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BANDED LEAF AND SHEATH BLIGHT DISEASE OF MAIZE - POTENTIAL THREAT TO FODDER AND GRAIN YIELD - A REVIEW

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SUMMARY

Maize (*Zea mays* L.) is important forage and cereal crop in world and occupies third position in India after rice and wheat (Kale and Takawale, 2019). It has extensive versatility and grown under different climatic conditions. It is a C_4 crop and possessing highest yielding potential. Banded leaf and sheath blight (BLSB) incited by *Rhizoctonia solani* f. sp. *sasakii* is highly responsible and serious impediment for quality fodder and grain production in maize. This pathogen has a very wide host range and affects the quality production of various crops including sorghum, rice, maize, pearl millet, finger millet, and sugarcane. The losses caused by this disease vary from 10 to 100 per cent in different maize cultivars. All plant parts are affected by this disease, starting from the foliage near ground level. Many attempts have been made to establish correlation between environmental conditions and epiphytotics of BLSB disease to manage it efficiently. Chemical fungicides are effective means to manage this disease but these chemical substances pose serious threats to living beings. For effective management of BLSB there is a requirement of combined management practices. The studies on the history, economic impacts, distribution, symptoms and different management aspects of this pathogen covering these perspectives are discussed here under.

Keywords: Banded leaf and sheath blight, disease management, maize, yield

Rhizoctonia solani f. sp. *sasakii* (Kuhn) is responsible for causing BLSB disease and is accountable for reducing quality maize production in world. This disease was first time reported and described by Bertus in 1927 as sclerotial disease of maize, but it was alleged as a disease of minor importance.

In 1932, Deighton reported this disease from Sierra Leone and from Philippines (Reyer, 1941). With the passage of time this disease was reported from various countries of world and described by different names. In Ivory Coast, it was described as banded sheath rot (Health, 1956). It was first time reported in maize field from Arkansas State as sheath blight disease (Hirel *et al.,* 1988). Now BLSB disease is prevalent in major maize growing countries including Bhutan, Bangladesh, Nepal, Cambodia, Korea, Myanmar, India, Malaysia, Kampuchea, South China, Philippines, Indonesia, Laos, Taiwan, Thailand and Vietnam.

First time reporting of BLSB disease of maize in India was done in 1960 from Tarai region of Uttar Pradesh and pathogen *Hypochonus sasakii* was reported to be the possible cause of this disease. It became threatening malady of maize when it caused an epidemic in foot slopes of Mandi region of Himachal Pradesh (Thakur *et al.,* 1973). In India, occurrence of this menacing disease has been reported from Haryana, Punjab, Himachal Pradesh, Rajasthan, Uttar Pradesh, Madhya Pradesh, Orissa, Assam, Meghalaya and West Bengal (Rani *et al.,* 2013).

Economic impact and yield losses

Banded leaf and sheath blight disease of maize has great importance from pathological point of view as it is a very serious disease and poses many difficulties for maize growers. Due to extreme losses caused by this disease, an extensive reduction in fodder and grain yield is observed affecting the quality and production of maize crop. Both direct as well as indirect losses are responsible for reducing and deteriorating the fodder quality and yield well. Lal *et al.,* (1980) reported 23.9 to 31.9 per cent losses in ten high yielding cultivars of maize in India. Buddemeyer *et al.,* (2004) showed that, there was 12 per cent and 37 per cent reduction in yield and fresh weight in maize due to infection of *R. solani* AG-2-2IIIB. BLSB disease can cause 60 per cent yield losses under natural conditions (Tang *et al.,* 2004), if ear rot stage prevails, the losses may attain 100 per cent yield reduction.

In India, disease severity was recorded ranging from 30.30 to 80.46 per cent in Jharkhand state by Akhtar *et al.,* (2009). This losses caused by this disease can range upto 100 per cent if rainy season prevails in Haryana (Mehra *et al.,* 2012). *R. solani* pathogen also causes sheath blight of rice; hence in areas where rice- maize cropping system is followed, the disease becomes more prevalent (Hooda *et al.,* 2017). Chaudhary *et al.,* (2016) revealed that about 87.5 per cent yield losses in maize hybrid Luyu 13 and 57.8 per cent in Guiding were reported in South China under natural epiphytotic conditions.

The Pathogen (*Rhizoctonia solani* f. sp. *sasakii*)

De Candolle in 1815 formed the genus *Rhizoctonia* to accommodate a non-sporulating root pathogen of crops i.e. *R. crocorum* D.C. ex. Fr. Later, it was identified as *Rhizoctonia solani* by a German scientist Julius Kuhn from diseased potato tubers (Hooda *et al.,* 2017). With the passage of time, *R. solani* f. sp. *sasakii* has attained the status of ubiquitous and versatile pathogen having wide host range. The sclerotium of this fungus has non- differentiated rind and medulla, colourless hyphae at young stage and light brown on maturing. At the base of lateral part of hyphae which has a width 8-12 ?m, a constriction in found at about 90° to main hyphae that contain dolipore septums (Singh and Shahi, 2012). Sclerotia of this pathogen survive in soil and spread is facilitated by irrigation, infected plant debris and movement of infected soil. Although 'Horse shoe' shaped lesions are formed on kernels but this pathogen is not reported to be seed born in nature. It produces silky white colonies on PDA at 28 ± 1° C having very fast growth which appears dull in later stages and sclerotia are also formed (Saxena, 1971).

Epidemiology

For executing any disease management programme more effectively, it is essential to understand the epidemiology of particular pathogen. The prerequisite for disease development depends on availability of susceptible host but the degree by which it outspreads depends on host vulnerability and amiable conditions of environment. *R. solani* f. sp. *sasakii* the inciting agent of BLSB disease is a soil born pathogen and it also survives and overwinters in and crop residue as sclerotia or mycelium. At the beginning of the growing period, the symptoms can be seen on leaves, stem, leaf sheath and ears. Weed plants grown voluntarily in the vicinity of maize plants harbour this pathogen and play important role to assist the primary spread of pathogen (Singh, 1984; Agrios, 1997 and Singh, 1998).

Temperature ranging from 26 to 30°C combined with 90-100 per cent humidity is most congenial for disease outbreaks in maize crop (Singh and Shahi, 2012). Similarly, if rainfall predominates resulting for more than 100 mm in the first 2 weeks, provides most amiable conditions for disease development. After the primary infection when diseased maize plants come in contact with healthy plants, they facilitate the secondary spread of disease. Hence, it is pragmatic that the progress of disease development and spread depends on the equilibrium between primary and secondary inoculum (Anees *et al.,* 2010). Singh *et al.,* (2017) studied the etiology of *R. solani* pathogen and from his findings, he concluded that humidity and temperature has vital importance in the development and spread of disease. Maximum disease intensity was observed when temperature and relative humidity ranged from 24.6-32.3°C and 69-95 per cent respectively and proved to be the extremely amiable conditions for disease progression.

Host range studies of the *R. solani.*

The *R. solani* pathogen has a very wide host range. Besides maize, many cultivated plant species along with weed species such as rice, sorghum, millets, sugarcane, lettuce, green gram, spinach, soybean, brassica, black gram and turmeric etc are known to harbour this pathogen (Kannaiyan and Prasad, 1979). Different isolates of *R. solani* pathogen have different level of virulence. Different levels of virulence were observed among 52 *R. solani* isolates collected from infected plant species along with maize crop belonging to anastomosis group AG1-IA, which causes BLSB disease of maize (Pascual and Hyakumachi, 2000).

Trivedi and Rathore, (2006) reported that various grasses including *Heteropogon melanocarpus*, *H. Contortus, Bothriochloa ischaemum*, *Brachiaria racemosa* and *Panicum maximu*m are also reported to get infected by this pathogen and act as reservoir of this pathogen and facilitate the spread of disease. Srinivas *et al.,* (2014) conducted studies on three families of plants and after observed symptoms and finally concluded that *R. solani* pathogen has a wide host range. The *R. solani* pathogen is responsible for causing various diseases in plants including sheath blight, collar rot, stem canker, root rot, web blight and damping off all over the world and it is obvious from the studies that this pathogen has wide host range (Debbarma and Dutta, 2015).

Disease symptoms

All plant parts of maize crop, except tassel are infected by *R. solani* as reported by Bertus (1927). This disease is more prevalent and high infection is seen on lower leaf sheath and ears. The BLSB disease emerges at pre-flowering stage, 30 to 40 days after sowing in field conditions but this pathogen is capable of infecting young plants also (Plate 2.1 & Plate 2.2). The symptoms produced on leaf sheath are straw coloured, round and water soaked in appearance whereas, the spots observed on leaves are irregular, stretched, straw coloured having diameter 1-3 mm.

The leaves of maize plants facilitate more spread of disease as compared to leaf sheaths. This pathogen spreads more vigorously in humid conditions on lower portions of plants but in dry conditions the spread of this pathogen is restricted (Ahuja and Payak, 1982). Lu *et al.,* (2012) from his study characterized that symptoms of BLSB disease are also developed on ears. The initial infection is seen on the leaves near to ground level because the pathogen is soil borne in nature and later on it expends itself to upper leaves, sheath and ears also. The cracking of leaf sheath and premature drying of plants is also observed.

Cultural control

Cultural methods are very cheap, easy and effective means for managing plant diseases from ancient times. Till date, various studies have been made to manage BLSB disease of maize caused by *Rhizoctonia solani*.

Kato and Inoue, (1995) observed that the maize plants were unaffected by BLSB pathogen whose lower leaves were removed, proving it a very efficient cultural practice for disease management. Maize inter-cropped with soybean is less affected by this pathogen because it checks the presence of fungal inoculum in soil. On contrary, Sharma (1996) revealed the method of removing lower leaves is not much effective in managing this disease. Mehra *et al.,* (2011) also demonstrated that stripping of lower leaves in rainy season drastically reduced disease intensity. A well-drained field and raised bed planting system is not only helps in avoiding direct contact of water but improves seedling growth also (Chaudhary *et al.,* 2016).

Biological control

Biological control is a safe approach and gaining importance day by day because it has become an important disease management measure. It is helpful

Plate 2.1. Disease symptoms on lower leaf sheath.

Plate 2.2. Disease symptoms on upper leaf and ear.

in controlling plant disease without causing any adverse effect on human health and environment. These biocontrol agents have good efficiency against various pathogens and facilitate the eco-friendly disease management of plant diseases. It also reduces adverse effects of chemicals by minimizing the residual effects of chemicals in food chain. There are various mechanisms involved in biological control including antibiosis, competition, siderophore production and induced resistance which are main tools of antagonists. Several antagonists are reported to parasitize *Rhizoctonia* species. Various species of fungus such as *Trichoderma*, *Gliocladium* and *Laetisaria*, bacteria (*Pseudomonas fluorescens*), and nematodes (*Aphelenchus avenae*) are tested by many researchers and proved their efficacy against *R. Solani* pathogen infecting various crops (Elad *et al.,* 1983 and Howell, 1987). Dumitras, (1984) recealed that *T. viride* used in combination with fungicide, its efficiency was increased by 20 per cent.

Krishnamurthy *et al.,* (1999) performed *in vitro* screening of various strains of *Trichoderma* to record the antagonistic activity against *R. solani* pathogen. Not only mycelia growth but sclerotia production was also checked by these species of *Trichoderma*. Khan and Zaidi, (2002) also reported antifungal activities of fluorescent *Pseudomonas* against BLSB pathogen. *Pseudomonas* strains such as PEn-4, PRS-1 and WRS-24 were reported to inhibit spore germination of BLSB pathogen (Tripathi and Johri, 2002). There were increased levels of phenolic content in the plants infected with *R. solani* pathogen (Sivakumar and Sharma, 2003).

Sharma *et al.,* (2002) evaluated *P. fluorescens* and *T. harzianum* against *R. solani* f. sp. *Sasakii* of maize and recorded maximum growth inhibition and lowest sclerotia production. Soil treatment with *B. subtilis* strain G3 prior to artificial inoculation of *R. solani* was highly effective against BLSB disease under field conditions. Sharma *et al.,* (2009) revealed that mycelia growth of *R.solani* was inhibited by *T. atroviride* II and *T. harzianum* III by 79.9 and 65.5 per cent, respectively. Three *Trichoderma* isolates recognized as *T. harzianum*, *T. aureoviride* and T. *longibrachiatum* were used against BLSB of maize and efficiencies of these isolates to control disease were recorded as 62.75, 64.48 and 68.52 per cent along with increasing grain yield by 29.77, 43.37 and 54.21 per cent, correspondingly. Agrawal and Kotasthane, (2010) evaluated twelve *Trichoderma* isolates against *R. solani* pathogen and recorded maximum growth inhibition by *T. harzianum i.e.,* 89.5 per cent and minimum by *T. aureoviride i.e.,* 62.5 per cent. Reddy *et al.,* (2010) tested five antagonists and concluded that *P. fluorescens* 003 strain recorded highest growth inhibition i.e. 78 per cent against *R. solani*. It was observed that *T. viride* followed by *T. harzianum* and *A. niger* were found efficient and inhibited *R. solani* growth by 70 per cent, 67 per cent and 57 per cent respectively and proved to be the potential biocontrol agents (Seema and Devaki, 2012). Among four antagonistic fungi and two bacteria tested, *T. harzianum* showed maximum growth inhibition by 65.13 per cent followed by *P. Fluorescens* (63.45%) as compared to untreated check (Rajput *et al.,* 2016).

Resistance Sources

Till today very fewer reports are available showing true resistant against banded leaf and sheath blight disease of maize. Less work has been done on developing resistant varieties due to less availability of true resistant sources (Pan and Rush, 1997 and Han *et al.,* 2002). On contrary there is availability of some resistance sources as many researchers had worked on screening of maize genotypes against BLSB disease of maize. Disease management through host resistance is an efficient method for controlling soil borne pathogens. Fewer reports are accessible on genetics of disease resistance (Sharma *et al.,* 2002).

Singh and Sharma, (1976) from their study concluded that, among 28 germplasm lines of maize, CM-105 (inbred), CM-200, CM-104, CM-107 x CM-108, A x GE 440, RN6 HT (single crosses), JMZ 306, JML 36, JML 403, JML 32 (composites) were found to be resistant against BLSB disease of maize. Among various inbred lines evaluated, CM-104, P-217407, CM-103, CM-600, CM-105, CM-300 and hybrid VL-43 were found resistant under both; *in vivo* and *in vitro* conditions (Ahuja and Payak, 1984). Kaiser and Chowdhari, (1986) evaluated 80 full sibs for multiple disease resistance and revealed that 34 showed resistant reaction against BLSB disease of maize. Sharma *et al.,* (2003) concluded that, among 128 maize genotypes screened against *R. solani* pathogen, 28 genotypes were resistant, seven genotypes were found to be highly susceptible and five inbred lines namely 15653, 15689, 15651, 15648 and 15650 showed resistant reaction. Meena, (2004) concluded that nine accessions *viz.* PRD-340, HKH-1140, FH-3097, F-7001, FH-3133, BIO-81009, NMH-9858, NECH-01 and PAC-79001 exhibit resistance reaction, some were moderately resistance and remaining were susceptible and highly susceptible. Among 13 released varieties of maize screened, 8 of them were tolerant against Udaipur isolate of this pathogen. Phenolic compounds play important role in providing resistance against BLSB disease of maize (Akhtar *et al.,* 2011). The level of phenolic content rise in all varieties of maize infected with *R. solani* pathogen and the level of increase was more profuse in resistant varieties in comparison to susceptible ones. Buddemeyer *et al.,* (2004) screened 55 breeding lines of maize against BLSB disease of maize.

Various hybrids as well as inbred lines were examined in All India Coordinated Research Project (AICRP) to record the reaction against BLSB disease of maize. The lines that showed resistance were CM-103, CM-108, CM-202, CM-216, CM-117, CM-205, CM-300, Eto 182, Aust 25, CM-500, RN6Ht1A 9 GE 440, P217, CM-500, CM-201, CM-105, P 407, Antigua Gr.II, CM 107 9, CML-267, VL-43, CM-118, JML-32, JML-403, JML-306. It was also revealed that BH11 inbred of maize was found resistant among twelve inbred lines tested in Maize research centre (Madhavi *et al.,* 2012).

Among screened maize germplasm lines the transitional disease of 2.5-3.0 score were found to be remained vigorous till ripening stage against BLSB (Bhavana and Gadag, 2011). Izhar and Chakraborty, (2013) performed line × tester analysis in which 12 inbred lines and 5 inbred testers were involved. Among these 17 lines, 3 lines showed resistant reaction while 12 lines were moderately resistant and 2 lines were found to be susceptible against *R. solani* pathogen. Three inbred lines namely BAUIM-3, BQPM-4 and BQPM-2 gave high yield and their performance of combining ability for resistance against BLSB disease of maize was also good. Limited availability of sources of resistance has become hindrance in conventional breeding to develop resistant hybrid. It is quite complex to identify resistant genotypes in maize against *R. solani* pathogen as compared to other crops. On the other hand, endeavours for screening disease resistance to find out new sources are being made in India and abroad (Hooda *et al.,* 2017).

Compost Extracts

Chemical fungicides have hazardous effects on human health and environment and there is need to develop alternative methods for managing plant diseases. For achieving this objective the interest on bio-rational approaches has been increased. Study on compost extracts is compulsory to check the efficacy of these products. For management of soil borne pathogens these extracts are used with other controlling options. Hoitink, (1997) concluded that compost and compost extracts prepared from wastes have the ability to efficiently manage plant diseases caused by soil borne pathogens. These composts contain various antagonistic agents such as bacteria, fungi and actinomycetes which are not only helpful in reducing disease intensity but also improve soil health and overall yield of crop. Sprays of compost extracts significantly checked growth of Rhizoctonia solani at different concentrations. Application of cow manure amendment reduced disease incidence and also checked the sclerotia production of R. solani by 17.04 to 21.28 per cent (Eklas *et al.,* 2006). Ingham (2002) concluded that compost extracts also known as compost teas are highly efficient in controlling various fungal pathogens. Kerkeni *et al.,* (2007) revealed that the mycelia growth of R. solani was reduced by 10.8 to 20 per cent when Potato Dextrose Agar (PDA) was supplemented with compost extracts as compared to untreated one. The availability of ammonia and amino acids can be responsible for this inhibitory effect (Raja and Kurucheve, 1997). Under in vitro conditions, pigeons manures gave highest inhibition of mycelia growth, followed by chicken and cow manure extracts. But under open greenhouse conditions cow manure was found highly efficient in controlling BLSB disease followed by pigeons manure and chicken manure (Abo-Elnaga et al., 2012). Raj et al., (2016) reported that Annamalai mixture and cow urine were highly efficient in inhibited spore germination of Rhizoctonia fungus. Cow urine inhibited spore germination by 23.50 per cent at 70 per cent concentration. Likewise, both in paper disc method and agar well method 11.60 and 47.90 per cent inhibition respectively, was recorded due to Annamalai mixture. Cow urine at 70 per cent concentration recorded 48.80 and 49.80 per cent growth inhibition of fungus in paper disc method and agar well method correspondingly.

Chemical control

Farmers have reliability on these chemical pesticides and abundantly use them against most of the plant diseases. For controlling BLSB disease of maize, use of chemicals is the key means in absence of resistant varieties. Use of chemicals against *R. solani* depends on correlation among host and pathogen, significance of crop; cultural practices used and fungicides performance. Various efforts have been made till date to control BLSB disease of maize with help of chemicals. Keyworth and Daw, (1961) evaluated the efficacy of Brassicol (PCNB) against this disease. Granular applications of Hinosan and Kitazin were highly efficient in managing BLSB disease of maize (Mathai and Nair, 1977 and Verma and Menon, 1977). Twenty five fungicides and nine antibiotics were tested against *R. solani* under *in vitro* conditions by Butchaiah (1977). Among those, vitavax, thiobendazole and Duter were venerable fungicides and all the nine antibiotics tested were efficient in controlling *R. solani* fungus. Dalmacio *et al.,* (1990) reported that validamycin efficiently controlled the spread of lesions of BLSB disease on maize plants. Pujari *et al.,* (1998) revealed that among different chemicals tested against BLSB, maximum disease control was recorded by validamycin (0.1 %). Mancozeb + thiophanate methyl (lndofil M-45), Captan, Rhizolex were also effective in controlling this menacing disease of maize. The efficacy of these chemicals increased when used in combination with lower leaves stripping method (Sharma and Saxena, 2002). Azoxystrobin was found highly efficient under *in vitro* conditions and recorded 100 per cent growth inhibition of *R. solani* fungus (Sundravadana *et al.,* 2007). Bag (2009) concluded that a new fungicide (combination of trifloxystrobin 25 % and tebuconazole 50%) was highly effective in reducing disease severity and increasing grain yield. Carbendazim utilized as seed dressing was also found effective in managing BLSB disease and getting better yield. Disease control of 48.7 per cent over check and 64.7q/ha grain yield was recorded (Devlash *et al.,* 2011). Rani *et al.,* (2013) evaluated various chemicals and bio-control agents against *R. solani* pathogen. The disease incidence recorded with carbendazim and thiram applications were 27.11 and 29.92 per cent respectively. Various newer fungicides like dicarboximide group, strobilurin or quinine outside inhibitor (QoI) and demethylation inhibitor (DMI) also gave prolific outcomes when applied in field against this disease (Amaradasa *et al.,* 2014). Bavistin even at 5 ppm concentration was found to be most effective in reducing fungus growth up to 77.1 per cent, while Tilt and Companion gave 100 per cent inhibition at 100 ppm concentrations. Devi and Thakur, (2018) revealed that fungicides namely Bavistin, Raxil, Tilt, Vitavax and Companion completely inhibit fungal growth at 100 ppm concentration. Among nine fungicides evaluated (seven systemic and two non-systemic) four fungicides *viz.,* tebuconazole, carbendazim, hexaconazole and propiconazole repressed mycelia growth by 100 per cent. Madhavi *et al.,* (2018) reported that new molecules, pyraclostrobin and Cabriotop were not much effective against this pathogen. Malik *et al.,* (2018) revealed from their study that validamycin at 0.1% concentration was most efficient among eight new fungicides tested. Disease index was lowest (43.56 and 36.57%) in comparison to other treatments and check plot. Applications of this fungicide not only controlled disease incidence but also enhanced yield by 48.18 per cent as compared to unprotected check plot.

CONCLUSION

Recently maize crop has been emerged as main crop for fodder and grain to achieve the goal of food security for livestock and human as well. Banded leaf and sheath blight disease caused by *Rhizoctonia solani* pathogen is menacing disease for maize production. The infection starts from the foliage, affecting all the plant parts except tassel. The quality of fodder is reduced and presence of fungal sclerotia makes it unhealthy for consumption. To minimize the fodder and grain yield losses there is need to utilize all the management options in as compatible manner as possible. In this review, the importance of this pathogen and how it hampered the maize production is discussed along with appropriate management options. These management options can be utilized by maize growers to achieve the objective of high forage yield and a healthy crop.

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