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Original Paper

Incidence of *Fusarium* head blight on winter wheat in ecological and integrated farming system

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Fusarium head blight (FHB) occurrence was evaluated in ecological (Komárno – Ďulov Dvor, South Slovakia) and conventional (Veľké Úľany, South Slovakia) farming system in Slovakia. The study was realized at the final phase of flowering stage – BBCH 69 of winter wheat (*Triticum aestivum* L.) in the years 2011 and 2012. 100 heads per crop of winter wheat were evaluated for FHB symptoms in three replications for each locality. The occurrence and severity of FHB was the highest in Ďulov Dvor every year, which corresponds to relatively high FHB index – 5.95 % (2011) and 12 % (2012). The lower FHB index (4.59 %) was recorded in Veľké Úľany in 2011. There were any symptoms of FHB in Veľké Úľany in 2012. Higher value of FHB index in Ďulov Dvor confirmed that the highest incidence and severity of FHB was in ecological farming system. Analysis of variance confirmed statistical difference between occurrence of FHB and locality. The amount of rainfall was the main factor which influenced the lowest occurrence of FHB in Veľké Úľany in each year. Conversely, the high amount of rainfall was related with high value of FHB index in Ďulov Dvor. Our results demonstrate that *Fusarium* head blight severity depends mainly on weather conditions. However, in years with average or high levels of disease, farming system affects disease severity. These results showed high incidence and severity of FHB in ecological crop production.

Keywords: wheat, *Fusarium* head blight, FHB index, farming systems, *Triticum aestivum* L.

1. Introduction

The incidence and severity of *Fusarium* head blight (FHB) has increased worldwide and has resulted in significant yield losses (Xu, 2003). These losses include discoloration, shriveled kernels, contamination of the infected grains with mycotoxins (Nakajima, 2007), and seedling blight when infected grains are used as a seeds for sowing (McMullen et al., 1997). Scherm (2013) describe FHB symptoms as a partial head blighting, with the appearance of one or more prematurely bleached spikelets, or blighting of the entire head, which is easily observed when wheat has not yet reached the ripening stage. Initially, infected spikelets show light-brown, water-soaked spots on the glumes, which then become dark brown. Infected spikelets remain empty or contain shrunken grey/brown kernels. Browning on the rachilla and the rachis can be observed and, under favourable conditions, the fungus may infect the stem below the head, inducing a brown/purplish discoloration (Hudec and Roháčik, 2008). The international Maize and Wheat Improvement Centre (CIMMYT) has identified FHB as a major factor limiting wheat production in many parts of the world (Xu, 2003). The distribution of this disease is determined by climatic parameters, particularly temperature, moisture (Parry et al., 1995; Xu, 2003) and cropping practices (Klix et al., 2008). The impact of the environment on such disease complexes is poorly understood (Xu, 2003). This fact can be caused that *Fusarium* species are able to cause the disease individually or in complex infections (Conrath et al., 2002). Organic grain production, which mainly characterizes the omission of mineral fertilizer and synthetic pesticide usage, is growing in importance and there is an urgent need for more data on *Fusarium* infestation in organically produced grains (Willer et al., 2008; Magdos et al., 2006). Several studies have reported increased *Fusarium* infestation and mycotoxin contamination in cereals associated with an increased level of nitrogen fertilization, and that mineral fertilizers seem to stimulate *Fusarium* infestation and infection more than organic fertilizers (Martin et al., 1991; Elen et al., 2000; Lemmens et al., 2004; Heier et al., 2005). Studies on *Fusarium* in organically and conventionally produced small grains and cereal products have reported different results. Some authors found significantly lower infestation of FHB in conventional crop production in compared with ecological (Birzele et al., 2002; Rossi et al., 2006; Harz et al., 2007). Several studies have found no significant influence of farming system on FHB infestation in cereals (Champeil et al., 2004; Hoogenboom et al., 2008; Edwards, 2009).

Reducing the occurrence of FHB, and therefore producing safer wheat and wheat products, is an important concern for farmers and consumers (Kubo et al., 2012). Better understanding of the interactions between wheat plants and

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FHB disease would contribute to the effective control of FHB and genetic improvement of resistance in wheat plants.

The aim of this study was to compare the incidence and severity of *Fusarium* head blight on winter wheat in two localities situated to the same climatic region in two different years. The localities can be differentiated by crop management – conventional and ecological.

2. Material and methods

2.1 Field assessment

The occurrence and severity of natural infection of FHB was investigated in Komárno – Ďulov Dvor and Veľké Úľany, in 2011–2012, in a randomized block design field trial. In Komárno – Ďulov Dvor, the winter wheat was cultivated in ecological farming system and in Veľké Úľany in conventional farming system (Table 1, Table 2, Table 3). 100 heads of winter wheat (*Triticum aestivum* L.) in three replications at each locality at the end of flowering stage – BBCH 69 were evaluated.

Except number of infected heads, the intensity of disease on heads was evaluated according to modified scale of Mielke (1988). Subsequently, the disease severity and incidence was expressed as the FHB index.

Table 1 Climate and soil characteristics of localities Komárno – Ďulov Dvor and Veľké Úľany (VÚPOP, 2013)

Climatic area	Sum of average daily temperature ≥10°	Soil type	Localities	Coordinates
Very warm, very dry, lowland	>3000 (3230–3000)	Chernozem	Komárno – Ďulov Dvor	47° 47´ 3´´S 18° 9´ 52´´V
			Veľké Úľany	48° 10´ 50´´S 17° 28´ 55´´V

Table 2 Crop management of evaluated winter wheat crops in localities Komárno - Ďulov Dvor and Veľké Úľany, 2011, 2012

Locality	Farming system	Pre-crop		Variety	
		2011	2012	2011	2012
Komárno – Ďulov Dvor	ecological	sunflower	soybean	Kolompos	Kolompos
Veľké Úľany	integrated	poppy seed	poppy seed	Alacris	Bertold

Table 3 Fertilization and chemical treatment of evaluated winter wheat stands in localities Komárno - Ďulov Dvor, Veľké Úľany in the years 2011, 2012

Fertilization and chemical treatment						
Locality	Year	Date of application	Rate	Preparation	Active ingredients	Authorization in Slovakia
Komárno – Ďulov Dvor	2011	11. 10. 2010	0.5 kg ha^{-1}	Trifender	*Trichoderma asperellum*	natural fertilizer
	2011	12. 10. 2010	0.5 l ha^{-1}	Orgevit	N (4 %), P (3 %), K (2%)	natural fertilizer
	2011	11. 10. 2010	1.5 l ha^{-1}	Baktomix UN	*Azobacter chroococcum, Cellulomonas uda, Bacillus megaterium*	natural fertilizer
	2011	03. 04. 2011	0.5 kg ha^{-1}	Trifender	*Trichoderma asperellum*	natural fertilizer
	2011	17. 05. 2011	3 l ha^{-1}	Vektafid A	parrafin oil (83 %), emulgator (17 %)	insecticide
	2012	02. 10. 2011	0.6 l ha^{-1}	Orgevit	N (4 %), P (3 %), K (2%)	natural fertilizer
	2012	02. 05. 2012	0.5 kg ha^{-1}	Trifender	*Trichoderma asperellum*	natural fertilizer
	2012	19. 05. 2012	3 l ha^{-1}	Alginure	seaweeds: *Ascofyllum nodosum, Laminaria* sp.	natural for increase resilience against fungal disease
	2012	19. 5. 2012	0.9 l ha^{-1}	PREV-B2	boron, orange oil (4.2 %)	natural foliage fertilizer
Veľké Úľany	2011	25. 02. 2011	150 kg ha^{-1}	LAD	N (27 %), MgO (4 %), CaO (7 %)	fertilizer
	2011	15. 04. 2011	150 l ha^{-1}	DAM	N (30 %)	fertilizer
	2011	15. 04. 2011	40 g ha^{-1}	Biplay	tribenuron-methyl, metsulfuron-methyl	herbicide
	2011	15. 04. 2011	0.4 l ha^{-1}	Starane	fluroxypyr	herbicide
	2012	05. 03. 2012	150 kg ha^{-1}	LAD	N (27 %), MgO (4 %), CaO (7 %)	fertilizer
	2012	21. 04. 2012	40g + 0.4 l ha^{-1}	Biplay + Starane	tribenuron-methyl, metsulfuron-methyl + fluroxypyr	herbicide
	2012	27. 04. 2012	150 l ha^{-1}	DAM	N (30 %)	fertilizer

Table 4 Long-term climate characteristics of localities Komárno – Ďulov Dvor and Veľké Úľany 2011, 2012

Locality	Climate characteristics of June 2011				Climate characteristics of June 2012			
	avetrage air temperature in °C		average precipitation		average air temperature in °C		average precipitation	
	June	deviation from the long-term average	June in mm	long-term average in %	June	deviation from the long-term average	June in mm	long-term average in %
Komárno – Ďulov Dvor	20.7	1.9	63	91	21.4	2.6	59	97
V. Úľany	20.1	1.8	77	107	21.4	3.1	45	67

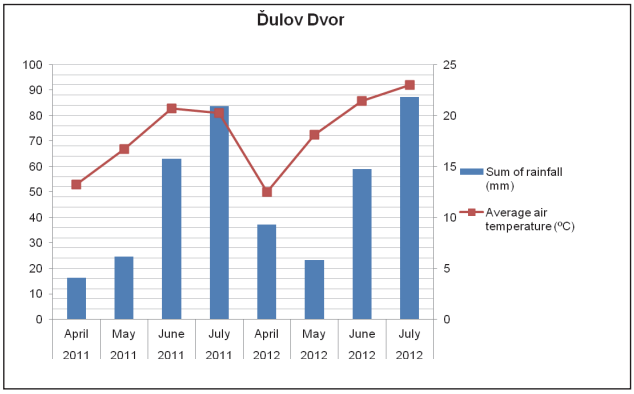

Figure 1 The sum of rainfall and average temperature during April, May, June and July in locality Komárno – Ďulov Dvor in 2011 (original dates, measurements on farms)

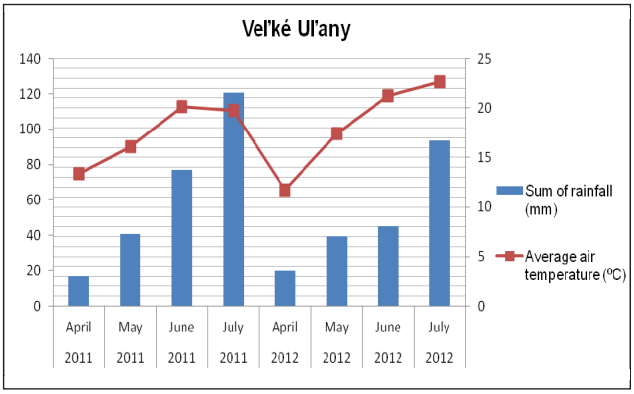

Figure 2 The sum of rainfall and average temperature during April, May, June and July in locality Veľké Úľany in 2011, 2012

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

$$\text{index FHB (\%)} = \frac{\sum(a \cdot k) \cdot 100}{K \cdot 6}$$

a – number of heads with the same symptoms
b – level of damage
K – total number of evaluated heads
6 – the highest level of damage

2.2 Statistical analysis

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

3. Results and discussion

The most frequent occurrence of spike fusaria was recorded on winter and spring wheat (Chrpová et al., 2007). We observed typically FHB symptoms as a partial head blighting, with the appearance of one or more prematurely bleached spikelets, or blighting of the entire head. Initially, infected spikelets show light-brown, water-soaked spots on the glumes, which become dark brown with age. Infected spikelets remain empty or contain shrunken grey/brown kernels. Pink to orange sporodochia were evident at the base of the spikelets or between the glumes and lemmas. These symptoms are similar as Shaner (2003) described.

The level of FHB index was 4.59 % (Veľké Úľany) and 5.95 % (Ďulov Dvor) in 2011. Analysis of variance confirmed statistical difference between occurrence of FHB and locality (Table 7). There were any symptoms of FHB on winter wheat heads in Veľké Úľany locality in 2012. The highest infection of heads corresponds to highest FHB index in Ďulov Dvor in 2012 (Table 5). Higher incidence of FHB was recorded in Ďulov Dvor in both of evaluated years (2011, 2012). In general, there were low intensity (≤5 %) of FHB found on infected heads in every locality and year (Table 6). The highest intensity of FHB on infected heads (50.1–75 %) was found in Veľké Úľany (Table 5). Lower incidence of FHB in integrated farming system likewise Voženílková et al. (2012) was found. They found lower incidence of *Fusarium* head blight on wheat in conventional farming system than in ecological during two years (2008, 2009).

According to Dill-Macky and Jones (2000) results, along influence of different pre-crop for FHB severity, the disease incidence used to be lower when forecrop was soybeans. In our results, the incidence and severity of FHB was the highest, when the pre-crop was soybean in Komárno – Ďulov Dvor in the year 2012. This highest incidence of FHB can be influenced by favorable weather. According to research of several authors (Parry et al., 1995; Chen et al., 2000; Lu et al., 2001) the higher precipitations are critical for FHB development. Winter wheat plants are most susceptible to the disease during anthesis, which is relatively short phase of the growth. For successful infection during anthesis, inoculum must be available and optimal weather conditions must prevail (Xu, 2003). In 2011, the average sum of rainfall in each locality was close to long-term average (Table 4).

Table 5 FHB occurrence and FHB index in localities Komárno – Ďulov Dvor and Veľké Úľany in the years 2011, 2012

Locality	The date of evaluate	$x \pm s$*	FHB index in %
Komárno – Ďulov Dvor	21. 06. 2011	0.23±0.42	5.95
Veľké Úľany	15. 06. 2011	0.16±0.37	4.59
Komárno – Ďulov Dvor	14. 06. 2012	0.54±0.5	12.00
Veľké Úľany	20. 06. 2012	0±0	0.00

*x = average, s = standard deviation

Table 6 Intensity of FHB on infection heads in localities Komárno – Ďulov Dvor, Veľké Úľany in the years 2011, 2012

Locality	Year	≤5%	5.1–10%	10.1–25%	25.1–50%	50.1–75%	over 75%
Komárno – Ďulov Dvor	2011	16.0	3.30	3.00	1.00	0.00	0.00
Veľké Úľany		9.70	4.00	1.00	1.30	0.30	0.00
Komárno –Ďulov Dvor	2012	38.67	12.00	2.67	0.33	0.00	0.00
Veľké Úľany		0.00	0.00	0.00	0.00	0.00	0.00

Table 7 Analysis of variance of FHB occurrence

Tukey HSD 95 %		
Locality	**LS Mean**	**P value**
Komárno – Ďulov Dvor	816.667a*	0.0076
Veľké Úľany	386.667b	

*differences between values followed by the same superscript are not significant (ANOVA Tukey test $p > 0.05$)

In 2012, the average precipitation was lower than long term average in Veľké Úľany. From this reason, the lowest incidence of FHB was recorded in Veľké Úľany 2012, where was the lowest rainfall (Table 4). According to the results of Snijders, (1990) and Moschini, Fortugno, (1996) statistical analyses based on field-collected data have confirmed the significant effect of weather on the disease development. The incidence of FHB was usually rised by increasing of sum of rainfall and air temperature.

Nitrogen application significantly increases the incidence of *Fusarium* infection in wheat grains (Martin et al., 1991; Lemmens et al., 2004). The higher amount of nitrogen application was recorded in Veľké Úľany (Table 3). In our trial, nitrogen application doesn´t increases incidence of FHB. Our results are not corresponding with results of Lemmens et al. (2004), because the higher nitrogen application doesn´t increases incidence of FHB in comparison with locality Komárno – Ďulov Dvor. On the other hand, our results are corresponding with Fauzi and Paulitz (1994) conclusions, which demonstrated that disease levels were similar with the presence or absence of 140 kg ha^{-1} ammonium nitrate application. Analysis of variance confirmed statistical difference between occurrence of FHB and locality (Table 7).

4. Conclusions

Based on our evaluation of winter wheat we can conclude that the highest occurrence and severity of FHB was in locality Komárno – Ďulov Dvor the FHB index was 5.95 % (2011) and 12 % (2012), respectively. The lower FHB index (4.59 %) was recorded in Veľké Úľany in 2011. There were not any symptoms of FHB in Veľké Úľany in 2012. This situation can be due by low precipitation in June in this locality. The results confirmed higher incidence and severity of FHB in ecological farming system in locality Komárno – Ďulov Dvor. Our results demonstrate that *Fusarium* head blight severity depends mainly on weather. However, in years with average or high levels of disease, cropping system affects disease severity. We can consider, that high level of FHB was in Komárno – Ďulov Dvor in 2012, which corresponds 12 % FHB index. These results showed for high incidence and severity FHB in ecological farming system.

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