8*	Heils Hanna	Va8

The obtained results were statistically evaluated. In order to asses differences between near-isogenic lines of Pallas, places and years analysis of variance was performed, then to choose near-isogenic lines with the highest and lowest powdery mildew incidence the multiple comparisons of the means for lines using the test based on LSD (least significant difference) was done.

Weather conditions were more favourable for powdery mildew occurrence in Bąków than in Słupia Wlk. Precipitation and temperatures were usually higher in Bąków than in Słupia Wlk.

RESULTS AND DISCUSSION

The obtained results from the experiments with *B. graminis* f. sp. *hordei* virulence frequency show that in *B. gramins* population there are genotypes able to affect all tested plants representing different sources of powdery mildew resistance. In terms of the autumn and last spring expositions there were significant differences only between near-isogenic lines. In other expositions interactions were observed, namely in term 3 – interaction between Pallas lines and places, in term 2 and 3 – interactions between Pallas lines and years (Table 3). Pallas lines with the highest and lowest incidence of powdery mildew are shown in Table 4.

Table 3. The results of analysis of variance for near-isogenic Pallas lines exposition (values of mean squares)

Term of exposition [1]	Source of variance			
	Pallas line	Pallas line x Place	Pallas line x Year	Error
1	8665**	2490	1678	2130
2	6729**	1357	1982**	986
3	10321**	1971**	2453**	885
4	10072**	1393	1899	1360

[1] term 1 – autumn expositions, term 2 – 4 spring expositions (average for years and places)
* significant differences, $\alpha = 0.05$
** significant differences, $\alpha = 0.01$

In the autumn exposition (Fig. 1, 2, Table 4) highest virulence was noticed in relation to two lines (P14, P15) with resistance genes *Mlra* and *Ml*(*Ru2*) and corresponding frequency Vra and Va13. A low powdery mildew frequency was observed in relation to 9 lines (P06, P07, P08A, P08B, P12, P13, P18, P19, P20) with resistance sources: Lyallpur+Long Glumes, Monte Christo+Kwan, Monte Christo, HOR 1657, HOR 1402, Nigrinudum, Psaknon, Atlas and Mlo. On the base of obtained results it can said that in the autumn expositions there were noticed Va7+VLG2, Va9+Vk, Va9, Va22, Va23, Vnn, Vp, Vat and Vo low virulence.

In first spring exposition 2004 (Fig. 3) at Bąków in relation to 6 and at Słupia Wlk. in relation to 4 lines high virulence frequency was noticed. At both places no virulence in relation to line P13 was observed. In first spring exposition 2005 (Fig. 4) high virulence in relation to 10 (Bąków) and 8 (Słupia Wlk.) lines was observed.

In term 3 of 2004 (Table 4, Fig. 5) at Bąków in relation to 16 and at Słupia Wlk. in relation to 11 lines high virulence frequency was noticed. In the same spring exposition in 2005 (Fig. 6) at both places lowest or no virulence in relation to lines P13 and P22 was noticed.

In last spring exposition 2004 (Fig. 7) at Bąków in relation to 10 and at Słupia Wlk. in relation to 7 lines virulence frequency was noticed. Again at both places no virulence or low virulence in relation to lines P13 and P22 was observed. In term 42005 (Fig. 8) high virulence in relation to 6 (Bąków) and 4 (Słupia Wlk.) lines was observed.

Table 4. Highest (b) and lowest (a) values of powdery mildew *Blumeria graminis* f. sp. *hordei* incidence on Pallas lines in terms of expositions (2003/04 and 2004/05)

Pallas line	Virulence frequency values							
	Term 1 (average for years and places)	Term 2		Term 3				Term 4 (average for years and places)
		2004 (average for places)	2005 (average for places)	2004 Bąków	2004 Słupia Wlk.	2005 Bąków	2005 Słupia Wlk.	
P 01	45.2	36.8	68.5	43.3 a	99.3	36.7 a	54.3	42.2
P 02	58.5	44.7	66.5	60.0 b	97.0	26.7 a	56.3	58.3
P 03	69.9	70.8	99.7 b	93.3 b	114.0 b	73.3 b	64.3	79.7
P 04A	54.9	44.7	75.3 b	53.3 b	103.7	53.3	84.7	58.3
P 04B	47.4	77.0 b	95.0 b	80.0 b	95.0	66.7 b	105.0	88.5 b
P 06	26.5 a	47.7	82.7 b	50.0 b	88.3	53.3	60.0	75.1
P 07	32.7 a	16.2 a	34.5 a	13.3 a	21.7 a	40.0 a	25.0 a	31.4
P 08A	23.7 a	20.7 a	43.0	20.0 a	27.0 a	33.3 a	38.0 a	33.1
P 08B	30.2 a	28.8 a	56.5	10.0 a	21.7 a	50.0	40.0 a	45.4
P 09	54.1	52.7	65.3	76.7 b	64.0	53.3	102.3	86.7 b
P 10	71.8	64.7	108.0 b	90.0 b	63.0	83.3 b	112.0	104.7 b
P 11	70.9	61.3	105.2 b	66.7 b	62.0	90.0 b	156.0 b	113.2 b
P 12	41.2 a	45.3	91.0 b	50.0 b	22.3 a	40.0 a	51.7	53.4
P 13	11.3 a	0.0 a	82.2 b	0.0 a	10.7 a	0.0 a	7.0 a	8.3 a
P 14	94.9 b	108.5 b	65.0	86.7 b	102.7	96.7 b	79.7	86.7 b
P 15	121.5 b	101.5 b	66.7	70.0 b	78.7	96.7 b	109.3	92.5 b
P 17	51.7	69.7	64.5	60.0 b	87.0	96.7 b	95.7	75.0
P 18	40.1 a	63.5	78.3 b	50.0 b	47.7 a	90.0 b	106.7	69.2
P 19	7.0 a	58.8	72.3 b	11.7 a	48.7 a	30.0 a	67.0	46.2
P 20	34.3 a	67.3	83.5 b	50.0 b	81.0	70.0 b	77.0	48.3
P 21	47.5	95.5 b	95.8 b	53.3 b	24.3 a	100.0 b	113.0	74.7
P 22	13.2 a	5.0 a	2.3 a	46.7 a	16.3 a	0.0 a	1.7 a	0.2 a
P 23	69.2	87.8 b	103.0 b	0.0 a	161.0 b	103.3 b	164.0 b	59.4
P 24	74.4	72.3	106.7 b	76.7 b	140.3 b	113.3 b	126.0 b	101.2 b

a – lowest incidence of powdery mildew without significant differences
b – highest incidence of powdery mildew without significant differences

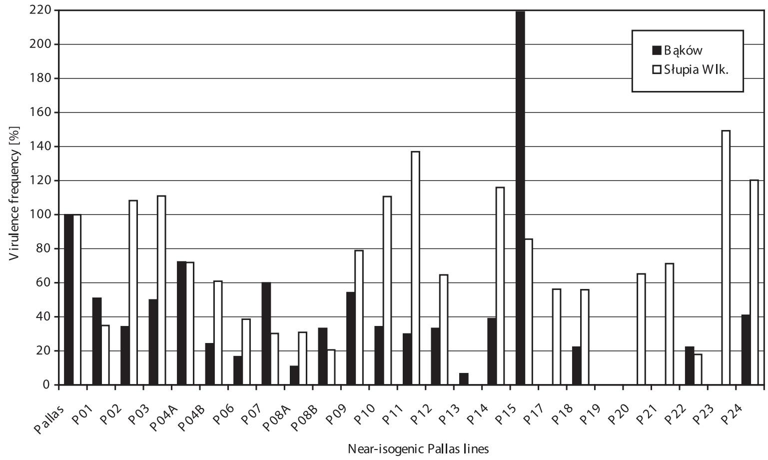

Fig. 1. Powdery mildew (*B. graminis* f. sp. *hordei*) virulence frequency in September/October 2003

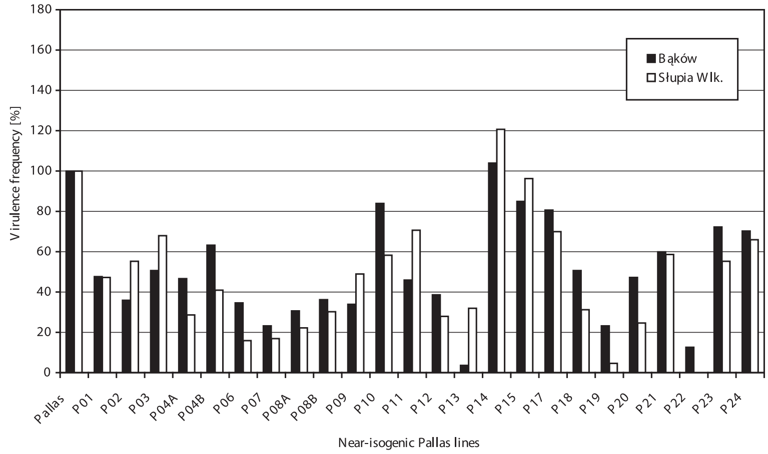

Fig. 2. Powdery mildew (*B. graminis* f. sp. *hordei*) virulence frequency in October 2004

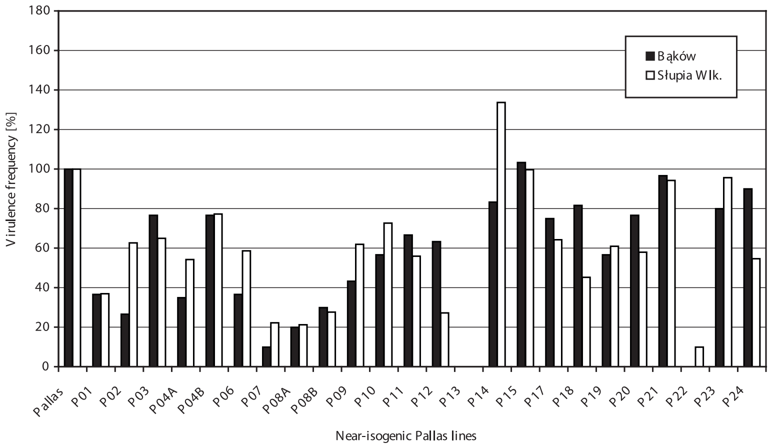

Fig. 3. Powdery mildew (*B. graminis* f. sp. *hordei*) virulence frequency in the end of April 2004

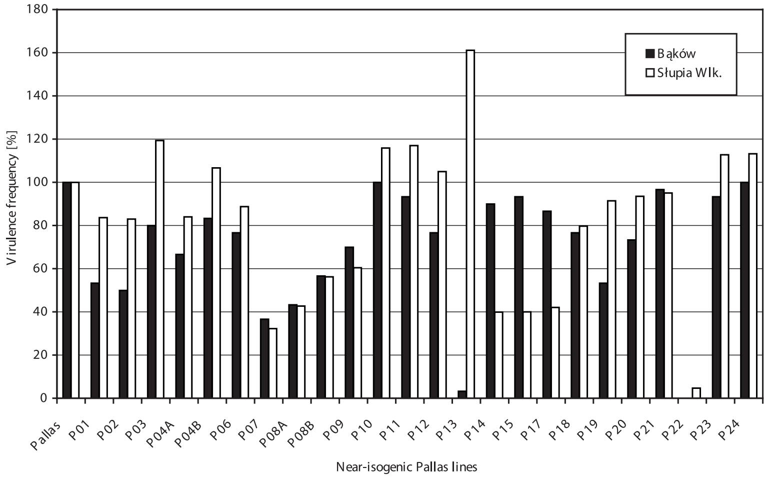

Fig. 4. Powdery mildew (*B. graminis* f. sp. *hordei*) in the end of April 2005

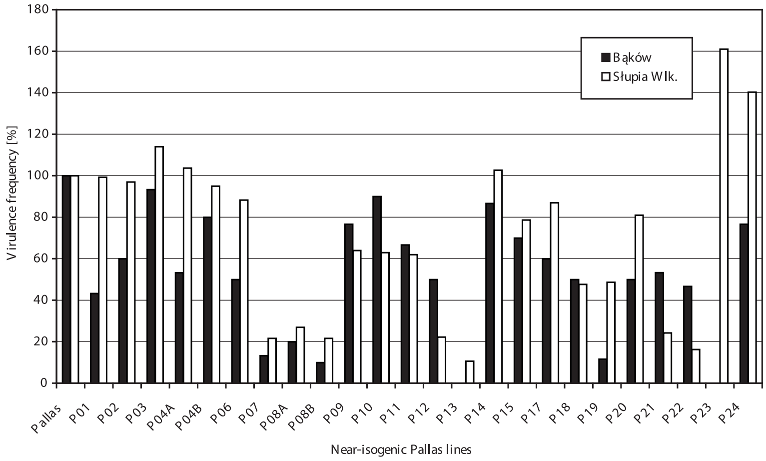

Fig. 5. Powdery mildew (*B. graminis* f. sp. *hordei*) virulence frequency in April/May 2004

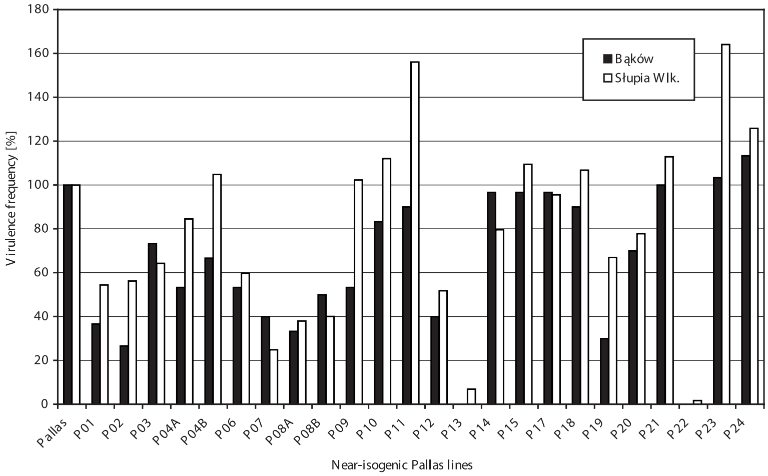

Fig. 6. Powdery mildew (*B. graminis* f. sp. *hordei*) virulence frequency at the beggining of May 2005

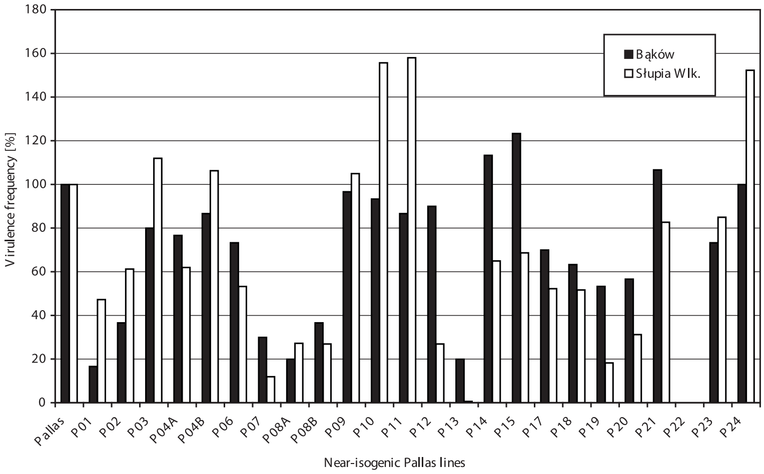

Fig. 7. Powdery mildew (*B. graminis* f. sp. *hordei*) virulence frequency in the end of May 2004

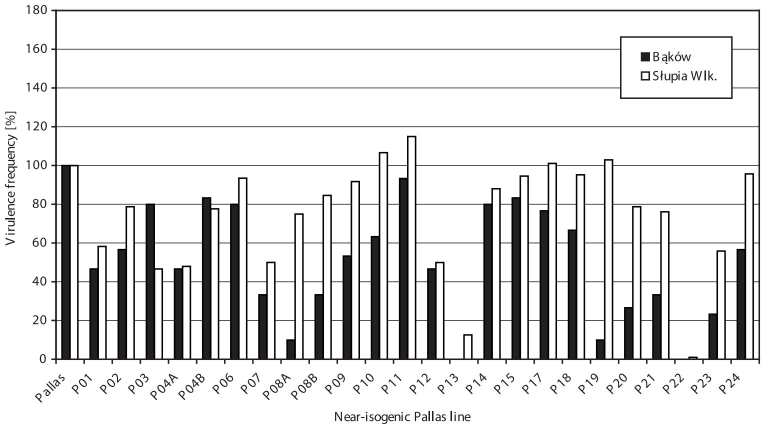

Fig. 8. Powdery mildew (*B. graminis* f. sp. *hordei*) virulence frequency in the end of May 2005

In conclusion, during three spring expositions (Figs 3–8, Table 4) high virulence was noticed in relation to seven lines (P04B, P10, P11, P14, P15, P23, P24) with resistance Lyallpur, Arabische, Ragusa, Rupee, Laevigatum and Hanna – corresponding frequency Va7, Va12, Va13+vRu3, Vra, Va13, V(La) and Vh. Low powdery mildew frequency was observed in relation to 3 lines with resistance sources Monte Christo+Kwan, HOR 1402 and *Mlo* – corresponding virulence Va9+Vk, Va23 and Vo.

Similar results, especially with low frequency virulence in relation to resistance *Mlo* (corresponding virulence Vo) were obtained by other researchers (Czembor and Czembor 2005; Gacek et al. 2004)

In the experiment due to diverse meteorological conditions some differences in powdery mildew incidence on winter barley cultivars were observed (Table 5).

In the vegetation seasons 2003/2004 and 2004/2005, at Bąków Bombay and Gil were most severely infected by powdery mildew, cultivar Bombay with resistance genes *Mla12+Mlra* (Arabische+Ragusa) and variety Gil with resistance genes *Mla13+Ml*(*La*) (Rupee+Laevigatum). At Słupia Wlk. in the first growing season cultivar Bombay was most severely infected whereas in 2004/2005 Gil was most severely infected by *B. graminis*

f. sp. *hordei* (Table 5). According to "*gen for* gen" Flor theory (Flor 1956) cultivar Bombay can be infected by powdery mildew races corresponding to Ar and Ra resistance. On the base of two years' experiment it can be said that results obtained from field observations are similar to results obtained from near-isogenic Pallas lines expositions. High virulence was observed in relation to lines with the same resistance as cultivars Bombay and Gil.

Table 5. Powdery mildew incidence according to AUDPC on winter barley cultivars in vegetation season 2003/04 and 2004/05

Year	Place	Cultivars/AUDPC			
		Bombay	Gil	Gregor	Bażant
2003/04	Bąków	349.0	481.7	82.1	101.5
	Słupia Wlk.	236.4	133.3	134.1	143.7
2004/05	Bąków	924.3	1495.4	610.9	674.1
	Słupia Wlk.	185.0	305.8	263.2	164.4

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POLISH SUMMARY

OCENA FREKWENCJI WIRULENCJI *BLUMERIA GRAMINIS* F. SP. *HORDEI* ORAZ NASIELNIA WYSTĘPOWANIA MĄCZNIAKA PRAWDZIWEGO NA CZTERECH ODMIANACH JĘCZMIWENIA OZIMEGO

Mączniak prawdziwy (*B. graminis* f.sp. *hordei*) jest jedną z najgroźniejszych chorób grzybowych występujących na jęczmieniu ozimym w Polsce. Patogen charakteryzuje się dużym zróżnicowaniem form specjalnych oraz ras fizjologicznych.

Celem przeprowadzonych badań była próba oceny frekwencji wirulencji w populacji *B. graminis* f. sp. *hordei* występującej w latach 2003/2004 i 2004/2005.

Doświadczenie zostały przeprowadzone w ciągu dwóch sezonów wegetacyjnych w dwóch miejscowościach (Bąków i Słupia Wlk.). Przedmiotem badan były izogeniczne linie odmiany Pallas oraz cztery odmiany jęczmienia ozimego (Bombay, Gil, Gregor, Bażant). Frekwencja wirulencji patogena zależała od miejscowości i terminu ekspozycji. Występowanie mączniaka prawdziwego na czterech odmianach jęczmienia ozimego zależało od frekwencji wirulencji patogena i warunków pogodowych.