Resistance of Winter Wheat Varieties Registered in the Czech Republic to Mycotoxin Accumulation in Grain Following Inoculation with *Fusarium culmorum*

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Abstract: Resistance of 35 winter wheat varieties to the accumulation of mycotoxins deoxynivalenol (DON) and zearalenone (ZEA) in grain was evaluated in field trials lasting three years (2004, 2005, 2006) after artificial inoculation with *Fusarium culmorum*. Data on DON and ZEA content were supplemented by symptom scores and determination of % of Fusarium damaged grains and % reductions of thousand grain weight and grain weight per spike due to infection. The conditions of experimental years highly influenced the performance of all characters. The highest production of DON occurred in 2006 at a high temperature and high moisture content during the infection period. Moderate resistance to the accumulation of DON (at the level of Swiss variety Arina) was detected in the varieties Apache, Samanta, Simila and Alana. Another six varieties (Rheia, Banquet, Ludwig, Rapsodia, Dromos and Globus) also showed relatively low average DON content, but a higher fluctuation in experimental years. DON content was positively related to ZEA content and significant correlations were also detected between DON content and the examined disease severity traits. In all years the earlier varieties showed lower DON accumulation than later varieties, but the effects of genotype earliness on the other traits, including ZEA content, were not often significant (not similar under different conditions). The obtained results could help to improve the classification of varieties from these aspects, which is desirable for recommendation on their use in practice and breeding.

Keywords: winter wheat; *Fusarium culmorum*; deoxynivalenol content; zearalenone content; disease severity traits; variety resistance

Fusarium head blight (FHB) belongs to the most harmful diseases, particularly in years with intensive rainfall. In Central Europe, the disease is caused by a complex of *Fusarium graminearum*, *F. culmorum* and some other species of minor importance. The fungus reduces grain yield substantially and affects grain quality. The mycotoxin contamination of human food and animal feed became a more important feature than the direct yield losses that often occur irregularly. Many mycotoxins are produced in culture, and the most important are trichothecenes (which include deoxynivalenol – DON, also known as vomitoxin, nivalenol – NIV, HT-2 and T-2 toxins), zearalenone (ZEA) and fumonisins (Edwards 2004). In the conditions of Central Europe DON is also reported to be the most frequent toxin reaching the highest concentration levels (Golinski *et al.* 1996). ZEA usually occurs in much lower concentrations, but it can be more toxic to humans and animals

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than DON, showing predominantly oestrogenic properties that are manifested especially in the form of hyperoestrogenism in female swine, cattle and sheep, causing severe reproductive problems (Kuiper-Goodman *et al.* 1987). Intensive discussions were carried out in EC bodies to set the limit values of Fusarium mycotoxins, and currently (since 1 July 2006) the respective limit values for DON and ZEA in unprocessed cereals are 1250 µg/kg and 100 µg/kg.

There is enough evidence that currently grown wheat varieties, fungicide applications and other protective precautions cannot separately guarantee sufficient protection against the disease. From practical aspects the "double protection" (consisting in growing less susceptible varieties and in fungicide treatment) with respect to factors decisive for development of FHB and accumulation of toxins in certain conditions is evidently needed to control the disease more effectively. It was lately demonstrated by Šíp *et al.* (2007) that the exploitation of moderate resistance (varieties Arina and Petrus) may result when combined with fungicide treatment in 89% DON reduction (96% reduction of the pathogen DNA content).

The mechanisms of plant resistance to FHB are very complex and it is now generally agreed that FHB resistance is controlled by a polygenic system. Two major types of host resistance were distinguished: Type I – resistance to initial infection and Type II – resistance to the spread of the pathogen within a spike (Schroeder & Christensen 1963). Resistance to initial infection has not been characterized very well because it is highly influenced by environmental conditions and can be detected only under a low disease pressure (Bai 2004). Resistance to the pathogen spread can be more stable, but it is not so tightly linked with the natural course of infection. Low FHB severity due to Type I and Type II resistance usually coincides with low DON because of fewer infected kernels (Bai *et al.* 2001). Other types of resistance described by Mesterházy (1995) are resistance to kernel infection, to toxin (DON) accumulation and tolerance. The resistance of studied wheat accessions could be described by disease score of the head, % of Fusarium damaged grains, kernel weight per head and DON content (Wisniewska *et al.* 2004). Though relationships between these traits are usually significant, their separate evaluation enables to characterize this complicated disease in a better way. Breeding for FHB resistance and low accumulation of mycotoxins would be greatly facilitated if the mycotoxin (DON) accumulation of a genotype could be predicted from indirect, easily determined FHB traits. It was shown in different experiments (e.g. Arseniuk *et al.* 1999; Ittu *et al.* 2000; Lemmens *et al.* 2003; Šíp *et al.* 2007) that particularly the determination of the percentage of Fusarium damaged grains (FDG) appeared to be useful from these aspects. Close correlations between DON content and FDG were also revealed in the experiments of Mesterházy *et al.* (2005), however, this research demonstrated the importance of measuring both FDG and DON in the breeding and selection of resistant germplasm and varieties.

Complete resistance has not been found in wheat or related species yet, but many sources of resistance are available for the use in breeding programmes (Zimmermann 2000). The search for FHB-resistance sources has shown progress in China, Japan, and some other countries in the last three decades (Bai 2004). Spring wheat germplasms (especially Sumai 3, Nobeoka Bozu, Frontana, Beijing 8 and Encruzilhada) were used by many breeders all over the world (Mesterházy 2002). In winter wheat no such progress has been made with the use of exotic germplasm because it appeared difficult to combine high resistance with an acceptable level of other important characters, especially with high bread-making quality. Therefore, the utilization of moderate resistance detected in some varieties (such as Arina, Petrus, Romanus or Solitär) seems to be more prospective. Ittu *et al.* (2002) reached substantial progress in breeding winter wheat for resistance to FHB through the recombination of resistance genes from various sources that were better adapted to European conditions. Selection progress is hampered mainly by the quantitative mode of inheritance of FHB resistance (Snijders 1990), occurrence of genotype by environment interactions (Miedaner *et al.* 2001) and necessity to test at flowering stage (Miedaner *et al.* 2006).

The objective of this paper was to present three-year results of field experiments in which the resistance of registered winter wheat varieties to the accumulation of mycotoxins DON and ZEA in grain was studied in relation to the other important FHB traits after artificial inoculation with *Fusarium culmorum*. The obtained results could help to improve the classification of varieties from these aspects.

MATERIALS AND METHODS

Plant materials. The response to artificial infection with *Fusarium culmorum* was studied in 35 winter wheat varieties. The set included 34 varieties registered in the Czech Republic and the Swiss variety Arina, generally known as a source of moderate resistance to FHB (Jenny *et al.* 2000). Characteristics of the examined varieties that are registered in the Czech Republic are available on the website of the Central Institute for Supervising and Testing in Agriculture, Brno, Czech Republic: http://odrudy.zeus.cz/ido/index.html?lang=en.

Description of field experiments, disease evaluation and examined characters. A field test was conducted in the Research Institute of Crop Production in Prague-Ruzyně in 2004–2006. Wheat varieties were planted on hill plots in three replications in two variants (infected and uninfected ones). Highly pathogenic isolate B of *F. culmorum* (Šíp *et al.* 2002) was used for the artificial inoculation of spikes. The spraying of the inoculum (conidial suspension 0.8×10^7/ml) was applied on one date within a hill plot onto bunches of selected 10 spikes at mid-flowering stage (GS 64: anthesis half-way). Inoculated spikes were then kept for 24 hours in polythene bags. To minimize the year/location effects on results, in these conditions it appeared necessary to support the disease development (when needed) by irrigation of plots. Head blight symptoms were evaluated at three intervals (14, 21 and 28 days after inoculation) on a 1–9 scale, where 1 < 5%, 2 = 5–17%, 3 = 18–30%, 4 = 31–43%, 5 = 44–56%, 6 = 57–69%, 7 = 70–82%, 8 = 83–95% and 9 > 95% of spikelets with FHB symptoms in the spike. Visual symptom scores (VSS) are based on the average value of three measurements. Determination of other resistance traits was based on seed samples obtained on each plot from randomly selected 50 spikes which were threshed at a low wind not to lose light infected scabby grains. Fusarium damaged (scabby) grains (FDG) were calculated as the percentage of the total seed number. Tolerance to the infection was expressed as percent reduction (R) compared to the non-inoculated control (C) in the traits thousand grain weight (TGW) and grain weight per spike (GWS). Seeds from infected spikes were analyzed for DON (deoxynivalenol) and ZEA (zearalenone) content.

Chemical analyses. The content of DON and ZEA was determined by ELISA with the use of RIDASCREEN® FAST DON (ZEA) kits from R-Biopharm GmbH, Darmstadt, Germany. A representative sample was ground and thoroughly mixed. For the determination of DON content 5 g of ground sample was shaken (3 min) with 100 ml of distilled water and filtered. To determine ZEA content 5 g of ground sample was shaken (3 min) with 25 ml of methanol (70%) and filtered. 1 ml of the filtrate was diluted with 1 ml of distilled water. In both cases (for DON and ZEA) 50 µl of the diluted filtrate was used for the test. Samples and standards were applied according to the manufacturer's instructions. The absorption of the final solution was measured at 450 nm, using a SUNRISE spectrophotometer. RIDAWIN® software was employed for data processing.

Statistical analyses. UNISTAT 5.0 package (UNISTAT Ltd., London W9 3DY, UK) was used for correlation analyses and multiple comparisons by ANOVA.

RESULTS AND DISCUSSION

Disease development under different conditions and relations between the examined traits

The response to the artificial infection of ears with isolate B of *Fusarium culmorum* was evaluated in 35 winter wheat varieties in 2004–2006. The development of Fusarium head blight apparently differed in the years of testing. In 2004 the infection was performed at a relatively lower daily temperature and in 2005 at a higher temperature in later stages of infection (Table 1). The conditions of the year 2006 were the most favourable for the disease spread. This year could be characterized by late flowering time and high temperatures in the time of inoculation of medium early-late varieties. A high temperature accompanied by sufficient humidity (when using the mist irrigation of plots) favoured early FHB development in the wheat spike and resulted in the high accumulation of DON. As shown in Table 2, in 2006 the average DON content was much higher (115 mg/kg) than in 2004 (23.3 mg/kg) and 2005 (39.9 mg/kg). The other traits were also more affected by the disease in 2006 than in previous years.

Besides mycotoxin (DON, ZEA) content the disease severity was also characterized by symptom expression (VSS), percentage of Fusarium damaged grains (FDG) and reductions in thousand

Table 1. Mean pentad temperatures (in °C) during the period of disease development in 2004–2006

		2004	2005	2006
May	27–31	13.6	21.2	11.2
June	1–5	14.2	15.9	10.5
	6–10	19.2	11.7	14.0
	11–15	16.9	15.6	20.7
	16–20	14.4	19.5	21.3
	21–25	16.4	21.5	22.4
	26–30	16.4	19.5	19.5
July	1–5	16.8	17.4	20.3
	6–10	17.1	15.6	23.2
	11–15	14.3	21.2	22.7
Mean temperature		15.9	17.9	18.6
Time of inoculation		3.6.–12.6.	30.5.–6.6.	9.6.–21.6.

grain weight (TGWR) and grain weight per spike (GWSR) due to the infection. In Table 2 variety and year ranking (in ascending order) is available for all examined traits. It is clear from this table that most varieties showed similar resistance levels in all traits, however, it was also possible to detect different ranks in variety resistance to e.g. accumulation of mycotoxins, tolerance to the disease or symptom expression, which indicates the presence of different resistance types. Similarly like in previous experiments (Šíp *et al.* 2007) the variety Ebi showed a lower disease incidence but high susceptibility to the accumulation of DON. On the contrary, the variety Apache expressed the highest resistance to the accumulation of DON and ZEA, but FHB symptoms were clearly developed. Bai *et al.* (2001) reported that severe visual symptoms may not always be associated with high DON levels, especially in varieties possessing moderate Type II resistance.

Table 3 presents the results of correlation analyses. A close relationship in all three years was detected between DON content and VSS, as well as between DON content and GWSR. Correlation coefficients between FDG and DON content, and TGWR and DON content were significant ($P < 0.01$) only in two years of testing (2004 and 2006). In these experiments also ZEA content was examined for its correlations with the other traits. ZEA content was positively correlated with DON content, however, no close relationship between ZEA content and the other traits was detected. It can be concluded from these studies that higher DON content could be an indicator of higher ZEA content.

The results document (Table 3) that resistance/tolerance to FHB in a variety could be affected by flowering date (inoculation date). The correlation between flowering date and DON content was significant in all years. A close relation was detected above all in the years 2004 and 2006. It is evident from these results that the earlier varieties showed lower DON accumulation than the later ones. Relatively higher resistance to the accumulation of DON was also detected in the early varieties Šárka and Hana (Šíp *et al.* 2002; Chrpová *et al.* 2006). The correlation between flowering date and ZEA content was not significant, and the performance in the other traits did not usually reflect the inoculation date (the relations were not consistent in different years).

Evaluation of variety resistance to the accumulation of mycotoxins DON and ZEA in grain

The classification of variety resistance (tolerance) to FHB and accumulation of DON in grain is undoubtedly connected with the inclusion of suitable characters and with the accuracy of their determination. In this study the great attention was paid to DON content, which can be con-

Table 2. Mean values (2004–2006) and variety and year ranking for DON content, visual symptom score (VSS), % of Fusarium damaged grains (FDG), reduction in thousand grain weight (TGW-R), reduction in grain weight per spike (GWS-R) and ZEA content

Variety	DON content (mg/kg)	Rank	VSS 1–9	Rank	FDG (%)	Rank	TGW-R (%)	Rank	GWS-R (%)	Rank	ZEA content (μg/kg)	Rank	Rank (6 traits)
Simila	30.4	3	3.3	2	37.7	2	20.7	4	44.8	6	102.0	2	3.2
Alana	32.5	7	3.3	3	36.5	1	21.2	5	43.5	4	218.7	7	4.5
Arina	31.0	4	3.1	1	42.6	4	18.0	1	31.4	1	447.6	18	4.8
Apache	24.4	1	4.2	19	51.4	10	18.7	2	43.9	5	48.9	1	6.3
Rheia	31.0	5	3.6	6	42.8	5	28.1	14	41.3	2	214.5	6	6.3
Samanta	30.0	2	3.7	7	39.4	3	25.4	10	50.5	13	164.4	4	6.5
Ludwig	41.4	8	3.6	4	43.3	6	20.4	3	41.5	3	513.3	22	7.7
Dromos	44.7	11	3.6	5	43.5	7	25.7	11	49.8	12	162.8	3	8.2
Banquet	31.8	6	4.1	16	51.8	11	29.5	15	49.1	11	237.7	8	11.2
Buteo	51.2	12	4.0	12	52.9	12	25.3	9	48.1	8	566.0	24	12.8
Sulamit	52.7	14	4.0	13	56.3	18	23.3	7	52.9	17	238.9	9	13.0
Rapsodia	43.1	9	4.3	22	56.3	17	21.3	6	47.8	7	453.1	18	13.2
Batis	63.3	22	3.9	9	49.8	8	23.6	8	48.6	9	642.8	27	13.8
Eurofit	53.5	15	3.8	8	54.5	14	29.7	16	52.6	16	423.5	15	14.0
Barokko	61.5	21	4.2	20	56.6	19	26.6	12	48.7	10	253.6	10	15.3
Globus	44.4	10	4.2	18	57.0	20	31.5	19	51.9	15	472.3	20	17.0
Cubus	59.5	18	3.9	10	54.3	13	26.9	13	57.0	19	797.3	31	17.3
Hedvika	59.5	19	4.1	15	57.6	22	33.3	21	58.5	21	348.2	12	18.3
Meritto	57.8	17	4.0	14	57.8	23	30.2	17	51.3	14	741.4	30	19.2
Ilias	66.8	23	4.2	17	66.4	30	33.7	23	58.0	20	197.3	5	19.7
Svitava	57.6	16	4.7	26	60.1	25	33.4	22	58.9	23	278.9	11	20.5
Akteur	73.3	26	4.3	21	51.0	9	39.7	30	56.1	18	602.1	25	21.5
Karolinum	61.1	20	4.7	25	63.9	27	31.3	18	60.8	25	431.7	16	21.8
Ebi	82.9	30	4.0	11	54.9	15	34.3	24	60.6	24	933.3	33	22.8
Caphorn	51.2	13	4.9	30	70.6	34	34.8	25	58.8	22	370.0	14	23.0
Etela	74.3	27	5.0	34	63.4	26	32.5	20	61.4	26	443.2	17	25.0
Darwin	69.0	25	4.8	29	55.4	16	37.6	28	71.1	35	561.6	23	26.0
Alibaba	76.4	28	4.9	31	57.3	21	37.4	27	66.3	30	453.6	19	26.0
Clarus	79.9	29	5.0	33	65.5	28	35.9	26	69.1	33	366.9	13	27.0
Heroldo	92.6	34	4.5	23	59.6	24	39.0	29	65.6	29	630.5	26	27.5
Vlasta	68.9	24	4.9	32	65.8	29	40.0	32	62.5	27	704.0	28	28.7
Biscay	90.1	31	4.6	24	68.5	32	42.6	34	67.6	31	496.5	21	28.8
Florett	91.6	33	4.7	27	68.4	31	39.9	31	63.0	28	709.2	29	29.8
Drifter	91.4	32	4.8	28	69.5	33	41.2	33	68.2	32	977.6	34	32.0
Complet	128.5	35	5.4	35	75.0	35	51.4	35	70.9	34	839.3	32	34.3
2004	23.3	1	3.7	1	30.0	1	19.1	1	45.5	1	324.8	1	1.0
2005	39.9	2	4.0	2	66.9	2	28.5	2	55.5	2	450.2	2	2.0
2006	115.0	3	5.1	3	70.7	3	45.3	3	64.9	3	601.4	3	3.0
Total average	60.0		4.2		55.8		30.9		55.3		458.8		

Table 3. Coefficients of correlation between the examined traits in three years (35 varieties)

Combination of traits*	2004		2005		2006	
	r	*P*	*r*	*P*	*r*	*P*
DON vs. ZEA	0.48	**0.0019**	0.48	**0.0019**	0.63	**0.0000**
DON vs. VSS	0.52	**0.0007**	0.51	**0.0008**	0.88	**0.0000**
DON vs. FDG	0.79	**0.0000**	0.37	**0.0147**	0.80	**0.0000**
DON vs. TGWR	0.83	**0.0000**	0.37	**0.0154**	0.84	**0.0000**
DON vs. GWSR	0.60	**0.0001**	0.54	**0.0005**	0.78	**0.0000**
DON vs. inoculation date	0.48	**0.0019**	0.39	**0.0101**	0.49	**0.0015**
ZEA vs. VSS	0.38	**0.0121**	0.27	0.0596	0.76	**0.0000**
ZEA vs. FDG	0.43	**0.0052**	0.27	0.0565	0.45	**0.0031**
ZEA vs. TGWR	0.39	**0.0108**	0.12	0.2379	0.35	**0.0196**
ZEA vs. GWSR	0.16	0.1849	0.19	0.1382	0.25	0.0724
ZEA vs. inoculation date	0.26	0.0697	0.05	0.3821	0.22	0.1014
VSS vs. FDG	0.69	**0.0000**	0.72	**0.0000**	0.78	**0.0000**
VSS vs. TGWR	0.60	**0.0001**	0.60	**0.0001**	0.70	**0.0000**
VSS vs. GWSR	0.64	**0.0000**	0.77	**0.0000**	0.62	**0.0000**
VSS vs. inoculation date	0.34	**0.0222**	0.27	0.0579	0.44	**0.0044**
FDG vs. TGWR	0.84	**0.0000**	0.52	**0.0007**	0.75	**0.0000**
FDG vs. GWSR	0.70	**0.0000**	0.59	**0.0001**	0.76	**0.0000**
FDG vs. inoculation date	0.16	0.1852	0.18	0.1462	0.29	**0.0438**
TGWR vs. GWSR	0.73	**0.0000**	0.72	**0.0000**	0.90	**0.0000**
TGWR vs. inoculation date	0.20	0.1285	0.53	**0.0006**	0.25	0.0776
GWSR vs. inoculation date	0.06	0.3755	0.49	**0.0014**	0.45	**0.0034**

*for the explanation of symbols see Table 2; *P* values in bold letters: $P < 0.05$

sidered as the character of crucial importance. Detailed characteristics of the variety response in individual years are given in Table 4. Based on multiple comparisons by ANOVA, the varieties could be arranged each year and across the examined years into homogeneous groups of similar resistance level. These groups were often large (particularly when examined across the years), which may indicate a high influence of environmental conditions on the DON content of a variety. Therefore, multiple testing is evidently necessary. The varieties Apache, Samanta, Simila, Arina and Alana were included in homogeneous group ´***a***´ in all years, which may indicate the higher stability of resistance. Relatively lower DON content was also detected in the varieties Rheia, Banquet, Ludwig, Rapsodia, Dromos and/or Globus, but not in all years. The resistance of these varieties can be considered as ´less stable´. The variety Complet was found to be the most susceptible variety in the examined set.

It is encouraging that at present we can find among the registered varieties a group of at least four varieties that are likely to show the same level of resistance to FHB as the control variety Arina, which is widely used as a source of moderate resistance. In 2000 for the first time Šíp and Stuchlíková reported on the resistance of the older Czech variety Alana when evaluating VSS and reduction in yield traits.

It is obvious that ZEA reached much lower concentrations than DON (Table 2). The varieties possessing relatively higher resistance to the accumulation of DON, mainly Apache, Simila, Samanta, Dromos, Rheia, Alana and Banquet, also showed the low accumulation of ZEA, but in Arina and Ludwig the low ZEA content was not detected.

Table 4. Mean DON content (mg/kg) of 35 winter wheat varieties in three years and inclusion of varieties in homogeneous groups (P = 95%, LSD test)

Variety	Average (2004–2006)		2004		2005		2006		Average rank (2004–2006)
Apache	24.35	a	19.60	abcde	22.26	abc	31.20	ab	7.0
Samanta	30.00	ab	15.17	abc	28.13	abcd	46.70	abcd	6.7
Simila	30.43	ab	4.00	a	15.41	a	71.87	abcdefg	3.7
Arina	30.95	abc	6.80	ab	33.92	abcdef	36.03	abc	5.3
Rheia	30.97	abc	15.30	abc	52.11	fghijkl	25.50	a	13.0
Banquet	31.78	abc	13.17	ab	38.37	cdefghi	43.80	abcd	9.7
Alana	32.50	abc	6.90	ab	17.24	ab	64.83	abcde	3.7
Ludwig	41.38	abcd	10.13	ab	36.64	bcdefgh	77.37	abcdefgh	9.7
Rapsodia	43.12	abcd	26.73	bcdefg	32.89	abcdef	69.73	abcdef	14.3
Globus	44.37	abcd	20.97	bcdef	47.03	defghijk	65.10	abcde	17.0
Dromos	44.69	abcd	14.23	ab	22.73	abc	97.10	bcdefghij	8.0
Buteo	51.17	abcde	19.23	abcde	25.36	abc	108.90	defghijk	12.3
Caphorn	51.21	abcde	34.57	efgh	34.47	abcdefg	84.60	abcdefghi	18.0
Sulamit	52.70	abcde	16.17	abcd	37.87	cdefghi	104.07	defghijk	14.7
Eurofit	53.53	abcde	20.67	bcdef	58.30	ijkl	81.63	abcdefghi	20.3
Svitava	57.63	abcde	19.70	abcdef	37.07	bcdefgh	103.47	cdefghijk	15.7
Meritto	57.79	abcde	24.03	bcdef	23.54	abc	125.80	efghijklm	15.7
Cubus	59.47	abcde	10.07	ab	36.00	abcdefg	132.33	efghijklm	13.3
Hedvika	59.53	abcde	19.50	abcde	37.40	bcdefgh	121.70	efghijkl	17.3
Karolinum	61.10	abcde	25.03	bcdef	30.66	abcde	127.60	efghijklm	17.3
Barroko	61.54	abcde	15.93	abc	47.59	defghijk	121.10	efghijkl	18.3
Batis	63.34	abcde	16.30	abcd	57.06	hijkl	116.67	efghijkl	20.3
Ilias	66.78	abcde	22.63	bcdef	38.79	cdefghij	138.90	ghijklm	22.0
Vlasta	68.92	bcde	19.17	abcde	46.83	defghijk	140.77	hijklm	21.0
Darwin	68.95	bcde	37.53	fgh	61.65	kl	107.67	defghijk	27.0
Akteur	73.33	bcde	46.30	hi	40.02	cdefghij	133.67	fghijklm	26.7
Etela	74.28	bcde	26.55	bcdefg	38.47	cdefghij	141.90	hijklm	23.7
Alibaba	76.41	cde	30.87	cdefgh	51.04	efghijkl	147.33	ijklm	27.3
Clarus	79.90	de	29.40	bcdefg	51.14	efghijkl	159.17	jklmn	28.0
Ebi	82.87	de	32.07	defgh	54.04	fghijkl	152.90	jklmn	29.0
Biscay	90.14	ef	43.30	ghi	36.77	bcdefgh	190.37	mn	27.0
Drifter	91.42	ef	32.80	efgh	59.01	jkl	182.47	lmn	31.3
Florett	91.61	ef	26.23	bcdef	32.52	abcdef	216.07	no	22.0
Heroldo	92.63	ef	37.60	fgh	70.63	l	169.67	klmn	32.7
Complet	128.46	f	56.13	i	41.89	cdefghijk	287.37	o	31.0
Mean value	59.98		23.28		39.85		115.01		

Means in columns followed by the same letter are not significantly different from each other (P < 0.05)

CONCLUSION

Mycotoxin content, grain yield losses and degree of effects on seed quality by infection are undoubtedly the most important characters from the practical point of view. A higher level of resistance to FHB will help farmers to lower the risks connected with this devastating disease (to reduce grain yield losses and adverse effects on grain quality). Breeding for FHB resistance and low accumulation of mycotoxins would be greatly facilitated if the resistance to mycotoxin accumulation in a genotype could be predicted from indirect, easily determined FHB traits. Correlation analyses indicate also in this study that symptom scores or the traits measuring damage to wheat seed due to infection can be exploited particularly in early hybrid generations to predict the resistance level. However, similarly like the experiments of Mesterházy *et al.* (2005), this research demonstrated that in the later stages of breeding process the determination of DON content, besides other important characters, was evidently needed to fully describe the state. Further research is required to confirm the important finding that resistance to the accumulation of DON may be an indicator of resistance to the accumulation of very deleterious mycotoxin ZEA.

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