International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

IJBSM March 2023, 14(3):485-491 Print ISSN 0976-3988 Online ISSN 0976-4038 Article AR3366a

Research Article Stress Management

DOI: HTTPS://DOI.ORG/10.23910/1.2023.3366a

Effect of Different Natural Products Against Leaf Blight Diseases of Maize

Srabani Debnath and Sonali Biswas

Dept. of Plant Pathology, AICRP on Maize, Bidhan Chandra Krishi Viswavidyalaya, West Bengal (741 252), India

Open Access

Corresponding srabanidebnath72@gmail.com

0000-0001-6886-4487

ABSTRACT

This experiment was conducted during *kharif* seasons (June to September) of 2016 and 2017 at District Seed Farm, Kalyani Simanta of Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India. The objective of the study was to find out the performance of natural products against maydis leaf blight of maize under artificial epiphytotic condition. The eleven natural products were namely; Neem leaves, Karanj leaf, Milkweed / Calotropis leaf, Datura leaf, Parthenium leaf, leaves of Umbelanterna / *Lantana camara*, leaves of False Ashoka, leaves of tulsi, bulb of garlic, cow urine and Hexaconazole as standard check. The experiment was laid out in Randomized Block Design with 12 treatments with three replications. The extracts of Plant products at 10% concentrations were then applied by spraying to plants in the field just after 24 h of inoculation. 2nd inoculation was done seven days after first inoculation. Severity was calculated for each replication of each treatment by using the Percent Disease Index (PDI). *Allium sativum* (garlic) bulb @ 10% resulted lowest Percent Disease Index i.e. 28.4% against the Maydis leaf blight and 25.8% against Turcicum leaf blight of maize with the concurrent 61.13% and 65.08% control of diseases. Cow urine @ 50% resulted 29.8% and 28.6% PDI which was statistically equally effective with *Allium sativum* (garlic) bulb @ 10%. Likewise, this *Allium sativum* (garlic) bulb @ 10% also produced highest yield (2910 kg ha^{-1}) which was 34 higher than the chemical, Hexaconazol used for these diseases.

KEYWORDS: Biotic, epiphytotic, natural products, standard check, yield loss

Citation* (VANCOUVER)*: Debnath and Biswas, Effect of Different Natural Products Against Leaf Blight Diseases of Maize. *International Journal of Bio-resource and Stress Management,* 2023; 14(3), 485-491. HTTPS://DOI.ORG/10.23910/1.2023.3366a.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 13th December 2022 RECEIVED in revised form on 25th February 2023 ACCEPTED in final form on 08th March 2023 PUBLISHED on 22nd March 2023

1. INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop in India and ranks third in production after wheat and rice (Yadav et al., 2015). Major proportion of the maize is used for human consumption in poorer countries, whereas in the industrialized countries, it is used for animals (Louie, 2017). Maize demand was expected to rise by 50% to over 800 million tons per year by 2020 (Pingali and Pandey, 2001, Fajemisin, 2003, Grote et al., 2021). Maize is an important crop for human consumption that can represent up to 65% of the total calories and 53% of the protein (Atlin et al. 2011). It is distributed worldwide and is the world's third highest-produced cereal (Magenya et al., 2009, Sharma and Misra, 2011, Wani et al., 2018).

The major factor for lower yields is sensitivity of maize to several diseases and abiotic stresses (Rahul & Singh, 2002; Arif et al., 2017; Zhou et al., 2019; Riffat and Ahmad, 2020). Northern leaf blight (TLB) of maize is caused by the fungus *Exserohilum turcicum* and southern leaf blight (MLB) by *Bipolaris maydis*. Accurate automated high-throughput phenotyping of plant diseases has the potential to aid crop management, speed up breeding, and contribute to fundamental and applied research efforts (Pauli et al., 2016).

Maydis leaf blight is considered as one of the most serious diseases and has attained the status of the economically important disease (Malik et al., 2018). This disease has been detected in almost all maize growing areas of India (Kaur et al., 2014). Bipolaris and related genera such as Curvularia, Dreschslera, and Exserohilum are ascomyceteous fungi known to infect maize (Manamgoda et al., 2014). Bipolaris is widely applied in taxonomy (Rossman et al., 2013). Species of Bipolaris infects 60 other host genera, either as saprophytes or phytopathogens (Manamgoda et al., 2011; Farr et al., 2013). Four races of *B. maydis* are reported viz. O, T, C, and S (Zhang et al., 2011; Wang et al., 2017). *Bipolaris sorokiniana* is reported in other countries as harmful pathogens of maize (Manamgoda, 2014; Guo et al., 2016; Guo et al., 2017). Similarly, *B. sacchari* a pathogen of sugarcane in India (Sivanesan et al., 1987), was reported as pathogen of maize in China (Farr et al., 2020). *B. maydis* is present in all maize producing zones, especially in Kharif maize (Kaur et al., 2014; Pal et al., 2015). Earlier, a leaf spot disease of maize caused by *C. clavata* and maize leaf spot caused by *C. geniculata* were recorded in India (Manzar et al., 2021). The presence of *C. papendorfii* in rice soil (Giridharan et al., 2014) has been documented from India. *Alternaria species* including *A. tenuissima*, *A. alternata*, and *A. burnsii* were shown to cause disease in maize (Cui et al., 2020). Significant yield losses (up to 40%) reported in Argentina (Couretot et al., 2014; De Rossi et al., 2010). Similarly, NCLB infections can reduce silage digestibility and predispose to stalk rot (Galiano-Carneiro et al., 2021). The NCLB disease symptoms appear on leaves and plants usually at or after anthesis (Wilcoxson, 1996, Scrivener et al., 2001, Sharma et al., 2015). High temperatures and humid tropical conditions in some African regions have caused some maize diseases and pests prevalent that have a significant effect on maize yield (Fajemisin, 2003, Abdelsalam et al., 2019a). The study was aimed to find out the performance of natural products against maydis leaf blight of maize under artificial epiphytotic condition.

2. MATERIALS AND METHODS

This experiment was conducted during *kharif* seasons (June to September) of 2016 and 2017 at District Seed Farm, Kalyani Simanta of Bidhan Chandra Krishi Viswavidyalaya, West Bengal, India. Experiment was laid out in Randomized Block Design with 12 treatments and three replications with the natural products taken were - Neem leaves, Karanj leaf, Milkweed/Calotropis leaf, Datura leaf, Parthenium leaf, leaves of Umbelanterna / *Lantana camara*, leaves of False Ashoka, leaves of tulsi, bulb of garlic, cow urine and hexaconazole as standard check (Table 1).

Table 1: List of plant products taken in this experiment

Sl. No.	Treatment	Name of the natural products	Plant parts used	Concentration used
1.	T_1	*Azadirachta indica*	Leaf	10% extract
2.	T_2	*Pongamia pinnata(Kranj)*	Leaf	10% extract
3.	T_3	*Calotropis sp.*	Leaf	10% extract
4.	T_4	*Datura stramonium (Datura)*	Leaf	10% extract
5.	T_5	*Parthenium hysterophorus*	Leaf	10% extract
6.	T_6	*Lantana camara*	Leaf	10% extract
7.	T_7	*Polyalthia longifolia (false Ashoka)*	Leaf	10% extract
8.	T_8	*Ocimum sanctum (Tulsi)*	Leaf	10% extract
9.	T_9	*Allium sativum (garlic)*	Bulb	10% extract
10.	T_{10}	Cow urine	Liquid	50%
11.	T_{11}	*Hexaconazole* (recommended dose)	NA	1ml/li of water
12.	T_{12}	Water		-

The experiment was conducted under artificial epiphytotic condition. The inoculation of fungal culture (MLB & TLB) was done at knee high stage of plants at 25 days after sowing. The inoculation for Maydis leaf blight and Turcicum leaf blight was done by the method as follows- after soaking of 40–45 gm of Sorghum grains in water in a conical flask, autoclaved twice. Then seeded with fungus under aseptic condition and kept for incubation at 25–27°C. The flasks are shaken once in 2–3 days to facilitate uniform growth on grains. After 10 days the material becomes ready for inoculation. Then after shade drying a fine powder was prepared with these sorghum grains. A pinch of this powder was put in the leaf whorl of 30–35 days old plant. Maintenance of adequate moisture for longer period must be confirmed to permit spore germination with the help of sprayer. The plants were inoculated on 30–35 days old plants with spraying a solution of fungal spore made by washing the inoculated sorghum seeds in water in late afternoon to avoid maximum day temperature during incubation period. Extracts of plant products was made by following procedure – The fresh leaves and other parts of healthy plants were collected, rinsed and washed with 10% sodium hypochlorite (NaOCl) prepared by adding 1-part bleach to 9-part water, air dried and packed in brown envelopes before oven drying at 70°C for 20 m (Akinbode and Ikotun, 2008). Then they were ground using pestle and mortar, sieved through a 40 mm mesh. 200 g powder of the respective plant parts was added to 500 ml of distilled water in a 1000 ml flat bottom flask. The suspension was then allowed to stand for 24 h and the content was filtered using a muslin cloth and kept in glass bottles until needed. The extracts at 10% concentrations were prepared by mixing 10 ml of the stock with 100 ml of distilled water. Extracts of Plant products (leaves/bulbs) were then applied by spraying to plants in the field just after 24 h of inoculation. 2nd inoculation was done seven days after first inoculation.

Disease scoring was done on randomly selected ten plants from each replication following disease rating scale (1–9 scale, Balint-Kurti et al., 2006) of MLB and TLB (Chung et al., 2010, Mitiku et al., 2014). (Table 2). For getting final disease score the scoring of three replications was averaged.

Table 2: Disease scoring scale (1–9) of TLB and MLB

Rating scale	Degree of infection (% Diseased leaf area)	PDI	Disease reaction
1.0	Nil to very slight infection (≤10%).	≤11.11	Resistant (R) (Score:≤3.0) (PDI:≤33.33)
2.0	Slight infection, a few lesions scattered on two lower leaves (10.1–20%).	22.22	
3.0	Light infection, moderate number of lesions scattered on four lower leaves (20.1–30%).	33.33	
4.0	Light infection, moderate number of lesions scattered on lower leaves, a few lesions scattered on middle leaves below the cob (30.1–40%).	44.44	Moderately resistant (MR) (Score: 3.1–5.0) (PDI: 33.34–55.55)
5.0	Moderate infection, abundant number of lesions scattered on lower leaves, moderate number of lesions scattered on middle leaves below the cob (40.1–50%).	55.55	
6.0	Heavy infection, abundant number of lesions scattered on lower leaves, moderate infection on middle leaves and a few lesions on two leaves above the cob (50.1–60%).	66.66	Mod. susceptible (MS) (Score: 5.1–7.0) (PDI: 55.56–77.77)
7.0	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%).	77.77	
8.0	Very heavy infection, lesions abundant scattered on lower and middle leaves and spreading up to the flag leaf (70.1–80%).	88.88	Susceptible (S) (Score: >7.0) (PDI: >77.77)
9.0	Very heavy infection, lesions abundant scattered on almost all the leaves, plant prematurely dried and killed (>80%).	99.99	

Percent Disease Index is calculated using the following formula of Mckinney (1923).

(Sum of all the individual disease ratings/Total number of plants observed)×(100/Maximum disease grade) ….(1)

(PDI - Percent Disease Index)

Severity was calculated for each replication of each treatment by using the above formula. Variety used in this experiment was PAN 6010 and standard agronomic practices were followed. Fertilizer dose used was 150:75:75 (N: P_2O_5: K_2O) and spacing of 60cm row-row and 20 cm plant-plant was given. There were four rows of plants with a row length of

4 m in each plot of this experiment.

3. RESULTS AND DISCUSSION

Among ten natural products used in this experiment all showed certain level of disease control and yield increase efficiency against both Northern and Southern leaf blight diseases of maize (Table -3). From ancient times natural products are used against different diseases of human being. Recently considering the health and environmental hazards of chemicals, efforts are going on to use natural products to minimize diseases of plants and agricultural crops. It was revealed that minimum PDI in both the cases of TLB (25.8) and MLB (28.4) was observed in case of application of 10% extract of garlic bulb followed by application of cow urine (PDI=28.55 in TLB and 29.8 in MLB) with no significant difference among them. Disease control percentage in case of *Allium sativum* (garlic) bulb @ 10% (T_9) for MLB was 61.13 and for TLB was 65.08 and in case of Cow urine @ 50% (T_{10}) for MLB it was 59.28 and for TLB it was 61.81. Garlic is utilized as folk medicine in many countries for its antimicrobial and other beneficial properties. Aqueous garlic extract was used against *Aspergillus sp*. Which is an infectious fungus under in-vitro study and better inhibitory effects than chemicals were obtained from the study of (Pai et al., 1995). In present study best result was obtained by applying garlic bulb extract (10%) among ten natural products. Allicin is the main component of garlic responsible for controlling fungal growth and most of its biological activities such as bactericidal, antifungal and antiviral actions. Garlic showed antifungal potential against *Sporothrix schenckii* (Burian et al., 2016). The volatile antimicrobial substance allicin (diallylthiosulphinate) is produced in garlic and allicin is readily membrane-permeable and undergoes thiol-disulphide exchange reactions with free thiol groups in proteins and this property of allicin is thought to be the basis of its antimicrobial action. Allicin effectively controls seed borne *Alternaria sp*. In carrot, *Phytophthora* leaf blight of tomato and potato and *Magnaporthe* on rice (Slusarenko et al., 2008). Garlic extract has potential, as a bio-fungicide, in the management of stalk and ear rot disease of maize (Ajayi, 2020).

Table 3: Effect of bio-extracts / natural products on the incidence of maize diseases

Sl. No.	Treatment	PDI		Disease control %		Yield (kg ha^{-1})		Yield increase (%)	
		MLB	TLB	MLB	TLB	MLB	TLB	MLB	TLB
1.	T_1 - *Azadirachta indica* leaves @ 10%	42.5	41.95	41.87	43.88	1985	2433	34.57	48.08
2.	T_2 - *Pongamia pinnata (Kranj*) @ 10% extract	42.95	35.1	41.30	53.04	1720	2643	16.61	61.34
3.	T_3 - *Calotropis* sp. @ 10%	43.35	40.95	40.71	45.22	1650	2760	11.86	67.98
4.	T_4 - *Datura stramonium* (*Datura*) @ 10%	30.1	26.55	58.82	64.48	2245	2720	52.20	65.55
5.	T_5 - *Parthenium hysterophorus* @ 10%	49.95	48.6	31.68	34.99	1945	2560	31.86	55.81
6.	T_6 - *Lantana camara*	46.2	46.9	36.78	37.26	1695	2433	14.91	48.08
7.	T_7 - *Polyalthia longifolia* (false *Ashoka*) @ 10%	43.85	45.5	40.02	39.13	1675	2403	13.55	46.25
8.	T_8 - *Ocimum sanctum* (Tulsi) @ 10%	41.95	42.1	42.6	43.68	1945	2303	31.86	40.17
9.	T_9 - *Allium sativum* (garlic) bulb @ 10%	28.4	25.8	61.13	65.08	2580	2910	74.91	77.11
10.	T_{10} - Cow urine @ 50%	29.8	28.6	59.28	61.81	2470	2793	67.45	69.99
11.	T_{11} - Hexaconazole (recommended dose)	37.35	47.9	48.91	35.92	1860	2170	26.10	32.07
12.	Water	73.1	74.76	0	0	1475	1643	0	0
SEm±		6.86	5.83			285	104		
CD (p=0.05)		14.24	12.09			591	217		

Higher yield and yield increase percentage was also observed in *Allium sativum* (garlic) bulb @ 10% (T_9) and for MLB yield was 2580kg ha^{-1} and yield increase was 74.91%. In Cow urine @ 50% (T_{10}), yield was 2470 kg ha^{-1} and yield increase was 67.45%. Cow urine has inhibitory effect for fungus and also growth promoting properties. In ancient Ayurveda it was mentioned for its pharmacological importance and it has excellent germicidal power and antimicrobial activity. Cow urine contains 95% water, 2.5% urea and rest 2.5% contains a mixture of salts, hormones, enzymes and minerals and it has antifungal against three fungal pathogens (*Fusarium oxysporum*, *Rhizoctonia solani*, and *Sclerotium rolfsii*) isolated from infected plants of Methi and Bhindi that showed symptoms of damping off and wilting disease (Jandaik et al., 2015). Cow urine was found effective in management of post-harvest rot in Apples (Manica Tomar and Harender Raj, 2015). The biochemical estimation of cow urine has shown that it contains Sodium, Nitrogen, Sulphur, Vitamin A, B, C, D, E, minerals, Manganese, Iron, Silicon, Chlorine, Magnesium, Citric acid, Creatinine and hormones (Jain et al., 2010). In present study maximum disease control, lowest PDI and highest yield was obtained in case of application of garlic bulb extract (10%) followed by application of cow urine (50%). For cow urine application 50% concentration is quite higher dose but in West Bengal during kharif season rainfall is very high and weather is highly humid, so this high dose can be considered. The references mentioned earlier is supportive to this result of present study. Yield advantage is also higher in this study because the natural products have anti-fungal as well as growth promoting activities also which helped in increase of yield in comparison to the commercial fungicides.

For TLB in case of T_9 yield was 2910 kg ha^{-1} and yield increase 77.11%. In T_{10} for TLB yield was 2793 kg ha^{-1} and yield increase 69.99%. There was no significant difference among the results obtained from T_9 and T_{10}. So, statistically T_9 and T_{10} are at par.

4. CONCLUSION

Ten natural products were tested against leaf blight diseases (Maydis leaf blight and Turcicum leaf blight) of maize for their better management. Considering the disease control percentage and yield, the application of garlic bulb extract followed by the application of diluted cow urine were found equally effective for managing both leaf blight diseases.

5. ACKNOWLEDGEMENT

We want to thankfully acknowledge the technical & financial support of Indian Institute of Maize Research, Ludhiana, Punjab and Bidhan Chandra Krishi Viswavidyalaya, West Bengal for other supports.

6. REFERENCES

Abdelsalam, N.R., Botros, W.A., Khaled, A.E., Ghonema, M.A., Hussein, S.G., Ali, H.M., Elshikh, M.S., 2019. Comparison of uridine diphosphate-glycosyltransferase UGT76G1 genes from some varieties of *Stevia rebaudiana* Bertoni. Scientific Report 9(1), 8559.

Ajayi, A.M., 2020. Seed dressing with aqueous *Allium sativum* L. extracts enhanced the tolerance of maize plant to stalk and ear rot disease caused by *Fusarium verticillioides*. Canadian Journal of Agriculture and Crops 5(2), 160–173.

Akinbode, O.A., Ikotun, T., 2008. Evaluation of some bioagents and botanicals in in vitro control of *Colletotrichum destructivum*. African Journal of Biotechnology 7(7), 868–872.

Arif, K., Ahmad, R., Khan, S.A., Asad, S.A., Ahmad, T., Abbasi, G.H., Shahzad, M., 2017. Molecular characterization of growth and proteolysis related genes in maize under drought stress. Pakistan Journal of Botany 49, 2127–2132.

Atlin G.N., Palacios, N., Babu, R., Das, B., Twumasi-Afriyie S., Friesen, D. K., 2011. Quality protein maize: progress and prospects. Plant Breeding Reviews 34, 83–130.

Balint-Kurti, P.J., Krakowsky, M.D., Jines, M.P., Robertson, L.A., Molnar, T.L., Goodman, M.M., Holland, J.B., 2006. Identification of quantitative trait loci for resistance to southern leaf blight and days to anthesis in a maize recombinant inbred line population. Phytopathology 96(10), 1067–1071.

Burian, J.P., Sacramento, L.V.S., Carlos, I.Z., 2017. Fungal infection control by garlic extracts (*Allium sativum* L.) and modulation of peritoneal macrophages activity in murine model of sporotrichosis. Brazilian Journal of Biology. DOI 10.1590/1519-6984.03716. Brazian Journal of Biology. 2017 Nov;77(4):848–855.

Chung, C., Longfellow, J.M., Walsh, E.K., Kerdieh, Z., Esbroeck, G.V., Balint-Kurti, P., Nelson, R.J., 2010. Resistance loci affecting distinct stages of fungal pathogenesis: use of introgression lines for QTL mapping and characterization in the maize-*Setosphaeria turcica* pathosystem. BMC Plant Biology 10, 103.

Fajemisin, J., 2003. International institute of tropical agriculture conference. Overview of maize viruses in sub-Saharan Africa, Plant virology in sub-Saharan Africa; pp. 158–171.

Farr, D.F., Rossman, A.Y., 2013. Fungal databases, systematic mycology and microbiology Laboratory; ARS, USDA: Beltsville, MD, USA. Available online: http://nt.arsgrin.gov/fungaldatabases.

Farr, D.F., Rossman, A.Y., 2020 Fungal databases, Systematic mycology and microbiology laboratory; ARS, USDA: Beltsville, MD, USA. Available online: https://nt.arsgrin.gov/fungaldatabases.

Ferguson, L.M., Carson, M.L., 2004. Spatial diversity of *Setosphaeria turcica* sampled from the Eastern United States. Phytopathology 94(8), 892–900.

Galiano-Carneiro, A.L., Kessel, B., Presterl, T., Miedaner, T., 2021. Intercontinental trials reveal stable QTL for

Northern corn leaf blight resistance in Europe and in Brazil. Theoretical and Applied Genetics 134(1), 63–79.

Giridharan, P., Verekar, S.A., Gohil, A.R., Mishra, P.D., Khanna, A., Deshmukh, S.K., 2014. Antiprolif-erative activity of hamigerone and radicinol isolated from *Bipolaris papendorfii*. BioMed Research International, 890904.

Grote, U., Fasse, A., Nguyen, T.T., Erenstein, O., 2021. Food security and the dynamics of wheat and maize value chains in Africa and Asia. Frontiers in Sustainable Food Systems 4, 317.

Guo, Y.J., Niu, Y.C., Deng, H., 2016. *Bipolaris* and *Curvularia species* associated with corn leaf spot in northern China. Plant Protection 42, 39–46.

Guo, N., Ni, X., Shi, J., Ma, J.Y., Xue, C.S., Chen, J., 2017. The occurrence and pathogen identification of leaf spot on maize. Acta Phytopathologica Sinica 47, 1–8.

ICAR-IIMR Annual Report, 2021. ICAR-Indian Institute of Maize Research, Punjab Agricultural University Campus, Ludhiana–141004; ICAR-IIMR.

Jain, N.K., Gupta, V.B., Garg, R., Silawat, N., 2010. Efficacy of cow urine therapy on various cancer patients in Mandsaur District, India -A survey. International Journal of Green Pharmacy 4, 29–35.

Jandaik, S., Thakur, P., Kumar, V., 2015. Efficacy of cow urine as plant growth enhancer and antifungal agent. Advances in Agriculture. vol. 2015, Article ID 620368, 7 pages.

Kaur, H., Hooda, K.S., Khokhar, M.K., 2014. Maydis leaf blight of maize: Historical perspective, impact and present status. Maize Journal 3, 1–8.

Louie, J., 2017. Food groups. Essentials of human nutrition. 5th edition, 2016 - Oxford University Press, 273pp.

Magenya, O., Mueke, J., Omwega, C., 2009. Association of maize streak virus disease and its vectors (Homoptera: Cicadelidae) with soil macronutrients and altitudes in Kenya. African Journal of Agricultural Research 4, 1284–1290.

Malik, V.K., Singh, M., Hooda, K.S., Yadav, N.K., Chauhan, P.K., 2018. Efficacy of newer molecules, bioagents and botanicals against Maydis leaf blight and Banded leaf and sheath blight of maize. Plant Pathology Journal 34(2), 121–125.

Manamgoda, D., Cai, L., Bahkali, A., Chukeatirote, E., Hyde, K.D., 2011. Cochliobolus: An overview and current status of species. Fungal Diversity 51, 3–42.

Manamgoda, D.S., Rossman, A.Y., Castlebury, L.A., Crous, P.W., Madrid, H., Chukeatirote, E., Hyde, K.D., 2014. The genus *Bipolaris*. Study Mycology 79, 221–288.

Manzar, N., Kashyap, A.S., Sharma, P.K., Saxena, A.K., 2021. First report of leaf spot of maize caused by *Curvularia geniculata* in India. Plant Disease 105(12), 4155

McKinney, H.H., 1923. Influence of soil temperature and moisture on infection of wheat seedlings by *Helminthosporium sativum*. Journal of Agricultural Research 26, 195–217.

Mitiku, M., Eshte, Y., Shiferaw, W., 2014. Evaluation of maize variety for northern leaf blight (*Trichometasphaeria turcica*) in south Omo zone. World Journal of Agricultural Research 2(5), 237–239.

Pai, S.T., Platt, M.W., 1995. Antifungal effects of *Allium sativum* (garlic) extract against the *Aspergillus species* involved in otomycosis. Letters in Applied Microbiology 20(1), 14–18.

Pal, I., Singh, V., Gogoi, R., Hooda, K.S., Bedi, N., 2015. Characterization of *Bipolaris maydis* isolates of different maize cropping zones of India. Indian Phytopathology 68, 63–66.

Pauli, D., Chapman, S.C., Bart, R., Topp, C.N., Lawrence-Dill, C.J., Poland, J., Gore, M.A., 2016. The quest for understanding phenotypic variation via integrated approaches in the field environment. Plant Physiology 172, 622–634.

Pratt, R.G., 2003. An excised leaf technique for host pathogen interactions and qualitative resistance of Bermudagrass genotypes to demataceous hyphomycetes. Phytopathology 93(12), 1565–1571.

Pingali, P., Pandey, S., 2001 Meeting world maize needs: technological opportunities and priorities for the public sector

Rahul, K., Singh, I.S., 2002. Inheritance of resistance to banded leaf and sheath blight *Rhizoctonia solam f. sp. Sasakii*) of maize. Proceeding 8th Asian Regional Maize Works Bangkok, Thailand: 5–8pp.

Riffat, A., Ahmad, M.S., 2020. Alleviation of adverse effects of salt stress on growth of maize (*Zea mays* L.) by sulfur supplementation. Pakistan Journal of Botany 52(3), 763–73.

Rossi, R.L., De., 2015. Concentracao de Referencia de Fungicidas para a Inibicao Miceliana de Isolados de *Exserohilum turcicum* Agente Causal da Helmintosporiose do Milho. Summary Phytopathology.

Rossman, A.Y., Manamgoda, D.S., Hyde, K.D., 2013. Proposal to conserve the name *Bipolaris* against *Cochliobolus* (Ascomycota: Pleosporales: Pleosporaceae). Taxon 62, 1331–1332.

Scrivener, S., Yemaneberhan, H., Zebenigus, M., Tilahun, D., Girma, S., Ali, S., Paul, M., Custovic, A., Woodcock, A., Pritchard, D., Venn, A., Britton, J., 2001. Independent effects of intestinal parasite infection and domestic allergen exposure on risk of wheeze in Ethiopia: a nested case-control study. The Lancet 358(9292), 1493–1499.

Sharma, I., Kumari, N., Sharma, V., 2015. Sorghum fungal diseases, Sustainable agriculture reviews. Springer, 141–172.

Sivanesan, A., 1987. Graminicolous species of *Bipolaris, Curvularia, Drechslera, Exserohilum* and Their Teleomorphs; Mycological Papers No. 158; C.A.B. International: Wallingford, UK, 1–261.

Slusarenko, A.J., Patel, A., Portz, D., 2008. Control of plant diseases by natural products: Allicin from garlic as a case study. In: Collinge, D.B., Munk, L., Cooke, B.M. (Eds.), Sustainable disease management in a european context. Springer, Dordrecht 121(3), 313–322.

Tomar, M., Raj, H., 2015. Use of aqueous and cow urine-based plant extracts against post-harvest diseases of apple. Journal of Mycology & Plant Pathology 43(2), 246–249.

Wang, M., Wang, S., Ma, J., Yu, C., Gao, J., Chen, J., 2017. Detection of *Cochliobolus heterostrophus* races in South China . Journal of Phytopathology 165: 681–691.

Wani, T.A., Bhat, G.N., Mushtaq, A., Anwar, A., Zaffar, G., 2018. Screening of maize germplasm for Turcicum leaf blight resistance. Journal of Applied and Natural Science. 10(1), 98–101.

Wilcoxson, RD., 1996. Bunt and smut diseases of wheat: concepts and methods of disease management, CIMMYT

Xu, X., Zhang, L., Yang, X., Cao, H., Li, J., Cao, P., Guo, L., Wang, X., Zhao, J., Xiang, W., 2021. *Alternaria spp*. associated with leaf blight of maize in Heilongjiang Province, China. Plant Disease 8(11), 1170.

Yadav, O.P., Hossain, F., Karjagi, C.G., Kumar, B., Zaidi, P.H., Jat, S.L., Chawla, J.S., Kaul, J., Hooda, K.S., Kumar, P., 2015. Genetic improvement of maize in India: Retrospect and prospects. Agricultural Research 4, 325–338.

Zhang, L.X., Dong, M., Yang, L.M., Wang, J.H., Tan, G.J., 2011. Identification of physiological races of *Bipolaris maydis* and their sensitivities to diniconazole in Anhui Province. Acta Phytopathologica Sinica 41, 441–444.

Zhou, J., Nadeem, A., Cheng, Y.A., Qin, C.H., Chen, P., Zhang, C., Zhang, L., 2019. Effect of inoculation of strains with acc deaminase isolated from vermicompost on seed germination and some physiological attributes in maize (*Zea mays* L.) exposed to salt stress. Pakistan Journal of Botany 51(4), 1169–1177.

