Occurrence of *Fusarium* head blight of barley in Slovakia

Výskyt fuzariózy klasov jačmeňa na Slovensku

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Abstract

Fusarium head blight and the negative influence of this dangerous disease is current worldwide problem. The aim of this work was the evaluation of incidence and severity of *Fusarium* head blight of barley according to different pre-crop in different locations of Slovakia. Occurrence of *Fusarium* head blight (FHB) was documented during two consecutive years in June 2011-2012 under the natural *Fusarium* infections in fields with spring barley (*Hordeum vulgare*). Observations were conducted at four different localities in four climatic regions in Slovakia. Incidence and severity of FHB were evaluated at the growth stages early milk to late milk in three replications. Each replication contained 100 spikes, the incidence of FHB was calculated as FHB index. During the observed period, the infestation of affected heads by FHB ranged from 0 - 12.67 %. The average infestation of heads was 5.16 % in 2011 and 5.42 % in 2012 year. Predominance intensity of FHB on infection heads were 5% or less in each locality. Higher FHB infestations were reached at Špačince (2011), Soblahov (2012) with higher precipitation when comparing long-term average. Conversely, the lowest FHB incidence was in locality with lowest precipitation in June (Veľké Úľany – 2011, Špačince – 2012). Important influence in the severity of FHB infection had also crop rotation. The highest FHB incidence was observed in localities where was maize use as a pre-crop (Špačince, 2011 – 12.67 %, Soblahov, 2012 – 11 %).

Keywords: barley, *Fusarium* head blight, *Hordeum vulgare* L., localities, Slovakia, pre-crop, winter crops

Abstrakt

Fuzarióza klasov patrí k nebezpečným chorobám a vďaka jej negatívnemu pôsobeniu na zdravie ľudí i zvierat je celosvetovým problémom. Cieľom tejto práce bolo hodnotiť výskyt a závažnosť FHB v závislosti od predplodiny a lokality, ktoré patria do rôznych klimatických regiónov na Slovensku. Sledovanie výskytu fuzariózy klasov na jačmeni ozimnom (*Hordeum vulgare*) v podmienkach prirodzenej infekcie sa uskutočnilo v júni

2011 a 2012. Hodnotenie sa uskutočnilo v štyroch sledovaných lokalitách patriacich do štyroch rôznych klimatických regiónov na Slovensku. Hodnotenie napadnutia klasov prebiehalo v rastovej fáze skorá až neskorá mliečna zrelosť, pričom bolo hodnotených sto klasov v troch opakovaniach. Na základe výsledkov hodnotenia napadnutia klasu FHB bol vyjadrený index fuzariózy klasu jačmeňa. Počas dvoch rokov sledovania bol zaznamenaný výskyt FHB v rozpätí 0 – 12.67 %. Priemerné napadnutie klasov bolo 5.16 % v roku 2011 a 5.42 v roku 2012. V oboch rokoch a na všetkých sledovaných lokalitách prevažovalo nízke napadnutie plochy klasu - do 5 %. Najvyššie napadnutie klasov bolo zaznamenané v lokalitách Špačince (2011) a Soblahov (2012), kde bol zaznamenaný najvyšší úhrn zrážok v porovnaní s dlhodobým priemerom. Naopak najnižšie napadnutie bolo pozorované v lokalitách (Veľké Úľany – 2011, Špačince – 2012) s najnižším úhrnom zrážok v mesiaci jún. Významný vplyv na závažnosť fuzariózy klasov má osevný postup. V lokalitách (Špačince, 2011 – 12.67 %, Soblahov, 2012 – 11 %), kde bola použitá predplodina kukurica, bolo zistené vyššie napadnutie klasov fuzariózou.

Kľúčové slová: fuzarióza klasov, *Hordeum vulgare* L., jačmeň siaty f. ozimná, lokality, Slovensko, predplodina

Detailný abstrakt

Fuzarióza klasov je celosvetovo rozšírená choroba hustosiatych obilnín vrátane jačmeňa. V dôsledku silného napadnutia jačmeňa hubami z rodu *Fusarium* sa môže znížiť počet zŕn v klase a celková hmotnosť klasu. Okrem toho druhy z rodu *Fusarium* sú nebezpečné tvorbou mykotoxínov, ktoré negatívne pôsobia na zdravie ľudí a zvierat. Cieľom tejto práce bolo vyhodnotenie výskytu a závažnosti fuzariózy klasov jačmeňa v podmienkach Slovenska. Klasy boli hodnotené v dvoch rokoch (2011, 2012), vždy v čase najvyššieho výskytu fuzariózy klasov, čomu zodpovedala rastová fáza skorá mliečna zrelosť (BBCH 73) až neskorá mliečna zrelosť (BBCH 77) jačmeňa. Hodnotilo sa 100 klasov v troch opakovaniach. Hodnotenie prebiehalo v štyroch lokalitách patriacich do rôznych klimatických regiónov na Slovensku. Lokalita Veľké Úľany je zaradená do klimatického regiónu 00 – veľmi teplý, veľmi suchý nížinný; Špačince patria do regiónu 01 – teplý, veľmi suchý, nížinný; Soblahov do klimatického regiónu 02 – dostatočne teplý, suchý, pahorkatinový a lokalita Sklabiná patrí do regiónu 04 - teplý, veľmi suchý, kotlinový, kontinentálny. Pri hodnotení boli zistené rozdiely v napadnutí klasov jačmeňa medzi jednotlivými lokalitami. V roku 2011 bolo zaznamenané vyššie napadnutie klasov FHB, ktoré sa pohybovalo v rozpätí 0.67 – 12.67 % v porovnaní s rokom 2012, kedy sa napadnutie klasov pohybovalo v rozmedzí 0 - 9.33 %. V roku 2011 bol zistený vyšší index fuzariózy klasov, ktorý sa pohyboval v rozpätí 0.11 – 2.44 %, v porovnaní s rokom 2012, kedy boli zistené hodnoty indexu v rozpätí 0 – 2.28 %. V oboch sledovaných rokoch a vo všetkých lokalitách prevládalo nízke napadnutie plochy klasu (≤ 5 %). Najvyšší stupeň napadnutia plochy klasu (25.1 – 50 %) bol zistený v lokalite Sklabiná (2012). Na výskyt fuzariózy klasu mali rozhodujúci vplyv zrážky v mesiaci jún. V lokalitách s vyšším úhrnom zrážok bol výskyt fuzariózy

klasov vyšší ako v lokalitách s nižším úhrnom zrážok. V lokalitách Špačince (2011) a Soblahov (2012) kukurica ako predplodina zvyšovala výskyt fuzariózy klasov.

Introduction

Fusarium head blight (FHB) is an important disease of barley in many countries in Asia, Europe, North America, South America (Bai, Shaner, 2004; Goswami, Kisler, 2004). Environmental factors play an important role in pathogenesis (Doohan et al., 2003). When warm and wet weather coincides with flowering and early kernel filling period, fungus can easily infect barley plants and develop FHB (Brennan et al., 2005; Cai, 2008). *Fusarium* pathogens attack barley spikes after their emergence from the flag leaf sheat in the late-milk to soft dough stages of seed development (Bushnell et al., 2003). Disease symptoms include premature necrosis and a brown/ grey discoloration of spike tissue (Geddes et al., 2008; Boddu et al., 2006). More intense *Fusarium* infections of barley can render it technologically non useable for malt production (Schwarz et al., 1997). The major negative effect of contamination of malt barley with these molds is reduced test weight of infected grains, which implies less endosperm, decreased protein ratio, resulting in reduced malting yields (Duijnhouwer et al., 1993). *Fusarium* molds also synthesize unidentified compounds called hydrophobins which cause beer gushing (Kleemola et al., 2001; Denschlag et al., 2012). Moreover, detrimental effects of *Fusarium*, infection on brewing performance and beer flavor have also been noted (Anderson et al., 1967; Haikara, 1983; Oliveira, 2012). *Fusarium* epidemics can result in significant economic losses to producers due to yield losses, lower prices and mycotoxin contaminations (Schaafsma, 2002; Mesterházy et al., 2003) and for this is the next research necessary.

In view of this interaction, the aim of our research was to examine the influence of locality and pre-crop on FHB occurrence under natural infections in large scale on-farm plots during a two – year's period.

Materials and Methods

Evaluations of the severity and incidence of *Fusarium* head blight (FHB) symptoms were carried out in June 2011 and 2012 at four localities in four climatic regions of Slovakia (Tab. 1). Three replications of groups of barley spikes (*Hordeum vulgare* L.) containing 100 spikes were evaluated for the incidence and severity of natural infection at BBCH 73 – 77 (Table 3). The modified scale of Mielke (1988) was used for the evaluation of FHB severity. Mielke (1988) introduced level of damage in range 0-6. Subsequently, the disease severity and incidence was expressed as the FHB index.

All mentioned parameters (incidence, severity and FHB Index) were calculated for each observed locality. The agronomic practices performed every year were similar. Barley crops were grown under the conventional tillage practices. Barley varieties, maturity, seed rates and preceding crops are summarized in the Table 2. Weeds, insects and pathogens were controlled with recommended chemicals. Nitrogen fertilizers were

applied in spring. Nitrogen content and its forms were calculated based on data sheets released by producer. Meteorological data were obtained from farmers.

Table 1 Climatic region and soil characteristics of evaluated localities in Slovakia (Linkeš et al., 1996)

Tabuľka 1 Charakteristika klimatických regiónov a typov pôdy hodnotených lokalít na Slovensku (Linkeš et al., 1996)

Code of climatic areas	Localities	Coordinates	Sum of average daily temperature ≥ 10°C	Rainfall VI – VIII [mm]	Average temperature [°C]		Soil type
					January	Vegetation period	
00 very warm, very dry, lowland	V. Úľany	48º10´50´´N 17º28´55´´E	>3000 (3230 - 3000)	200	-3	16 - 17	chernozem
01 warm, very dry, lowland	Špačince	48º27´21´´N 17º 36´44´´E	3000 - 2800	200 - 150	-4	15 - 17	chernozem
02 quite warm, dry, hilly	Soblahov	48º51´47´´N 18º04´14´´E	2800 - 2500	150 - 100	-4	15 - 16	gleyic fluvisols
04 hot, very dry, hollow basin	Sklabiná	48º07´27´´N 19º21´22´´E	3030 - 2800	200 - 100	-6	15 - 16	brown soil

FHB index was calculated by using formula of Haidukowski et al. (2005):

$$\text{index}_{FHB}\ (\%) = \frac{\Sigma(a.b).100}{K.6}$$

a – number of heads with the same symptoms

b – level of damage

K – total number of evaluated heads

6 – the highest level of damage

Statistical analysis

For statistical evaluation of collected data, the analysis of variance (ANOVA, Statgraphics Centurion XV.I.) was used, followed by Tukey HSD test, p = 0.95.

Table 2 Characteristics of the barley varieties grown in 2011, 2012 seed rates and preceding crops

Tabuľka 2 Charakteristika odrôd jačmeňa pestovaných v roku 2011, 2012, výsevky a predplodiny

The date of evaluation FHB	Growth stage – BBCH code	Locality	Variety	Maturity	Seed rate ($kg*ha^{-1}$)	Pre-crop
15.6.2011	early milk 73	V. Úľany	Malz	medium late	220	maize
15.6.2011	early milk 73	Špačince	Marthe	medium early	200	maize
22.6.2011	early milk 73	Soblahov	Malz	medium late	210	soybean
22.6.2011	medium milk 75	Sklabiná	Bojos	medium late	240	maize
20.6.2012	late milk 77	V. Úľany	Malz	medium late	240	flax
20.6.2012	late milk 77	Špačince	Xanadu	medium early	170	wheat
20.6.2012	medium milk 75	Soblahov	Malz	medium late	230	maize
21.6.2012	medium milk 75	Sklabiná	Bojos	medium late	240	wheat

Results and Discussion

The typical FHB symptoms on barley´s head and leaf were observed in each locality. Wolf et al. (2003) describe that the symptoms starts as a tan or brown discoloration at the base of an inoculated floret. In our case this light tan or bleached symptom will spread to entire inoculated spikelet. Infected florets on spike can be fertile, or kernels become shrivelled, bleached and chalky, also known as “tombstone”, if they are produced (Bai, Shaner, 1994). Except this, in many cases we observed a pink or orange colored mold on flag leaf.

The average occurrence of *Fusarium* spp. in barley was 5.16 % in 2011 (Table 3), higher occurrence was recorded in 2012 – 5.42 % (Table 3). We recorded higher values of FHB index in 2011 (0.11 % – 2.44 %) than in 2012 (0.00 % – 2.28 %) (Table 3). The highest infection of heads corresponds with the highest FHB index in Špačince in 2011 (Table 3). However no FHB symptoms were detected in barley heads in Špačince in 2012. The second highest incidence of *Fusarium* was observed in Soblahov in both years (4 % - 2011, 11 % - 2012). Slightly lower FHB infection was recorded in Sklabiná every year. Locality Veľké Úľany had a very low incidence of FHB every year. In two years average of FHB index, the highest FHB incidence of Barley was observed in evaluated localities in following downward order: Soblahov, Špačince, Sklabiná, Veľké Úľany.

In general, there was relatively low intensity (≤ 5 %) of FHB found on the infected heads in every locality in both years (Table 4). According to Mielke scale Mielke (1988) we observed two intensity of FHB - ≤ 5 % and 5.1-10 % in 2011. Higher infestation areas of heads was recorded in 2012, where was the highest FHB intensity in infected heads (25.1 - 50 %) was found in Sklabiná, 2012 (Table 4).

The analysis of the variance didn't confirm the statistical difference between the occurrence of FHB and the locality (Table 5).

Rainfall and warm weather around the time of flowering create suitable conditions for infection of barley (Kriss et al., 2010; Landschoot et al., 2012). Higher FHB infestations were reached at localities with higher precipitations when comparing long-term average (more than 100 % of long term average) (Table 3). This situation was observed in Špačince 2011 (there were observed 53 mm) and Soblahov 2012 (difference 19 mm). The lowest incidence of FHB was in – V. Úľany (2011) and Špačince (2012). In these localities, there was recorded the lowest rainfall every year in comparison with other evaluated localities (Table 3). Langseth et al. (1995) and Champeil et al. (2004) confirmed fact that *Fusarium* head blight severity depends mainly on climatic effects. Although the differences between localities and years were recorded, there were not statistically significant (Table 5).

Agriculture practices such as crop rotation and crop management have significant effects on FHB (Dill-Macky, Jones, 2000). According Champeil et al. (2004) wheat and non-host crop rotations may reduce the head blight incidence. This statement was confirmed based on results from Špačince 2012, where the wheat as a pre-crop was used. Also the low incidence of FHB (Table 3) was in Soblahov 2011 and Veľké Úľany 2012, where the good crop rotation was used (Table 2). The low value of FHB in Soblahov 2011 can be explained by soybean as a pre-crop. Recent studies on the effect of previous crop residues on FHB development also demonstrated that the incidence and severity of FHB was greater when corn is followed by wheat and lower incidence when soybeans is followed by wheat (Dill-Macky, Jones, 2000). The pre-crop flax was used in Veľké Úľany in 2012. There was a low incidence FHB. According Caron (1993) flax can be used as a clean-up crop, after which no disease is observed. Conversely, according to several authors, maize has a positive influence on incidence and severity FHB infection. (Cromey et al., 2002; McMullen et al., 1997). We found the highest incidence and severity of FHB on localities, where maize as a pre crop was used.

Table 3 Climatic condition in June, head affected and FHB index in 2011 and 2012, Slovakia

Tabuľka 3 Klimatické podmienky v mesiaci jún, napadnutie klasov a FHB index v rokoch 2011, 2012 na Slovensku

Year	Locality	Average air temperature (ºC)		Average precipitation		Head affected (%)	FHB index (%)
		June	Deviation from the long-term average *	June (mm)	Long-term average (%) *		
2011	V. Úľany	20.1	1.8	77	107	0.67	0.11
	Špačince	18.8	1.0	142	195	12.67	2.44

	Soblahov	18.4	-	132	153	4	0.72
	Sklabiná	19.5	1.2	80	99	3.3	2
	Average					5.16	1.32
2012	V. Úľany	21.4	3.1	45	63	1.33	0.28
	Špačince	20.6	2.8	40	55	0	0
	Soblahov	19.1	1.8	118	137	11	2.28
	Sklabiná	20.1	1.8	58	72	9.33	2.17
	Average					5.42	1.18

* 1951 - 1980

Table 4 Head area infected with FHB in monitored locality, 2011, 2012

Tabuľka 4 Napadnutie plochy klasu Fuzariózou v sledovaných lokalitách, 2011, 2012

% of head area damaged by FHB							
Year	Locality	≤ 5	5.1 – 10	10.1 – 25	25.1 – 50	50.1 – 75	over 75
2011	V. Úľany	0.67	0.00	0.00	0.00	0.00	0.00
	Špačince	10.67	2.00	0.00	0.00	0.00	0.00
	Soblahov	3.67	0.33	0.00	0.00	0.00	0.00
	Sklabiná	2.67	0.67	0.00	0.00	0.00	0.00
2012	V. Úľany	1.00	0.33	0.00	0.00	0.00	0.00
	Špačince	0.00	0.00	0.00	0.00	0.00	0.00
	Soblahov	8.67	2.00	0.33	0.00	0.00	0.00
	Sklabiná	6.67	2.00	0.33	0.33	0.00	0.00

Table 5 Results of multifactor ANOVA for tested number of infected heads according to locality and year

Tabuľka 5 Porovnanie výskytu napadnutých klasov jačmeňa viacfaktorovou analýzou rozptylu (ANOVA) v závislosti od roku a locality

Effect	*df*	SS	MS	*F*	*p*
Year	1	816.667	816.667	0.29	0.5966
Locality	3	181.667	605.556	2.15	0.1277
Residual	19	535.5	281.842		
Total	23	725.333			

Statistically significant at a level of $p < 0.05$, *df*: degrees of freedom; SS: Sum of squares; MS: Mean square; *F*: *F-ratio*; *p*: *p-value*

Conclusions

The *Fusarium* head blight belongs to dangerous and annually occurring disease of barley. From this reason we focus our research to examine the influence of locality and pre-crop on FHB occurrence under natural infections. Predominance intensity of FHB on infection heads were 5 % or less in each locality. The average incidence of FHB on barley heads was 5.16 % (2011) and 5.42 % (2012). We recorded higher values of FHB index in 2011 than in 2012. Higher FHB infestations were reached at localities with higher precipitations (Špačince – 2011, Soblahov -2012) in June when comparing long-term average. Conversely, the lowest FHB incidence was in locality with lowest precipitation in June (Veľké Úľany – 2011, Špačince – 2012). In two years average of FHB index, the highest FHB incidence of Barley was observed in evaluated localities in following downward order: Soblahov, Špačince, Sklabiná, Veľké Úľany. Important influence in the severity of FHB infection had also crop rotation. The highest FHB incidence was observed in localities where maize use as a pre-crop.

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