Response of some cultivars of spring spelt *(Triticum spelta)* to *Fusarium culmorum* infection

M. Wiwart, J. Perkowski, H. Jackowiak, D. Packa, A. Borusiewicz and M. Buśko

Reaktion einiger Sommerdinkelsorten *(Triticum spelta)* auf *Fusarium culmorum* Infektion

1. Introduction

The growing and breeding of spelt (*Triticum spelta* L.) has been gaining an increasing interest in recent years (KLING, 1989; MOUDRY, 1999; SCHMID and WINZELER, 1990). Notwithstanding several agriculturally disadvantageous traits (fragile rachis, highly compact glumes and floral bracts making the threshing of kernels difficult, susceptibility to lodging especially among winter cultivars), this hexaploid wheat possesses many valuable characteristics (KELLER et al., 1999). Compared to common wheat, spelt grain is usually richer in protein of superior biological value for human nutrition and contains larger quantities of minerals. Spelt is also known for its high tolerance to several environmental stresses, particularly to cold stress, and has relatively low soil quality requirements (RÜEGGER et al., 1990).

However, the available reference data on the response of spelt to major fungal pathogens are scarce and incomplete, which encourages researchers to undertake studies on this question (SCHMID et al., 1994). Knowledge of the reaction to infection by pathogenic fungi, including the pathogens of the genus *Fusarium* sp., is useful not only for the breeding of new *T. spelta* varieties, but also for all breeding programs which involve crossbreeding between *T. aestivum* and *T. spelta*. Owing to the effect of heterosis such hybrids are characterized by higher yields (WINZELER et al., 1994). They also can produce better quality seeds with higher contents of desirable nutrients.

The aim of this paper is to present an initial assessment of the response of five varieties of spring spelt to the infection of heads and seedlings by *F. culmorum* compared to two cultivars of spring wheat.

Zusammenfassung

Fünf Sommerdinkel- (*Triticum spelta*) und zwei Kulturweizensorten (*T. aestivum*) wurden hinsichtlich ihrer Reaktion auf *Fusarium culmorum* Infektion von Pflanzen und keimender Saat untersucht. In allen Fällen senkte eine Beimpfung die Werte der analysierten Ertragskomponenten signifikant: Korngewicht, Körnerzahl pro Ähre und Tausendkorngewicht. Körner der Kontrollgruppe enthielten 0,01 bis 0,9 $\mu g \cdot g^{-1}$ Deoxynivalenol während bei Beimpfung die Deoxynivalenolgehalte der Dinkelkörner von 33,7 bis 108,4 $\mu g \cdot g^{-1}$ kg verglichen mit 32,5 bis 57,1$\mu g \cdot g^{-1}$ bei Kulturweizenkörnern. Keimung und Keimlinge der *T. spelta*-Sorten wiesen eine bessere Resistenz gegenüber Fusarieninfektion auf als die beiden Weizensorten.

Schlagworte: Kulturweizensorten, Deoxynivalenol, *Fusarium culmorum*, Keimlingtest, Dinkel.

Summary

Five spring spelt (*Triticum spelta*) and two common wheat (*T. aestivum*) cultivars were examined for their response to *Fusarium culmorum* infection of heads and germinating kernels. In all objects inoculation significantly depressed values of the yield components analyzed: kernel weight, and kernel number per head and thousand kernel weight. Kernels from the control heads contained from 0.01 to 0.9 $\mu g \cdot g^{-1}$ deoxynivalenol whereas under artificial inoculation, the DON content of spelt kernels ranged from 33.7 to 108.4 $\mu g \cdot g^{-1}$ compared to 32.5 and 57.1 $\mu g \cdot g^{-1}$ in common wheat kernels. Germinating kernels and seedlings of *T. spelta* were characterized by better resistance to the infection relative to either of the two wheat cultivars.

Key words: common wheat, deoxynivalenol, *Fusarium culmorum*, head blight, seedling test, spelt.

2. Material and Methods

2.1 Source of spelt and common wheat seeds

The material was composed of the five cultivars of spring spelt: Weisser Grannenspeltz, Roter Sommerkolben, Blauer Samtiger, Speltz aus Tzari Brod and Lohnauer Sommerspeltz, whose seeds were obtained from the National Centre for Plant Genetic Resources in the Plant Breeding and Acclimatization Institute in Radzików (Poland), and two cultivars of spring wheat registered in Poland: Torka and Broma, whose prebasic seeds were made available directly by breeders. Cv. Torka has a very good bread-making quality ("E" quality group according to the classification of the Research Centre for Cultivar Testing). The bread-making quality of cv. Broma is poor ("C" quality group according to the same classification) (LIST OF AGRICULTURAL CULTIVARS, 2001).

The infection material consisted of *F. culmorum* isolate I_1 (identified according to NELSON et al., 1983) originating from our own collection of the Chair of Plant Breeding and Seed Science, University of Warmia and Mazury in Olsztyn. Pathogenicity and toxin productivity were checked prior to the experiments (WIWART et al., 2000).

2.2 Field experiments

The seeds of all the cultivars tested was single-grain sown in a field experiment established in a random block design with three replications, and plot size of 3 m^2. The field experiment was localized at the Experimental Station in Balcyny, in the vicinity of the city of Olsztyn (NE Poland).

Inoculation was performed using aqueous suspension of conidial spores (500,000 spores · cm^{-3}) obtained from 14-day cultures grown on PDA medium (Merck) at 22 °C, using a light cycle of 12 h darkness and 12 h NUV light (Philips ‚TL'D 36W). The treatment was carried out at the flowering phase (Zadoks scale 65, ZADOKS et al., 1974) by spraying 30 randomly chosen heads for each replication. The control consisted of heads free from spraying with any preparation. Immediately after the spraying, heads were covered with polyethylene bags for 48 h. Some biometrical measurements followed the harvest, including the percentage of *Fusarium* damaged kernels (FDK), number of kernels per head (KN), weight of kernels per head (KW) and thousand kernel weight (TKW).

2.3 Greenhouse experiment

The greenhouse experiment, in which the response of the spelt varieties to infection of seedlings was examined, was conducted using the same *F. culmorum* I_1 isolate in 2001 in four replications, according to the method described by CHEŁKOWSKI and MAŃKA (1983). Normally formed kernels without any visible symptoms of infection were surface disinfected in 5 % NaOCl for 15 minutes, rinsed three times in sterile water and germinated at 22 °C in complete darkness. The kernels which germinated properly were put on the surface of a 7-day fungal culture on PDA (10 kernels per culture), placed in pots measuring 10 cm in diameter, previously filled with disinfected soil. One replication consisted of two pots (20 kernels). Having being placed on cultures, the kernels were covered with the same kind of soil. The conditions maintained during the growth of mycelium were analogous to those during the preparation of inoculum previously used for the infection of heads. The control objects were prepared on sterile PDA discs. After 14 days the number, height and weight of seedlings were determined.

2.4 Statistical analyses

The results were subject to correlation analysis, calculating the Pearson correlation coefficient. In addition, a two-factor analysis of variance was calculated. The multiple Student Newman-Keuls (SNK) test was applied to compare the means.

2.5 Microscopic analysis

In order to visualize morphological changes in kernels caused by the infection with *F. culmorum*, observations using scanning electron microscope (SEM) were carried out. For the observations of the surface of kernels, dry samples were fixed in vapors from 1 % osmium tetroxide-cacodylate buffer for 12 h and air-dried. The specimens were mounted with double-adhesive tape on aluminum stubs and sputtered with gold coat. All samples of kernels were examined by means of LEO 435 VP SEM in high vacuum mode at accelerating voltage 10–15 kV.

2.6 Chemical analysis

Kernel samples (each sample 10 g in weight of manually dehulled grain) obtained from all experimental objects were examined for the content of deoxynivalenol (DON) according to method described by PERKOWSKI et al. (1997). Deoxynivalenol was determined by HPLC using a Waters 501 apparatus with a Waters 486 UV detector (l_{max} = 224 nm) and a C_{18} Nova Pak column (3.9 x 300 mm). The concentration of the toxin was analyzed with detection limits of 0.015 $mg \cdot g^{-1}$, by retention time 7.5 min. Recoveries reached 85 % when water-methanol (3:1 v/v) with flow rate 0.5 $mg \cdot min^{-1}$ was used as a developing solvent. Confirmation of DON identity was performed by the gas chromatography-mass spectrometry (GC/MS) method (Hewlett Packard HP 6890 apparatus) in the Selected Ion Monitoring (SIM) technique, after trimethylsilyl (TMS) derivatization.

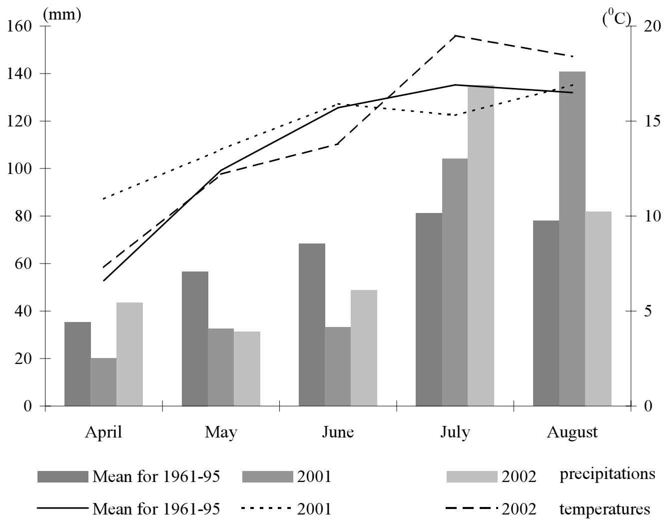


Figure 1: Sums of precipitation and average temperatures in the growing season under experimental conditions

Abbildung 1: Niederschlagsmengen und Durchschnittstemperaturen während der Wachstumsperiode im Versuchtszeitraum

3. Results

The climatic conditions during the growing seasons 2001 and 2002 at the Experimental Station in Bałcyny are presented in Figure 1. Against the background of many years‘ tendencies, average temperatures in all the months of the year 2001, except July, were higher and favorable for the vegetation of wheat and spelt. On the other hand, weaker precipitation in June, may have had an important effect on depressing the values of the major yield components. Higher precipitation observed from early flowering to kernel maturity phase (Zadoks scale 60–90) created favorable conditions for the development of head blight. The weather conditions in the year 2002 were slightly different, as the mean temperature in June was by 2.1 °C lower, and the mean temperature in July by 4.2 °C higher, compared with the previous year.

3.1 Morphological and microscopic analyses of kernels

The artificial inoculation of heads with *F. culmorum* had a significant influence on the development of kernels of all tested varieties, which was confirmed by the FDK fraction values obtained (Tab. 1). In 2001 the strongest response to infection was reported for spelt Speltz aus Tzari Brod (over 90 % of kernels classified as FDK), whereas the weakest reaction was noted for wheat Torka (47.2 %). After infection in 2002 the highest share of FDK was recorded for cv. Roter Sommerkolben (36.4 %), and the lowest – for cv. Weisser Grannenspeltz (11.2 %) and, again, cv. Torka (11.4 %). After infection with *F. culmorum* the percentage of spelt kernels classified as FDK was on average over 1.4-fold higher than that of common wheat kernels. A small number of kernels, similar for all combinations, with symptoms of fusariosis was observed in the control samples. This proves that under natural conditions the effects of *Fusarium* infection of common wheat and spelt can be approximately identical.

Generally healthy looking kernels from control, non-inoculated heads of booth cereals were either free from mycelium or else hyphae were present on the kernel surface only (Fig. 2, 4). The results of observations of kernels harvested from inoculated heads show that under *F. culmorum* infection the hyphae grew abundantly on the surface of kernels, and the seed coat (pericarp) was frequently injured (Fig. 3, 5). The microscopic observations confirmed that irrespective of the species hyphae grew abundantly on the crease both on the brush end (Fig. 6) and germ end (Fig. 7, 8). Frequently determined was the incidence of conidial spores, which may implicate that this part of a kernel provided conditions favorable to the growth of the pathogen (Fig. 9).

Table 1: Percentage of kernels classified as Fusarium damaged kernels (FDK) for the spelt and common wheat cultivars under control and inoculation conditions
Tabelle 1: Anteil der fusariumgeschädigten Körner (FDK) an den untersuchten Körnern bei Dinkel- und Kulturweizensorten in der Kontroll- und der Inokulationsgruppe

Year	2001		2002		mean	
Cultivar	C	I	C	I	C	I
Lohnauer Sommerspeltz	2.2	68.6[ab]	0.0	25.8[a]	1.1	47.2[ab]
Roter Sommerkolben	1.0	66.4[ab]	0.0	36.4[a]	0.5	51.4[a]
Blauer Samtiger	1.9	66.2[ab]	0.0	12.7[b]	1.0	39.5[ab]
Weisser Grannenspeltz	2.4	67.3[ab]	0.0	11.2[b]	1.2	39.3[ab]
Speltz aus Tzari Brod	1.3	90.1[a]	0.9	19.2[ab]	1.1	54.7[a]
Torka	1.2	47.2[b]	0.0	11.4[b]	0.6	29.3[b]
Broma	2.7	50.4[ab]	0.3	21.7[ab]	1.5	36.0[ab]
Mean for spelt	1.76	71.72	0.18	21.06	0.98	46.42
Mean for common wheat	1.95	48.80	0.15	16.55	1.05	32.65

C – non-inoculated control, I – inoculation
a,b – homogenous groups according to SNK test (P = 0.05) (for each year separately)

3.2 Inoculation effect on yield structure and DON content of the grain

Head inoculation in all the cultivars caused a significant decrease in the values of the three yield components analyzed, accompanied by considerable DON accumulation in kernels (Tab. 2). *F. culmorum* infection affected to the highest degree a decrease in kernel weight per head: on average by 53.8 % in spelt varieties, and by 42.9 % in common wheat. The strongest response was observed in cv. Speltz aus Tzari Brod (decrease by 64.2 % compared with the control), and the weakest – in Broma (33.0 %). Compared with the decrease in kernel weight per head, the reduction in TKW and KN in all cultivars examined was lower, and so was the difference between common wheat and spelt.

In our experiment kernels of all inoculated varieties were found to be contaminated with DON. In the year 2001 the mean concentration of this toxin in grain of all cultivars tested was over 13-fold higher than in the year 2002 (Tab. 2). The highest level of this metabolite concentration (108.4 $\mu g \cdot g^{-1}$) was detected in cv. Lohnauer Sommerspelz and Spelz aus Tzari Brod (105.0 $\mu g \cdot g^{-1}$). The lowest DON concentrations were detected in grain of Blauer Samtiger and Roter Sommerkolben (33.7 and 36.9 $\mu g \cdot g^{-1}$, respectively). For comparison, the concentration of this toxin in the grains of common wheat cultivars was 32.5 $\mu g \cdot g^{-1}$ (cv. Torka) and 57.1 $\mu g \cdot g^{-1}$ (cv. Broma). In two years of investigations mean DON concentration in spelt grain (37.3 $\mu g \cdot g^{-1}$) was over 1.5-fold higher than in grain of both common wheat cultivars (23.7 $\mu g \cdot g^{-1}$). The results concerning DON concentration in grain and yield components show that weather condition in 2001 were more conducive to *F. culmorum* infection than in 2002.

The value of Pearson correlation coefficient for DON concentration in kernels harvested from the inoculated and control (non-inoculated) heads, calculated for all experimental objects in both years, was high (r = 0.80). Moreover, the strong correlation between DON concentration and percentage of FDK (r = 0.90, Tab. 3) may be indicative of some diversification of the cultivars tested both in terms of their resistance to DON accumulation in grain and tolerance to primary infection and colonization of kernels. The values of the remaining correlation coefficient computed (Tab. 3) reveal an extremely strong relationship between percentage of FDK and kernel weight per head (r = -0.84) and kernel number per head (KN) (r = -0.77).

3.3 Effect of inoculation on seedlings

Inoculation of seedlings with *F. culmorum* caused a considerable decline in the number, length and weight of seedlings of the cultivars assayed (Tab. 4), coinciding with a very strong correlation between the two latter traits (r = 0.97). Germinating kernels and seedlings of *T. spelta* were characterized by higher resistance to infection compared with both common wheat cultivars. The strongest response to *F. culmorum* infection was observed in cv. Torka (30.3 % of the number of seedlings versus the non-inoculated control). Among the spelt forms tested, cv. Weisser Grannenspeltz proved to be most susceptible to infection with slightly above 51 % of the plants destroyed versus the control (the

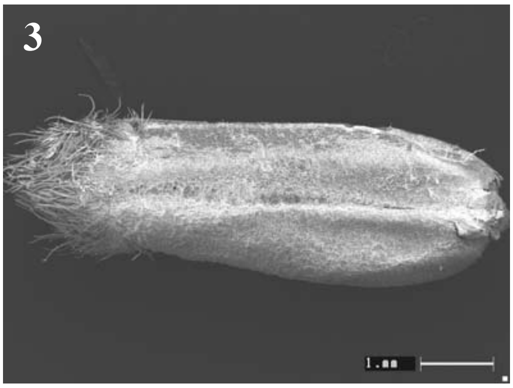
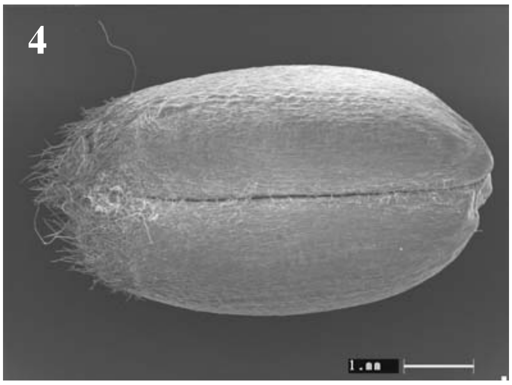


Figure 2: Healthy well-formed *T. spelta* (cv. Blauer Samtiger) kernel
Abbildung 2: Gesundes normal geformtes *T. spelta* Korn (cv. Blauer Samtiger)

Figure 3: *T. spelta* (cv. Blauer Samtiger) kernel classified as FDK fraction. Visible damage of the seed coat tissues near the germ
Abbildung 3: Fusariengeschädigtes *T. spelta* Korn (cv. Blauer Samtiger). Deutliche Schädigung der Samenhaut um den Keim



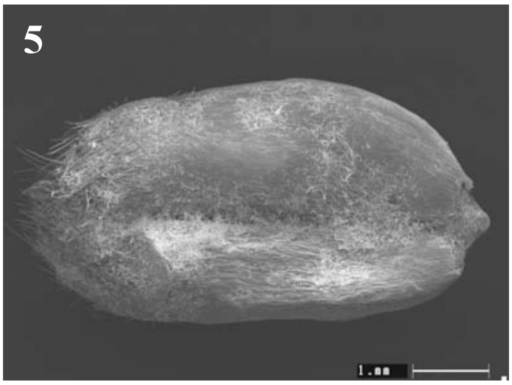
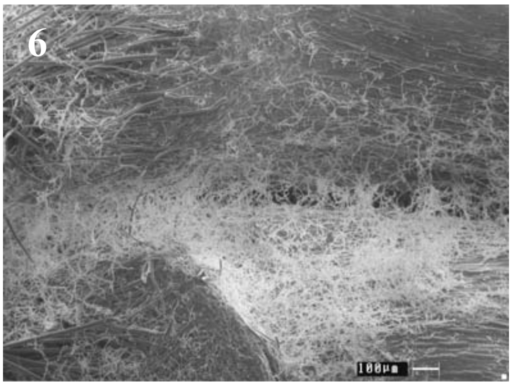


Figure 4: Healthy well-formed *T. aestivum* kernel (cv. Torka)
Abbildung 4: Gesundes normal geformtes *T. aestivum* Korn (cv. Torka)

Figure 5: *T. aestivum* kernel (cv. Torka) classified as FDK fraction. Visible damage of the seed coat tissue near the germ
Abbildung 5: Fusariengeschädigtes *T. aestivum* Korn (cv. Torka). Sichtbare Schädigung der Samenhaut um den Keim



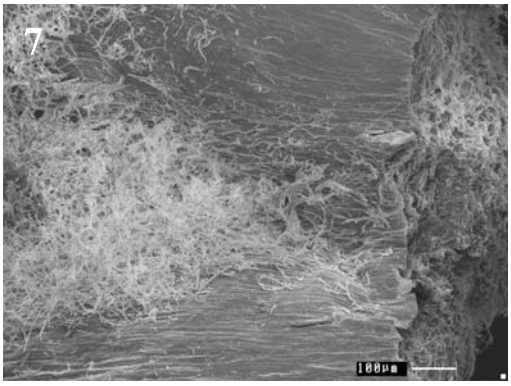
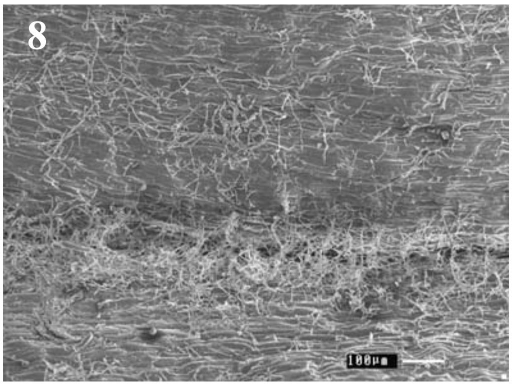


Figure 6: Abundant fungal mycelium in the furrow at the base of the brush (*T. aestivum* cv. Torka)
Abbildung 6: Pilzmycelausprägung entlang der Kerbe im Bereich der Siebplatte (*T. aestivum* cv. Torka)

Figure 7: Abundant fungal mycelium in the furrow from the side of the germ (*T. aestivum* cv. Torka)
Abbildung 7: Pilzmycelausprägung entlang der Kerbe im Bereich des Keimes (*T. aestivum* cv. Torka)



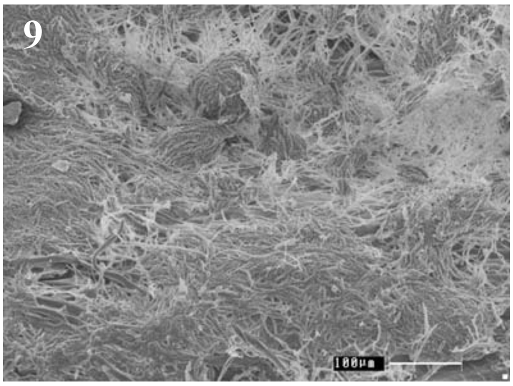


Figure 8: Abundant mycelium in the medial part of the furrow of *T. spelta* cv. Blauer Samtiger kernel
Abildung 8: Pilzmycelausprägung im mittleren Teil der Kerbe eines *T. spelta* cv. Blauer Samtiger Korns

Figure 9: Mycelium and conidial spores near the furrow of the kernel of *T. aestivum* cv. Broma
Abbildung 9: Mycelium Konidiensporen an der Kerbe eines *T. aestivum* cv. Broma Kornes

Table 2: The values of the yield structure components: number of kernels per head (KN), weight of kernels per head (KW), thousand kernel weight (TKW) and concentration of deoxynivalenol (DON) in the kernels of the cultivars assayed

Tabelle 2: Die Werte von den die Ertagsstruktur bestimmenden Komponenten: Körnerzahl, Korngewicht, Tausendkorngewicht und Deoxynivalenolkonzentration in den Körnern der untersuchten Sorten

Trait	KN				
Year	2001		2002		Mean
Cultivar	C	I	C	I	(I)
Lohnauer Sommer-speltz	26.5^{y}	8.6^{b}	28.1^{yz}	22.3^{b}	15.45
Roter Sommerkolben	23.9^{y}	10.7^{b}	26.0^{yz}	19.4^{b}	15.05
Blauer Samtiger	30.3^{y}	11.0^{b}	36.4^{yz}	32.0^{ab}	21.50
Weisser Grannenspeltz	27.0^{y}	13.9^{ab}	31.1^{yz}	29.7^{ab}	21.80
Speltz aus Tzari Brod	28.8^{y}	9.6^{b}	28.1^{yz}	25.7^{ab}	17.65
Torka	38.2^{z}	19.4^{a}	45.3^{z}	35.4^{a}	27.40
Broma	37.6^{z}	23.0^{a}	51.4^{z}	46.1^{a}	34.55
Mean for spelt	27.30	10.76	29.94	25.82	18.29
Mean for common wheat	37.90	21.20	48.35	40.75	30.98

Trait	KW				
Year	2001		2002		Mean
Cultivar	C	I	C	I	(I)
Lohnauer Sommer-speltz	1.1^{y}	0.2^{c}	1.0^{b}	0.7^{b}	0.45
Roter Sommerkolben	1.1^{y}	0.3^{bc}	0.9^{b}	0.5^{b}	0.40
Blauer Samtiger	1.5^{z}	0.3^{bc}	1.6^{ab}	1.5^{a}	0.90
Weisser Grannenspeltz	1.2^{yz}	0.5^{ab}	1.1^{b}	0.9^{ab}	0.70
Speltz aus Tzari Brod	1.4^{z}	0.2^{c}	0.9^{b}	0.6^{b}	0.40
Torka	1.4^{z}	0.5^{ab}	1.5^{ab}	0.9^{ab}	0.70
Broma	1.3^{yz}	0.5^{a}	1.8^{a}	1.6^{a}	1.05
Mean for spelt	1.26	0.30	1.10	0.84	0.57
Mean for common wheat	1.35	0.50	1.65	1.25	0.88

Trait	TKW				
Year	2001		2002		Mean
Cultivar	C	I	C	I	(I)
Lohnauer Sommer-speltz	42.4^{z}	25.6^{ab}	32.8^{b}	23.6^{b}	24.60
Roter Sommerkolben	45.0^{z}	30.3^{ab}	32.9^{b}	24.4^{b}	27.35
Blauer Samtiger	51.3^{z}	29.7^{ab}	44.7^{a}	39.9^{a}	34.80
Weisser Grannenspeltz	45.9^{z}	34.1^{a}	38.3^{ab}	29.2^{ab}	31.65
Speltz aus Tzari Brod	47.3^{z}	20.0^{b}	32.1^{b}	23.9^{b}	21.95
Torka	36.0^{z}	23.6^{ab}	34.8^{ab}	25.4^{b}	24.50
Broma	34.3^{y}	21.8^{b}	40.6^{ab}	30.8^{ab}	26.30
Mean for spelt	46.38	27.94	36.16	28.20	28.07
Mean for common wheat	35.15	22.70	37.70	28.10	25.40

Trait	DON (µg·g^{-1})				
Year	2001		2002		Mean
Cultivar	C	I	C	I	(I)
Lohnauer Sommer-speltz	0.9	108.4	<0.1	10.2	59.30
Roter Sommerkolben	0.1	36.9	<0.1	3.2	20.05
Blauer Samtiger	<0.1	33.7	<0.1	2.3	18.00
Weisser Grannenspeltz	0.2	61.4	<0.1	5.7	33.55
Speltz aus Tzari Brod	0.5	105.0	0.28	5.9	55.45
Torka	<0.1	32.5	<0.1	0.9	16.70
Broma	0.1	57.1	<0.1	4.1	30.60
Mean for spelt	0.43	69.08	0.28	5.46	37.27
Mean for common wheat	<0.1	44.80	<0.1	2.50	23.65

(C non-inoculated control, I inoculation)
y,z, – homogenous groups assigned to control combinations according to particular traits
a,b,c – homogenous groups assigned to inoculated combinations according to particular traits; P = 0.05

Table 3: Pearson correlation coefficient values for the analyzed traits in two years of field experiment

Tabelle 3: Pearson Korrelationskoeffizient für die untersuchten Merkmale während des zweijährigen Feldversuches

Trait	FDK	KN	KW	TKW
KN	-0.77**			
KW	-0.84**	0.91**		
TKW	-0.64**	0.39	0.72**	
DON	0.90**	-0.71**	-0.74**	-0.53*

* significant at P = 0.05
** significant at P = 0.01

result similar to that of wheat cv. Broma). Spelt cv. Blauer Samtiger turned out to be the most resistant.

4. Discussion

Spelt, one of the oldest cultivated crops and closely related to common wheat, has recently drawn attention of cereal plant breeders around the world (MESSMER et al., 1999). Most of the spelt forms grown in Europe are winter varieties, which produce higher yields than spring forms, but are more susceptible to lodging (SCHMID and WINZELER, 1990). Resistance of *T. spelta* to pathogenic fungi has not been an object of broader investigations. Apart from the paper by KELLER et al. (1999) on the mapping and characterization of quantitative trait loci (QTL) related to the resistance of this crop to powdery mildew (*Erysiphe graminis*), no specific information is available on spelt reaction to infection. The question of the resistance of *T. spelta* to *Fusarium* spp. pathogens has not been thoroughly examined either, even though it seems to be of great importance to some wheat breeding programs. Compared with common wheat, spelt is characterized by superior tolerance to some abiotic stress factors. Therefore it is an interesting parent material in wheat breeding programs (SCHMID and WINZLER, 1990; SCHMID et al., 1994). Such characteristics, combined with good quality and high nutritional value of grain, make spelt a suitable crop for organic farming practices (WIESER et al., 1998). However, as MARX et al. (1995) implied, without chemical control the risk of more intensive *Fusarium* head blight incidence and consequently toxic grain contamination is higher. The results cited by those authors showed that the concentration of zearalenon in rye and wheat grains from organic farms in Bavaria was several times higher relative to the control. Based on these results, the researchers concluded that grains from organic farms generally contained higher amounts of mycotoxins.

Table 4: Number, length and weight of seedlings of the studied varieties (greenhouse experiment)
Tabelle 4: Anzahl, Länge und Gewicht der untersuchten Keimlinge (Glashausversuch)

Cultivar	Number of seedlings (% of control)	Length of seedlings (cm)		Weight of seedlings (g)	
		C	I	C	I
Lohnauer Sommerspeltz	76.0^{c}	34.6	26.9^{b}	17.2	5.8^{b}
Roter Sommerkolben	51.9^{b}	40.3	19.5^{a}	15.2	1.8^{a}
Blauer Samtiger	79.49^{c}	48.5	35.3^{b}	20.4	9.4^{c}
Weisser Grannenspeltz	51.3^{b}	39.7	25.6^{ab}	16.7	6.0^{b}
Speltz aus Tzari Brod	67.5^{bc}	43.7	23.2^{ab}	18.0	3.7^{b}
Torka	30.3^{a}	44.9	19.4^{a}	17.5	1.4^{a}
Broma	51.3^{b}	39.8	26.2^{ab}	16.0	3.2^{b}
Mean for spelt	65.24	41.36	26.10	17.50	5.34
Mean for common wheat	40.80	42.35	22.80	16.75	2.30

(C non-inoculated control, I inoculation).
a,b,c – homogenous groups according to SNK test (P = 0.01)

Abundant growth of *F. culmorum* can cause biosynthesis of deoxynivalenol (DON), 3-acetyldeoxynivalenol and 15-acetyldeoxynivalenol (3-AcDON and 15-AcDON) and zearalenone (ZEA) (SCOTT, 1989; GAREIS et al., 1989). Nivalenol (NIV) was also found in samples infected by *F. culmorum* (MIROCHA et al., 1994). In our experiment kernels of all inoculated varieties were found to be contaminated with DON. Our results on DON concentration in spelt grain are consistent with those quoted in references. Such high levels of this mycotoxin found in *F. culmorum* inoculated barley and wheat were reported by MIROCHA et al. (1994), PERKOWSKI et al. (1996) and by SNIJDERS and KRECHTING (1992). As regards spelt, no data have been found in the available literature on the resistance of this cereal to DON accumulation in grain. MASTEL and MICHELS (2000) reported that the concentration of this toxin in naturally infected spelt grain collected in Baden-Württemberg was small, with a mean of 0.05 $mg \cdot kg^{-1}$. This value was several times lower compared with the respective values for grain of different *Triticum durum* and winter wheat cultivars analyzed under the same conditions. Our results obtained do not allow to formulate indisputable conclusions regarding differences between spelt and common wheat in the resistance to DON accumulation in grain. It seems, however, that the high value of the correlation coefficient between DON concentration in kernels from inoculated and control (non-inoculated) heads ($r = 0.80$) suggests that the *T. spelta* genotypes analyzed in our experiment may differ in their ability for accumulating DON in grain. This type of resistance, previously described by WANG and MILLER (1988) and later referred to by MESTERHAZY (1995) as resistance to accumulation or decomposition of mycotoxins, plays an important role in breeding works targeted on producing wheat cultivars resistant to *Fusarium* sp. (MESTERHAZY et al., 1999). Although a significant correlation between more intensive *Fusarium* head blight incidence under field conditions and DON content of cereal grains does not occur in all cases, it is observed for small grain with visible symptoms of infection. LIU et al. (1997) found that such a correlation appeared for severely infected spring ($r > 0.90$) and winter wheat kernels, as well as barley and oat. The high value of the correlation coefficient for FDK vs. DON attained in our research seems to provide more evidence in favor of such a correlation. In the context of high DON concentration in grain, cv. Roter Sommerkolben and Blauer Samtiger, for both of which the concentration of this toxin was the smallest, seem to be most promising as potential material for further recombination breeding.

The morphometric measurements on the response of spelt to head infection largely correspond with the information cited by other authors on wheat and other small grain cereals (MIEDANER, 1997; PARRY et al., 1995). Considering the fact that kernel weight per head is strongly correlated with the yield of wheat and other cereals per hectare (ODENBACH, 1985), it can be claimed that the decrease in yield attributed to *F. culmorum* infection observed in our study was lower in common wheat than in spelt varieties. Relatively high percentages of FDK, especially in cv. Spelz aus Tzari Brod, indicate that spelt responded to *Fusarium* infection in a different way than the two wheat cultivars. It does not seem plausible that the differences between *T. spelta* and *T. aestivum* caused by floral brackets in wheat being more compact can produce a notable effect. On the other hand, RÜEGGER et al. (1990) claimed that healthier seedlings were obtained from kernels more tightly enveloped with floral brackets, which could protect germinating kernels from soilborne pathogens. This conclusion was to a certain extent confirmed by the results presented in our paper.

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Abbreviations

DON – deoxynivalenol
FDK – *Fusarium* damaged kernels
KN – kernel number per head
KW – kernel weight per head
r – Pearson correlation coefficient
SEM – scanning electron microscopy
TKW – thousand kernel weight

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Address of authors

Marian Wiwart, Danuta Packa, Andrzej Borusiewicz, University of Warmia and Mazury, Chair of Plant Breeding and Seed Production, 10-724 Olsztyn, pl. Lódzki 3, Poland; e-mail: wiwart@moskit.uwm.edu.pl

Juliusz Perkowski, Maciej Buśko, August Cieszkowski Agricultural University of Poznań, Chair of Chemistry, 60-625 Poznań, ul. Wojska Polskiego 75, Poland;
e-mail: julperk@au.poznan.pl

Hanna Jackowiak, August Cieszkowski Agricultural University of Poznań, Chair of Animal Anatomy, 60-625 Poznań, ul. Wojska Polskiego 71c, Poland;
e-mail: hannaj@ au.poznan.pl

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