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RESEARCH PAPER

Surveillance of major maize diseases and their distribution scenario in different agroclimatic zones of India

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Abstract: The maize is third most significant cereal crop after rice and wheat. To know changes in the pattern of disease distribution under global climate change, hence surveying is a crucial activity. The five maize-growing zones of India *viz*. Northern Hill Zone (NHZ), North West Plain Zone (NWPZ), North East Plain Zone (NEPZ), Peninsular Zone (PZ), and Central Western Zone (CWZ) were surveyed from 2013 to 2018 for major maize diseases. Two to three talukas were chosen in each district for the roaming survey, two to three villages per taluka were chosen, and three fields on either side of the road were chosen at random in each hamlet. In four zones (NHZ, NWPZ, NEPZ, and PZ), the maydis leaf blight severity was high (67.7%) in NEPZ. Further, NHZ showed the highest severity of turcicum leaf blight (55.5%) and banded leaf and sheath blight (77.7%). Moreover, *Curvularia* leaf spot prevalence (53.3%) and post flowering stalk rot (74%) was highest in CWZ, and bacterial stalk rot in NWPZ (56%). PZ was the only region where sorghum downy mildew was common. In India, a significant maize disease is now being assessed and banded leaf and sheath blight, maydis leaf blight, Turcicum leaf blight, and others were the most prevalent diseases. This study will help to develop management strategies, identify the races of the pathogens, and recommend the resistant varieties.

Keywords: Diseases · Distribution · Maize · Surveillance

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Introduction

Maize (*Zea mays* L.) is the most versatile crop grown under diversity of environments unmatched by any other crop (Ahangar *et al*., 2022). Among major cereal crops in production, maize is the world's third leading crop after wheat and rice. It has highest genetic yield potential amongst the cereal crops (Debnath *et al*., 2020; Rathore *et al*., 2021). Use of maize as feed, food, fodder and specialty corn as pop-corn, sweet corn, baby corns make it one of the main crops par excellences for industrial use adapted to different agro-ecological and climatic conditions (Vardhan *et al*., 2020; Gul et al.,2021). In

India, maize is planted on a 9.02 mha plot with a 27.71 mt yield and a productivity of 3.1 t/ha (FAOSTAT, 2021). About 112 diseases of maize have been documented from various regions of the world; 65 of them are known to occur in India (Saxena, 2002). Out of 65, 11 significant maize diseases, including one cyst nematode, are of national significance (AICRPM, 2018).

Diseases are the main biotic constraints that restrict maize productivity. Major diseases are maydis leaf blight (MLB) caused by *Bipolaris maydis*, Turcicum leaf blight (TLB) caused by *Exserohilum turcicum*, Banded leaf and sheath blight (BLSB) caused by *Rhizoctonia solani*, and Curvularia leaf spot (CLS) caused by *Curvularia lunata*. Other disease like post flowering stalk rot (PFSR- charcoal rot-*caused by Macrophomina phaseolina* and Fusarium stalk rot caused by *Fusarium verticillioides*, bacterial stalk rot (BSR) caused by *Dickeya zeae* and sorghum downy mildew (SDM) caused by *Pernosclespora* sorghi. The *Bipolaris maydis* is a necrotrophic plant pathogen that actively kills tissues of the host, colonizing and thriving on the contents of dried and dead cells. The pathogen allows penetration and colonization by producing a range of toxins and secondary metabolites. Race 2 *O2* (Old race) and Race 2 *T*2 (Virulent on corn containing T-CMS) produce phytotoxins, which were designated as Hm-O and Hm-T toxins, respectively, by Lim & Hooker (1972). The *Exserohilum turcicum* is heterothallic ascomycete and act as a facultative parasite of maize (Zhang *et al*., 2012; Ahangar *et al*., 2022). The *Rhozoctonia solani* pathogen is soilborne as it survives in the soil and on diseased crop debris in the form of sclerotia or mycelium. Sclerotia can survive for several years in the soil. The fungi proliferate by irrigation and by the motion of affected soil and debris (Kaur *et al*., 2021). The *Curvularia lunata* This pathogen is seed and soil borne causing disease prevalent in the hot, humid maize growing areas and causes approximately 10-60% yield losses due to loss of photosynthetic region of the crop and up to 33.4% losses in grain number (DingFa *et al.*, 1999). The *Marcophomina phaseolina* is a primarily soil-borne and seed-borne pathogen (Babu *et al*., 2010). *Fusarium verticillioides* survives on crop residue in the soil or on the soil surface (Nyvall and Kommedahl, 1970). Under favorable condition, it may infect roots as well as stalk (Lipps and Deep, 1991). The soil represents a favorable habitat for microorganisms and is inhabited by a wide range of microorganisms, including bacteria, fungi and proto-zoa. *D. zeae* survives in plant debris but the survival period varies from different environmental conditions (Anil Kumar and Chakravarti, 1971; Prasad and Sinha, 1977; Saxena and Lal, 1982). *P. sorghi* can produce symptoms on both maize and sorghum, it typically does not complete sexual reproduction on maize, so no oospores are formed (Jegera *et al*., 1998). Understanding how prevalent some serious diseases are around the globe is crucial. Consequently, a regular study was conducted for eight significant diseases to determine the severity and current pattern of dispersion. Due to global climate change and co-evolution of pathogen with their host, the occurrence of diseases for any crop may be changed. Therefore, survey from 2013-2018 was done to know the current patterns of maize disease in India.

Materials and methods

Methods of survey

A systematic and intensive survey was carried out in series to measure disease severity and know prevalence of important naturally occurring diseases of maize. These surveyed areas covered the maize growing regions by involving All India Coordinated Research Project (AICRP) Centers (Figure 1 and Table 1). The *roving* survey was conducted in five zones for six years (*kharif* 2013-18) in India. In this survey, 2-3 taluka were selected in each district. In each taluka, 2-3 villages were identified and, in each village, three fields were randomly selected on both sides of the road. From each field, 100 plants were randomly selected when crop was flowering to grain filling stage.

Scoring of the diseases

The severity of the disease was recorded by following 1 to 9 rating scale (Table 2) given by Chung *et al.* (2010) and Mitiku *et al.* (2014), and later the percent disease index (PDI) was calculated by the formula given by Wheeler (1969). Individual scoring and PDI was calculated was done as prescribed by Hooda *et al*. (2018); Aggarwal *et al*. (2021).

$$PDI = \frac{\text{Sum of numerical rating}}{\text{Total No. of plants observed x Maximum rating}} \times 100$$

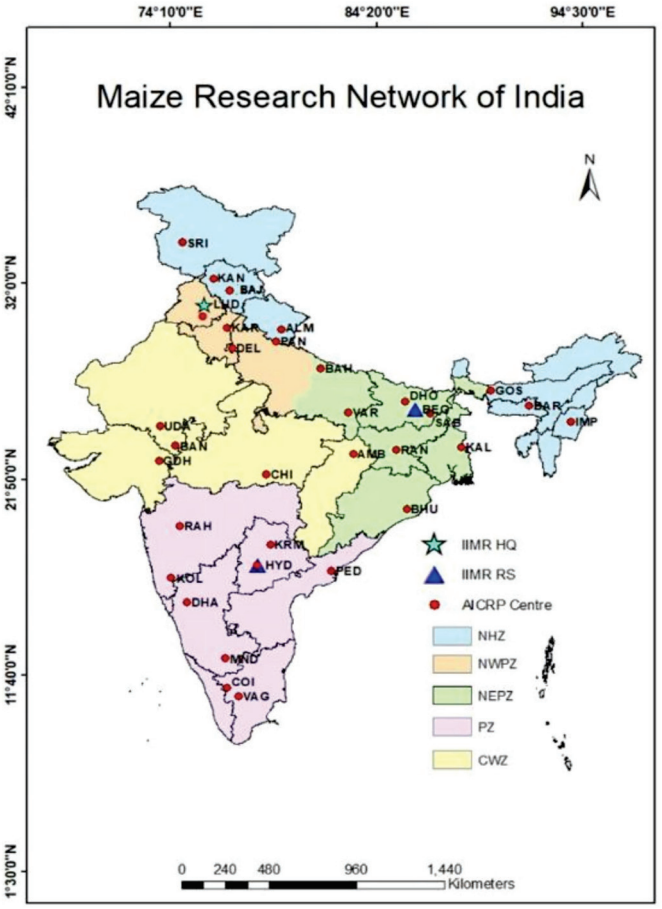

Figure 1. Maize growing zones of India (*Source:* https://iimr.icar.gov.in)

Results and discussion

During the *kharif* season 2013-18, disease survey was carried out in the all-maize growing zones of India. The purpose of keep monitoring disease severity in places where maize is grown in order to detect any outbreaks and gauge any changes in disease severity. Symptoms of major maize diseases have been depicted in Figure 3. The severity of MLB was highest (67.7%) in NEPZ during year 2016. The TLB disease severity was highest (55.5%) in NHZ during year 2015. The BLSB disease severity was highest (77.70%) in NHZ during year 2013. The CLS disease severity was highest (53.30%) in CWZ during year 2016. The BSR disease severity was highest (56%) in NWPZ during year 2016. The PFSR disease severity was highest (74%) in CWZ during year 2015. The SDM disease severity was highest (50%) in PZ during year 2016.

The MLB and CLS diseases were observed to be widespread in practically every zone based on observation data. However, NWPZ and NEPZ had the highest severity, followed by NHZ and PZ (Figure 2; Table 3). Previously thought to be minor, both diseases are now responsible for yield losses that can be avoided that range from 19–24% (AICRPM, 2018). Hulagappa *et al.* (2011) noted a

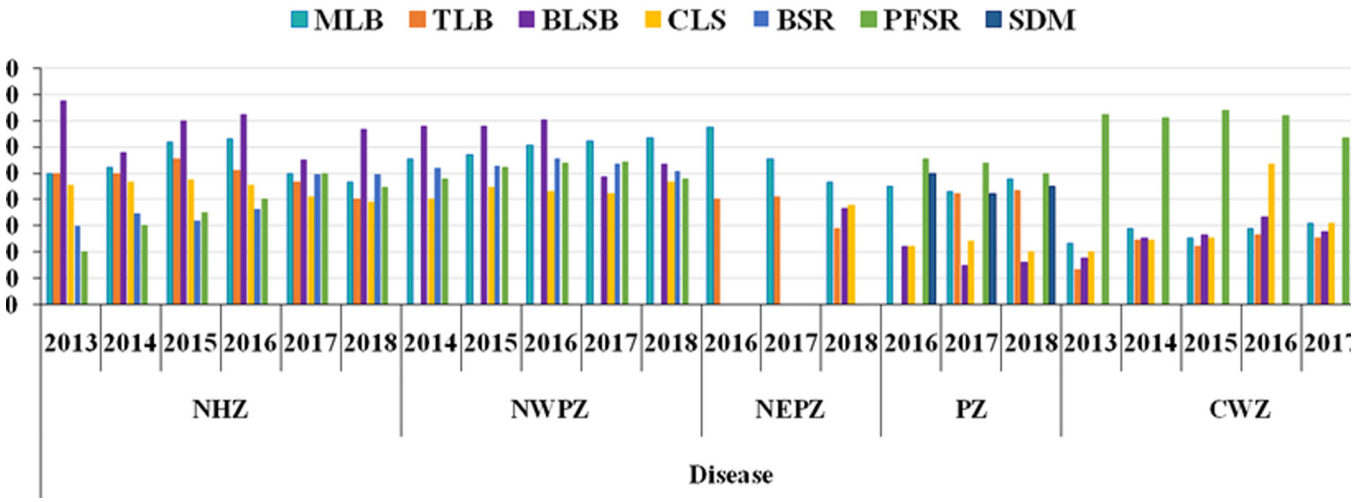

Figure 2. Severity of different maize diseases recorded from 2013 to 2018

Table 1. Zone-wise location of the AICRP centers in India

Zone code	Zone name	Maize growing centre
I	Northern Hill Zones (NHZ)	Bajaura, Almora, Dhaulakuan, Barapani and Imphal
II	North West Plain Zone (NWPZ)	Ludhiana, Karnal, Pantnagar and Delhi
III	North East Plain Zone (NEPZ)	Dholi, Sabour and Kalyani
IV	Peninsular Zone (PZ)	Hyderabad, Dharwad, Mandya and Coimbatore
V	Central Western Zone (CWZ)	Udaipur and Godhra

Table 2. Disease scoring scale for foliar diseases of maize (MLB, TLB, BLSB, CLS, PFSR (charcoal rot and *Fusarium* stalk rot) and BSR)

Rating scale	Degree of infection (% Diseased leaf area)	Disease reaction
1	Nil to very slight infection (≤10%)	Resistant (R)
2	Slight infection, a few lesions scattered on two lower leaves (10.1-20%)	(Score: ≤ 3.0)
3	Light infection, moderate number of lesions scattered on four lower leaves (20.1-30%).	(PDI: ≤ 33.33)
4	Light infection, moderate number of lesions scattered on lower leaves, a few lesions scattered on middle leaves below the cob (30.1-40%).	Moderately resistant (MR) (Score: 3.1–5.0)
5	Moderate infection, abundant number of lesions scattered on lower leaves, moderate number of lesions scattered on middle leaves below the cob (40.1-50%).	PDI: 33.3455.55)
6	Heavy infection, abundant number of lesions scattered on lower leaves, moderate infection on middle leaves & a few lesions on two leaves above the cob (50.1-60%)	Mod. susceptible (MS) (Score: 5.1-7.0)
7	Heavy infection, abundant number of lesions scattered on lower and middle leaves and moderate number of lesions on two to four leaves above the cob (60.1-70%).	(PDI: 55.5677.77)
8	Very heavy infection, lesions abundant scattered on lower and middle leaves and spreading up to the flag leaf (70.1-80%).	Susceptible (S) (Score: >7.0)
9	Very infection, lesions abundant scattered on almost all the leave plant prematurely dried and killed (>80%).	PDI: >77.77)

Main disease score recorded was converted to percent disease index (PDI). For BSR (percent basis) while for SDM the PDI was calculated as described by Lal and Singh (1984) using the formula PDI = (Number of plants infected / Total number of plants) × 100(percent disease index) = MDS X 100/9(MDS= Mean disease severity)

broad range of MLB disease severity during *kharif* and *rabi* crop from several areas in Northern Karnataka, while the *kharif* season showed the highest disease severity. The cropping season is the main element to affect an increase or reduction in the disease severity of TLB, according to Geeta *et al.* (2018), the high turcicum leaf blight severity was noticed in Eastern Karnataka during *kharif* 2016. Except NWPZ, all four zones had a high TLB prevalence.

As previously mentioned, CLS is a new maize disease that is now prevalent in all of India's maize-growing regions. In places with frequent excessive rainfall or even on prolonged wet days, the disease is reported to be more severe. The severity of the CLS disease also worsens with the crop's maturation. The maize crop's grain filling stage is when the disease severity peaks. Although the CWZ has the highest disease severity of CLS, this disease is currently reemerging in all areas of maize. Additionally, it was shown that the pattern of disease prevalence varied according to the crop season, with MLB being more common at 35–40 DAS and CLS being more severe at 55–75 DAS. Akinbode *et al.* (2014) discovered during their investigation on the recurrence of maize diseases in the southwest and Kwara states of Nigeria that the entire farm was entirely infected by the CLS disease, which posed a possible danger to maize output owing to its direct impact on photosynthesis.

Except for PZ, all the zones were affected by BLSB disease. Most of the survey locations in PZ had the lowest severity of this disease. According to Sharma and Saxena (2002), one of the most significant diseases affecting maize in South and South-East Asia is the BLSB disease. This disease has been reported to occur in Indian states like Haryana, Himachal Pradesh, Punjab, Uttar Pradesh, Rajasthan, Madhya Pradesh, Meghalaya, Orissa, West Bengal, and Assam (Payak and Sharma, 1985; Rani *et al.*, 2013). The various areas appear to have endemic BLSB disease. According to a survey, BLSB is common in north Karnataka's main maize-growing regions and ranges in severity from low to severe (Rajput *et al.*, 2014). In West Bengal, the disease is also seen at the pre-flowering stages (Patra, 2007).

The incidence of bacterial stalk rot (BSR), which ranged from 30 to 56%, was higher in NHZ and NWPZ. In India, the Northern Hill Zone (NHZ) and North Western Plain Zone (NWPZ) both exhibit BSR prevalence. In comparison to NHZ, the severity of BSR is substantially higher (56%) in NWPZ during year 2016. BSR disease has become one of the most significant diseases affecting the kharif-sown maize crop in India in recent years (Kumar *et al.*, 2015). These findings suggest that BSR may soon affect all the maize growing regions in India, and if

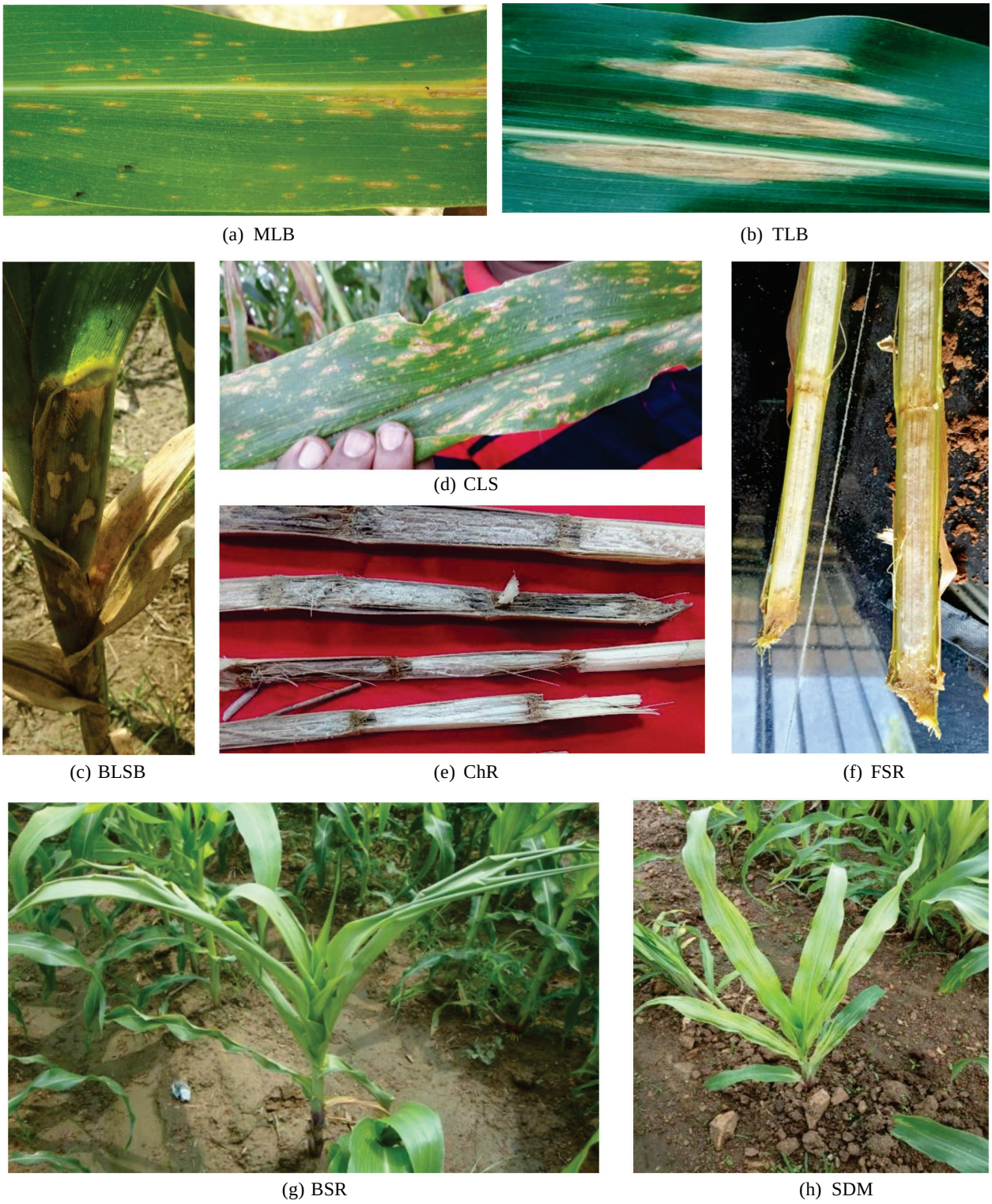

Figure 3. Symptoms of major maize diseases (a to h)

suitable precautions are not done, it might become a terrible disease that spreads across the whole country. Mandya and Chikkabalapura districts of Karnataka experienced moderate to severe stalk rot incidence. However, NWPZ, PZ, and CWZ had higher rates of PFSR disease.

Conclusion

Our research showed that MLB, TLB, BLSB, and CLS were found in all of India's maize-growing regions due to varietal differences, susceptibility with variable disease responses, increased relative humidity, and frequent and

Table 3. Severity of maize diseases (percentage) in different maize growing zones of India (2013-18)

Diseases	Disease severity (%) and maize growing zones																				
	NHZ						NWPZ					NEPZ			PZ			CWZ					
	2013	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2016	2017	2018	2016	2017	2018	2013	2014	2015	2016	2017	2018
MLB	50	52.2	62	63.2	50	46.6	55.5	57	60.5	62.2	63.3	67.7	55.5	46.6	45	43	47.7	23.3	28.8	25.5	28.8	31.1	34.4
TLB	50	50	55.5	51.1	46.6	40	*					40	41.1	28.8	*	42.2	43.3	13.3	24.4	22.2	26.6	25.5	38.8
BLSB	77.7	57.7	70	72.2	55	66.6	67.9	68	70.5	48.8	53.3	*		36.6	22.2	15	16	17.7	25.5	26.6	33.3	27.7	30
CLS	45.5	46.5	47.5	45.5	41.1	38.8	40	44.4	43	42.2	46.6	*		37.7	22.2	24	20	20	24.4	25.5	53.3	31.1	35.5
BSR	30	35	32	36.6	50	50	52.2	53	56	54	51.1	*			*			*					
PFSR	20	30	35	40	50	44.4	47.7	52.2	53.9	54.4	47.7	*			55.5	53.9	50	72.2	71	74	72	63.3	66.6
SDM	*	*	*	*	*	*	*	*	*	*	*	*			50	42.2	45	*	*	*	*	*	*

*The particular disease not prevalent in the zone
MLB– Maydis leaf blight, TLB– Turcicum leaf blight, BLSB– Banded leaf and sheath blight, CLS– Curvularia leaf spot, BSR– Bacterial stalk rot, PFSR (Charcoal rot and FSR), SDM– Sorghum downy mildew

heavy rainfall, which created favorable environmental conditions for the development of the foliar diseases. These diseases have been widely distributed, and because of their great degree of diversity, if any isolate becomes more virulent, an epidemic might develop.

Future research

The present study will support in to make decision and experiment according to status of important disease of maize in India.

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