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Survey and Assessment of Fungicides and Botanicals against Southern Corn Leaf Blight of Maize in Kashmir

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ABSTRACT

Background: Maize (*Zea mays* L.) is an important cereal crop in Kashmir temperate zones, used for both human consumption and cattle feed. Southern Corn Leaf Blight (SCLB) caused by *Bipolaris maydis* is an emerging concern for maize cultivation in the Kashmir Valley. This disease poses a substantial threat to maize farming in this region which is need for disease surveillance and management strategies. The purpose of this study was to determine the prevalence and severity of SCLB in Kashmir as well as to investigate the efficacy of various fungicides and botanicals against *B. maydis* under *in vitro* conditions.

Methods: To document the disease incidence and severity, survey was carried out in six districts of Kashmir during the *kharif* seasons of 2022 and 2023. The antifungal efficacy of botanical extracts along with systemic and non-systemic fungicides were evaluated against *B. maydis* under laboratory conditions.

Result: Field surveys during *kharif* season of 2022 and 2023 across six districts showed significant variability in disease incidence and severity which is influenced by temperature, humidity and altitude. The highest disease incidence (18.3%) and severity (15.6%) were recorded in Anantnag and Budgam districts of Kashmir, respectively, while Baramulla showed the lowest incidence (4.16%). Among systemic fungicides, Propiconazole exhibited the highest efficacy and when combined with Carbendazim, recorded 100% mycelial growth inhibition. Mancozeb, a non-systemic fungicide, also showed strong inhibition activity up to 93.4% at 500 ppm. Hexaconazole was the least effective among the systemics, especially at lower concentrations. Botanical extracts were also tested for antifungal potential. Turmeric (*Curcuma longa*) at 20% concentration exhibited the highest inhibition (93.44%) due to its active compounds like curcuminoids.

Key words: *Bipolaris maydis*, Botanical, Fungicides, Management, Southern corn leaf blight.

INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop in India and is considered at the center of food security for our world, being a principal food for humans and a major animal feed (Bhupender *et al.*, 2022; Singh *et al.*, 2021). Because of its wide adaptability to various agroclimatic zones, maize is often referred to as the queen of cereals (Tripathi *et al.*, 2023). The prime maize-growing crop in Jammu and Kashmir (J and K) thrives, mainly in 1524 to 2500 meters above sea level on rain-fed marginal lands (Baba *et al.*, 2019). Maize like other plants is affected by a range of pathogens (biotic stresses) *viz.,* fungi, bacteria and viruses (Savary *et al.*, 2019) at pre-harvest and post-harvest stages posing a serious threat to global food security (Craze *et al.*, 2022). Plant diseases are a significant cause of biotic stress (Koder *et al.*, 2022). Among the fungal diseases Southern corn leaf blight play a significant role in the reduction of quality and quantity of maize production across the globe (Bhupender *et al.*, 2022). Southern corn leaf blight also known as *maydis* leaf blight (MLB) is a serious foliar disease of maize occurring widely in maize growing regions of the world including the Indian subcontinent (Kuilya *et al.*, 2018; Shah *et al.*, 2020). However, it has recently been introduced in Jammu and Kashmir, thus causing concern in mountainous communities of Pir Panjal range. Southern corn leaf blight is caused by a notorious Ascomycete fungus, *Cochliobolus heterostrophus/Bipolaris maydis* predominantly found in warm (20-30°C), humid (>80%) tropical, sub-tropical to temperate regions of the world (Bhupender *et al.*, 2022). The wind-borne spores from this fungus are being deposited on the leaf surface, germinate and penetrate either directly through the stomata or the leaf cuticle and epidermis and establishes infection. As infection progresses the leaf develops characteristic elliptical lesions with slightly dark brown margins (Chavan *et al.*, 2024).

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These lesions start as small greyish discolorations on the leaf surface and gradually turns to yellowish-brown in due course of hue. In the era of global climate change, Integrated disease management (IDM) practices together with host plant resistance has been seen as the way forward for sustainable management of the disease in question. Both, qualitative and quantitative resistances have been reported in the literature, but quantitative is preferable over qualitative one, as it is non-race specific and highly durable. Cultural practices like management of crop debris which helps to reduce the amount of inoculum, tillage, crop rotation with non-host plants, reduced monoculture, decreased density and residue management can help in reducing prevalence of infection and the subsequent loss of yield (Altieri *et al.*, 2015). Chemical control for the disease can be applied in absence of host resistance. Fungicides like Mancozeb, Thiram, Carboxin have been found to be effective (Kumar *et al.,* 2016). Management of SCLB holds paramount significance amid global climate change. Effective management strategies can improve yield in the affected regions in view keeping of the increasing global food demands. Historically reported from tropical and subtropical areas, SCLB is now affecting Kashmir agroclimate zones, where prolonged humidity and moderate temperatures (20-30°C) favours pathogen development (Chen *et al.*, 2023; Aregbesola *et al.*, 2020). The disease causes elliptical, necrotic lesions on leaves, leading to significant losses in photosynthetic efficacy and yield reduction of about 35-40% (Bruns, 2017). Maize, not withstanding its significance and spread over 2.9 lakh hectares (2015-16), remains low in JandK productivity to the tune of 22642.5 tons/ha which is much below the national average. Such low productivity is the result of biotic stresses, use of old landraces and the advent of new pathogens (Ahangar *et al.*, 2015; Hayford *et al.*, 2024). Among these threats, fungal diseases are particularly serious. Southern Corn Leaf Blight (SCLB), caused by *Bipolaris maydis* (teleomorph: *Cochliobolus heterostrophus*), has emerged as a major concern in the temperate regions of Kashmir (Banah *et al.*, 2024). The rapid spread and infection cycle of the pathogen (Kumar *et al.*, 2016) necessitate the development of region-specific management strategies. This study was undertaken to assess the incidence, severity and control options for SCLB in temperate Kashmir and focusing on the evaluation of systemic and non-systemic fungicides and plant-based alternatives to support sustainable maize cultivation.

MATERIALS AND METHODS

Survey and assessment of southern corn leaf blight

Roving field surveys were conducted during the *kharif* season of 2022 and 2023 across six districts of the Kashmir Valley to determine the incidence and severity of Southern Corn Leaf Blight (SCLB) caused by *Bipolaris maydis*. Two districts each were selected from three major agro-climatic regions *viz.,* South, Central and North Kashmir. In each district, two key maize-growing villages were identified and three fields per village were sampled for disease assessment. The selection of districts and villages were based on several criteria, including the extent of maize cultivation, the crop's importance to local livelihoods, variations in production systems, climatic conditions (relative humidity, maximum and minimum temperatures) and altitudinal differences, following the methodology of Ramathani *et al.* (2011). In each field, 120 maize plants were randomly selected along two diagonals (60 plants along each diagonal). Observations were recorded between 50 to 90 days after sowing (DAS) for disease incidence and severity.

Calculation of disease incidence

The percentage of disease incidence was calculated using the following formula:

Per cent disease incidence =

$$\frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

Assessment of disease severity

Disease severity was assessed based on lesion size, abundance and distribution on infected plant parts, using a standard 1-6 disease scoring scale as recommended by Mayee and Datar (1986); Jakhar *et al.* (2017) (Table 1).

Disease severity scores were used to compute the Disease Severity Index (DSI) using the following formula:

Disease severity index % =

$$\frac{\text{Sun of all numerical ratings}}{\text{Total number of observations} \times \text{Highest disease score}} \times 100$$

The disease deverity index provides a standardized measure of the extent of disease damage across surveyed fields (Shi *et al.*, 2023).

Evaluation of different fungicides against *Bipolaris maydis*

The study of Southern Corn Leaf Blight (SCLB) was carried out during *kharif* 2022 and 2023 at the Mountain Maize Research Centre, Larnoo and the Plant Breeding and Genetics Division, Rice Research and Regional Station, Khudwani, Anantnag, Jammu and Kashmir. The effectiveness of systemic, non-systemic (contact) and combination fungicides were evaluated against *Bipolaris maydis* using the poison food technique as described by Nene and Thapliyal, (1979). Four systemic fungicides (including one combination) and two non-systemic fungicides were tested on potato dextrose agar (PDA) medium to assess their efficacy in inhibiting the mycelial growth of the pathogen (Table 3). A stock solution of each fungicide was prepared at a concentration of 10,000 ppm by dissolving the required amount of fungicide in distilled water. To achieve the final concentrations of 10, 50 and 100 ppm (and 100, 250 and 500 ppm for Hexaconazole and Mancozeb), appropriate volumes of the stock solution were added to 50 ml of sterilized PDA medium.

Before pouring, the medium was thoroughly mixed to ensure uniform distribution of the fungicide. The fungicide-amended medium was poured into three petri plates for each concentration using a micropipette. Plates without fungicide were used as untreated controls. All plating was performed under aseptic conditions inside a laminar airflow chamber. The experiment was laid out in a completely randomized design (CRD) with three replications for each treatment. After solidification of the medium, a 3 mm mycelial disc was aseptically cut from a 9-day-old culture of *B. maydis* using a sterile cork borer and placed at the center of each plate. The plates were incubated at 25°C for 9 days in a BOD incubator.

After incubation, the radial growth of the fungus was measured and the percentage inhibition of mycelial growth was calculated by using the formula given by Vincent, (1947):

$$\text{Per cent inhibition over check} = \frac{C\text{-}T}{C} \times 100$$

Where,
C= Growth of pathogen in check.
T = Growth of pathogen in treatment.

In-vitro evaluation of botanicals against *Bipolaris maydis*

The use of plant extracts (botanicals) offers a cost-effective strategy for disease management (Kansotia *et al.,* 2024). In this experiment, efforts were made to evaluate the antifungal efficacy of different botanicals against *Bipolaris maydis* under *in-vitro* conditions. We used fresh plant material to make aqueous extracts of *Allium sativum*, *Allium cepa, Zingiber officinale, Curcuma longa* and *Cymbopogon citratus*. Fresh plant material (100 g) was collected, thoroughly washed under tap water followed by distilled water, chopped and crushed using a pestle and mortar with 100 ml sterile distilled water (1:1 w/v ratio), filtered through muslin cloth, followed by Whatman No. 1 filter paper and used for antifungal activity. This study employed no oil-based compounds or essential oils. The leaf and bulb extracts were prepared using the cold-water extraction method as described by (23) Shekhawat and Prasad, (1971). For bioassay, appropriate volumes of the stock extract were diluted with sterilized distilled water to prepare concentrations of 5%, 10%, 15% and 20% (v/v). Double strength concentrations were made by dissolving 10, 20, 30 and 40 ml of extract into 90, 80, 70 and 60 ml of sterilized distilled water, respectively. The poison food technique was employed to test the antifungal activity of the extracts against *B. maydis* under *in-vitro* conditions. Details of the botanicals and plant parts used are provided in Table 4. Inoculated petri plates were incubated at 25°C. After 10 days of incubation, radial growth of the fungus was measured and percentage inhibition of mycelial growth was calculated using the formula proposed by Vincent, (1947).

RESULTS AND DISCUSSION

Disease prevalence and severity

The field surveys were conducted during the *kharif* season of 2022 and 2023 across six districts of the Kashmir Valley revealed varying levels of prevalence and severity of Southern Corn Leaf Blight (SCLB) caused by *Bipolaris maydis*. Disease incidence and severity exhibited significant variation between districts, influenced by local agro-climatic conditions such as temperature, humidity and altitude. The observed variation in disease expression under scores the need for region-specific disease management strategies, considering factors such as climatic conditions that are conducive to pathogen development, particularly in areas with moderate temperatures (20-30°C) and high humidity. During *kharif* 2022, disease incidence in the Kashmir Valley ranged from 5.0% to 18.3%, with an overall mean of 13.11%. In *kharif* 2023, incidence ranged from 4.16% to 11.6%, with an overall mean of 7.68% (Table 2). The highest incidence (18.3%) was recorded in village Nanil, District Anantnag, followed by Suhama, District Ganderbal (17.5%) and Soibugh, District Budgam (16.6%). The lowest incidence was recorded at Wagora, District Baramulla (4.16%), followed by Mohra, Baramulla; Tillanpora, Budgam (5.0%); and DH Pora, District Kulgam (5.8%). Similarly, disease severity during *kharif* 2022 ranged from 4.3% to 15.6%, with an overall mean of 9.26%. In *kharif* 2023, severity ranged between 4.6% and 12.6%, with an overall mean of 7.45%. The highest severity (15.6%) was observed in Soibugh, District Budgam, followed by Tillanpora, Budgam (13.2%) and Nanil, Anantnag (12.3%). The lowest disease severity was recorded in Mohra, Baramulla (4.3%) and Arin, Bandipora (4.5%) (Table 2).

Table 1: 5-Point scale for measuring disease intensity Mayee and Datar (1986).

Disease reaction	Severity grade	Description
Symptom less	0	No lesions
Highly resistant	1	Very slight infection; one or two restricted lesions on lower Leaves.
Highly resistant	2	Slight infection; a few scattered lesions on lower leaves.
Highly resistant	3	Light infection; moderate number of lesions on lower leaves.
Moderately resistant/susceptible	4	Moderate infection; abundant lesions on lower leaves, few on middle leaves.
Susceptible	5	Heavy infection; lesions abundant on lower and middle leaves extending to upper leaves.
Highly susceptible	6	Very heavy infection, lesions abundant on all leaves; plants prematurely killed.

In vitro evaluation of fungicides against *Bipolaris maydis*

Due to lack of resistant varieties, the use of fungicides has become essential for managing Southern Corn Leaf Blight. In order to control Southern Corn Leaf Blight (SCLB), the poisoned food technique was used to assess six fungicides: Propiconazole, Carbendazim, Hexaconazole, Carbendazim + Propiconazole, Mancozeb and Captan. Mancozeb and Captan were evaluated at 100, 250 and 500 ppm in accordance with their field-use concentrations, whereas systemic fungicides (Propiconazole, Carbendazim and Hexaconazole) were examined at 10, 50 and 100 ppm (Table 3). The efficacy of these fungicides increased with concentration, showing a dose-dependent effect. At all concentrations, propiconazole showed the greatest inhibition of any systemic fungicide. When combined with carbendazim at 50 and 100 ppm, total (100%) growth suppression was seen. Mancozeb and Captan both showed dose-dependent inhibition; At 500 ppm Mancozeb inhibition reached up to 93.4%. On the other hand, the least effective systemic fungicide at lower concentrations was hexaconazole which showed inhibition ranging from 64.4% to 86.9% between 10 and 100 ppm. Hexaconazole limited effectiveness against *B. maydis* may indicate its decreased efficacy at lower doses under testing conditions.

In vitro assessment of botanicals against *Bipolaris maydis*

Plant extracts, especially turmeric (*Curcuma longa*), appeared to form viable substitutes for synthetic fungicides, rendering 93.44% inhibition towards *Bipolaris maydis* at 20% concentration (Table 4) followed by lemon grass leaves (*Cymbopogon citratus*) and garlic cloves (*Allium sativum*) at the same concentration *i.e.*, 83.30% and 80.04%, respectively.

Field surveys revealed characteristic SCLB symptoms on maize leaves, distinct from those of Northern corn leaf blight (NCLB). Initial symptoms of SCLB appeared as small, water-soaked, brownish lesions on lower leaves. As the infection progressed, these lesions expanded into elongated, spindle-shaped necrotic patches (2-6 mm wide, 3-22 mm long) with tan or light-brown centers and sharply defined dark reddish-brown to purplish margins. In severe cases, lesions coalesced, resulting in extensive foliar necrosis and significant yield losses (Singh *et al.*, 2021). These morphological characteristics were consistent with previous descriptions of *B. maydis* infection (Liu *et al.*, 2014; Dai *et al.*, 2016; Sun *et al.*, 2020; Chen *et al.*, 2023).

Action of the fungicide mixture is explainable through Carbendazim inhibits β-tubulin synthesis as well as Propiconazole's inhibition of ergosterol biosynthesis, both of which target crucial pathways in the fungi (Dai *et al.*, 2018; Vela-Corcía *et al.*, 2018; Aregbesola *et al.*, 2020). Other non-systemic agents, such as Mancozeb (74.8-93.4%) and Captan (64.4-86.9%), had a moderate degree of efficacy, in keeping with their modes of action as contact fungicides requiring repeated applications under field conditions (Mubeen *et al.*, 2017). However, chemicals are recommended for use in the proper management of this disease however excessive use of fungicides can cause environmental pollution so the use of bio-agents should be prioritized. The use of chemicals should be done only if the other means fail to control the disease (Jangid *et al.,* 2025).

Table 2: Survey on disease incidence and severity of southern corn leaf blight disease in different districts of Kashmir valley, during the year 2022-23.

Region	District	Locations	Disease incidence (%)		Disease severity (%)	
			2022	2023	2022	2023
South Kashmir	Anantnag	Larnoo	14.16	9.16	6.16	4.6
		Nanil	18.3	11.6	12.3	6.6
		Mean	16.23	10.38	9.23	5.6
	Kulgam	DH Pora	12.5	5.8	8.5	6.8
		Gassiraina	13.3	8.3	13.3	8.3
		Mean	12.9	7.05	10.9	7.5
Central Kashmir	Ganderbal	Suhama	17.5	10.83	11.5	8.83
		Kangan	11.66	7.5	6.66	8.3
		Mean	14.58	9.16	9.08	8.5
	Budgam	Soibugh	16.6	6.6	15.6	12.3
		Tillanpora	15.0	5.0	13.2	12.6
		Mean	15.8	5.83	14.4	12.4
North Kashmir	Bandipora	Sonerwani	10.0	5.83	7.3	4.8
		Arin	7.5	8.3	4.5	6.0
		Mean	8.75	7.06	5.9	5.4
	Baramulla	Wagora	15.8	4.16	8.2	5.6
		Mohra	5.0	9.16	4.3	5.1
		Mean	10.4	6.66	6.2	5.35

The utilization of microbial bio-pesticides and botanicals is emerging as a sustainable alternative to the chemical pesticides (Manda *et al.*, 2020). The inhibitory action of the turmeric extract was said to be due to the presence of antifungal phenolic compounds, among them curcuminoids, which disrupt integrity of fungal cell wall and membrane and inhibit spore germination (Kumar *et al.*, 2014). The extracts of ginger and of lemon grass also inhibited *B. maydis* in a dose-dependent manner, but the lower rates of inhibition as compared to turmeric could be explained by variations in the concentration of active phytochemicals. The gradual reduction of effectiveness of plant extracts with prolonged inoculation suggests that these bio-agents may be acting primarily as fungistatic instead of fungicidal agents and would hence require repeated applications during critical infection periods. Although the use of botanicals provides an environmentally friendly and sustainable disease management option, the drawback of requiring them in high concentrations (20%) may inhibit a pragmatic approach for the poor farmers. Future studies ought to optimize extraction processes and design stable and economical botanical formulations to permit wide field use. A new approach to control the pathogens which hampers quality food production has been implemented by the application of plant extracts. Various studies have explained that plant extracts contain various kind of bioactive components that can inhibit the fungal growth (Choudhury *et al.*, 2018).

Table 3: Evaluation of chemicals against of *Bipolaris maydis* under *in vitro* condition.

Fungicide	Concentration (ppm)	Colony diameter (mm)	Per cent inhibition over control
		Systemic fungicides	
Propiconazole 25 EC	10	15.3	76.6
	50	8.3	87.3
	100	4.9	92.5
Carbendazim 50 WP	10	20.3	69.0
	50	9.7	85.2
	100	5.9	91.0
Hexaconazole	10	16.3	75.1
	50	6.3	90.4
	100	4.3	93.4
Carbendazim + Propiconazole	10	8.9	86.4
	50	0	100.0
	100	0	100.0
		Non-systemic (contact) fungicides	
Mancozeb	100	19.3	70.5
	250	10.6	83.8
	500	8.9	86.4
Captan 50 WP	100	23.3	64.4
	250	17.6	73.1
	500	8.6	86.9
Control	--	65.5	--
CD (P=0.05)		1.34	

Table 4: Efficacy of botanicals against test pathogen *Bipolaris maydis* under *in-vitro* condition.

Scientific name of plant	Botanical extract	Per cent inhibition of radial growth (mean of 3 replications)							
		Concentration							
		5		10		15		20	
		G	I	G	I	G	I	G	I
Allium sativum	Bulb/leaves	24.90	72.33	24.26	73.04	22.36	75.15	17.96	80.04
Allium cepa	Bulb/leaves	40.56	54.93	34.26	61.93	33.26	63.04	30.96	65.6
Zingiber officinale	Rhizome	30.96	65.60	28.50	68.33	25.43	71.74	21.20	76.44
Curcuma longa	Rhizome	14.00	84.44	10.66	88.15	9.36	89.60	5.90	93.44
Cymbopogon citratus	leaves	34.60	61.55	31.33	65.18	27.80	69.11	15.03	83.3
Control		90 (mm)S							
CD at 5%		1.81							

CONCLUSION

A thorough and area-specific management approach is required due to the growing threat of Southern Corn Leaf Blight (SCLB) in Kashmir's temperate zones. The combination of carbendazim and propiconazole showed the highest efficacy among the fungicides studied and it ought to be given priority during severe disease index. Furthermore, botanicals like turmeric showed encouraging antifungal action and could be viable substitutes, especially in integrated resistance control initiatives and organic farming systems. The creation and use of SCLB-tolerant maize cultivars that are appropriate for Kashmir's agroclimatic conditions are crucial for long-term resilience. The spread of better integrated disease management (IDM) techniques among farmers *via* focused education and training programs is equally crucial. In order to create affordable, useful disease management guidelines for maize farming in the area, future research should concentrate on confirming in *vitro* results through comprehensive field experiments and evaluating the viability of fungicide-botanical combinations.

Conflict of interest

There is no conflict of interest declared by any of the authors.

REFERENCES

Ahangar, M.A., Najeeb, S., Sheikh, F.A., Rather, A.G. and Teeli, N.A. (2015). Enhancing food and livelihood security of highland temperate rainfed ecologies using improved maize cultivars. *Int. J. Bio-resource Stress Manag.* **6(3):** 572-578. doi: 10. 5958/0976-4038.2015.00086.X.

Altieri, M.A., Nicholls, C.I., Henao, A. and Lana, M.A. (2015). Agroecology and the design of climate change-resilient farming systems. *Agron. Sustain. Dev.* **35(3):** 869-890. doi:10.1007/s135 93-015-0285-2.

Aregbesola, E., Ortega-Beltran, A., Falade, T., Jonathan, G., Hearne, S. and Bandyopadhyay, R. (2020). A detached leaf assay to rapidly screen for resistance of maize to *Bipolaris maydis*, the causal agent of Southern Corn Leaf Blight. *Eur. J. Plant Pathol.* **156(1):** 133-145. doi: 10.1007/s106 58-019-01870-4.

Baba, S.H., Zargar, B.A., Husain, N., Malik, I. and Bhat, I.F. (2019). Trends in maize production in Jammu and Kashmir. *J. Pharmacogn. Phytochem.* **8(3):** 4558-4561.

Banah, H., Balint-Kurti, P.J., Houdinet, G., Hawkes, C.V. and Kudenov, M. (2024). The quantification of Southern corn leaf blight disease using deep UV fluorescence spectroscopy and autoencoder anomaly detection techniques. *PLoS One.* **19(5):** e0301779. doi:10.1371/journal.pone.0301779.

Bhupender, K., Choudhary, M., Kumar, K., Kumar, P., Kumar, S., Bagaria, P.K., Sharma, P., Bharadwaj, C., Sekhar, J.C. and Prasanna, B.M. (2022). Maydis leaf blight of maize: Update on status, sustainable management and genetic architecture of its resistance. *Physiol. Mol. Plant Pathol.* **121:** 101889. doi: 10.1016/j.pmpp.2022.101889.

Bruns, H.A. (2017). Southern corn leaf blight: A story worth retelling. *Agron. J.* **109:** 1218-1224. doi:10.2134/agronj 2017. 01. 0006.

Chavan, S.S., Kumar, R., Gaurav, Rana, M., Manda, R.R. and Srivastava, S. (2024). Management of Southern Corn Leaf Blight (SCLB) with antagonists, botanicals and fungicides. *Pestic. Res. J.* **36(1):** 74-79. doi: 10.5958/2249-524X.2024.00013.6.

Chen, G., Xiao, Y., Dai, S., Dai, Z., Wang, X., Li, B. *et al.* (2023). Genetic basis of resistance to Southern Corn leaf blight in the maize multi-parent population and diversity panel. *Plant Biotechnol. J.* **21(3):** 506-520. doi:10.1111/pbi. 13967.

Choudhury, D., Dobhal, P., Srivastava, S., Saha, S. and Kundu, S. (2018). Role of botanical plant extracts to control plant pathogens-A review. *Indian Journal of Agricultural Research.* **52(4):** 341-346. doi: 10.18805/IJARe.A-5005.

Craze, H.A., Pillay, N., Joubert, F. and Berger, D.K. (2022). Deep learning diagnostics of gray leaf spot in maize under mixed disease field conditions. *Plants*. **11:** 1-12.

Dai, Y., Gan, L., Ruan, H., Chen, F. and Gao, Z. (2018). Sensitivity of *Cochliobolus heterostrophus* to demethylation inhibitor fungicides and their efficacy against Southern corn leaf blight in fujian province, China. *Eur. J. Plant Pathol.* **152:** 447-459. doi: 10.1007/s10658-018-1490-z.

Dai, Y.L., Yang, X.J., Gan, L., Chen, F.R., Ruan, H.C., Du, Y.X. and Gao, Z.M. (2016). First report of Southern Leaf Blight caused by *Cochliobolus heterostrophus* on corn (*Zea mays*) in Fujian Province, China. *Plant Dis.* **100(8):** 1781.

Hayford, R.K., Haley, O.C., Cannon, E.K., Portwood, J.L., Gardiner, J.M. andorf, C.M. and Woodhouse, M.R. (2024). Functional annotation and meta-analysis of maize transcriptomes reveal genes involved in biotic and abiotic stress. *BMC Genomics*. **25(1):** 10443. doi:10.1186/s12864-024-10443-7.

Jakhar, D.S., Singh, R., Kumar, S., Singh, P. and Ojha, V. (2017). Turcicum leaf blight: A ubiquitous foliar disease of maize (*Zea mays* L.). *Int. J. Curr. Microbiol. Appl. Sci.* **6(3):** 825-831.

Jangid, A., Shringi, A., Chakma, M., Srivastava, S. and Rana, M. (2025). Evaluation of biocontrol agents and fungicides against Alternaria leaf spot of spinach. *Agricultural Science Digest*. **45(2):** 312-316. doi: 10.18805/ag.D-5657.

Kansotia, K., Meena, A.K., Sharma, P., Kumawat, K., Meena, D.K. and Maurya, S. (2024). Evaluation of bioagents and phytoextract against *Alternaria* leaf spot disease of coriander caused by *Alternaria alternata*. *Biopestic. Int.* **20:** 39-44. doi: 10.59467/BI.2024.20.39.

Koder, S.B., Nawale, R., Abhishek, Katyayani, K.K.S., Rana, M. and Srivastava, S. (2022). Symptoms, biology and management of Ascochyta blight (*Phoma exigua*) of French beans: A review. *Agricultural Science Digest*. **42(6):** 657-664. doi: 10.18805/ag.D-5393.

Kuilya, J., Debnath, S., Chhetri, S. and Biswas, S. (2018). Studies on Southern corn leaf blight disease in West Bengal. *Maize J.* **7(1):** 20-25.

Kumar, A., Dhamgaye, S., Maurya, I.K., Singh, A., Sharma, M. and Prasad, R. (2014). Curcumin targets cell wall integrity *via* calcineurin-mediated signaling in *Candida albicans*. *Antimicrob. Agents Chemother.* **58(1):** 167-175. doi: 10. 1128/AAC.01385-13.

Kumar, R., Mina, U., Gogoi, R., Singh, B. and Agrawal, P.K. (2016). Effect of elevated temperature and carbon dioxide levels on maydis leaf blight disease tolerance attributes in maize. *Agric. Ecosyst. Environ.* **231:** 98-104. doi: 10.1016/j. agee. 2016.06.006.

Liu, L.M., Huang, S.W., Wang, L., Hou, E.Q. and Xiao, D.F. (2014). First report of leaf blight of rice caused by *Cochliobolus lunatus* in China. *Plant Dis*. **98**: 686. doi: 10.1094/PDIS-03-13-0303-PDN.

Manda, R.R., Addanki, V.A. and Srivastava, S. (2020). Microbial biopesticides and botanicals as an alternative to synthetic pesticides in the sustainable agricultural production. *Plant Cell Biotechnol. Mol. Biol.* **21(61-62):** 31-48.

Mayee, C.D. and Datar, V.V. (1986). *Phyto-pathometry.* Tech. Bulletin. 1 (Special Bul. 3), p: 95. Marathwada Agricultural University Parbhani, Maharashtra, India.

Mubeen, S., Rafique, M., Munis, M.F.H. and Chaudhary, H.J. (2017). Study of Southern corn leaf blight (SCLB) on maize genotypes and its effect on yield. *J. Saudi Soc. Agric. Sci.* **16(3):** 210-217. doi: 10.1016/j.jssas.2015.06.006.

Nene, Y.L. and Thapliyal, P.N. (1979). *Fungicides in Plant Disease Control*. New Delhi: Oxford and IBH Publishing Co., 163p.

Ramathani, I., Biruma, M., Martin, T., Dixelius, C. and Okori, P. (2011). Disease severity, incidence and races of *Setosphaeria turcica* on sorghum in Uganda. *Eur. J. Plant Pathol.* **131:** 383-392.

Savary, S., Willocquet, L., Pethybridge, S.J., Esker, P., McRoberts, N. and Nelson, A. (2019). The global burden of pathogens and pests on major food crops. *Nat. Ecol. Evol.* **3:** 430-439.

Shah, K., Pande, S., Acharya, B., Poudel, A. and Shrestha, J. (2020). Study of Southern leaf blight (*Bipolaris maydis*) on maize genotypes and its effect on grain yield. *Agrica*. **9(1):** 69-76.

Shekhawat, P.S. and Prasada, R. (1971). Antifungal properties of some plant extracts: Inhibition of spore germination. *Indian Phytopathol.* **24:** 800-802.

Shi, T., Liu, Y., Zheng, X., Hu, K., Huang, H. and Liu, H. (2023). Recent advances in plant disease severity assessment using convolutional neural networks. *Sci. Rep.* **13:** 29230. doi:10. 1038/s41598-023-29230-7.

Singh, V., Lakshman, D.K., Roberts, D.P., Ismaiel, A., Abhishek, A., Kumar, S. and Hooda, K.S. (2021). Fungal species causing maize leaf blight in different agro-ecologies in India. *Pathogens*. **10(12):** 1-17. doi:10.3390/pathogens10121621.

Sun, X., Qi, X., Wang, W., Liu, X., Zhao, H. and Wu, C. *et al.* (2020). Etiology and symptoms of maize leaf spot caused by *Bipolaris* spp. in Sichuan, China. *Pathogens*. **9(3):** 229. doi: 10.3390/pathogens9030229.

Tripathi, A., Akhtar, J., Kumar, P., Kalaiponmani, K. and Chalam, V.C. (2023). Diagnostic assay for molecular detection of *Bipolaris maydis* and *Stenocarpella maydis* for safe exchange and long-term conservation of maize germplasm. *Physiol. Mol. Plant Pathol.* **128:** 102165. doi:10.1016/j.pmpp. 2023. 102165.

Vela-Corcía, D., Romero, D., de Vicente, A. and Pérez-García, A. (2018). Analysis of β-tubulin-carbendazim interaction reveals that binding site for MBC fungicides does not include residues involved in fungicide resistance. *Sci. Rep*. **8:** 7161. doi: 10.1038/s41598-018-25336-5.

Vincent, J.M. (1947). Distortion of fungal hyphae in the presence of certain inhibitors. *Nature*. **159:** 239.