AGRONOMIC IMPACTS ON FUSARIUM INFECTION AND MYCOTOXIN CONTAMINATION OF WHEAT GRAIN

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Abstract

Agronomic impacts often determine plant physiological processes. The value of grain yield may be deteriorated by fungal infections as well as contaminated by its mycotoxin metabolites. *Fusarium* spp. is a major plant pathogen of wheat. *Fusarium* infection and mycotoxin production cause serious losses in wheat and wheat-based products. Three major mycotoxins; deoxynivalenol, zearalenone and fumonisin were studied in a three years' series of winter wheat (*Triticum aestivum* L.) trial at the MATE Agronomy Institute in 2018, 2019 and 2020. 3 varieties and 5 levels of N fertilization were applied in a replicated field trial. Grain samples of harvested yield were tested for *Fusarium* infection as well as the occurrence and magnitude of mycotoxin contamination were determined.

The results obtained suggest that there were no statistically significant direct relations between the fungal infection and the presence and level of mycotoxin contamination, however certain varietal and crop year differences could be detected by fuzzy logic modelling approach for each mycotoxines.

Keywords: agronomic impacts, mycotoxins, deoxynivalenol, zearalenone, fumonisin

Összefoglalás

Agrotechnikai tényezők hatása búzafajták termésének fuzárium fertőzöttségére és mikotoxin szennyezettségére. A termesztési tényezők alapvetően befolyásolják a növények élettani folyamatait. A szemtermés értékét jelentősen leronthatják a gombás fertőződések, valamint ezek toxikus metabolitjai. A *Fusarium* fajok a búza jelentősebb kórokozói közé tartoznak. Fertőzésük és mikotoxin termelésük súlyos veszteséget okoz a búza termelésében és a termény felhasználásában. A jelen kísérletben három mikotoxin – deoxynivalenol, zearaleneon és fumonisin – vizsgálatát végezték egy hároméves (2018, 2019 és 2020) agrotechnikai kísérletsorozatban őszi búza (*Triticum aestivum* L.) szemtermés mintáin. A szabadföldi kísérletben a MATE Növénytermesztési-tudományok Intézetében, Gödöllőn 3 búzafajta és 5 N fejtrágyázási kezelés mintáin meghatározták a *Fusarium* fertőzöttség, illetve a mikotoxin szennyezettség előfordulását és mértékét.

A kísérleti eredmények alapján megállapították, hogy a fuzárium fertőzés, valamint a mikotoxin előfordulás és annak mértéke között statisztikailag igazolható szignifikáns összefüggés egyik kísérleti variáns esetében sem volt igazolható. Ugyanakkor fuzzy logic matematikai módszer alapján végzett elemzés során konkrét fajta, illetve évjárati különbségek voltak kimutathatók a vizsgált mikotoxinok esetében.

Kulcsszavak: agrotechnikai hatások, mikotoxinok, dezoxinivalenol, zearalenon, fumonisin

Introduction

Agronomic impacts often determine plant physiological processes. The value of grain yield may be deteriorated by fungal infections as well as contaminated by its mycotoxin metabolites

(Mesterházy et al., 2012; Mesterházy et al., 2020; Naguib, 2018; Parry et al., 1995). Fusarium spp. is a major plant pathogen of wheat. Mycotoxins are secondary metabolites produced by fungi, capable of causing disease and death in humans and animals. Dietary, respiratory, dermal, and other exposures to mycotoxins produce the diseases collectively called mycotoxicosis (Adejumo et al.,. 2007; Dexter et al., 1997; Kende et al., 2019). The most important Fusarium spp. mycotoxins in wheat are: deoxynivalenol, zearalenone and fumonisins. Deoxynivalenol is a vomitoxin, Fumonisins are carcinogenic, Zearalenone causes hyperestrogenism and infertility (Kurtz et al., 1978; Marasas et al., 2001; Rotter et al., 1996; Salas et al., 1999).

Fusarium infection and mycotoxin production may be affected by the cultivation of different wheat varieties and the rate of nitrogen fertilization in wheat cultivation. The aim of the research was to study the impact of management techniques (varieties and nitrogen fertilization) on Fusarium infection and mycotoxin production in wheat. Measure fusarium percentage and DON/ZEA/FUM concentration and find ways to prevent or reduce fusarium infection and mycotoxin production.

Material and method

The experiment was conducted during three consecutive years 2018, 2019 and 2020 at the experimental field of the Hungarian University of Agriculture and Life Sciences (MATE). The experimental design was that of a split-plot with main plots consisting of different wheat varieties and subplots consisting of different nitrogen fertilizer treatments. Each treatment had three replications. The wheat varieties used were obtained from the ARI Martonvásár representing three different genotypes labelled with a code 1 2 and 3 respectively. The nitrogen fertilizer (ammonium nitrate) was applied as single dose topdressing (0, 40, 80, 120 and 160 kg N/ha ai. at tillering stage). Fusarium percentage was calculated by counting the number of colonies that formed on wheat kernels (10 from each treatment) incubated for 7 days in laboratory conditions on Nash and Snider Fusarium selective medium petri dishes. Deoxynivalenol (DON), Zearalenone (ZEA) and Fumonisin (FUM) mycotoxin levels were analysed using ROSA Fast5 Quantitative tests (El Chami et al 2020; Kassai et al 2020).

Statistically, the linear regression module of the IBM SPSS V.21 software was used to determine the effect of the nitrogen fertilization and the wheat varieties on the rate of fusarium infection and mycotoxin production.

For a non-parametrised approach of the mycotoxin trial Fuzzy logic sets were applied. Fuzzy logic is based on the observation that people make decisions based on imprecise and non-numerical information. These models have the capability of recognising, representing, manipulating, interpreting, and utilising data and information that are vague and lack certainty (Hárs, 2006; Fogarassy, 2000; En.Wikipedia, 2021). Fig 1 presents a simple model applied in converting mycotoxin measured contamination ppb values to fuzzy $\mu\bar{A}$ sets. The margins given were Fopt1 0,2; Fopt2 0,8 with a 10 ppb threshold of the original measured data.

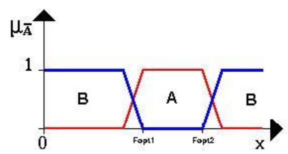

Figure 1 A simple Fuzzy logic model for creating data sets Source: En.Wikipedia 2021

Results and discussion

The three consecutive crop years were proved to be different regarding the Fusarium occurrence in the harvested wheat grain samples. Fig 2 provides information on the varietal and crop year averages of infection percentage.

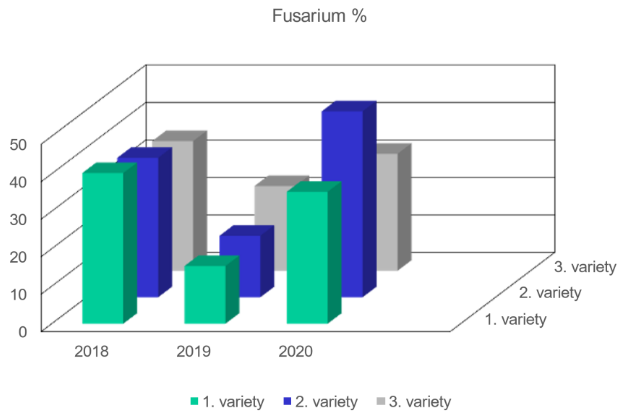

Figure 2 The magnitude of Fusarium infection by varieties and crop years

Statistically none of the variables proved to be significant, however marked differences are to be seen in the case of crop years, since 2019 data are almost half of that of the other two crop years. For a plausible evaluation of the mycotoxin trial of a non-parametrised approach using Fuzzy logic sets were applied. In the following tables converted data are presented.

Table 1 Fuzzy set of mycotoxin measurements by crop years and varieties Gödöllő, 2018-2020

Variety	**DON µĀ**	**ZEA µĀ**	**FUM µĀ**	**Fusarium % x̄**
2018				
1	0,2	0,2	0,32	40,2
2	0,32	0,2	0,44	37,2
3	0,2	0,2	0,44	34,6
				37,3
2019				
1	0,68	0,2	0,56	15,4
2	0,44	0,32	0,44	16,4
3	0,2	0,32	0,2	22,6

				18,1
2020				
1	0,2	0,2	0,44	35,2
2	0,32	0,2	0,44	49,6
3	0,44	0,2	0,2	31,2
				38,6

According to the non-parametrised data sets of Table 1, the μĀ values of the respective mycotoxins suggest that from among the three contaminants zearalenone seems to be present in the least amount, while fumonisin values are rather high, but not dominant. Deoxynivalenol values are rather variable. According to the relation with Fusarium infection figures there are no detectable relations between. Since fuzzy sets have no abilities for evaluating mathematical relations, the magnitude of data sets provide us with qualitative information only.

Table 2 Fuzzy sets by wheat varieties Gödöllő, 2018-2020

Variety	**DON μĀ**	**ZEA μĀ**	**FUM μĀ**	**mean**
1	0,36	0,2	0,44	0,33
2	0,36	0,24	0,44	0,35
3	0,28	0,24	0,28	0,27
	0,33	0,23	0,39	

Table 2 presents data of the performance of the varieties examined. The magnitude of the fuzzy values seems to support the idea that variety “3” was less susceptible regarding mycotoxin contamination, however this fact could not be proven by statistical evaluations. Also, in this set of μĀ ranges the data support the differences that ZEA values are in a lower range than that of DON and FUM.

Table 3 Fuzzy sets by N doses Gödöllő, 2018-2020

N doses	**DON μĀ**	**ZEA μĀ**	**FUM μĀ**	**mean**
0	0,44	0,2	0,33	0,32
40	0,2	0,27	0,53	0,33
80	0,4	0,2	0,27	0,29
120	0,4	0,2	0,33	0,31
160	0,33	0,27	0,47	0,36

The information of Table 3 highlight data on the plant nutrition applications. The magnitude of the fuzzy values seems to be almost uniform regarding the ascending doses of nitrogen topdressing. However, in this set of μĀ ranges the data also show the differences between ZEA values and that of DON and FUM.

Finally, the results obtained suggest that there were no statistically significant direct relations between the fungal infection and the presence and level of mycotoxin contamination, however certain varietal and crop year differences could be detected by fuzzy logic modelling approach for each mycotoxin. In this context it may be stated that fuzzy logic may be used as an informal method in the evaluation processes of physiological phenomena. Due to this approach this study has yielded information on two valuable characteristics, namely contributed to the non-parametric evaluation and distinction between varieties and have provided the researchers with detectable data on the magnitude of mycotoxin contamination.

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