ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 5–6 2011

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IMPACT OF ABIOTIC FACTORS ON *FUSARIUM* MYCOTOXIN OCCURRENCE IN CEREAL GRAIN

WPŁYW CZYNNIKÓW ABIOTYCZNYCH NA WYSTĘPOWANIE MIKOTOKSYN FUZARYJNYCH W ZIARNIE ZBÓŻ

Abstract: The paper focuses on an analysis of the abiotic factors impact on *Fusarium* mycotoxin cumulation in cereal grain. The mycotoxins most frequently determined in cereal grain include deoxynivalenol (DON), zearaleon (ZEN) and fumonisins. There are numerous causes of the presence and cumulation of these toxic compounds. The main factors promoting *Fusarium* fungi parasitising and mycotoxin production comprise the weather conditions and region of cultivation, species and cultivar susceptibility, the wrong forecrop, shallow placement of harvest residue or leaving it on the soil surface, as well as abandoning plant protection during the vegetation period.

Keywords: mycotoxins, grain, cereals, abiotic factors

The presence of mycotoxins in cereal grain poses a hazard to humans and animals causing diseases and economic losses [1]. The problem of mycotoxin presence in food and animal feeds is still important. According to FAO, about 25 % of world food production is significantly contaminated with mycotoxins. The mycotoxins most frequently determined in the grain of Polish cereals are trichothecenes, zearaleon (ZEN) and fumonisins, which are counted to *Fusarium* mycotoxins [2–5]. These metabolites are produced by fungi of the genus *Fusarium* [2, 3, 6]. Trichothecenes comprise highly toxic compounds of A type (T-2, HT-2, diacetoxyscirpenol – DAS, neosolaniol – NEO) and less toxic B type (deoxynivalenol – DON and nivalenol – NIV [7]). The production of mycotoxins by fungi of the genus *Fusarium* depends on many environmental factors and on the resistance of plant species and cultivars [3, 8, 9]. *Fusarium* mycotoxins may be produced already during the plant vegetation period [3, 4, 8, 10, 11]. Apart from the weather conditions, the *Fusarium* fungi development is promoted by simplified

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crop rotation, harvest residue left on the soil surface or a delayed crop harvest date [8, 12, 13]. The problem becomes serious particularly in the areas where cereal share the cropping system is high and out of necessity the crops are cultivated one after another, which favours the development of among others *Fusarium*. Among cereals, wheat is the most susceptible to fungal infections [14] and triticale, rye, barley and oat place next.

Fusarium fungi which infect plants during the vegetation period cause pre- and after-emergence blight, stem base rot and *Fusarium* ear disease [13]. Production of mycotoxins is usually connected with plant susceptibility to *Fusarium* head blight. Numerous authors [6, 11, 15] consider this disease the most serious. In the opinion of Perkowski et al [2], Perkowski [3] and Arseniuk and Goral [9], in Poland *Fusarium* head blight is caused by a complex of various *Fusarium* species (*F. graminearum, F. culmorum, F.avenaceum, F. poae*). However, the research conducted so far [9–11] indicates that an individual *Fusarium* species starts to dominate on the infected ears depending on the temperature, which is often connected with the region where the plants are cultivated [16]. *F. culmorum* prevails in the fungi species structure in the areas with moderate climate, whereas *F. graminearum* attacks cereal ears more in warmer regions, with higher air temperature. The hitherto conducted investigations [2–4] reveal that *F. garminearum* and *F. culmorum* are mainly responsible for deoxynivalenol (DON) and zearaleon presence in cereal grain. On the other hand fumosins found in maize grain are produced by *F. moniliforme* and *F. proliferatum*.

Literature data indicate a considerable diversity in mycotoxin cumulation in cereal grain. Hooker et al [8] think that DON cumulation depends mainly on the weather conditions during the plant flowering period, whereas according to Weber [13] ears become infected by fungi of *Fusarium* genus particularly during the prolonged flowering period.

In many countries considerable amounts of cumulated DON are assessed in cereal grain, whereas in Canada the presence of this toxin in wheat has been monitored since 1980 [10]. In his research, Tekauz [10] detected a similar level of DON presence in grains of wheat, barley and oats when the plants were growing in the same conditions (western Canada). Langseth and Rundberget [11] think that the presence of this mycotoxin depends on the plant species. The research results were confirmed by reports of Perkowski [2, 3]. Under natural conditions the greatest quantities of toxins accumulated in oat grain, next in barley and wheat grain (Fig. 1). The amounts assessed in the territory of Poland are comparable with the data obtained for other countries with similar climatic conditions. More intensive occurrence of *Fusarium* head blight (5 % of infected ears per plantation) poses a hazard of *Fusarium* toxin accumulation (for DON > 1 mg/kg). According to Perkowski [3] and Arseniuk and Goral [9] the proportion of grain samples or cereal products contaminated with mycotoxins is high (Table 1). The latest research of Perkowski et al [17] revealed the dependence of trichothecene content in oat grain on the region of its cultivation (Fig. 2) and as a result on climatic conditions.

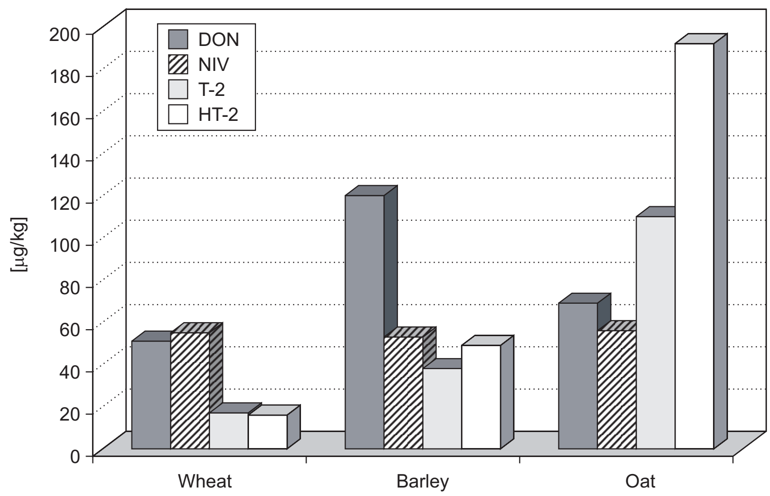

Fig. 1. Mean content of *Fusarium* toxins in Polish cereals [2]

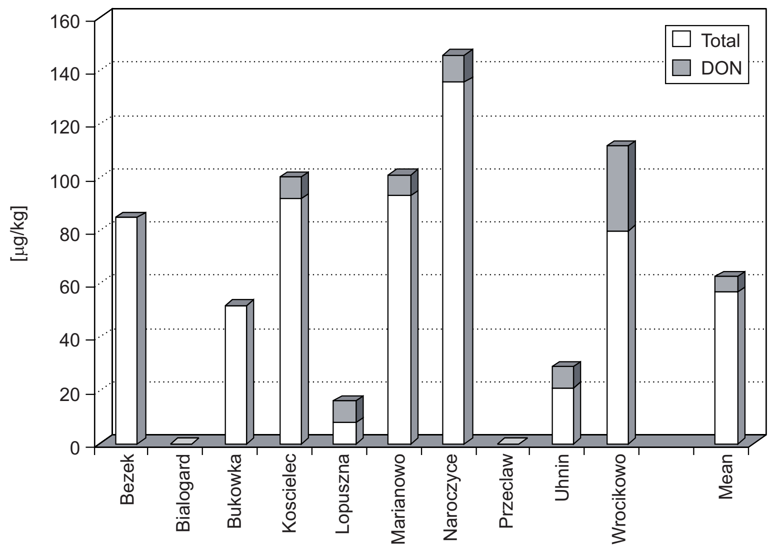

Fig. 2. Mean content of trichothecenes in grain of three oat varieties in the regions of Poland [17]

According to Solarska [5], the presence of *Fusarium* mycotoxins depends not only on the species but also on the cultivar. Winter maize Kobra c.v. revealed greater susceptibility to *Fusarium* head blight and higher cumulation of mycotoxins in grain. Busko et al [18] registered a higher DON accumulation in grain of 37 winter triticale breeding lines (Table 2). However, they assessed a significant correlation between ear infection by *F. culmorum* and DON content only in 2001.

Table 1

List of cereal and maize grains containing trichothecenes [9]

Toxin	Product or group of products with highest contamination (percent of samples with toxin presence)
Deoxynivalenol (DON)	Maize (89 %), wheat (61 %, including flour)
Nivalenol	Maize (35 %), oat (21 %), wheat (14 % including flour)
T-2	Maize (28 %), oat (21 %), wheat (21 %)
Zearalenon	Maize (79 %), milled maize (51 %), wheat (30 %), milled wheat (79 %)
Fumonisin B1	Maize (66 %), maize flour (79 %), wheat (79 %)
Fumonisin B2	Maize (51 %)

Table 2

Deoxynivalenol (DON) accumulation in triticale grain infected by *Fusarium culmorum* [18]

Year	Specification	Fusarium head blight [%]	DON [mg/kg]
2000	Average	21.53	41.86
	Maximum value	36.40	86.25
	Minimum value	10.30	6.25
2001	Average	24.76	75.82
	Maximum value	56.50	128.63
	Minimum value	11.50	21.39

In the opinion of Arseniuk and Goral [9] a majority of winter and spring wheat cultivars listed in the Polish cultivar register are prone to head blight and may accumulate mycotoxins in grain. Therefore, it is necessary to continue breeding experiments aimed to improve Polish cereal cultivars' resistance to head blight. *Fusarium* disease of maize cobs is counted to the most dangerous diseases, although it does not cause any major yield losses [19]. According to Tekiela [19, 20] even a small *Fusarium* infection of maize cobs leads to fumonisine cumulation in grain (Table 3).

Table 3

Percentage of infected maize cobs and mean content of fumonisines (B1, B2) in 2006 [19]

Cultivar	Wielkopolska		Podkarpacie	
	Cobs infected by *Fusarium* [%]	Content of fumonisines [ppb]	Cobs infected by *Fusarium* [%]	Content of fumonisines [ppb]
DKC 3420	74	4727	21	56
DKC3421YG	56	947	27	0
PR38F70	42	1330	51	288
PR39D81	24	304	50	847
PR39F58	80	1559	28	18

Conducted mycological analysis revealed mainly the presence of *Fusarium subglutions* [(Wollenw. et Reiking) Nelson et al], *F. graminearum* (Schwabe) and *F. culmorum* [(W. G. Smith.) Sacc.].

So far no monitoring of the mycotoxin content in maize grain has been conducted in Poland. On the basis of dispersed research it may be assumed that between several and 30 % of maize grain samples may contain the amounts of harmful substances exceeding permissible standards [21]. The content of mycotoxins in maize grain may be limited not only through proper protection of this crop, but also by cultivating genetically modified varieties because GMO grains did not contain or had only small amounts of fumonisines in comparison with maize initial forms [19, 20].

Among the abiotic factors, crop rotation has a considerable effect upon plant infection by *Fusarium* ssp. It is a common view that wheat cultivation after forecrops (cereals or maize), which are *Fusarium* pathogen hosts poses a greater risk of head blight occurrence and grain contamination with mycotoxins. However, Obst et al [22] registered lower DON values in wheat grain cultivated in monoculture than on the stand after potatoes or beetroots. A similar dependence was noticed by Fernandez et al [23], but Dill-Macky and Jones [24] obtained different results. Higher amounts of DON were assessed in wheat grain cultivated after maize, than on the stand after soybeans. The right crop rotation, ie the right selection of plant succession decreases the level of *Fusarium* inoculums and as a result the presence of mycotoxins in grain. The experiments conducted by Mazurkiewicz and Solarska [25] confirmed this thesis. Conventional and organic cultivation of barley after onion forecrop reduced grain contamination with *Fusarium* trichothecenes. However, grain originating from organic cultivation revealed a higher content of these mycotoxins. On the other hand, Vanova et al [26] did not assess any difference in DON cumulation in winter wheat grain cultivated in conventional and organic crop rotation.

The other factor which affects the increased plant infection by *Fusarium* is the tillage method. *Fusarium* fungi survive on harvest residue and are the source of infection for the subsequent crops. Their deep covering using the tillage system increases the soil biological activity and a growth of antagonist microorganisms occurs leading to lesser plant infection by diseases [27, 28]. On the other hand, leaving harvest residue on the soil surface or its shallow mixing, favours development of pathogens. Nitzsche et al [29] demonstrated that simplified tillage and direct sowing promote DON cumulation in wheat grain (Table 4).

Table 4

DON content [μ/kg] depending on tillage [29]

Cultivar	Soil cultivation method		
	Tillage	Simplified	Direct sowing
Petrus	210	220	960
Banit	940	1050	1600

Obst et al [22] found that simplified tillage caused a 10-fold increase in DON in wheat grain after maize forecrop. Dill-Macky and Jones [24] obtained a similar result, in comparison with conventional tillage, while cultivating wheat in monoculture or after maize in a no-tillage system. However, they revealed that the depth of harvest residue placing has no significant impact on DON cumulation in wheat grain grown on the stand after soybeans.

Research was also conducted on the nitrogen fertilization effect of cumulation of selected trichothecenes in cereal and maize grain. However, the results concerning the doses and forms of fertilization are not unanimous. Beta et al [30] and Bladino et al [31] registered ZEN increase in maize with increasing nitrogen dose. On the other hand, Yoshida et al [32] did not find any significant influence of fertilizer doses on wheat head blight and cumulation of mycotoxins. Further research is advisable in this field. Plants which are left unprotected against pathogenic fungi are most exposed to *Fusarium* mycotoxins presence in cereal and maize grain.

Conclusion

The presented material shows that beside the climatic conditions, cultivar and species plant resistance, also application of good agricultural practices – crop rotation, deep cover of harvest residue, proper plant protection against agrophages during the vegetation period) may limit the occurrence of *Fusarium* fungi and provide a basis to reduce cereal contamination with *Fusarium* toxins.

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WPŁYW CZYNNIKÓW ABIOTYCZNYCH NA WYSTĘPOWANIE MIKOTOKSYN FUZARYJNYCH W ZIARNIE ZBÓŻ

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Abstrakt: Praca dotyczy analizy wpływu czynników abiotycznych na kumulację mikotoksyn fuzaryjnych w ziarnie zbóż. Najczęściej w ziarnie zbóż wykrywa się deoksyniwalenol (DON), zearalenon (ZEN) oraz fumonizyny. Przyczyn obecności i kumulacji tych toksycznych związków jest wiele. Do podstawowych czynników, które sprzyjają pasożytowaniu grzybów *Fusarium* i produkowaniu mikotksyn, należy zaliczyć: warunki pogodowe i rejon uprawy, podatność gatunkową i odmianową roślin, nieodpowiedni przedplon, płytkie umieszczenie resztek pożniwnych w glebie lub pozostawienie ich na powierzchni oraz rezygnacja z ochrony roślin w okresie wegetacji.

Słowa kluczowe: mikotoksyny, ziarno, zboża, czynniki abiotyczne