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THE INFLUENCE OF PATHOGENIC FUNGI AND WEATHER CONDITIONS ON WINTER WHEAT YIELD

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Abstract: The investigations were carried out in 1996–2005 on the fields of Agricultural Experimental Station Department of SGGW Chylice in Mazowieckie voivodeship. The occurrence of diseases was assessed in 1996–2000 on winter wheat cv. Kobra, and in 2001–2005 on cv. Mikon. Weather conditions in ten-year experimental period were differentiated and had a distinct influence on plant infection by pathogens, as well as on the level of winter wheat yielding. In the first part of experimental period (1996–2000) the weather was characterized by higher temperatures compared to long-term average and higher amount of rainfall, with the exception of the year 2000 when the summer drought occurred. The highest for that period grain yield (54.70 dt/ha) was obtained in 1998. This was related to the lowest total infection of leaf surface area (22.76%) and a relatively low index of infection of stem base by *Tapesia yallundae*. In that year mass of 1 000 grain was also the highest. The lowest grain yield (40.80 dt/ha) was recorded in 2000 due to summer drought. In 1997 characterized by a high level of infection by *T. yallundae* (eyespot) obtained grain yield was also relatively low. In the second part of the experiment conducted on cv. Mikon (2001–2005) the lowest grain yield was recorded in 2001 (28.85 dt/ha) when per cent of leaf area infection of 2 upper leaves by *Puccinia recondita* (brown rust) was very high (44.79%), and the highest yield was obtained in 2003 (57.27 dt/ha). This was due to a moderate level of total leaf infection (30.21%) with fungal pathogens and favourable weather conditions for wheat development. In that year mass of 1 000 grain was also the highest. The occurrence of stem base infection by *Fusarium* spp. was maintained in the years 1996–2005 on differentiated level and it was lower in earlier years compared to the later period. The infection of ears by *Leptosphaeria nodorum* and *Fusarium* spp. was usually not high and its influence on the amount of grain yield not clearly evident. Chemical control of diseases influenced grain yield increase which was the highest in 2001 when winter wheat leaves were heavily infected by *Puccinia recondita*. The yield increase on fungicide treated plots was in that year 53.15%. It was evident that brown rust may pose a serious threat to winter wheat in the years of its high occurrence.

Key words: winter wheat, weather conditions, fungal diseases, grain yield

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INTRODUCTION

In the period of last 40 years (1961–2000) cultivation area of wheat in the world increased by around 5%, grain yield was higher by 117% and global production of grain increased by around 130%.

At the same time in Poland cultivation area of wheat increased by 63%, productiveness per ha by above 70% and total grain production by around 190%. The increase of grain yield at that time was possible owing to interdisciplinary achievements in the field of breeding of new varieties, progress in the application of mineral fertilizers as well as plant protection products, and also the possibilities of application of improved techniques in soil cultivation, efficient harvest, satisfactory grain cleaning and storage. At present in Poland cereals are cultivated on the area of over 8 million ha. Wheat occupies around 30% of this area and its average yield amounts to 40 dt/ha (Gąsiorowski 2004). Apart of the amount of yield particular attention is attributed to its quality. To obtain the yield of a good quality it is essential: choosing of a cultivar suitable for a given environment, type of soil indicated for wheat cultivation as well as an appropriate preceding crop. Mineral fertilization, optimal sowing rate and date, weed and lodging control, protection against diseases and conditions of harvest and storage are also important. In case of wheat production for milling purposes especially important is full protection against diseases assuring high quality of grain parameters (Podolska and Hołubowicz-Kliza 2005). The research work was conducted in the Experimental Station of Plant Protection Institute in Grodzisk Mazowiecki, on the fields of Agricultural Experimental Department of SGGW Chylice, Mazowieckie voivodeship. The aim of the study was to determine relationships between the occurrence and severity of fungal diseases on 2 varieties of winter wheat (Mikon and Kobra), environmental conditions, and the amount of grain yield as well as its quality.

MATERIALS AND METHODS

The experiments were performed using randomized block design in 4 replications on plots measuring 25 m^2, on winter wheat cv. Kobra (1996–2000) and cv. Mikon (2001–2005). The experiments comprised a continuation of a long-term study on the influence of different factors, mainly the severity of fungal diseases on the amount and quality of yield (Jaczewska-Kalicka 2002, 2004, 2005). Winter wheat was cultivated on black soils class III, after cereal preceding crops. Agricultural measures were carried out according to the conventional agricultural system. The source of infection with fungal pathogens was present in ambient environment. In order to provide protection against disease development 2 treatments with fungicides were performed: at growth stage of shooting (BBCH 30–31) and at growth stage of earing (BBCH 51–55). Fungicides with a broad spectrum of activity were used: triazoles, benzimidazoles, strobilurine, oxazolines and morpholines. Control treatment consisted of untreated with fungicides plots.

In each vegetative season the development of diseases on leaves, ears and stem bases was recorded at 2 assessment dates.

In the presented tables are given results obtained at the time of maximum disease development on examined organs. The assessment of leaf diseases was done at full earing (BBCH 55) and milky ripe (BBCH 75) stages. Per cent of infected flag and

second leaf area was recorded. Also per cent of ear area infection was assessed at the stage of milky ripe (BBCH 75). The healthiness of stem base was determined at full earing (BBCH 55) and full grain maturity (BBCH 92) using Scott and Hollins index (1974). The assessment of pathogens were based on the presence of typical disease symptoms and microscopic examination of experimental material. After harvest with plot combine values of grain yield from each plot were converted to dt/ha and 15% of moisture. Description of weather conditions was based on data obtained from the local meteorological station Ekomet. Obtained results were analysed using analysis of variance and significance of differences was verified by T-Student test.

RESULTS AND DISCUSSION

In the period of investigations carried out on winter wheat cv. Kobra (1996–2000), in the vegetative seasons 1995/1996–1998/1999 were characterized by rainfall considerably exceeding long-term yearly norm (519.0 mm). The exception was the vegetative season 1999/2000 which was similar to the normal, however it was dry at the end of the season. In total, for the whole experimental period the amount of rainfall was higher by 16% compared to long-term average, and in the months April–July by 28.5%. Air temperatures in this period were quite differentiated. The season 1995/1996 was the coolest because of the winter which lasted 4 months. Average air temperature (7.3°C) was lower compared to long-term average (8.0°C). In the next vegetative season (1996/1997) frosts occurred in December and January; the remaining winter periods were milder. In the spring–summer period (April–July) of the years 1996–2000 air temperatures exceeded long-term average (Tables 1, 3, 5).

Table 1. Temperature at the RZD SGGW Chylice from 1995/1996 to 1999/2000 cropping seasons compared with long-term averages

Month	Average temperature [°C]					
	1971–2000 mean	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000
September	13.0	13.9	10.6	14.2	14.4	17.1
October	8.1	11.2	9.9	7.0	9.5	8.8
November	2.8	0.1	6.7	3.6	–1.7	1.3
December	–0.4	–5.0	–4.7	0.8	–2.5	1.1
January	–2.2	–5.4	–4.7	1.3	0.9	–1.5
February	–1.2	–4.7	2.3	3.9	–1.2	2.4
March	2.6	–1.0	3.5	2.4	3.5	3.2
April	7.9	9.4	6.1	11.0	9.8	11.8
May	13.7	15.3	15.0	16.4	12.2	15.1
June	16.5	17.9	18.3	18.6	17.8	17.8
July	18.1	17.0	19.0	18.0	19.6	16.0
August	17.7	19.1	20.1	17.6	18.0	16.9
Mean	8.0	7.3	8.5	9.6	8.4	9.2

Table 2. Temperature at the RZD SGGW Chylice from 2000/2001 to 2004/2005 cropping seasons compared with long – term averages

Month	Average temperature [°C]					
	1971–2000 mean	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005
September	13.0	9.9	12.0	13.3	13.3	12.4
October	8.1	9.2	11.3	6.5	6.2	9.6
November	2.8	4.1	2.7	4.5	4.9	3.3
December	–0.4	1.4	–4.0	–6.2	1.3	1.7
January	–2.2	–0.7	–1.2	–6.0	–5.5	0.7
February	–1.2	–0.8	3.9	–4.7	0.5	–2.9
March	2.6	1.7	4.9	0.9	3.4	0.0
April	7.9	3.1	8.5	6.6	8.9	8.9
May	13.7	11.5	17.4	15.4	11.8	13.2
June	16.5	11.9	17.3	17.5	15.6	17.7
July	18.1	18.4	20.3	19.5	17.3	19.7
August	17.7	19.0	20.1	17.6	17.5	16.9
Mean	8.0	7.4	9.4	7.1	7.9	9.3

Table 3. Rainfall at the RZD SGGW Chylice from 1995/1996 to 1999/2000 cropping seasons compared with long – term averages

Month	Total rainfall [mm]					
	1971–2000 mean	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000
September	48.9	195.0	95.6	15.4	8.5	34.6
October	38.2	17.6	41.0	62.0	62.3	44.2
November	36.5	23.3	32.8	89.6	33.7	14.0
December	34.5	24.1	15.4	30.1	37.5	27.4
January	22.1	12.5	3.1	25.3	20.6	26.1
February	22.0	0.0	29.3	51.5	22.7	34.1
March	28.1	12.1	24.7	37.9	17.8	53.1
April	34.7	22.8	32.7	74.1	74.6	11.5
May	50.7	90.1	86.1	48.1	67.4	12.9
June	41.2	48.4	73.6	114.2	160.8	9.2
July	73.2	100.4	155.7	90.4	33.5	160.1
August	58.9	97.3	24.1	44.1	37.7	55.0
Total	519.0	643.6	614.3	682.8	577.1	492.2

In the next stage of investigations conducted on winter wheat cv. Mikon in the vegetative seasons 2000/2001 to 2004/2005 the amount of rainfall was closer to the norm. The vegetative season 2000/2001 could be regarded as normal, but in the period from April to July it was moist, the season 2001/2002 was normal, however dry at the end of vegetation, the season 2002/2003 was normal with a slight deficit of rainfall in the months April–July, the season 2003/2004 was moist but normal at the end of vegetation, and the season 2004/2005 was normal with rainfall difficiency from April to July. In total, for the whole five-year period of investigations the sum of rainfall was higher by 5.5% as compared to long-term average, and from April to July it was maintained within the norm with a tendency of rainfall deficit. The average air temperature for the whole vegetative periods was lower compared to long-term average in the seasons 2000/2001, 2002/2003 (long and a relatively heavy winter) and the season 2003/2004 and it amounted to 7.4°C, 7.1°C and 7.9°C, respectively. The temperature in the spring-summer period was lower compared to long-term average in the years 2001 and 2004, and higher than long-term average in the years 2002, 2003 and 2005 (Tables 2, 4, 5).

Table 4. Rainfall at the RZD SGGW Chylice from 2000/2001 to 2004/2005 cropping seasons compared with long-term averages

Month	Total rainfall [mm]					
	1971-2000 mean	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005
September	48.9	45.6	70.5	77.8	39.1	21.2
October	38.2	7.1	29.7	72.8	76.1	40.3
November	36.5	55.4	34.8	38.9	30.0	54.8
December	34.5	41.5	28.9	11.0	50.1	21.5
January	22.1	22.6	26.8	26.4	42.2	33.1
February	22.0	25.7	71.5	15.7	65.0	42.4
March	28.1	28.2	42.2	17.3	42.6	49.0
April	34.7	92.5	11.1	32.5	78.7	23.7
May	50.7	21.6	66.4	70.9	38.8	56.6
June	41.2	64.3	71.7	47.3	69.5	39.6
July	73.2	104.3	43.0	68.1	55.2	102.4
August	58.9	27.1	40.4	45.0	40.8	27.9
Total	519.0	535.9	537.0	523.9	628.1	512.5

The varieties Kobra and Mikon belong to the group B (bread wheat) and differ in susceptibility to occurring pathogens. Environmental and climatic conditions have a significant influence on plant condition and the amount and quality of obtained yield. Their effects are closely related to the development of diseases, the level of which reflects direct dependence on weather. In other words, although the amount of rainfall, its distribution in time and temperatures are essential for maintaining plants in a good

condition, intensity of infection by pathogens affects independently and considerably occurring losses by lowering potential grain yield. Thus the analysis of the influence of weather conditions on grain yield was based on its effect on plant healthiness.

Table 5. Rainfall at the RZD SGGW Chylice from 1995/1996–2004/2005 compared with long-term average

Year	Total rainfall		Rainfall April–July	
	[mm]	[%]	[mm]	[%]
1995/1996	643.6	124.0	261.7	113.9
1996/1997	614.3	118.4	348.1	151.5
1997/1998	682.8	131.6	326.9	142.3
1998/1999	577.1	111.2	336.3	146.3
1999/2000	492.2	94.8	203.7	88.6
2000/2001	535.9	103.3	282.7	123.1
2001/2002	537.0	103.5	192.2	83.6
2002/2003	523.9	100.9	218.8	95.2
2003/2004	628.1	121.0	242.2	105.4
2004/2005	512.5	98.6	222.3	96.7
Long-term Average 1971–2000	519.0	100.0	229.8	100.0

In the period of investigations conducted on winter wheat cv. Kobra (1996–2000) at the milky ripe stage (BBCH 75) a recorded level of leaf blade area infection by *Septoria* spp. was in average 15.36% (10.52–18.07%). Every year also powdery mildew (*Blumeria graminis*) was present on leaves at the average level of 8.87% of leaf area infection (4.04–14.79%). Brown rust (*Puccinia recondita*) occurred twice in this five-year period at a moderate severity. In the years 1996 and 2000 the infection level of leaf blades amounted to 14.99% and 19.24%, respectively. The level of infection by *Pyrenophora tritici-repentis*, a causal agent of tan leaf spot, was in average 6.53%. Total infection of leaf area (cv. Kobra) of untreated with fungicides plants was the lowest in 1998 (22.94%) and the highest in 2000 (48.70%).

On winter wheat cv. Mikon (2001–2005) a dominant disease was brown rust. The pathogen (*P. recondita*) appeared every year at varying severity, infecting in average 17.59% of leaf area (0.25–44.79%). Septoria leaf blotch occurred every year, mean leaf area infection amounted to 10.89% (5.64–14.32%). Tan leaf spot was also found every year, mean leaf area infection was 4.91% (2.37–7.34%). Each year but at a lower severity powdery mildew occurred. Mean leaf area infection amounted to 3–4%. The exception was the year 2004 when infection exceeded 7.5% of leaf blade area. In total, in the years of frequent occurrence of brown rust, the infection of cv. Mikon by pathogens was high: 64.32% in 2001 and 59.01% in 2002. However in 2003–2005 when the occurrence of brown rust was very low, total infection of leaf area was much lower and amounted to 24.21%, 19.30% and 20.91%, respectively (Table 6).

Table 6. Fungal diseases occurring on winter wheat leaves of cv. Kobra in 1996–2000 and Mikon in 2001–2005

Year	Objects	Mean % of infected surface of 2 upper leaves ($L_1 + L_2$) at BBCH 75			
		Blumeria graminis	*Puccinia recondita*	*Septoria* spp.	*Pyrenophora tritici-repentis.*
1996	F	2.78 abc	2.52 abc	5.24 abc	0.00
	K	14.79 d	14.99 d	14.66 d	0.00
	LSD (0.05)	0.96	1.24	0.90	
1997	F	0.82 abc	0.00	3.01 abc	0.71 abc
	K	9.23 d	0.00	17.29 d	8.54 d
	LSD (0.05)	0.36		1.34	0.81
1998	F	0.31 a	0.00	0.40 ab	0.75 abc
	K	8.75 b	0.00	10.52 c	3.27 d
	LSD (0.05)	0.80		0.56	0.58
1999	F	0.73 abc	0.00	4.05 abc	1.92 a–d
	K	7.56 d	0.00	18.07 d	11.71 e
	LSD (0.05)	1.47		1.79	1.04
2000	F	0.35 abc	0.26 a	3.25 abc	0.78 abc
	K	4.04 d	19.24 b	16.29 d	9.13 d
	LSD (0.05)	0.25	2.88	1.18	0.76
2001	F	0.36 abc	0.89 ab	1.34 a–d	1.02 abc
	K	3.45 d	44.79 c	10.32 c	5.76 d
	LSD (0.05)	0.37	2.13	0.83	0.44
2002	F	0.26 abc	0.94 ab	0.43 ab	0.05 a
	K	3.38 d	37.13 c	14.32 c	4.18 b
	LSD (0.05)	0.29	1.41	0.62	0.46
2003	F	0.12 a	0.00 a	1.10 ab	0.38 a
	K	3.29 b	2.09 b	13.89 c	4.94 b
	LSD (0.05)	0.49	0.73	1.35	0.65
2004	F	0.00 a	0.00 a	0.57 abc	0.10 ab
	K	7.57 b	3.72 b	5.64 d	2.37 c
	LSD (0.05)	0.17	0.16	0.12	0.65
2005	F	0.29 ab	0.00 a	1.67 ab	0.06 a
	K	3.00 c	0.25 b	10.32 c	7.34 b
	LSD (0.05)	0.30	0.02	1.21	0.46

F – fungicides, K – untreated, BBCH – 75 – milky ripe stage
Values followed by the same letters are not significantly different at the level p = 0.05

On the ears of winter wheat cv. Kobra (1996–2000) at the stage of full maturity (BBCH 92) the fungus *Leptosphaeria nodorum* causing glume blotch was present every year. With the exception of 1997 it was the dominant pathogen. Mean infection of ear area amounted to 9.57% (2.72–19.67%). Powdery mildew occurred every year at varying intensity, infecting from 10.57% of ear area and being the main pathogen in 1997, to 0.69% of ear area in a dry year 2000. Mean recorded infection was 5.21%. Fungi from the genus *Fusarium* occurred at low severity, infecting in average 0.39% of ear area. At the end of vegetative season *Altenaria* and *Cladosporium* fungi appeared on ears. In 1998–2000 they colonized 6.87–25.69% of ear surface.

Ears of winter wheat cv. Mikon (2001–2005), alike those of cv. Kobra were infected at the stage of full maturity (BBCH 95) in the highest degree by *L. nodorum*. The disease was most severe in 2001 and amounted to 23.78% of ear area infection. In 2005 the degree of infection was the lowest and amounted to 4.85% of ear area. The average value for those 5 years of investigation was 10.73%. A second important disease was Fusarium head blight which occurred at different severity, infecting in average 2.47% of ear area, from 0.12% in 2003 to 4.27% in 2001. The infection of winter wheat cv. Mikon was higher compared to cv. Kobra. The ability of toxin production by *Fusarium* spp. which are harmful to human and animals creates the necessity of their efficient control in order to obtain healthy grain of a high quality (Korbas 2006). Powdery mildew occurred every year in five-year period of investigations. Mean ear area infection was 2.16%, from 5.25% in 2001 to 0.59% in 2003. In favourable conditions prior to the harvest, especially at high humidity level, sooty moulds may strongly develop. High severity of ear area colonization by these fungi was noted in 2001 and 2004, 29.43% and 26.85%, respectively. In the years 2002 and 2005 the disease was not observed (Table 7).

At the stage of full maturity (BBCH 92) stem bases of cv. Kobra (1997–2000) were infected by eyespot pathogen (*Tapesia yallundae*). This pathogen occurred at a higher severity in 1997 with infection index of 26.00, and 1999 with infection index of 29.00. For the whole experimental period average infection index was represented by the value of 13.23. Brown foot rot caused by *Fusarium* spp. occurred in this experimental period on 23.60% of stem bases. A relatively high occurrence was recorded in 1998 (37.00% of infected stem bases) and in 1999 (34.00% of infected stem bases). Sharp eyespot caused by *Rhizoctonia* spp. was noted almost each year at low severity. This disease seems to be at present of minor importance.

Winter wheat cv. Mikon (2001–2005) was also infected by stem base pathogens. Eyespot (*T. yallundae*) occurred every year. The highest severity expressed as infection index (29.00) was stated in 2004, and the lowest (4.67) in 2003. In average, infection index for this experimental period was 14.93. Brown foot rot occurred frequently. In the 5-year experimental period mean per cent of infected stem bases amounted to 42.40% and ranged from 54.00% in 2001 to 32.00% in 2004. At lower severity occurred sharp eyespot (*Rhizoctonia* spp.). However this disease was present every year and mean per cent of infected stem bases amounted to 5.50%, ranging from 8.50% in 2001 to 1.00% in 2003 (Table 8). The differences in infection severity on particular plant organs of winter wheat varieties should be related to their biological potential (Zych 2005), but this may be also strongly modified by environmental and weather conditions (Abbate and al. 2004; Eyal 1999; Jaczewska-Kalicka 2002, 2004; Pokacka 1985).

Table 7. Fungal diseases occurring on winter wheat ears of cv. Kobra in 1996–2000 and Mikon in 2001–2005

Year	Objects	Mean % of infected surface of ears at BBCH 92			
		Blumeria graminis	*Leptosphaeria nodorum*	*Fusarium* spp.	*Alternaria* spp. *Cladosporium* spp.
1996	F K LSD (0.05)	0.38 ab 2.48 c 0.18	1.81. ab 7.78 c 0.42	0.07 a 0.21 b 0.08	0.00 0.00
1997	F K LSD (0.05)	1.02 ab 10.56 c 0.24	0.36 abc 7.79 d 0.27	0.00 0.00	0.00 0.00
1998	F K LSD (0.05)	0.24 a 8.70 b 0.61	0.29 ab 9.90 c 0.35	0.40 ab 0.74 c 0.15	6.86 abc 8.50 c 1.56
1999	F K LSD (0.05)	0.55 abd 3.62 d 0.40	2.10 ab 19.69 c 1.83	0.09 a 0.49 b 0.11	1.15 abc 6.87 d 0.51
2000	F K LSD (0.05)	0.18 ab 0.69 c 0.15	0.34 a 2.72 b 0.37	0.07 ab 0.53 c 0.09	7.57 abc 25.69 d 3.62
2001	F K LSD (0.05)	1.20 ab 5.25 c 0.54	4.74 ab 23.78 c 1.24	1.37 a–d 4.27 e 0.38	20.47 a–e 29.43 cd 2.45
2002	F K LSD (0.05)	0.07 ab 1.61 c 0.07	1.04 a–d 7.34 e 0.32	1.91 a–d 3.45 e 0.48	0.00 0.00
2003	F K LSD (0.05)	0.07a 0.59 b 0.15	0.82 ab 4.87 c 0.39	0.01 a 0.12 b 0.05	0.82 abc 3.24 d 0.54
2004	F K LSD (0.05)	0.24 abc 2.05 d 0.09	1.18 ab 12.84 c 0.28	0.11 abc 1.42 d 0.10	11.77 a–d 26.85 e 1.10
2005	F K LSD (0.05)	0.12 a 1.34 b 0.12	0.59 ab 4.85 c 0.22	0.90 ab 3.13 c 0.47	0.00 0.00

F – fungicides, K – untreated, BBCH – 92 – fully ripe stage
Values followed by the same letters are not significantly different at the level p = 0.05

Table 8. Fungal diseases occurring on winter wheat stem bases of cv. Kobra in 1996–2000 and Mikon in 2001–2005

Year	Objects	*Tapesia yallundae* index	Mean % of infected stem bases at BBCH 92	
			Fusarium spp.	*Rhizoctonia* spp.
1996	F K LSD (0.05)	0.53 ab 3.00 b 1.96	8.80. a 20.00 a 14.93	0.00 0.00
1997	F K LSD (0.05)	2.73 a 26.00 b 5.01	0.00 0.00	2.10 a 2.60 a 4.21
1998	F K LSD (0.05)	0.78 ab 4.83 c 1.33	20.00 a 37.00 a 21.15	0.00 0.00
1999	F K LSD (0.05)	1.66 a 29.00 b 8.40	30.00 a 34.00 a 24.37	4.40 a 3.00 a 5.98
2000	F K LSD (0.05)	1.20 ab 3.33 b 1.44	19.00 a 27.00 a 16.92	2.00 a 2.20 a 3.52
2001	F K LSD (0.05)	5.33 a 6.33 a 8.53	21.60 abc 54.00 d 9.68	2.30 ab 8.50 b 5.12
2002	F K LSD (0.05)	5.00 a 18.00 b 5.96	25.00 abc 36.00 d 6.05	2.00 ab 8.00 b 4.49
2003	F K LSD (0.05)	0.40 a 4.67 b 1.56	24.00 a 42.00 b 12.47	0.20 a 1.00 a 1.80
2004	F K LSD (0.05)	2.60 a 29.00 b 7.18	12.20 a 32.00 b 13.64	3.20 ab 5.00 b 3.22
2005	F K LSD (0.05)	2.85 a 16.67 b 8.37	17.80 a 48.00 b 11.09	1.60 ab 5.00 b 3.77

F – fungicides, K – untreated, BBCH – 92 – fully ripe stage
Values followed by the same letters are not significantly different at the level p = 0.05

Complex action of numerous factors influenced the amount of grain yield of winter wheat and its quality as defined by 1000 grain mass. In this study a special attention was paid to weather conditions and intensity of occurrence of fungal diseases in the whole vegetative period of the years 1996–2005. Investigated winter wheat varieties were cultivated every year in similar agrotechnical and soil conditions. Weather conditions and severity of diseases were variable. Both factors are closely related, but each pathogen has definite requirements. In dependence on weather conditions the development of diseases is more or less dynamic.

The influence of weather conditions was most evident in case of eyespot. In periods of relatively severe winters in the seasons 1995/1996 and 2002/2003 characterized by atmospheric precipitation difficiency the lowest levels of infection was recorded. While mild weather conditions in the winter with sufficient atmospheric precipitation favoured the development of eyespot. In the years with greater amount of rainfall from April to July (1996–1999, 2001, 2004) a higher severity of *Blumeria graminis* on leaves and ears, as well as more intense development of *L. nodorum* on ears was recorded. Also the occurrence of sooty moulds (*Alternaria* spp., *Cladosporium* spp.) before harvest was related to greater amount of rainfall (2000, 2001 and 2004). Pathogenic species of *Fusarium* (*F. culmorum, F. avenaceum* or *F. graminearum*) had in most years favourable conditions for their development. In case of stem base infection high severity of eyespot was a limiting factor for wheat productivity (1997, 1999, 2004).

The amount of obtained grain yield and mass of 1000 grain (TGM) of cv. Kobra (1996–2000) was differentiated in successive years. The highest yield from untreated control plots (54.70 dt/ha) was obtained in 1998, and the lowest (40.80 dt/ha) in 2000, when summer drought occurred. On average, grain yield from untreated plots in the period of 5 years was 49.23 dt/ha and on protected with fungicides plots it was higher by 14.89%, and amounted to 56.56 dt/ha. Mass of 1 000 grains (TGM) which is one of qualitative parameters for winter wheat was the highest in 1996 (50.57 g and 52.04 g on unprotected and protected plots), and the lowest in 1999 (35.65 g and 39.06 g) respectively. This was the year with rainfall excess and high severity of Septoria glume blotch and eyespot. The average TGM for the whole experimental period of 5 years was for untreated plots 42.87 g and for treated plots higher by 4.59% and amounted to 44.87 g (Table 9).

Winter wheat cv. Mikon was cultivated in 2001–2005. This was the period of more stabilized weather conditions,especially in the aspect of rainfall. The highest grain yield was obtained in 2003 (57.27 dt/ha). This year was less favourable for the development of some fungal diseases, and especially for brown rust and eyespot. The lowest grain yield (28.85 dt/ha) was obtained on untreated plots in 2001, when a very high severity of brown rust, Septoria glume blotch and brown foot rot was recorded. Average grain yield for untreated plots in that experimental period amounted to 45.54 dt/ha, and for protected plots it was higher by 30% and amounted to 58.28 dt/ha. The differences recorded each year for unprotected and protected plots were always statistically significant. Mass of 1 000 grains was the lowest in 2001 and 2002 and amounted to 34.43 g and 34.18 g, respectively. These were the years of the highest severity of brown rust (44.79% and 37.13% of infected leaf area, respectively). The highest TGM was obtained in 2003 (47.12 g). The average values for that experimental period for unprotected and protected plots amounted to 40.33 g and 44.66 g (the increase by 10.73%), respectively (Table 9).

Table 9. Influence of fungal diseases on grain yield and 1000 grain mass (TGM) of winter wheat cv. Kobra in 1996–2000 and Mikon in 2001–2005

Year	Objects	Yield		TGM	
		[dt/ha]	Increase of yield [%]	[g]	[%]
1996	F K LSD (0.05)	53.16 abc 47.48 d 1.30	111.96 100.00	52.04 abc 50.57 c 1.06	102.70 100.00
1997	F K LSD (0.05)	57.17 abc 50.31 d 0.69	113.,63 100.00	42.08 a–d 41.02 d 0.61	102.58 100.00
1998	F K LSD (0.05)	64.35 a–d 54.70 e 1.25	117.64 100.00	47.96 a 44.91 b 1.53	106.80 100.00
1999	F K LSD (0.05)	64.37 a–d 52.90 e 0.68	121.68 100.00	39.06 abc 35.65 d 0.89	109.56 100.00
2000	F K LSD (0.05)	43.79 a–d 40.80 d 1.14	107.34 100.00	43.08 abc 42.23 c 0.97	102.00 100.00
2001	F K LSD (0.05)	44.18 a–d 28.85 e 0.58	153.15 100.00	42.04 abc 34.43 d 0.66	122.12 100.00
2002	F K LSD (0.05)	61.43 abc 47.95 d 1.20	128.11 100.00	39.27 abc 34.18 d 1.09	114.89 100.00
2003	F K LSD (0.05)	66.37 abc 57.27 d 1.02	115.89 100.00	50.36 a–d 47.12 e 0.70	106.87 100.00
2004	F K LSD (0.05)	60.53 abc 47.95 d 1.39	126.40 100.00	48.01 abc 43.12 d 0.67	111.35 100.00
2005	F K LSD (0.05)	58.93 ab 45.70 c 1.19	128.96 100.00	43.64 abc 42.80 c 0.81	101.96 100.00

F – fungicides, K – untreated
Values followed by the same letters are not significantly different at the level p = 0.05

CONCLUSIONS

On the basis of performed experiments the following conclusions may be drawn. In climatic conditions of Central Poland, Mazowieckie voivodeship, eyespot (*Tapesia yallundae*) is a disease of a primary importance which can considerably lower grain yield of winter wheat, especially after mild winters. Other stem base diseases were in the experimental period of 10 years of less importance, however it should be noted that brown foot rot (*Fusarium* spp.) may create a greater danger in the future as its occurrence was most frequent in the later years of investigations. Of leaf diseases brown rust (*Puccinia recondita*) proved to be the most dangerous disease as in some years (2001, 2002) its severity was high and resulted in significant decrease of grain yield. The analysis of the influence of weather conditions on its occurrence showed this fungus may develop well in differentiated weather. Thus the availability of inoculum may be of essential importance. Of ear diseases, intensity of head blight caused by *Fusarium* spp. was not high in the experimental period, however obtained results showed that the infection was higher in dry seasons. Chemical control of this disease should be recommended in conditions favouring its development because of the ability of toxin production by these fungi. Glume blotch (*Leptosphaeria nodorum*) occurred at higher severity only in some seasons characterized by higher amount of rainfall. Thus future prospects for importance of ear diseases will depend on weather conditions which are hardly predictable on a long-term scale.

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POLISH SUMMARY

WPŁYW GRZYBÓW PATOGENICZNYCH I WARUNKÓW POGODOWYCH NA PLON PSZENICY OZIMEJ

Badania prowadzono w latach 1996–2005 na polach Rolniczego Zakładu Doświadczalnego SGGW Chylice, województwo mazowieckie. Występowanie chorób grzybowych na pszenicy ozimej odmiany Kobra określano w latach 1996–2000, a na odmianie Mikon w latach 2001–2005. Warunki pogodowe w 10-letnim okresie badań były zróżnicowane i miały wyraźny wpływ na porażenie roślin przez patogeny oraz na plon pszenicy. W latach 1996–2000 pogoda charakteryzowała się wyższymi od średniej wieloletniej temperaturami powietrza, oraz większą ilością opadów. Wyjątek stanowi 2000 rok, w którym wystąpiła susza. Najwyższy plon ziarna w kontroli (54,70 dt/ha) uzyskano w 1998 roku. Związane to było z najniższym ogólnym porażeniem powierzchni liści oraz stosunkowo niskim indeksem porażenia źdźbeł przez *Tapesia yalludae*. Najniższy plon (40,80 dt/ha), który wystąpił w 2000 roku był spowodowany suszą.

W okresie prowadzenia doświadczeń na pszenicy ozimej odmiany Mikon (2001–2005) najniższy plon w kontroli (28,85 dt/ha) wystąpił w 2001 roku w efekcie silnego wystąpienia rdzy brunatnej (*Puccinia recondita*). Natomiast najwyższy plon (57,27 dt/ha) uzyskano w 2003 roku, co miało związek z umiarkowanym ogólnym porażeniem liści przez patogeny, oraz warunkami meteorologicznymi sprzyjającymi rozwojowi pszenicy.

Chemiczne zwalczanie grzybów patogenicznych w każdym roku badań przyczyniło się do wzrostu plonu ziarna pszenicy ozimej. Najniższy wzrost plonu – 7,34% wystąpił w 2000 roku charakteryzującym się suszą. Najwyższy wzrost plonu – 53,15% odnotowano w 2001 roku, w którym liście pszenicy ozimej w kombinacji kontrolnej były silnie porażone przez *Puccinia recondita*, czynnik sprawczy rdzy brunatnej. Patogen ten może stanowić poważne zagrożenie w uprawie pszenicy ozimej, w latach sprzyjających silnemu występowaniu choroby.