ROLE OF HYBRID AND FERTILIZATION IN MYCOTOXIN CONTAMINATION OF MAIZE

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RESEARCH ARTICLE

Abstract

Maize is used as food, feed and raw materials for industries. Unfortunately maize is contaminated very often by different fungi which produce different mycotoxins. We studied the role of nitrogen fertilization and genotypes in relation to fungal colonization and mycotoxin contamination. We stated that F. graminearum was recorded as the most aggressive to all hybrids and nitrogen fertilizer levels than F. verticilliodes and A. flavus. There was a strong correlation (r=0,7271) between disease severity of F. graminearum and DON production. A medium relationship (r=0,5608) but significant was recorded between F. verticillioides and FUM contamination but there was no relationship between A. flavus and AFB1 contamination.

Keywords: maize, hybrid, N-fertilizer, mycotoxins

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INTRODUCTION

Primarily, maize is used as food, feed, and raw materials for industries. It is a more versatile multipurpose crop than wheat and rice. Maize plays an important, diverse, and dynamic role in the global agricultural food systems, and nutrition food and security.

Despite the significant global roles played by maize, it is affected by three main toxin-producing fungi namely; *Fusarium graminearum* which produces deoxynivalenol (DON) and zearalenone (ZEA), *Fusarium verticillioides* producing fumonisins toxins and *Aspergillus flavus* which produces aflatoxins. *F. graminearum* is favored in warm and humid environments, antagonistic to *F. verticillioides* which is favorable in warm and dry conditions while *A flavus* is favorable in the warmest areas (Mesterhazy et al., 2022), and recorded as more prevalent in the tropics with high temperature but below 41°C (Paterson & Lima, 2017). The effects of mycotoxins contamination in maize pose negative effects on its uses as food, feed, and, trade making many governments enact laws and regulations to prevent mycotoxins contamination of food and feed. The contamination levels are aggravated by other factors such as the tolerance level of the host (hybrids), climatic and weather conditions of the year, the agrotechnical influence, and the crop microclimate (Doohan et al., 2003; Nicholson et al., 2004).

This study aimed to assess the influence of nitrogen fertilization and maize hybrid genotypes in relation to fungal colonization, and disease development as well as the resulting mycotoxins contaminations.

MATERIAL AND METHODS

The study tested three (3) maize hybrids selected from registered companies in Hungary. The companies and hybrids included; Pioneer (P9610) with undefined sensitivity and high yielding, Bayer (DKC4590) tolerant, and the Cereal Research Nonprofit Ltd-GK Szeged (GKT376), sensitive variety. The experiment was set up in 2022 spring (2022.04.12) at the Látókép long-term research site of the University of Debrecen. The soil conditions are homogenous calciferous chernozem formed on the Hajdúság loess ridge with an upper layer humus content average of 2.7–2.8% and a thickness of around 80 cm. The acidity of the upper soil layers is almost neutral (pH_{KCl}=6.46-6.60). The phosphorus supply of the calcareous soil is average (AL-soluble P_2O_5 133 mg kg^{-1}), while its potassium supply is average-good (AL-soluble K_2O 240 mg kg^{-1}). The soil moisture content during sowing was suitable for germination. However, May, June, and July were dry, and therefore, two supplementary irrigation was performed in May and early July during the critical periods of fertilization, silking, and grain filling.

The experiment was carried out in a tetraplicate using a split-split plot design. The main plots were nitrogen rates (N=0, 90, 150 kg ha^{-1}, the sub-plot treatment was the maize hybrids and the sub-sub plot treatment was the fungal ear inoculation. Three of the rows were exposed to artificial inoculation; according to international guidelines, one inoculum was employed for a single pathogen. one with a strain of *F. graminearum* that produces DON, one with a strain of *F. verticillioides* that produces FUM, and the third raw sample was inoculated with a strain of *A. flavus* that produces AFB1. The untreated check was the fourth raw.

The influence of N rates and maize hybrids on the severity of ear and kernel coverage and mycotoxins contamination levels were determined by analysis of variance using statistical software Genistat 18th edition registered for plant research international after subjecting the data to a normality test.

RESULTS AND DISCUSSIONS

The results of the study investigating the roles played by nitrogen fertilization and maize hybrid genotypes on fungal ear rot disease development and production of resulting mycotoxins indicated some significant variations between and within factors after the performance of statistical evaluations.

The incidence of ear and kernel rot showed a varying infection level due to the effects of hybrids tolerance and fertilization ($LSD_{0.05}$) as demonstrated in *(Table 1).* The mean ear rot severity across nitrogen levels and hybrids varied from 1.99% to 8.22%. *F. graminearum* was recorded as the most aggressive to all hybrids and nitrogen fertilizer levels than *F. verticillioides,* and *A. flavus* counterparts varying from 9.60% to 40.10%, thus, there was variation between hybrids. *F. graminearum* ear rot severity between hybrids significantly followed the trend P9610>GKT376>DKC4590, likely, nitrogen levels also followed a similar trend from the highest level to the control.

The average contamination of the investigated mycotoxins DON, FUM (total, fumonisins), and AFB1 is presented in *table 2.* For inoculated treatment, the average amount of mycotoxins detected was above the detection limits. There were significant differences ($LSD_{0.05}$) in DON and FUM contamination hybrids at N150 and Ø nitrogen fertilizer rates and no differences were recorded for AFB1. DON contamination indicated P9610 as the most contaminated hybrid while GKT376 was the most FUM-contaminated hybrid leaving DKC4590 as the least contaminated for the respective mycotoxins.

To study the relationships between the measured data within and between fungal species, a two-tailed Pearson's correlation was performed (*Table 3).* The results indicated that there was a strong correlation (r=0.7271) and significant ($p<0.001$) between disease severity for *F. graminearum (FG%)* and DON production. A medium relationship but significant (r= 0.5608, $p<0.001$) was recorded for *F. verticillioides (FV%)* and FUM contamination respectively, however, there was no relationship and insignificant between *A. flavus* (AF%) and AFB1 production and contamination. On the other hand, AF% showed a significant medium relationship in the production of DON and FUM (r=0.5028 and r=0.3567, $p<0.001$ and $p<0.05$) respectively. Further, FG% and FV% indicated a significant medium relationship in the production of FUM and DON (r=0.4594 and r=0.4584, $P<0.001$) respectively.

CONCLUSIONS

The results of this study demonstrate the significant role that nitrogen fertilization as one of the agrotechnical factors on the one side and interactively with maize hybrid genotype may play in reducing fungal infestation and the resulting mycotoxins contamination. The results indicate significant but complex trends played by the factors individually and interactively in agreement with previous studies indicating a lack of consistency in the connections between *Fusarium* infection, visible FER symptoms, and toxins production (Krnjaja et al., 2021; Schaafsma et al., 2006; Blandino and Reyneri, 2008). Further, a study by Stumpf et al., (2013) on maize samples with highly damaged kernels showed less concentration of fumonisins contamination.

Table 1

Interactive effect of nitrogen fertilizer application rate and hybrid genotypes on ear and kernel rot severity

N level	Hybrids	Artificial inoculated			Untreated Control		Mean
		AF%	FV%	FG%	Aspergillus %	Fusarium %	
	DKC4590	0.04	0.09	10.30	0.01	0.10	2.11
Ø	GKT376	0.15	0.22	9.60	0.00	0.00	1.99
	P9610	0.21	0.12	25.60	0.05	0.00	5.20
	DKC4590	0.29	0.14	19.70	0.08	0.10	4.06
N90	GKT376	0.34	0.57	19.50	0.09	0.11	4.12
	P9610	0.24	0.21	39.00	0.21	0.10	7.95
	DKC4590	0.07	0.57	13.90	0.03	0.00	2.91
N150	GKT376	0.77	0.66	28.20	0.01	0.10	5.95
	P9610	0.43	0.34	40.10	0.01	0.20	8.22
Mean		0.28	0.33	22.88	0.05	0.08	4.72
$LSD_{0,05}$		0.3458	0.2190	13.40	*	*	

Table 2

Interactive effect of nitrogen fertilizer application rate and hybrid genotypes on the amount of toxins contamination

N level	Hybrids	Artificial inoculated			Untreated Control		
		DON (ppm)	FUM (ppm)	AFB1 (ppb)	DON (ppm)	FUM (ppm)	AFB1 (ppb)
	DKC4590	4.11	0.97	19.95	0.00	0.47	4.44
Ø	GKT376	9.78	2.49	15.94	0.00	0.93	4.23
	P9610	12.33	1.71	14.41	0.00	0.48	0.00
	DKC4590	5.82	3.06	26.68	0.00	2.34	14.21
N90	GKT376	8.98	3.90	24.91	0.00	1.48	1.49
	P9610	8.21	2.26	29.99	0.00	1.33	0.00
	DKC4590	2.71	2.37	33.10	0.00	1.15	41.74
N150	GKT376	9.60	6.59	27.93	3.1	0.33	34.46
	P9610	11.48	3.81	17.53	0.00	3.09	3.00
Mean		8.11	3.02	23.38	0.34	1.29	11.51
$LSD_{0,05}$		4.597	1.687	26.637	*	*	*

Table 3

Coefficient values of Pearson correlation between the severity of ear and kernel rot and mycotoxin contamination of selected maize hybrids on nitrogen fertilizer rates

	AF(%)	*FV(%)*	*FG(%)*	*AFB1(ppb)*	*FUM(ppm)*	*DON(ppm)*
AF(%)	1					
FV(%)	0.3495	1				
FG(%)	0.4736	0.5433	1			
AFB1(ppb)	0.0785	0.2064	0.2196	1		
FUM(ppm)	0.3567**	0.5608***	0.4594***	0.1814	1	
DON(ppm)	0.5028***	0.4584***	0.7271***	0.1406	0.3741	1

***Correlation is significant at p=0.001, ** Correlation is significant at p=0.05

REFERENCES

Blandino, M., & Reyneri, A., 2008. Effect of maize hybrid maturity and grain hardness on fumonisin and zearalenone contamination. Italian Journal of Agronomy, 3(2), 107-117.

Doohan, F. M., Brennan, J., & Cooke, B. M., 2003. Influence of climatic factors on Fusarium species pathogenic to cereals. Epidemiology of Mycotoxin Producing Fungi: Under the aegis of COST Action 835 'Agriculturally Important Toxigenic Fungi 1998–2003', EU project (QLK 1-CT-1998–01380), 755-768.

Krnjaja, V., Mandić, V., Bijelić, Z., Stanković, S., Obradović, A., Petrović, T., & Radović, Č., 2021. Influence of nitrogen rates and Fusarium verticillioides infection on Fusarium spp. and fumonisin contamination of maize kernels. *Crop Protection*,*144*, 105601.

Mesterhazy, A., Toldine Toth, E., Szel, S., Varga, M., & Toth, B., 2020. Resistance of maize hybrids to Fusarium graminearum, F. culmorum, and F. verticillioides ear rots with toothpick and silk channel inoculation, as well as their toxin production. Agronomy, 10(9), 1283.

Nicholson, P., Gosman, N., Draeger, R., & Steed, A., 2004. Control of Fusarium and Aspergillus species and associated mycotoxins on wheat and maize. In Meeting the mycotoxin menace (pp. 113-132). Wageningen Academic Publishers.

Paterson, R. R. M., & Lima, N., 2017. Thermophilic fungi to dominate aflatoxigenic/mycotoxigenic fungi on food under global warming. International journal of environmental research and public health, 14(2), 199.

Schaafsma, A. W., Tamburic-Ilincic, L., & Reid, L. M., 2006. Fumonisin B1 accumulation and severity of Fusarium ear rot and Gibberella ear rot in food-grade corn hybrids in Ontario after inoculation according to two methods. Canadian journal of plant pathology, 28(4), 548-557.

Stumpf, R., Santos, J. D., Gomes, L. B., Silva, C. N., Tessmann, D. J., Ferreira, F. D., & Del Ponte, E. M., 2013. Fusarium species and fumonisins associated with maize kernels produced in Rio Grande do Sul State for the 2008/09 and 2009/10 growing seasons. Brazilian Journal of Microbiology, 44, 89-95.