International Journal of Plant & Soil Science

Volume 35, Issue 8, Page 188-195, 2023; Article no.IJPSS.98283
ISSN: 2320-7035

Surveillance of Mycotoxin contamination and Production of Aflatoxin by *A. flavus* in Contaminated Maize Seeds in Bihar

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2023/v35i82895

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/98283

Original Research Article

Received: 01/02/2023
Accepted: 03/04/2023
Published: 07/04/2023

ABSTRACT

Aflatoxin- producing fungi like *Aspergillus flavus* contaminate maize crops in the agricultural field at harvest, post- harvest, and during storage making them one of the most widespread and dangerous mycotoxins. It has been directly correlated to adverse health effects, such as liver cancer in many animal species as well as plant systems.

Maize samples were collected from seven districts of Bihar viz, Begusari, East Champaran, Khagaria, Bhagalpur, Saharsa, Madhepura, and Samastipur. The collected sample was examined for associated mycoflora and aflatoxin-producing prospective of *Aspergillus flavus*. It was determined that *A. flavus* was of presiding occurrence accompanied by *Penicillium* spp., *Fusarium*, *A. nigar*, *Rhizopus, Trichoderma, Mucor* and *A. ochraceus*. 119 strains of the total *A. flavus* isolates were toxigenic, producing aflatoxin B1, B2, and G1. The highest Aflatoxin is all probability due to complementary environmental conditions, undeveloped agricultural practices, poor storage circumstances of grains, and because of yearly flood problems in this region.

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Keywords: Maize seeds; aflatoxin; mycoflora; aspergillus.

1. INTRODUCTION

Mycotoxin (Greek word Mykes = Fungus and Toxin = Toxin) is a toxic secondary metabolite produced by an organism of Kingdom Fungi [1-3] and is capable of causing disease and death in humans and animals [4]. They are stable, invisible, and toxic chemical compounds, found to be common in the farm environment surviving in several places as well as on many different types of feedstuffs.

The growing moulds and production of mycotoxin are most encouraged by environmental factors like temperature (cool/hot) and moisture (wet/dry) [5,6]. However, mycotoxins may also be produced by moulds when other stress conditions occur to the host plant or the mould.

Aflatoxins are a type of mycotoxin produced by *Aspergillus* spp. such as *A. flavus* and *A. parasiticus* [7-10]. The umbrella term aflatoxin refers to four different compounds which are B1, B2, G1, and G2 [11,12] where Aflatoxin B1, the most toxic, is a potent carcinogen and has been directly correlated to adverse health effects, such as Liver cancer in many animals as well as plant system [9,13,14]. Aflatoxin is largely associated with commodities produced in the tropics and subtropics region in cotton, wheat, millet, spices, rice, sorghum, peanuts, sunflower, pistachios, and maize crops [9,11].

Maize is widely cultivated throughout the world and a greater weight of maize is produced each year than any other grain [15]. In 2021, total world production was 1.2 billion tonnes. Maize is the most widely grown grain crop throughout America. Out of 38 administrative districts of Bihar only seven districts, viz. Begusarai, East Champaran, Khagaria, Bhagalpur, Saharsa, Madhepura, and Samastipur constitute about half of the total maize acreage. These districts are historically flood-prone areas during the rainy season and fall north of the Gangas, having several seasonal river tributaries.

These seven districts of Bihar have recorded in April 2021, the highest maize productivity in the world. Maize cultivation provides livelihood to approx. 1.3 million farmers in Bihar state. Maize has become a staple food in many parts of the world with the total production surpassing that of wheat or rice. In addition to being consumed directly by humans (often in the form of masal). Maize is used for corn ethanol, animal feed, and other products, such as corn starch and corn syrup [16]. It is also used in making ethanol and other biofuels.

Therefore, an attempt has been made to surveillance of mycotoxigenic fungi and the production of aflatoxin by *A. flavus* in contaminated maize seeds of major growing districts of Bihar.

1.1 Occurrence of Mycotoxin in Maize Crop

Aflatoxin–producing fungi like *A. flavus* contaminate maize crops in the agricultural field at harvest and during storage making them one of the most widespread and dangerous mycotoxins. In Kenya (2004), about 125 people died, and nearly approx. 200 others required medical treatment after eating aflatoxin-contaminated maize [17]. The death was associated with home-grown maize that had not been treated with fungicides or properly dried before storage. At that time, due to food shortages, farmers may have been harvesting maize earlier than normal to prevent thefts from their agricultural fields, so the grain had not fully matured and was more susceptible to infection with *A. flavus*.

2. MATERALS AND METHODS

2.1 Sample Collection

Maize seed samples were collected from a farmer's field in seven districts viz. Begusarai, East champaran, Khagaria, Bhagalpur, Saharsa, Madhepura and Samastipur of Bihar. Maize seed samples were kept in sterile polythene bags for further experiments. The moisture content of each sample was recorded with the help of an OSAW moisture meter and pH readings were taken by using a digital pH meter [18].

2.2 Isolation and Identification of Mycoflora

100 kernels of all seven- sampling site (districts) was surface sterilized in 2% Naocl and plated on moist blotting paper in sterile Petri dishes (ISTA, 1966). Plates were incubated at room temperature for 7 days followed by macro and microscopic identification [19,20]. Fungal colonies were maintained on PDA media for further use and identification.

2.3 Aflatoxin Analysis of Toxigenic Isolates

Aspergillus flavus isolates were allowed to grow on SMKY liquid media [21] for one week at 30 ± 2˚c and aflatoxin was extracted [22]. It was extracted with chloroform, and dried in a water bath and concentrated extracts were kept in screw-tight bottles for qualitative and quantitative analysis.

2.4 Qualitative and Quantitative Analysis

Qualitative analysis of aflatoxin was done using TLC (Thin layer chromatography), toluene-isoamyl alcohol- methanol (90: 32: 2 v/v) solvent system [23], and for chemical conformation trifluoroacetic acid [24] or 25% sulphuric acid spray was used.

Quantitative estimation of aflatoxin was done spectrophotometrically [25].

3. RESULTS

Table 1 and Fig. 1, indicates the association of mycoflora in seven districts of Bihar in flood–prone areas during the rainy season (Agroclimatic zone in Fig. 2) and observed during the study, moisture content, and pH of the sample. *A. flavus, Penicillium* spp., *Fusarium, A. nigar*, and *Rhizopus* were present in all the seven districts in large amounts whereas *Trichoderma, Mucor*, and *A. ochraceus* were present in a rare amount of all districts but absent in Khagaria and Saharsa districts, respectively (Fig. 3). pH ranged between 5.8 to 6.7 and moisture content was recorded at 10.8, 10.5, 10.0, 9.6, 10.1, 10.4, and 10.7 for Begusarai, East Champaran, Khagaria, Bhagalpur, Saharsa, Madhepura, and Samastipur, respectively.

Table 2 represents that *A. flavus* sample of 7 districts having 385 isolates of *A. flavus*. 119 strains were found to be toxigenic with which 86 positives to AFT- B1, 24 positives to AFT-B1B2, and only 9 positives for AFT-B1B2G1. The amount of AFT-B1 was, however very low at 0.2-1.3, 0.0- 1.0, and 0.0- 1.1 µg/ml, respectively. Whenever, the maximum aflatoxin was recorded from Begusarai samples at 0.2- 1.8 µg/ml followed by East Champaran, Khagaria, Saharsa, Bhagalpur, Samastipur, and Madhepura districts, respectively.

Maize samples collected from seven districts in flood-prone areas during the rainy season were highly contaminated with *A. flavus* and other genera of fungi like, *Penicillium, Fusarium, A. nigar, Rhizopus, Trichoderma, Mucor*, and *A. ochraceus*. Mycotoxin-producing fungi like *Aspergillus* and *Fusarium* spp. were of predominant occurrence (Figs. 4 and 5). The moisture contents were also observed in all the samples which influence the aflatoxin production.

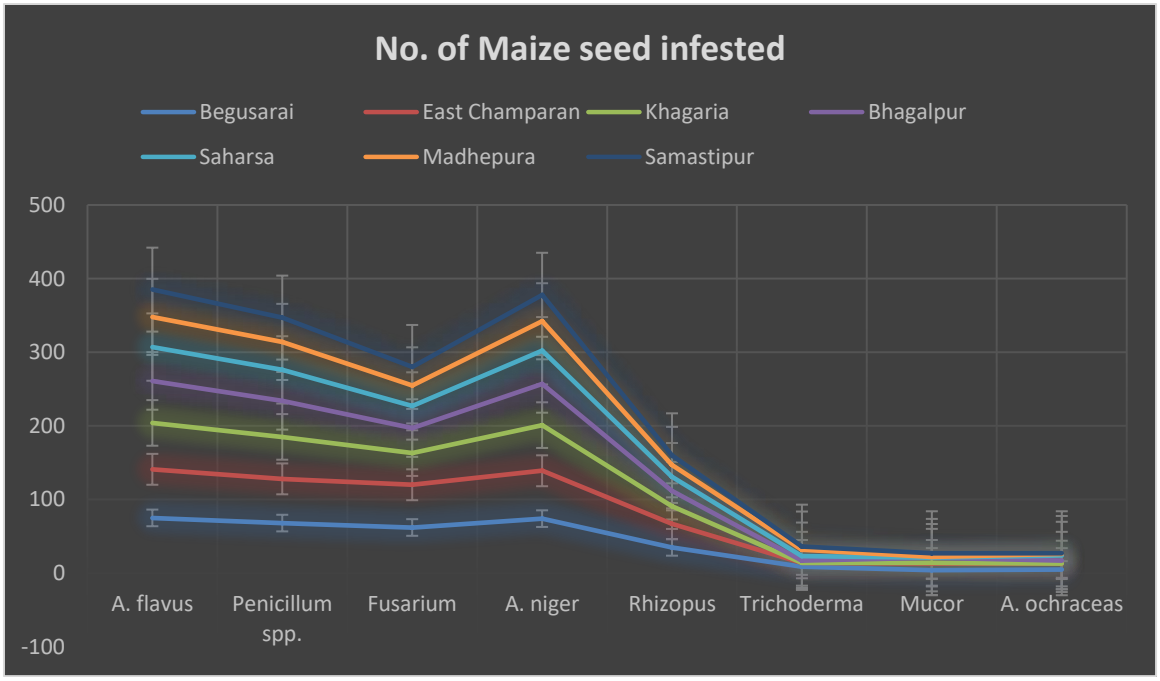

Fig. 1. Line showing No. of maize seed infested in seven districts of Bihar

Table 1. Mycoflora associated with maize seeds collected from seven districts of Bihar

Sl. No.	Fungus	Maize Seed Samples from Seven District																		
		Begusari (N =100)			East Champaran (N =100)			Khagaria (N =100)			Bhagalpur (N =100)			Saharsa (N =100)			Madhepura (N =100)			Samstipur (N =100)		
1	*A. flavus*	75			66			63			57			46			41			37		
2	*Penicillum Spp.*	68			60			57			49			42			38			33		
3	*Fusarium Spp.*	62			58			43			34			30			28			25		
4	*A. nigar*	74			65			62			56			45			40			36		
5	*Rhizopus Spp.*	35	10.8	6.7	32	10.5	6.3	24	10.0	6.0	21	9.6	5.8	19	10.1	5.9	16	10.4	6.2	13	10.7	6.5
6	*Trichoderma*	9			5			0			3			6			9			4		
7	*Mucor*	4			9			1			7			0			1			5		
8	*A. ochraceus*	5			8			0			4			7			2			1		

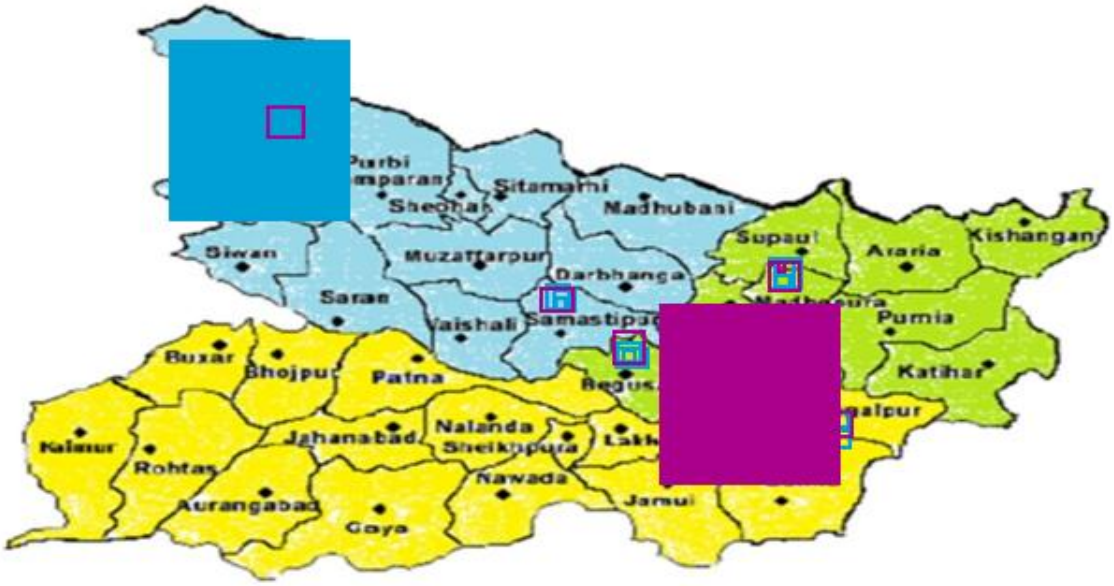

Fig. 2. Pink dot indicates agroclimatic zone of seven districts of Bihar

Fig. 3. Association of mycoflora in PDA media of seven districts of Bihar

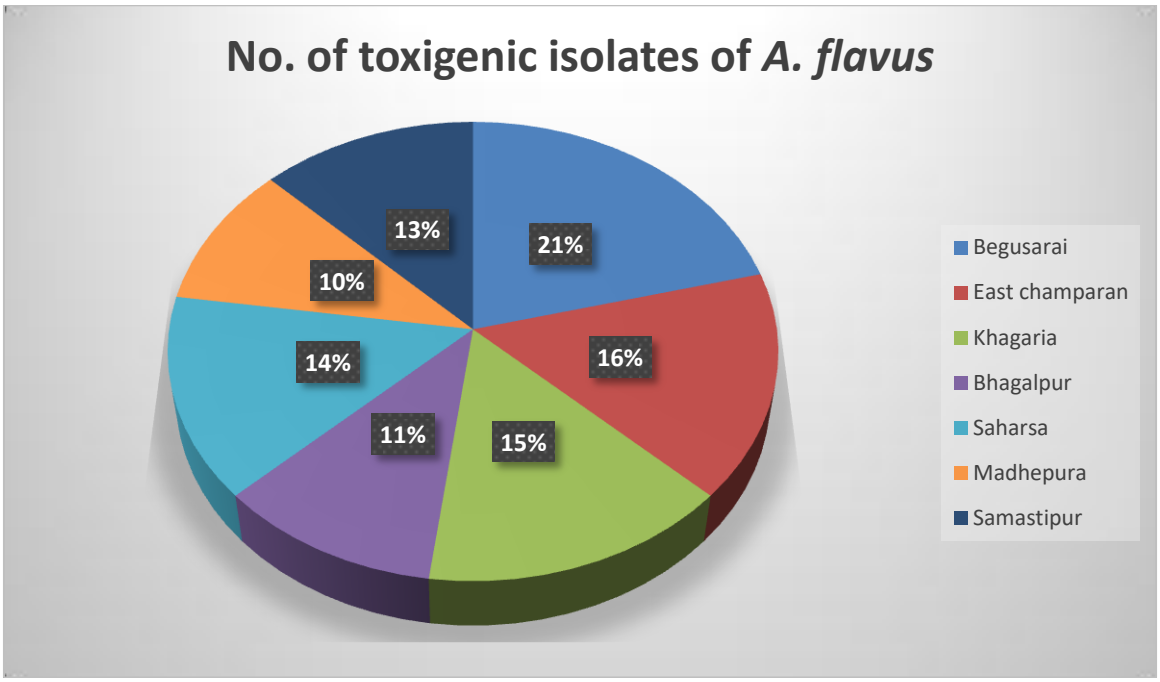

Fig. 4. Pie chart showing No. of toxigenic isolates of *A. flavus* (%) in seven district of Bihar

Fig. 5. Association of mycoflora in maize comb during flood situation

Table 2. *Aspergillus flavus* isolates from maize Seed samples

Sl. No.	Districts of Bihar	No. of *A. flavus* strains isolates	No. of toxigenic isolates of *A. flavus*	Positive isolates			Range of aflatoxin B_1 concentration µg/ml (ppm)
				B_1	B_1B_2	$B_1B_2G_1$	
1	Begusari	75	25	15	7	3	0.2- 1.8
2	East Champaran	66	19	13	5	1	0.1- 1.6
3	Khagaria	63	18	12	4	2	0.2- 1.4
4	Bhagalpur	57	13	11	1	1	0.2- 1.3
5	Saharsa	46	17	14	2	1	0.0- 1.2
6	Madhepura	41	12	10	2	0	0.0- 1.0
7	Samstipur	37	15	11	3	1	0.0- 1.1
	Total	385	119	86	24	9	-

4. DISCUSSION

Recently, about 125 people died, and nearly approx. 200 others required medical treatment after eating aflatoxin-contaminated maize [17]. In Kenya (2004), the death was associated with homegrown maize that had not been treated with fungicides or properly dried before storage. At that time, due to food shortages, farmers may have been harvesting maize earlier than normal to prevent thefts from their agricultural field, so the grain had not fully matured and was more susceptible to infection with *A. flavus* and aflatoxin-producing potentiality of toxigenic strains of *A. flavus* were higher, due to moisture content in rainy season in a flooded area as well as poor storage conditions that provide an opportunity for fungal growth like Aflatoxin to easily invade the maize seeds.

Bihar has experienced serious aflatoxicosis outbreaks associated with maize which has claimed lives as well as maize yield losses. Our findings from the various sites (districts) revealed that potentially mycotoxigenic fungal isolates were found on maize samples. Maize samples from each district were more infested by a specific fungal genus. Maize grains from Begusarai were heavily contaminated by *Aspergillus* spp. while those collected from Khagaria and Saharsa were not contaminated with *Trichoderma* and *Mucor* [26,27].

5. CONCLUSION

Maize samples from the seven districts tested were infested by different mycotoxigenic fungi. The existence of mould on the maize samples shows the possibility of the occurrence of more than one mycotoxin but dominant by Aflatoxin B1. The maize has the potential to enhance the income of 1.3 million maize growers in Bihar State, thereby significantly reducing the poverty of the poorest states in India.

So, it was important to determine the distribution and incidence of fungi that exist in maize from different districts.

ACKNOWLEDGEMENTS

The authors are grateful to Prof. and Head, (Dr.) Shahnaz Jamil, University Department of Botany, L. N. Mithila University, Darbhanga for providing laboratory facilities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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