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Banded Leaf and Sheath Blight in Maize: Inheritance of Resistance, Associated QTLs and Management

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ABSTRACT: The Banded Leaf and Sheath Blight caused by basidiomycetes fungus *Rhizoctonia solani* which was previously considered as a minor disease in maize, has now quickly gained the status of an economically significant disease in maize growing areas of the world. This disease is threatening the production of maize worldwide, particularly in South Asia, South East Asian countries and especially in China with a potential of causing up to a 100 per cent crop loss. The management of this disease is complex and various studies have been conducted to decipher the inheritance of resistance to BLSB. The analysis of combining ability indicates that the resistance to BLSB is both specifically and generally transferable among the crosses. Recently, the F-box gene ZmFBL41 has been identified as conferring quantitative resistance to BLSB. Several QTLs associated with banded leaf and sheath blight resistance have been identified which can be used to enhance BLSB resistance. This review briefly spans the etiology, disease symptoms, economic significance, inheritance of resistance, associated QTLs and management of this disease.

Keywords: Maize, BLSB, QTLs, Management, Inheritance of Resistance, *Rhizoctonia solani*

INTRODUCTION

A. Banded Leaf and Sheath Blight: Its inheritance of Resistance, Associated QTLs and Management

Banded leaf and sheath blight incited by the pathogen *Rhizoctonia solani* f.sp. *sasakii* Exner. has become an economically significant disease of maize in several countries of Asia with a potential of causing upto a 100 per cent crop loss. This disease, in the crop of maize, was for the first time recorded from Sri Lanka (Bertus, 1927), under the name of sclerotial disease. Later, it was also recorded, under the name of 'banded sheath rot' from Malaysia, from Philippines as 'Banded sclerotial rot' and in Japan as 'summer sheath blight' (Wiltshire, 1956). The recent years have seen the disease outbreaks in many more countries with the disease having assumed epidemic dimensions. BLSB has posed a serious limitation to maize production worldwide especially in areas like the tropics and the subtropics, where hot and humid environments are prevalent. The characteristic symptoms of the disease manifest as concentric bands and rings which can be observed on the leaves and sheath of the corn plant, these bands and rings are discoloured and can be tan, brown or grey in colour. This disease affects the leaves, sheaths and stalks of the maize plant and may spread to the ear which ultimately leads to rotting of the ear. This disease may result in the breakage of the stalk, ear rot and in worst cases may result in the premature death of the plant. The disease results not only in the reduction of the yield but also lowers the quality of the produce.

ETIOLOGY AND DISEASE SYMPTOMS

The pathogen *Rhizoctonia solani* causing BLSB, has an especially wide range of hosts. This pathogen is known to infect plants of 32 diverse families and its host range spans over 188 genera (Roy, 1993). Some of its hosts besides maize are sorghum, finger millet, rice, pearl millet, spinach, napier grass, sugarcane, black gram, green gram, lettuce, soybean, pigeon pea, turmeric and brassica, to name a few (Kannaiyan and Prasad 1979). Grasses like *Heteropogon contortus*, *Panicum maximum*, *H. melanocarpus*, *Bothriochloa ischaemum* and *Brachiaria racemosa* have been reported as the recently introduced hosts of this pathogen (Sagar and Bhusal 2019). The plant can be infected by this pathogen at all stages of growth, from the seedling stage to the maturity stage of the crop. Since the disease is soil borne, the initial infection usually appears on the lowest leaf sheath or on the leaves that are in close contact with the soil. The infection may then gradually travel or spread to the ear causing it to rot. The three types of ear rots that can be observed have been delineated by Kumari (2012) as: (i) if the infection occurs before the emergence of the ear, the ear will not develop, if it develops it will remain rudimentary (ii) if the infection has occurred after the emergence of the ear, it will be observed that the stalk fiber at the tip darkens, it will cake up and turn into a hardened lump which will eventually lead to poor grain fill (iii) if the infection occurs after the formation of the grains, it will be seen that the kernels have become chaffy, light in weight and lustreless. The presence of cottony growth of light brown mycelium which is on the ear of the plant accompanied by the presence of tiny and circular black sclerotia, premature dying of the ears and the caking up of the ear sheaths are the characteristic symptoms of ear rot (Rajput and Harlapur 2014). The infection will travel from the lower sheath to the upper leaf sheaths under humid conditions, leading to the rotting of leaf sheath and drying of the whole leaf. In severe cases majority of the plant leaves get blighted and on the lesions the formation of sclerotia is noticeable. The soil factors, environmental conditions and the variety involved, affect the colour and size of the sclerotia (Ou, 1972).

ECONOMIC SIGNIFICANCE AND WIDESPREAD NATURE OF THE DISEASE

The disease has been reported from many parts of the globe, from countries like USA, Germany, England, Nigeria, Venezuela, Sierra Leone and Ivory Coast. In the Asian continent BLSB has been recognised as a severe constraint to the cultivation of maize in China, South Asia and Southeast Asia *viz.* Japan, Indonesia, Nepal, Cambodia, Laos, Bangladesh, Korea, Myanmar, Thailand, Pakistan, Vietnam, Philippines, Taiwan, Malaysia and Sri Lanka (Singh and Shahi 2012). In certain countries like China, the losses in yield, due to this disease have been recorded close to a 100 per cent. Butchaiah (1977) has reported a high and a positive correlation between disease index and premature death of the plants which can cause a severe decline of upto 97 per cent in grain yield. When the ear rot phase of the disease is predominating, a 100 per cent gain loss maybe experienced (Rajput and Harlapur 2014). Akhtar *et al*., (2009) have estimated the disease severity to range from 30.30 to 80.46 per cent.

FUNCTIONAL GENOMICS OF DISEASE RESISTANCE TO BLSB IN MAIZE

(i) Inheritance of resistance to BLSB in maize

The genetics of inheritance of BLSB is not very clear. Researchers have reported its inheritance to be digenic as well as oligogenic (Singh and Shahi 2012). Kumar and Singh discerned the pattern of F_2 segregation for BLSB reaction and reported 15: 1 ratio in crosses with the resistant parent CM104 and a ratio of 13:3 in crosses with resistant parent CML1. The study of BLSB reaction in F_2 and the backcrosses involving CM104 and susceptible lines suggested the control of resistance in CM104 by duplicate dominant genes whereas the crosses of CML1 exhibited dominance and recessive reaction. In an association mapping study 26 loci distributed across chromosomes 2, 3, 4, 5, 7, 8, 9 and 10 were reported for resistance to BLSB by Lin *et al.* (2013). Among which umc1202, umc1505 and umc2190 were found to be significantly related to BLSB resistance. The analysis of combining ability indicated that the resistance to BLSB is both specifically and generally transferable among the crosses (Garg *et al.,* 2008). Of late, the F-box gene ZmFBL41 has been identified for conferring quantitative resistance to BLSB. The transposon induction line zmfbl41 taken from maize Uniform Mu resource was utilised to assess the activity of ZmFBL41. Further when infected with *Rhizoctonia solani*, the zmfbl41 line exhibited relatively weaker symptoms than recorded on W22, the wild type (Li *et al*., 2019).

(ii) QTLs associated with resistance to BLSB

The morphological traits and QTLs which have been found to be associated with BLSB resistance can be further exploited to augment resistance against this disease. For enhancing BLSB resistance through QTL pyramiding, the exploitation of QTLs governing morphological traits like days to anthesis, plant height, days to silking, flag leaf architecture etc., along with the QTLs influencing BLSB resistance could be a good choice (Adhikari *et al.,* 2021). Eleven QTLs for resistance to BLSB through composite interval mapping, located on chromosomes 1, 2, 3, 4, 5, 6 and 10 and further 4 more QTLs located on chromosome 2, 6 and 10 across two locations, have been identified for resistance to BLSB (Zhao *et al.,* 2006). Four QTLs for resistance to BLSB have also been recorded on chromosome 6, 7 and 10 respectively by Chen *et al.*, (2009). They further recorded two QTLs for disease incidence on chromosome 7 and 10 which were found to be linked with markers bnlg1161 and phi059. One major QTL on chromosome 5 and 4 minor QTLs on chromosomes 1, 3, 4, and 8 respectively (under first sowing) and another 4 minor QTLs on 4 chromosomes 1, 3, 5 and 8 (under second sowing) have been identified for resistance against BLSB (Adhikari *et al*., 2021). Eight QTLs influencing resistance to BLSB in corn across three location (Delhi, Udaipur and Pantnagar) in India have been recognized; 3 QTLs one on chromosome 4 (bnlg252- bnlg1621), the second on chromosome 8 (umc2146- umc1172) and the third on chromosome 9 (phi108411- umc2346) (location, Delhi), 4 QTLs one on chromosome 2 (umc2363-umc1622), one on chromosome 3 (umc2101-umc1892), one on chromosome 6 (umc1127) and one on chromosome 10 (bnlg1518- bnlg1526 (location, Udaipur) and a single QTL on chromosome 7 (umc1066- bnlg1792) (location, Pantanagar) have been identified (Garg *et al*., 2008). The information procured by mapping resistance can be further utilised in marker assisted selection (MAS) program to develop BLSB resistant germplasm (Zhao *et al.,* 2006).

DISEASE MANAGEMENT

Currently, the researchers don't have much information regarding the sustainable management of the disease. At present the disease is generally being treated by the use of chemicals. But the use of chemicals is not an eco- friendly approach and its use may not always be desirable. Since these pathogens are now developing resistance against these chemical fungicides, biocontrol agents and botanicals are gaining significance in the management of plant diseases (Rajput *et al*., 2016). Other than chemical application, cultural, biological, botanical methods or an integrated approach can also be used to manage BLSB. Besides, researchers have identified a number of QTLs which will immensely expedite the breeding of cultivars resistant to BLSB (Singh and Shahi 2012). Management of disease through genetic resistance is rapidly become more and more desirable as it is an environmental friendly way to manage the disease.

a. Cultural management

The cultural practice of selecting a well drained field and raising the crop on raised beds is known to control the pathogen *R. solani*. On *Rhizoctonia* infested soil, the composting of hardwood has been found to be effective in reducing the disease severity. This practice is apparently known to promote the growth of the fungi *Trichoderma* and other micro- organisms antagonistic to *Rhizoctonia solani* (Hoitink, 1980). The disease can also be controlled by stripping of the lowermost two to three leaf sheaths (Sharma and Hembram 1990). The stripping of leaves prevents the upward movement of the pathogen by limiting its contact with the succeeding leaf sheath. Sharma and Saxena (2002) observed that the cultural practice of removing the lower leaves were not alone helpful in controlling BLSB.

b. Biological management

Certain fungi *viz. Gliocladium virens*, *T. viride*, *Trichoderma harzianum*, *Neurospora crassa*, *Penicillium* spp. and *Aspergillus* spp. have been known to hamper the growth of mycelia, as well as sclerotia formation in *R.solani* (Mew and Rosales, 1984). An eighty per cent inhibition in the mycelia growth after an incubation period of 72 hours and an inhibition of 35.5 per cent in the sclerotial formation after the incubation of this pathogen with *T. harzianum* for a period 10 days was observed (Biswas *et al.*, 2011). The antagonistic activity of the fungus *Trichoderma*, maybe attributed to its fast growing ability and its capability to produce toxins (Sharma *et al.,* 2002). The bacterium *Pseudomanas fluorescence* has also been reported to show antimicrobial activity against a number of fungi (Khan and Zaidi, 2002) including *R. solani*. Treatment of seed, soil treatment and foliar application of *P. fluorescence* resulted in the reduction of disease incidence of BLSB (Meena *et al.,* 2003).

c. Chemical management

Fungicides like TPTH, carboxin and thiobendazole can give effective control of the disease (Baruah, 1979). Chemicals like carbendazim, validamycin A, dichlorine, aureofungin, benodamil, thiobendazole and thiophanate methyl were also reported to be effective against the isolates of *R. solani* by Ahuja and Payak (1988). Thiophanate and Rhizolex were found effective for controlling the pathogen *R. solani* (Sharma and Rai 1999). Formulations of anti- biotic validamycin has shown to be effective against BLSB (Jiang *et al.,* 1991) but taking into consideration its high cost, its usage in disease control cannot be justified (Sharma *et al*., 2002). In vitro investigation of azoxystrobin concluded that it can completely inhibit the mycelia growth of *Rhizoctonia* at 1, 2 and 4 ppm (Sundravadana *et al*., 2007). Sinha (1992) reported the most efficient control of the sclerotial state of the disease was with Bavistin 50 WP (fentin) with 87 per cent disease control followed by Brestan 60 WP (fentin) with 77 percent, Calixin 75 EC (tridemorph) with 74 per cent, Difolatan 80 WP (Captafol) with 72 per cent and Benlate 50 WP (benomyl) with 32 per cent disease control.

d. Botanical management

The botanical extracts of *Ocimum sanctum*, *Mentha arvensis* and *Eucalyptus spp*. have exhibited fungistatic activity against *R. solani* (Ansari, 1995). The plant extracts of *Croton tiglium* and seed powder of *Impatiens balsmina* can also be used as an effective therapeutic control against the leaf blight caused by *R. solani* (Tangonan and Cuambat, 2002). The bulb extract of garlic at 5 per cent concentration (w/v) has also been observed to inhibit the growth of the fungus (Meena *et al.,* 2003). The use of plant products in disease management is an environment friendly approach which is becoming popular since it has a plethora of advantages to offer over chemicals. These botanical extracts are biodegradable and degrade quickly without having any residual effects on the plants, these also get readily absorbed by the plants besides being cost effective (Rajput *et al*., 2016).

CONCLUSION

Maize is the third most important cereal crop after wheat and rice. Maize has also established itself as a staple in many regions of the world like the Sub-Saharan Africa. BLSB is a destructive disease of maize crop which not only adversely affects its yield but also the quality of the produce. This disease has severely affected many maize growing areas of the world which makes it imperative that this disease be managed effectively. BLSB can be managed through cultural practices, chemicals, biological control, by the use of botanicals, by developing genetic resistance or by an integrated approach. This disease which was once considered an insignificant disease in maize is now escalating in magnitude and disease severity and hence the research on managing the disease is also gaining momentum among the researchers. Various studies have been conducted to augment the understanding of inheritance of resistance to BLSB, various QTLs associated with BLSB have been discovered by the scientists including the F-box gene ZmFBL41 conferring quantitative resistance to BLSB. The plethora of vital information thus generated through mapping resistance can be further utilised in marker assisted breeding programmes for development of resistant germplasm.

FUTURE SCOPE

BLSB poses a serious threat to maize growers. It is indicated that it is a difficult to manage disease. A better comprehension of the etiology and inheritance of resistance to BLSB will lead to a better understanding of its control and management.

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