Rice is one of the most widely consumed staple food for more than half of the population in the world. Brown spot caused by Helminthosporium oryzae accounts for 5% yield loss worldwide annually. Adversely affected fields show yield loss as high as 45%. The present study focuses on the several management aspects that are currently used to curb out the disease incidence and measures to be taken in near future for designing effective disease management protocol. The disease is of historic significance and a devastating outbreak in the Bengal Province during 1943 ended as the Great Bengal famine resulting in starvation and an estimated demise of 2.1 to 3 million people. Brown spot is still devastating on looking the present scenario of damage to rice. Different approaches have been adopted ranging from the use of brown spot resistant rice cultivars, chemical ameliorations and biological control measures for the management of the disease. But, still the disease seems to be chronic and adverse in the current scenario. In this review, we have highlighted epidemiology, control measures practiced and several quantitative and qualitative gaps with respect to disease management, which if rectified, would lead to a strong impact on crop disease control and the sustainable Rice production that are pertinent to the present situation of farmers.

Key words: Bio-control, Brown spot, Fungicides, Helminthosporium oryzae, Management, Resistance, Rice.

Abbreviations: QTL- Quantitative Trait Loci.
combinations. This review is intended to pinpoint the nature of the pathogen, disease epidemiology and various control measures to check the Blast disease and the knowledge gaps in the present perspective that could lead to much-needed, high-impact researches and future thrusts in disease epidemics.

The research works so for undertaken relating to the field of identification, isolation, culturing, characterization of *Helminthosporium oryzae* and ultimately leading to framing the control and management measures of rice brown spot disease at field level were critically examined from published sources at the Department of Genetics and Plant Breeding, Faculty of Agriculture, Anamalai University, Chidambaram, Tamil Nadu, India during the period of 2019-2020. This review provides a clear cut picture of the pathogenic nature, disease prevalence and different managerial aspects of *Helminthosporium oryzae* and the knowledge gaps in realizing the disease free crop cultivation in near future.

**The pathogen**

*Bipolaris oryzae* (syn. *Helminthosporium oryzae*) causing Brown spot in rice, belongs to the subdivision Deuteromycotina (imperfect fungi), class Deuteromycetes, order Moniliales and family Dematiaceae. The disease was first described by Breda de Haan in 1900. Shoemaker (1959) described it to *Bipolaris oryzae* as the two end cells gives rise to the conidia. The perfect stage of the fungus is *Ophiobolus miyabeanus* as reported by Ito and Kuribayashi in 1927. The fungus like many other fungi gives raise to inter and intra-cellular mycelium which further differentiates into brownish grey to dark brown mat like growth on the infected plant tissues. Sakamoto (1934) reported that *H. oryzae* had well branched mycelium and septate conidia with wide variations in size. The optimum temperature for the fungal growth is found to be 27-30°C (Ou, 1985). Conidial germination required an optimum temperature range of 25-20°C and the optimum pH range of 6.8-7 as reported by Ou in 1985. Based on the morphological and growth culture characteristics, the isolates of *H. oryzae* were classified into several groups (Vijayakumar, 1998). This resulted in the variability of pathogenicity among different isolates of *H. oryzae* as reported Peeyush et al., 2011.

**Symptoms produced**

The pathogen causes blighting of coleoptiles, formation of oval, dark brown to purplish-brown spots on the leaves and reduces the photosynthesizing ability of rice plants, ultimately scorching and killing of the leaves. Early senescence of the infected leaves (Klomp, 1977), reduced number of tillers and reduced elongation of root and shoots have been reported by Vidhyasekharan et al., 1973. Glume blotching phase of *H. oryzae* has been identified to result in more damage (Kulkarni et al., 1986). The pathogen infection is noticed from seedling to the milk stage. Leaf symptom includes typical brown spots with grey or whitish centre, oval to cylindrical in shape mimicking the sesame seeds. The leaf dies up when several spots coalesce together. The seedlings usually gives a scorched appearance and finally dies up, which can be recognized very well from a distance far away from the infected field. The spots size may reach upto1cm or even more in the susceptible varieties.

Shriveled grains are produced when the glumes are infected and are discolored. The spots are observed even on the endosperm. *Helminthosporium oryzae* results in the development of grain discoloration (Bhat et al., 2009). Conidiophores which are dark brown and the conidia over infected parts give a velvety appearance. The symptoms on the leaf sheaths are similar to those on the leaves. These symptoms altogether coupled to give a yield loss of 30 to 43% (Ou, 1985). The ophiobolins, which are excreted by the pathogen are highly phytotoxic and causes the inhibition of root and coleoptile initiation and further elongation on host and non-host plants of *H. oryzae* (Nakamura and Oku, 1960).

**Mode of dispersal and survival**

Damicone et al. (2001) and Spradley et al. (2003) reported that the disease spreads primarily as a seed-borne and the air borne conidia serves as the source of the secondary inoculum (Ou, 1985; Sato et al., 2008). The pathogen is reported to survive in the infected plant debris and some other weed hosts (Biswas et al., 2008) like *Setaria italica* (German millet), *Zizania aquatica* (commercial wild rice), *Leersia hexandra* (southern cut grass), etc. More than 50 species of gramineous family are found to be infected by the pathogen (Dagnachew Lule et al., 2014). The spore of the pathogen is reported to occur throughout the year in air and their survival and dispersal were greater during cooler seasons of the year (Kulkarni et al., 1982). The appresoria penetrates easily the host epidermis and starts its infection (Ou, 1985). Some of the metabolites secreted by the host plants like glutamic acid, aspartic acid, methionine and alanine acts as a stimulating agent for the establishment of the *H. oryzae* (Purkayastha et al., 1974). The compound microscopic analysis of the spores reveals that the conidia are fusiform or obclavate, with widest middle and tapering ends, inconspicuous hilum, visible as a minute papilla like structure, 6-14 distoseptate, measuring 63-153 x 13-22 µm as reported by Mathur and Kongsdal in 2003.

**Disease epidemiology**

The disease spread is rapid when continuous rain and cloudy weather and high day temperature couples together. The host leaf has to remain wet for 8 to 24 hours for the establishment of the pathogen (Luo, 1996). Padmanabhan and Ganguly (1954) identified that the intensity of infection is increased with the age of the host tissues i.e., the later stages of rice plants are more affected. Further, deficiency of N or K also increases the disease intensity as reported by Carvalho et al., (2010). As in many fungal necrotic pathogens, *H. oryzae* also has a short incubation period of less than 24 hours (Klomp, 1977). The maximum sporulation occurs about 6 days of initial establishment (Sarkar and Sen Gupta, 1977). Dough and mature stage of grains are most
affected by the disease (Ou, 1985). Fertigation, time of sowing, micro-climate and soil type influences the survival rate of the fungus in soil and in seeds as stated by Jha, 2001. The disease is limited to areas with uneven distribution of rainfall with heavy dew (Singh et al., 2005). Pannu et al. (2005) reported that the disease incidence varied by 8.8 and 9.2% when the annual rainfall is 410.5 mm (during 2001) and 502 mm (2003) respectively.

**Disease management practices**

**Host plant resistance**

Innate or induced resistance of host plants is considered economical, efficient and environmentally friendly means of resistance to the brown spot disease as reported by Roy et al., in 2020. At present, screening for resistance to the disease has been extended to O. nivara in order to identify alternate source of resistance (Goel et al., 2006). Oryzae has a broad genetic base ranging from completely susceptible [Mithila (2.34 ton/ha)] to moderately tolerant [Radha-4 variety (5.420 ton/ha)] cultivars to Brown spot disease as reported by Laxman Aryal et al. (2019). No major gene is found to confer immunity to the Brown spot pathogen (Sato et al. 2008) but many quantitative genes were reported to govern immunity to the disease. Quantitative trait loci (QTL’s) governing resistance has been reported by Mizobuchi et al., 2016. CH45, an Indica cultivar native to India showing a high level of partial resistance was confirmed by (Matsumoto et al., 2016). Source of the disease resistance gene have been found in Asian and African cultivars and these can be used as a parentage in designing breeding programs for the development of disease tolerant rice varieties (Yaqoob et al., 2011; Nneke, 2012). Difference in the susceptibility level and the development of new race of pathogens pose a severe constraint in breeding for tolerant cultivars (Kamal and Mia, 2009).

**Biological control**

*(Trichoderma sp. especially T. harzianum)* is known to produce a large number of metabolites such as cyclic polypeptides, antibiotics, peptides, volatile and non-volatile compounds which has an allelopathic effect on the fungal growth (Vinale et al., 2005; Angelica et al., 2001; Harish et al., 2008). *T. pseudokoningii* is identified to be the most beneficial in terms of disease reduction and the enhancement of seed germination and growth of the seedlings (Krishnamurthy et al., 2001). Applications of *Pseudomonas* have also reported to reduce the brown spot incidence (Ray et al., 1990). Fioni et al. (2000) concluded that the leaf extracts of *Eucalyptus citriodora* and *Ageratum conyzoides* have shown positive results by checking the fungal growth. Among the commercially available bio-control agents, *Trichoderna, Bacillus and Pseudomonas* were most widely used (Saravananakumar et al., 2007). The leaf extracts of *Azadirachta indica* @ 10% increased the yield of the rice fields infested with brown spot as reported by Kumar et al., (2016). The leaf extracts of *Piper caninum* has shown some positive effects in checking the fungal growth as reported by Ni Luh Suriani in 2020. *Bacillus megaterium* inhibited the fungal growth of B. oryzae at 10⁴ cells per ml with 1 x 10⁵ cell per ml ED₅₀ reduced the disease incidence as reported by Islam and Nandi, 1985. *Cladosporium spp.* is found to be very efficient in controlling the growth of B. oryzae (Harish et al., 2007). The antagonistic nature of these microbes are due to the synthesis of antimicrobial compounds like compounds such as 2, 4-diacetylphloroglucinol (2, 4-DAPG), pyrrolnitrin (PRN), phenazines (PHZ), hydrogen cyanide (HCN), pyoluteorin (PLT) and biosurfactant antibiotics etc. Picard (2008). Urine of sheep and goat dung has also a good result in controlling the disease (Selvi et al., 2008).

**Role of plant nutrients in evading stress**

Mineral nutrition plays a very significant role in disease management practices (Huber and Wilhelm, 1988). With the increase or decrease in the fertilizer application, the disease development also alters (Walters and Bingham, 2007). A balanced nutrition is the best approach to reduce the incidence of many diseases, especially brown spot (Carvalho et al., 2010). Even resistant varieties become susceptible due to leaching down of essential nutrients like Fe, Mn, K and Zn which are to be found essential for *H. oryzae* resistance (Singh, 2005). It is reported that, application of Silicon, not only reduces the brown spot incidence but also increases the immunogenic activity of the host plants to other biotic stresses (Van Bockhaven et al., 2015). Orthosilicic acid were readily absorbed by the plant roots and loaded into the xylem vessels by a specific transporter system residing in the plant system (Ma and Yamaji, 2006). Silicon based amendments gives satisfactory results owing to the control of brown spot disease, especially when applied in the silicon deficit soils (Datnoff et al., 1991, 1997).

**Chemical management**

The fungicidal applications provide an effective control of Brown spot disease in a short time span and it is the most widely used control measure (Biswas et al., 2008). The fungicides such as Propiconazole @ 1ml/l and Hexaconazole @ 2ml/l have provided outstanding results under laboratory and field conditions as recorded by Sunder et al. (2010). Gupta et al. (2013) recorded 97.89% inhibition of the *H. oryzae* using Propiconazole @ 0.1% concentration. Other fungicides like propiconazole, iprodione, carbendazim and azoxystrobin also shown inhibiting effect on the brown spot pathogen (Mandal and Jha, 2008). Haq et al. 2002 conducted experiments under laboratory conditions with the eight fungicidal chemicals (Dithane M-45, Sunlet, Bayeltan, Derosal, Trimiltox, Acrobat and Captan) and concluded that Acrobat and Captan are the effective fungicides among all other fungicides in controlling the brown spot. The effectiveness of Topsin M + Indofil M-45 have been recorded against brown spot control have been recorded by Dubey in 1995. Lore et al. (2007) concluded that the spraying of Hexaconazole and Propiconazole during early booting stage and at 50% flowering reduced brown spot incidence and yield loss associated with the disease.
Future thrusts

Due to the lack of promising disease resistant high yielding varieties and non-availability of large scale biological control measures, chemical control practices are in vogue. The research for screening and utilization of resistant gene has to be intensified. Further, molecular researches for the identification and characterization of QTLs responsible for the resistance to brown spot are oblige. Due to the development of new pathotypes and resistant strains of the pathogen, more emphasis should be given for the development of the stable integrated disease management approach involving the judicious application of various cultural, biological and chemical measures is the immense need of the hour. Till date, only a very few biological control measures are available, but their application under field conditions are very limited which needs further experimentation before recommending for commercial usage.

REFERENCES

Angelica, M., Barbosa, G., Rehn, K.G., Menezes, M. and Mariano, R.R. (2001). Antagonism of Trichoderma species on Cladosporium herbarium and their enzymatic characterization. Brazilian Journal of Microbiology. 32: 98-104.

Arshad, H.M.I., Khan, J.A. and Jamil F.F. (2008). Screening of rice germplasm against blast and brown spot diseases. Pak J. Phytopathol. 20(1): 52-57.

Aryal, L., Bhattarai, G. and Subedi, A., Subedi, M. and Subedi, B. and Sah, Guduo. (2019). Response of rice varieties to brown spot disease of rice at Paklíhawa, Rupandehi. 5(2): 50-54.

Baranwal, M.K., Kotasthane, A., Magculia, N., Mukherjee, P.K., Savary, S., Sharma, A.K., Singh, H. B., Singh, U.S., Sparks, A. H., Variar, M. and Zaidi, N. (2013). A review on crop losses, epidemiology and disease management of rice brown spot to identify research priorities and knowledge gaps. Eur. J. Plant Pathol. 136: 443-457.

Bhat, G.N., Nasreen Fatima, Mohd. Shafait Rehman and Ali Anwar (2008). Occurrence of Mycoflora causing Glume Discoloration in Rice under temperate conditions of Kashmir valley. Agricultural Science Digest. (29): 297-299.

Biswas, S.K., Ratan, V., Srivasta, S. and Singh, R. (2008). Influence of seed treatment with biocides and foliar spray with fungicides for management of brown leaf spot and sheath blight of paddy. Indian Phytopathology. 61(1): 55-59.

Carvalho, M.P., Rodrigues, F.A., Silveira, P.R. andrade, C.C.L., Baroni, J.C.P., Paye, H.S., et al. (2010). Rice resistance to brown spot mediated by nitrogen and potassium. Journal of Phytopathology. 158: 160-166.

Chakrabarti, N.K. (2001). Epidemiology and disease management of brown spot of rice in India. In: Major Fungal Disease of Rice: Recent Advances. Kluwer Academic Publishers. pp. 293-306.

Dagnachew Lule, Santie de Villiers, Masresha Fetene, Teshome Bogale, Tesfaye Alemu, Geleta Geremew, Getachew Gashaw and Kassahun Tesfaye. (2014). Pathogenicity and yield loss assessment caused by Magnaporthe oryzae isolates in cultivated and wild relatives of Finger millet (Eleusine coracana). Indian Journal of Agricultural Research. (48): 258-268.

Damicone, J., Moore, B., Fox, J., and Scimbato, G. (2001). Rice diseases in Mississippi: A guide to identification. Mississippi State University Extension Service.

Datnoff, L.E., Deren, C.W., and Snyder, G.H. (1997). Silicon fertilization for disease management of rice in Florida. Crop Protection. 16: 525-531.

Dubey, S.C. (1995). Evaluation of different fungitoxicant against blast of rice. Plant Dis. Res. 10: 38-41.

Fahad, S., Muhammad, Z.I., Abdul, K., Ihsanullah, D., Saud, S., Saleh, A. (2018). Consequences of high temperature under changing climate optima for rice pollen characteristics and perspectives. Arch. Agron. Soil Sci. Available from: https://doi.org/10.1080/03650340.2018.1443213.

Goel, R.K., Bala, R., and Singh, K. (2006). Genetic characterization of resistance to brown leaf spot caused by Drechslera oryzae in some wild rice (Oryza sativa) lines. Indian Journal of Agricultural Sciences. 76: 705-707.

Gupta, V., Shamas, N., Razdan, V.K., Sharma, B.C., Sharma, R., Kaur, K. et al. (2013). Application of fungicides for the management of brown spot disease in rice (Oryza sativa L.) caused by Bipolaris oryzae. African Journal of Agricultural Research. 8(25): 3303-3309.

Haq, I.M., Adnan, M.F., Jamil, F.F., Rehman, A. (2002). Screening of rice germplasm against Pyricularia oryzae and evaluation of various fungitoxicants for control of disease. Pak J. Phytopathol. 14: 32-35.

Harish, S., Duraiswamy, S., Ramalingam, R., Ebenezar, E.G. and Seetharaman, K. (2008). Use of plant extracts and biocontrol agents for the management of brown spot disease in rice. Biocontrol. 53: 555-567.

Harish, S., Saravanakumar, D., Kamalakannan, A., Vivekananthan, R., Ebenezar, E.G. and Seetharaman, K. (2007). Phyloplane microorganisms as a potential biocontrol agent against Helminthosporium oryzae Breda de Haan, the incitant of brown spot. Arch. Phytopathol. Pl. Prot. 40(1): 148-157.

Huber, D.M. and Wilhelm N.S. (1988). The role of manganese in resistance of plant diseases. In: Manganese in Soils and Plants. [Graham, R.D, Hannam R.J. and Uren N.C. (eds)]. Kluwer Academic Publishers, Dordrecht, The Netherlands. 155-173.

IRRI, Africa Rice and C.I.A.T. (2010). Global Rice Science Partnership (GRiSP). November 2010.

Islam, K.Z. and Nandi, B. (1985). Control of brown spot of rice by Bacillus megaterium. Z. Phanzenkrankh. Pflanzenzsch. 92: 241-246.
Ito, S. and Kunibayashi, K. (1927). Production of ascigerous stage in culture of *Helminthosporium oryzae*, Annals of the Phytopathological Society of Japan 2, 1-8.

Jha, A.C. (2001). Development and management brown spot of rice caused by *Drechslera oryzae* (Breda de Haan) Subramanian and Jain. Ph.D. Thesis, RAU Bihar, Pusa (Samastipur).

Kamal, M.M., Mia, M.A.T. (2009). Diversity and pathogenicity of the rice brown spot pathogen, *Bipolaris oryzae* (Breda de Haan) Shoem. Bang. J. Bot. 38(2): 119-25.

Klopp, A.O. (1977). Early senescence of rice and *Deschlera oryzae* in Wageningen polder. Wageningen: Surinam Agricultural Research. No 859.

Krishnamurthy, C.D., Lokesh, S. and Shetty, H.S. (2001). Occurrence, transmission and remedial aspects of *Drechslera oryzae* in paddy (*Oryza sativa L.*). Seed Res. 29: 63-70.

Kulkarni, S., Ramakrishnan, K. and Hegde, R.K. (1982). Epidemiology and control of brown leaf spot of rice in Karnataka. IX. Atmospheric variation in spore load of *Drechslera oryzae*. Indian Phytopathol. 35: 80-82.

Kulkarni, S., Ramakrishnan, K. and Hegde, R.K. (1986). Demonstration on supervisory control of brown leaf spot of rice caused by *Drechslera oryzae* (Breda de Haan) Subram. and Jain ex. M.B. Ellis. PI. Pathol. Newsl. 4: 22.

Kumar, M., Simon, S. (2016). Efficacy of Certain Botanical Extracts in the Management of Brown Leaf Spot of Rice Cause by *Helminthosporium Oryzae*. Biosci Biotech Res Asia; 13(4)

Lore, J.S., Thind, T.S., Hunjan, M.S., Goel, R.K. (2007). Performance of different fungicides against multiple diseases of rice. Indian Phytopathol. 60: 296-301.

Luo, W.H. (1996). Simulation and measurement of leaf wetness formation in paddy rice crops. Wageningen: PhD Thesis, Wageningen Agricultural University.

Ma, J.F. and Yamaji, N. (2006). Silicon uptake and accumulation in higher plants. Trends Plant Sci. 11: 392-397.

Mandal, S.K. and V.B. Jha. (2008). Management of foliar disease of rice through fungicides. Ann. Plant Protection Science 30: 258-259.

Mathur, S.B., Kongsdal, O. (2003). Common Laboratory Seed Health Testing Methods for Detecting Fungi. Bassendorf, Switzerland: International Seed Testing Association. pp 425.

Matsumoto, K., Sato, H., Ota, C., Seta, S., Yamakawa, T., Suzuki, H. and Nakayama, Y. (2016). A new method for evaluating field resistance to brown spot in rice. Breed. Res. 18: 103-111.

Mizobuchi, R., Fukuoka, S., Tsushima, S., Yano, M., Sato, H. (2016). *Rice* (N Y). QTLs for Resistance to Major Rice Diseases Exacerbated by Global Warming: Brown Spot, Bacterial Seedling Rot and Bacterial Grain Rot. 9(1): 23.

Nakamura, M., Oku, H. (1960). Biochemical studies of *Chochiobolus miyabeanus*. IX. Detection of ophiobolin in the diseased rice leaves and its toxicity against higher plants. - Ann. Takamine Lab. 12: 266-271.

Nneke, N.E. (2012). Screening lowland rice varieties for resistance to brown spot disease in Enyong creek rice field in Akwa Ibom state of Nigeria. Glob. J. Pure Appl. Sci. 18(1): 5-10.

Ou, S.H. (1985). Rice disease 2nd edn. Kew, Commonwealth Mycological Institute. 380 pp.

Padmanabhan, S.Y. and Ganguly, D. (1954). Relation between the age of the rice plant and its susceptibility to helminthosporium and blast disease. Indian Academy of Science. 29: 44-50.

Padmanabhan, S.Y. (1973). The Great Bengal Famine. Annual Review of Phytopathology. 11: 11-24.

Pannu, P.P.S., Chahal, S.S., Kaur, M., and Sidhu, S.S. (2005). Influence of weather variable on the development of brown leaf spot caused by *Helminthosporium oryzae* in rice. Indian Phytopathology. 58: 489-492.

Peeyush, K. Anshu, V and Kumar, S. (2011). Morpho-pathological and Molecular characterization of *Bipolaris oryzae* in rice (*Oryza sativa*). Journal of Phytopathology. 159: 51-56.

Picard, C. (2008) Genotypic and phenotypic diversity in populations of plant-probiotic *Pseudomonas* spp. colonizing roots. Naturwissenschaften. 95:1-16

Purkayastha, R.P. and Mukhopadhyay, R. (1974). Factors affecting colonization of rice leaves by *Helminthosporium oryzae*. Trans. British Mycol. Soc. 62: 402-406.

Ray, S., Ghosh, M. and Mukharjee, N. (1990). Fluorescent pseudomonads for plant disease control. Journal of Mycopathological Research. 28: 135-140.

Reddy, C.S., Laha, G.S., Prasad, M.S., Krishnaveni, D., Castilla, N.P., Nelson, A., et al. (2010). Characterizing multiple linkages between individual diseases, crop health syndromes, germplasm deployment and rice production situations in India. Field Crops Research. 120: 241-253.

Roy, S., Mili, C., Talukdar, R., Wary, S. and Tayung, K. (2020). Seed Borne Endophytic Fungi Associated with Some Indigenous Rice Varieties of North East India and Their Growth Promotion and Antifungal Potential. Indian Journal of Agricultural Research. 10.18805/IJARe.A-5581.

Sakamoto, M. (1934). Catenulate conidia formation in *Ophiobolus miyabeanus* Ito and Kunibayashi. Trans. Sapporo nat. Hist. Soc. 13: 237-240.

Saravanakumar, D., Vijayakumar, C., Kumar, N., Samiyappan, R. (2007). PGPR-induced defense responses in the tea plant against blister blight disease. Crop Protection. 26: 556-565.

Sarkar, A.K., and Sen Gupta, P.K. (1977). Effect of temperature and humidity on disease development and sporulation of *Helminthosporium oryzae* on rice. Indian Phytopathology. 30: 258-259.

Sato, H. ando, I., Hirabayashi, H., Takeuchi, Y., Arase, S., Kihara, J., et al. (2008). QTL analysis of brown spot resistance in rice (*Oryza sativa* L.). Breeding Science. 58: 93-96.

Savary, S., Castilla, N.P., Elazegui, F.A., and Teng, P.S. (2005). Multiple effects of two drivers of agricultural change, labour shortage and water scarcity, on rice pest profiles in tropical Asia. Field Crops Research. 91: 263-271.

Savary, S., Willocquet, L.F.A., Elazegui, N.F.C., Teng, P.S. and Zhu, D. (2000). Rice pest constraints in Tropical Asia: Characterization of injury profiles in relation to production situations. Plant Disease. 84: 341-356.

Selvi, M.T., Balabaskar, P. and Kurucchev, V. (2008). Field evaluation of certain animal excreta against brown leaf spot of rice (*Helminthosporium oryzae* Breda de Haan) Subram. and Jain. Adv. Pl. Sci. 21: 51-53.

Sharma, O.P. and Bambarwale, O.M. (2008). Integrated management of key diseases of cotton and rice. Integrated Management...
of Plant Pest and Diseases. 4: 271-302.
Shoemaker, R.A. (1959). Nomenclature of Drechslera and Bipolaris, grass parasites segregated from Helminthosporium. Canadian J. Bot. 37: 879-887.
Singh, R.K., Singh, C.V., and Shukla, V.D. (2005). Phosphorus nutrition reduces brown spot incidence in rainfed upland rice. International Rice Research Notes. 30(2): 31-32.
Spradley, P., Shipp, M., Grodner, M., and Collum, E. (2003). Pest Management Strategic Plan for Midsouth Rice (Arkansas, Louisiana, Mississippi). 58 pp.
Sunder, S., Singh, R. and Agarwal, R. (2014). Brown spot of rice: an overview. Indian Phytopath. 67(3): 201-215.
Sunder, S., Singh, R., Dodan, D. S., (2010) Evaluation of fungicides, botanicals and non-conventional chemicals against brown spot of rice. Indian Phytopathology. 63(2): 192-194.
Suria, N.L., Suprapt, D.N., Nazir, N., Darmadi, A.A.K., Parwanayoni, N.M.S., Sudatir, N.W. and Yamin, B.M. (2020). Inhibitory activity of Piper caninum leaf extract against curvularia spotting disease on rice plants. Indian Journal of Agricultural Research. 54(4): 411-419.
Van Bockhaven, J., Steppe, K., Bauweraerts, I., et al. (2015) Primary metabolism plays a central role in moulding silicon-inducible brown spot resistance in rice. Mol Plant Pathol. 16(8): 811-824. doi:10.1111/mpp.12236.
Vidyasekharan, P., Ramadoss, N., and Srinivasalu, N. (1973). Quantitative and qualitative losses in paddy due to Helminthosporiose epidemic. Indian Phytopathology. 26: 479-484.
Vijayakumar, S. (1998). Use of plant oils and oil cakes in the management of rice diseases. M.Sc. (Agri.) Thesis, Tamil Nadu Agricultural University, Coimbatore.
Vinale, F., Marra, R., Scala, F., Lorito, M., Ghisalberti, E.L. and Sivasithampram, K. (2005). Secondary metabolites produced by two commercial strains of Trichoderma harzianum. Journal of Plant Pathology. 87(4): 267-309.
Walters, D.R. and Bingham, I.J. (2007). Influence of nutrition on disease development caused by fungal pathogens: implications for plant disease control. Annals Appl. Biol. 151: 307-324.
Yaqoob, M., Mann. R.A., Iqbal S. M., Anwar, M. (2011). Reaction of rice genotypes to brown spot disease pathogen Cochliobolus miyabeanus under drought conditions. Mycopathology. 9(1): 9-11.
Zadoks, J.C. (2002). Fifty years of crop protection, 1950-2000. Neth. J. Agric. Sci. 2002:181-193.
Zadoks, J.C. (2008). On the political economy of plant disease epidemics-capita selecta in historical epidemiology. Wageningen: Wageningen Academic. 249p.