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Ajithkumar K
Main Agricultural Research Station, University of Agricultural Sciences, Raichur, Karnataka, India

Naik MK
University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India

Savitha AS
Department of Plant Pathology, University of Agricultural Sciences, Raichur, Karnataka, India

Corresponding Author:
Ajithkumar K
Main Agricultural Research Station, University of Agricultural Sciences, Raichur, Karnataka, India

Assessment for the mycotoxigenic fungi and mycotoxin contamination of maize in Karnataka

Ajithkumar K, Naik MK and Savitha AS

Abstract
Maize is one of the most important cereal crops in the world agricultural economy, cultivated throughout the world in all the seasons. A roving survey for the severity and incidence of mycotoxin producing fungi was taken up in fields, storage as well as in markets of the major maize growing districts of Karnataka during 2017-18 and 2018-19. The maximum per cent severity was recorded in Gunnal village (14.29) of Koppal taluk and Kadamanahalli village (25.71) of Haveri taluk during 2017-18 and 2018-19, respectively. Concurrently, from 21 taluk, storages and markets were also surveyed for per cent incidence of mycotoxin producing fungi. Among the surveyed localities, maximum per cent incidence was recorded in the godowns of Sagara (47.20) and H. Hadagali (65.60) during 2017-18 and 2018-19, respectively. Overall the higher mycotoxigenic fungi contamination was seen in Shivamogga and Koppal districts, whereas least severity was recorded in Raichur. Clearly the present investigation provides the information to locate the areas with high prevalence and less prevalence of mycotoxin in maize growing districts of Karnataka.

Keywords: *Aspergillus flavus*, disease incidence, disease severity, *Fusarium verticillioides*, Mycotoxin

Introduction
Maize (*Zea mays* L., 2n = 20) being C4 plant and important cereal crop belonging to tribe *Maydeae* of the grass family *Poaceae*. Central America is considered as centre of origin of maize. It is grown at an altitude of 58 °N to 40 °S, from below mean sea level to altitudes of higher than 3000 m and in areas with 250 mm to more than 5000 mm of rainfall per year [1]. The crop is grown in the warmer parts of temperate regions and in humid subtropical climate.
Maize is well known as "Queen of Cereals" or "Miracle Crop" due to its highest genetic yield potential than any other cereal crops[2]. Globally maize is grown on an area of 193.7 m. ha. with the production of 1147.7 m. t. and productivity of 5.75 t/ha [3]. In India, maize is the third most important food crop (after rice and wheat) and is cultivated in an area of 9.2 m. ha. with the production of 27.8 m. t. and the productivity of 2965 kg/ha [4]. India, Karnataka and Madhya Pradesh have maximum area under maize (1.34 m. ha and 1.27 m. ha, respectively) followed by Maharashtra (0.93 m. ha), Rajasthan (0.84 m. ha) and Uttar Pradesh (0.02 m. ha) [5]. In Karnataka, the crop is cultivated in an area of 1.34 m. ha. with 3.76 m. t. of production and 2085 kg/ha of productivity [6]. In Karnataka the crop is mainly grown in Davanagere, Shivamogga, Belagavi, Dharwad, Mysuru, Mandya, Chamarajanagar, Koppal and Ballari districts.
Major biotic constraints in maize production are pests and diseases. Important diseases which are yield limiting factors of maize are downy mildews, leaf blights, stalk rots, ear rots and rusts under field conditions. In storage condition, mycotoxin contamination is the major problem which affects the quality and sometimes the quantity of the produce throughout the year, thereby it affects exporting prospects of maize. In Karnataka, there is a problem for storage and preservation of maize due to higher production and lack of proper storage units resulting in more chances for mycotoxin contamination.
Survey for the mycotoxigenic fungal infection and mycotoxin contamination at field, godown and market provides the information to locate the areas with varied levels of mycotoxigenic fungal and mycotoxin contamination in maize growing districts such as Raichur, Ballari, Koppal, Haveri, Davanagere, Shivamogga and Mandya. The information will also elicits the idea of conducive ecological situations and the possible entry of mycotoxin contamination in to the food chain system.

Materials and Method

Survey for the mycotoxigenic fungal infection and mycotoxin contamination in maize growing districts of Karnataka

A roving survey for the severity and incidence of mycotoxigenic fungal infection and mycotoxin contamination was taken up from major maize growing areas, storage as well as in markets of the major maize growing districts of Karnataka during 2017-18 and 2018-19. From each location samples were collected from the freshly harvested crop or one week before harvesting by grid sampling method. The fields were divided into four quadrants, from each quadrant the samples were collected randomly, pooled and made into one representative sample. Similarly, the samples from storage and markets were also collected randomly, pooled and made into one representative sample.

Per cent infection of cobs and per cent infection of grains per cob was calculated by using the following formula[7],

$$\text{Per cent infection of cob} = \frac{\text{Number of infected cobs}}{\text{Total number of cobs observed}} \times 100$$

$$\text{Per cent infection of grain per cob} = \frac{\text{Number of infected grains}}{\text{Total number of grains observed}} \times 100$$

Results and Discussion

Severity of mycotoxin producing fungi, *Aspergillus* spp. and *Fusarium* spp. contamination in maize fields

A survey on the severity of mycotoxin producing fungi in maize from seven major maize growing districts of Karnataka during 2017-18 and 2018-19 revealed that the severity of mycotoxin producing fungi in the fields differed spatially and temporally. During 2017-18, the maximum per cent severity (14.29) was recorded in Gunnal village whereas minimum per cent severity (1.43) was registered in Nandibanda and Varadapura villages. However the maize crop was found free of mycotoxigenic fungal infection in the fields of Kommerahalli, Shivangi and Chigateri villages. Among the 21 taluks surveyed for the severity of the *Aspergillus* spp. and *Fusarium* spp. in maize, the maximum per cent disease severity of 11.43 was noticed in Koppal and least severity was noticed in Hosapete, Harapanahalli and Mandya taluks. Shivamogga and Koppal stand first in the catalogue among the seven districts assessed for per cent contamination severity of mycotoxigenic fungi in maize with 8.57. Whereas, the least severity of 3.81 per cent was noticed in Raichur (Plate 1, Fig. 1 and 2).

The subsequent 2018-19 survey data exhibited slight increment in per cent disease severity of mycotoxigenic fungi in the fields varied from 0.00 to 25.71 from that of 2017-18 (0.00 to 14.29). The maximum severity of the fungus infection was recorded in Kadamanahalli village and the minimum severity of 1.43 per cent was recorded in seven villages namely Kakargal, Nasalapur, Yarmaldoddi, Gidigera, Belluru, Sadolalu and Channasandra. The maize crop was found free of mycotoxigenic fungi in the fields of Nilogal village. Among the 21 taluks surveyed the maximum per cent disease severity of 22.15 was noticed in H. Hadagali and least severity of 1.43 per cent was noticed in Maddur and Koppal. Among the seven districts surveyed for mycotoxigenic fungi Haveri and Ballari stood top in the list with 17.64 and 15.48 per cent disease severity, respectively. Whereas, the least per cent severity of 2.38 was noticed in Raichur (Table 2, Plate 2, Fig. 3 and 4).

Among the fields surveyed, the mean maximum severity was noticed in Shivamogga and Koppal district (8.57% each) during 2017-18 and during 2018-19 maximum severity was observed in Haveri district (17.64%). Hence, these locations can be considered as mycotoxigenic fungi prone areas. On contrary in Raichur district minimum mean per cent severity of 3.81 and 2.38 was noticed during 2017-18 and 2018-19, respectively. Therefore it was considered as mycotoxigenic fungi less prone areas.

The higher mycotoxigenic fungal contamination in Shivamogga and Koppal might be due to intensively grown cropping area with irrigation and high inputs, besides the practice of heaping maize produces after harvest in field itself resulting in direct contact of grains with soil fungi. Such heaping also creates congenial moist condition and relative humidity which is favourable for growth of the moulds[8]. The mycotoxigenic fungi contamination was also attributed to the prevailing average temperature of 27.3 ℃ coinciding with more RH and moisture levels. The monocropping of maize in these areas and storage the produce in the field after threshing of the grains in husked condition also resulted in the maximum severity of mycotoxigenic fungi. The least severity of mycotoxigenic fungi was noticed in Raichur which was attributed to maximum average temperature of 31.5 ℃ with less relative humidity (50 to 70%).

Incidence of mycotoxin producing fungi, *Aspergillus* spp. and *Fusarium* spp. in maize godowns and markets:

Simultaneously survey on the incidence of mycotoxigenic fungi was also carried out in all the 21 taluks, storages and markets (Table 1). Among all the surveyed locations maximum per cent incidence of 47.20 was recorded in the godowns of Sagara and the minimum per cent incidence of 12.00 was documented in the godowns of Mandya during 2017-18. A mere elevation of disease incidence was recorded during the subsequent year 2018-19 (Table 2), where per cent incidence was recorded in the godowns of H. Hadagali with 65.60 and the minimum per cent incidence of 24.40 was noticed in the godowns of Mandya. Shivamogga (40.40%) and Ballari (58.67%) district showed higher incidence in godowns and markets during 2017-18 and 2018-19, respectively. Hence, these locations can be considered as mycotoxigenic fungi prone areas. Whereas minimum mean incidence was witnessed in storage and markets of Haveri (22.73%) during 2017-18 and Mandya and Shivamogga (31.87% each) during 2018-19 were considered as mycotoxigenic fungi less prone areas. Comparison of the severity between the field and the storage to the tune of 2 to 3 folds indicating more the field occurrence more likely the incidence under storage. Field severity depends on the climatic and crop conditions.

The present investigation revealed the occurrence of high per cent incidence and frequency of *Aspergillus* spp. and *Fusarium* spp. on maize samples produced in Karnataka. The incidence of *Fusarium* spp. was comparatively higher on maize kernels in the fields compared to the incidence of *Aspergillus* spp., whereas the incidence of *Aspergillus* spp. was more in markets and godowns than the *Fusarium* spp. The results of this investigation are similar to those obtained by earlier workers [9, 10].

Investigations made by other researchers in Mysore and Tamil Nadu indicated that *Aspergillus* spp. and *Fusarium* spp. occur

quite frequently on different genotypes though the proportion of their occurrence on different genotypes varies[11]. The incidence of *A. flavus* and *Fusarium* spp. in all the surveyed areas, during *Kharif* 2013 and *rabi* 2103-14[12]. Mycotoxin contamination was determined in 150 freshly harvested maize samples collected from major maize growing areas of Karnataka, Andhra Pradesh and Tamil Nadu[13]. A total of 288 fungal isolates were determined, of which *Fusarium*, *Aspergillus* and *Penicillium* were predominant. The study on the mapping of mycotoxigenic fungi revealed the occurrence of *Aspergillus* spp. and *Fusarium* spp. on maize produced in Karnataka with relatively high per cent incidence.

It should be noted here that, among the storage fungal pathogens *Aspergillus*, *Fusarium* and *Penicillium* are the most predominant species invading maize seed and producing mycotoxin. The *Aspregillus* spp. are the most dominant fungi followed by *Fusarium* spp. was evidenced in the present study as well as in Ethiopia [14]. These fungi are important in producing secondary metabolites which are carcinogenic to both humans and animals.

Table 1: Assessment of severity of mycotoxin producing fungi in maize during 2017-18

Districts and Taluks	Place	Varieties/ Hybrids	Fungal Infection (%)	
			Field	Storage and Market
Raichur				
1. Raichur	Kurubadoddi	NK-6240	4.29	
	Agapura	CP-818	5.71	
Taluk Mean			5.00	17.20
2. Deodurga	Ginnapura	NK-6240	4.29	
	Shivangi	NK-6240	0.00	
Taluk Mean			2.15	30.40
3. Manvi	Kapgal	CP-818	4.29	
	Kodla Camp	NK-6240	4.29	
Taluk Mean			4.29	25.02
District Mean			3.81	24.27
Koppal				
1. Koppal	Jarkunti	Deccalb	8.57	
	Gunnal	Deccalb	14.29	
Taluk Mean			11.43	38.60
2. Kushtagi	Madalgatti	NK-6240	8.57	
	Shakapur	Deccalb	11.43	
Taluk Mean			10.00	21.80
3. Yelburga	Hanmapur	CP-818	5.71	
	Tumurguddi	Deccalb	2.86	
Taluk Mean			4.29	31.60
District Mean			8.57	30.67
Haveri				
1. Haveri	Kanavalli	Laxmi-4959	5.71	
	Honnatti	Kaveri-244	2.86	
Taluk Mean			4.29	22.40
2. Ranenennuru	Devaragundi	CP-818	4.29	
	Chatra	NK-30	7.14	
Taluk Mean			5.72	25.60
3. Hirekeruru	Abalur	CP-818	5.71	
	Mutturu	CP-818	2.86	
Taluk Mean			4.29	20.20
District Mean			4.77	22.73
Ballari				
1. Hospete	Nandibanda	CP-828	1.43	
	Varadapura	CP-828	1.43	
Taluk Mean			1.43	25.40
2. H. B. Halli	Chintrapalli	P-3501	2.86	
	Malavi	CP-818	5.71	
Taluk Mean			4.29	24.00
3. H. Hadagali	Hire Hadagali	CP-828	10.00	
	Mylara	CP-818	8.57	
Taluk Mean			9.29	39.20
District Mean			5.00	29.53
Davanagere				
1. Honnalli	Surahonne	K-25K55	7.14	
	Madanbhavi	K-25K55	10.00	
Taluk Mean			8.57	31.20
2. Harapanahalli	Telagi	CP-818	2.86	
	Chigateri	CP-818	0.00	
Taluk Mean			1.43	15.60
3. Harihara	G. T. Katti	CP-818	5.71	

	Hindusghatta	CP-818	2.86	
Taluk Mean			4.29	28.80
District Mean			4.76	25.20
Shivamogga				
1. Shivamogga	Harnahalli	K-2288	10.00	
	Kumsi	K-25K55	5.71	
Taluk Mean			7.86	32.40
2. Soraba	Bedavatti	K-244	8.57	
	Shivapura	K-244	8.57	
Taluk Mean			8.57	41.60
3. Sagara	Yadehalli	K-2288	10.00	
	Adur	K-244	8.57	
Taluk Mean			9.29	47.20
District Mean			8.57	40.40
Mandya				
1. Mandya	Kommerahalli	GK-3045	0.00	
	Yaliyur	K-2288	2.86	
Taluk Mean			1.43	12.00
2. Malavalli	Kyathanahalli	K-2288	12.86	
	Kunduru	Super Kanaka	8.57	
Taluk Mean			10.72	46.40
3. Maddur	Belathuru	S-517	1.43	
	Kothanahalli	S-641	2.86	
Taluk Mean			2.15	15.20
District Mean			4.77	24.53

Table 2: Assessment of severity of mycotoxin producing fungi in maize during 2018-19

Districts & Taluks	Place	Varieties/ Hybrids	Fungal Infection (%)	
			Field	Storage and Market
Raichur				
1. Raichur	Arsegeri	CP-818	2.86	
	Kadgamdoddi	CP-818	2.86	
Taluk Mean			2.86	-
2. Deodurga	Kakargal	NK-6240	1.43	
	Masarkal	NK-6240	4.29	
Taluk Mean			2.86	36.80
3. Manvi	Nasalapur	SM-1	1.43	
	Yarmaldoddi	K-244	1.43	
Taluk Mean			1.43	32.00
District Mean			2.38	34.00
Koppal				
1. Koppal	Mataldinni	Deccalb	2.86	
	Nilogal	Deccalb	0.00	
Taluk Mean			1.43	38.20
2. Kushtagi	Vanagera	Deccalb	2.86	
	Nerebanch	Deccalb	2.86	
Taluk Mean			2.86	36.60
3. Yelburga	Madlur	CP-818	5.71	
	Gidigera	CP-818	1.43	
Taluk Mean			3.57	44.60
District Mean			2.62	39.80
Haveri				
1. Haveri	Kallihal	Laxmi-4959	18.57	
	Kadamanahalli	P-3501	25.71	
Taluk Mean			22.14	58.00
2. Ranenennuru	Devaragudda	CP-818	21.43	
	Chatra	P-3501	18.57	
Taluk Mean			20.07	52.40
3. Hirekeruru	Arikatti	Laxmi-4959	8.57	
	Kod	Laxmi-4959	12.86	
Taluk Mean			10.72	34.40
District Mean			17.64	48.27
Ballari				
1. Hospete	Mariyammanahalli	CP-818	8.57	
	Ayyanahalli	CP-828	5.71	
Taluk Mean			7.14	49.20

2. H. B. Halli	Hampapatna	SM-1	15.71	
	Chilakanahatti	SM-1	18.57	
Taluk Mean			17.14	61.20
3. H. Hadagali	Hyarada	CP-828	24.29	
	Dasanahalli	CP-828	20.00	
Taluk Mean			22.15	65.60
District Mean			15.48	58.67
Davanagere				
1. Honnalli	Sasvehalli	P-3501	11.43	
	Hosahalli	P-3501	10.00	
Taluk Mean			10.72	44.80
2. Harapanahalli	Neelgunda	CP-828	10.00	
	Bagali	CP-828	7.14	
Taluk Mean			8.57	41.60
3. Harihara	Kondaji	CP-828	8.57	
	Airani	CP-828	5.71	
Taluk Mean			7.14	38.40
District Mean			8.81	
Shivamogga				
1. Shivamogga	Yerekoppa	P-3501	5.71	
	Tyajavalli	P-3501	4.29	
Taluk Mean			5.00	30.00
2. Soraba	Nadahalli	K-2288	7.14	
	Kuppe	K-244	4.29	
Taluk Mean			5.72	35.20
3. Sagara	Bhimaneri	K-2288	7.14	
	Suranagadde	SM-1	7.14	
Taluk Mean			7.14	30.40
District Mean			5.95	31.87
Mandya				
1. Mandya	Cheeranahalli	Super Kanaka	2.86	
	Belluru	CP-828	1.43	
Taluk Mean			2.15	24.40
2. Malavalli	Thalagavadi	K-2288	8.57	
	Dugganahalli	K-244	5.71	
Taluk Mean			7.14	42.80
3. Maddur	Sadolalu	SM-1	1.43	
	Channasandra	SM-1	1.43	
Taluk Mean			1.43	28.40
District Mean			3.57	31.87

Plate 1: Overview of areas surveyed for the severity of mycotoxin producing organisms A: collection of infected grains in the stored heap B and C: Mycotoxigenic fungi infected dehusked cobs D and E: Mycotoxigenic fungi infected dehusked cobs F: *Aspergillus flavus* infected maize grains

Plate 2: Assessment of mycotoxin contamination at different storage conditions A: Dehusking of cobs in the field; B: Dehusked cobs in the field C: Drying of maize grains; D: Threshed maize grains stored in gunny bags

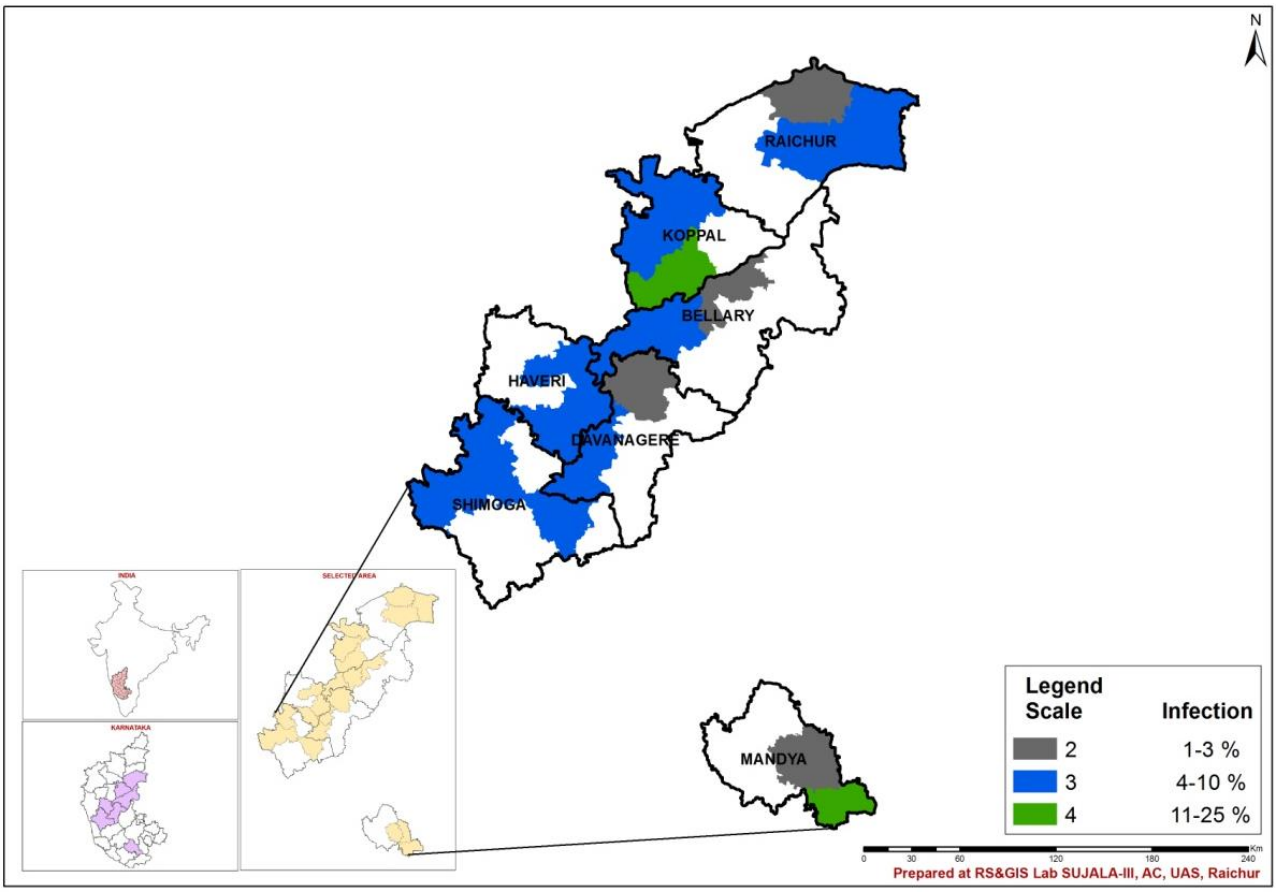

Fig 1: GIS map indicating occurrence of mycotoxigenic fungi in maize fields during 2017-18

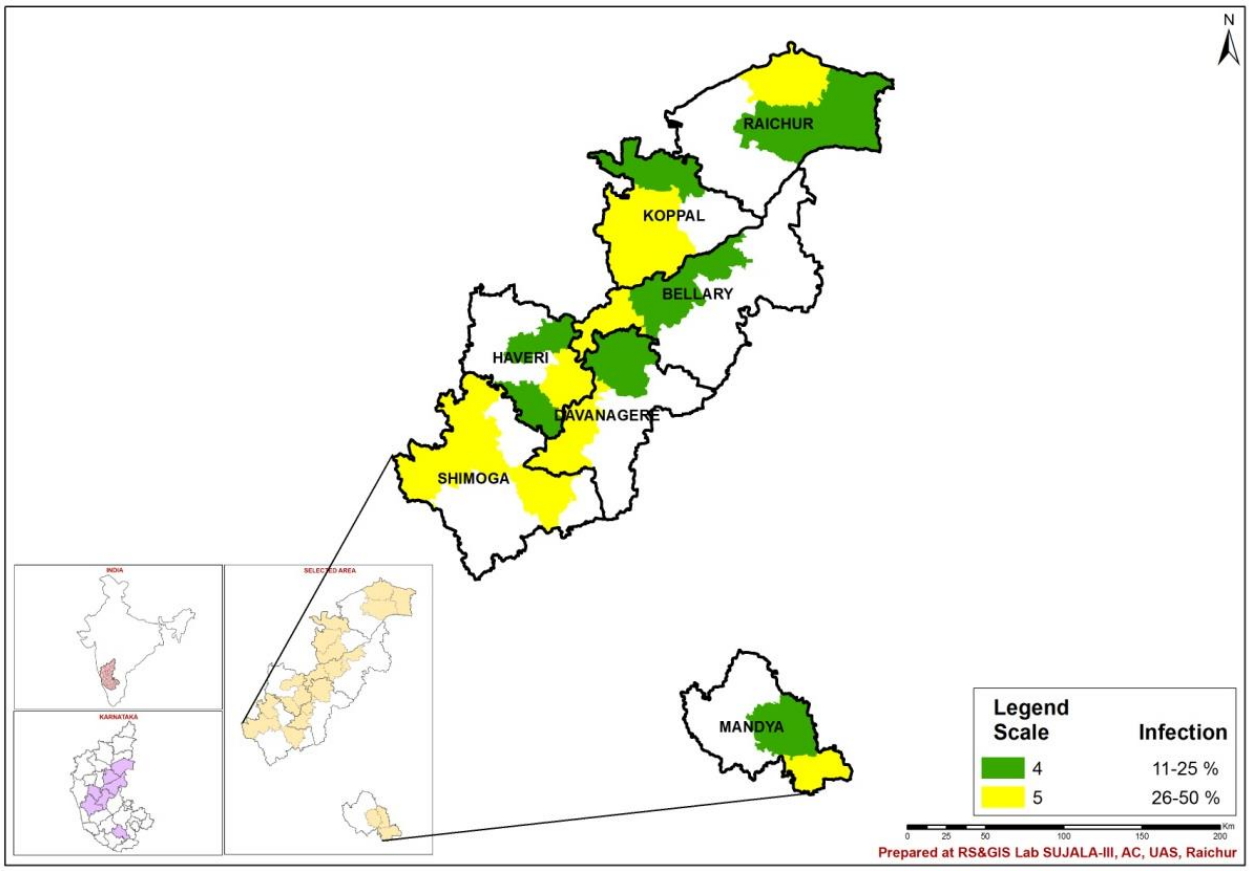

Fig 2: GIS map indicating occurrence of mycotoxigenic fungi in maize storage and markets during 2017-18

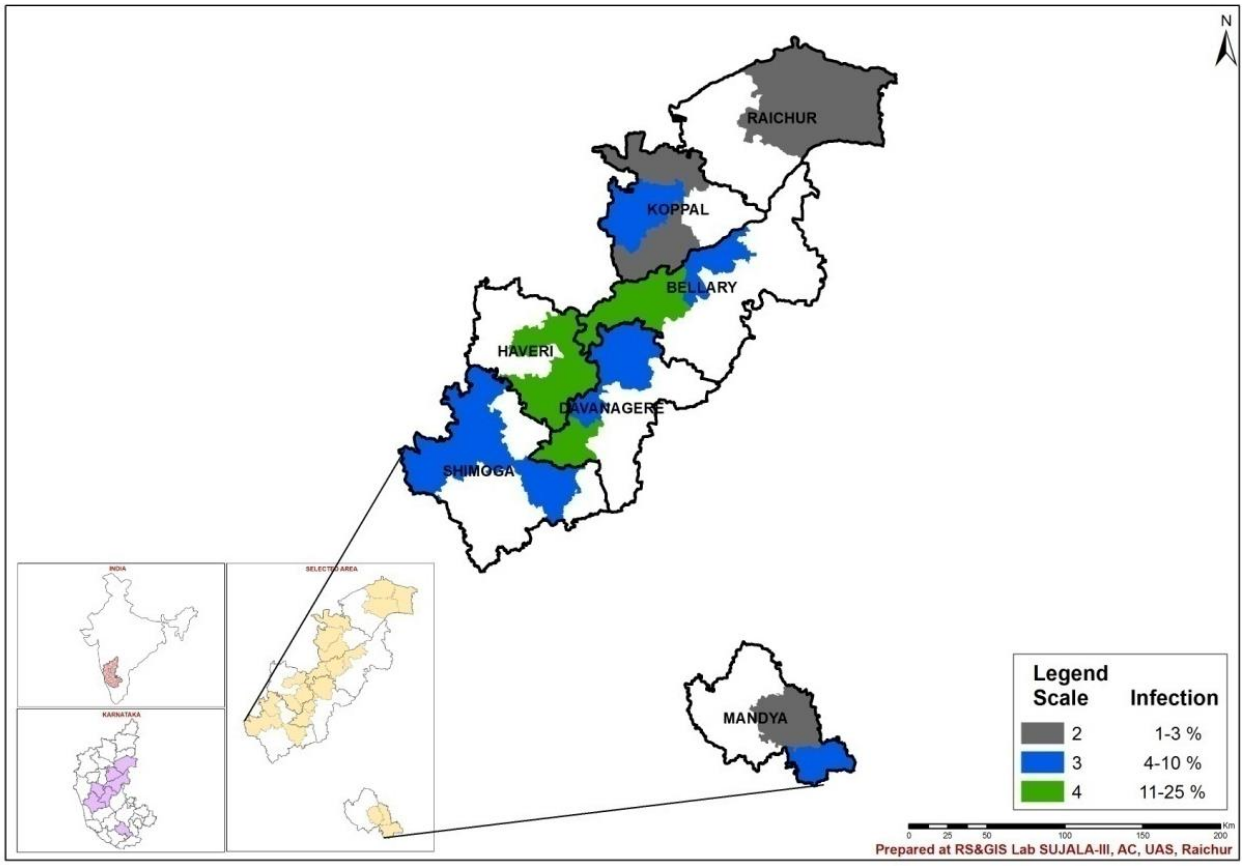

Fig 3: GIS map indicating occurrence of mycotoxigenic fungi in maize fields during 2018-19

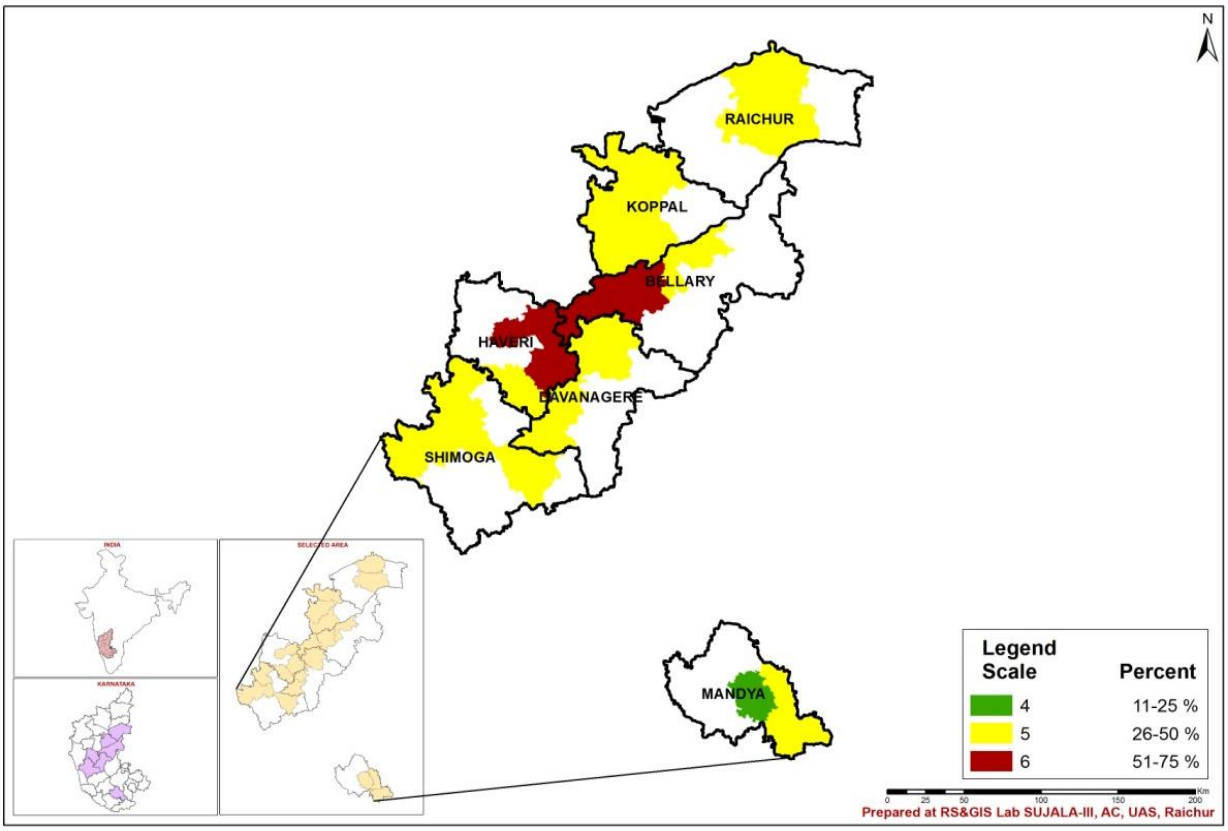

Fig 4: GIS map indicating occurrence of mycotoxigenic fungi in maize storage and markets during 2018-19

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