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Spot blotch: A threat to wheat in changing climate-an overview

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Abstract
Wheat (*Triticum aestivum* L.) is the world's most important food crop, serve as the prime item in the diet of millions of people. Spot blotch caused by *Bipolaris sorokiniana* is a destructive disease of wheat (*Triticum* spp.) in warm and humid wheat growing regions of the world. The fungus has a worldwide distribution but as a pathogen it is the most aggressive under the conditions of high relative humidity and temperature associated with the low fertility of soils. The yield loss due to the disease is very significant especially in North Eastern Plains Zone (NEPZ) of India, Nepal Terai and North Western Bangladesh. Estimates of yield losses due to spot blotch were reported to vary from 15.5 to 19.6% and up to 100% under severe infection conditions. Early symptoms are characterized by small, dark brown lesions ranging 1 to 2 millimeter long without chlorotic margin. In susceptible varieties, these lesions can extend very quickly in oval to elongated blotches, light brown to dark brown in colour. They may reach several centimeters before coalescing and inducing the death of the leaf. The pathogen has morphological and molecular variations among the isolates. Ideal conditions for spot blotch development on the leaves are relative humidity of near 95 per cent with an average temperature in the coolest month above 17°C and long periods (more than 12 to 18 hours) of leafs wetness caused by rainfall, irrigation, fog or dew. Recently a number of genotypes have been identified as donors for improving host resistance. The best way to control spot blotch is through an integrated approach including varietal replacement, agronomic management and need based application of fungicides.

Keywords: *Triticum aestivum*, *Bipolaris sorokiniana*, yield loss, leaf wetness, spot blotch

Introduction

Wheat (*Triticum aestivum* L.) is one of the oldest and most important cereal crop. It is the second important staple cereal food in India after rice and has played vital role in stabilizing the food grain production in the country. Wheat is believed to have originated in south west part of Asia. Some of the earliest remains of the crop have been found in Syria, Jordan and Turkey (Feldman, 2001) [20]. It provides edible grain which forms staple food for a large number of people across the world.

The world's major wheat producing areas are northern China, northern India, northern USA and adjoining areas of Canada, Europe, Russia, Latin America and Africa. Globally, total area under wheat production is 215.48 million hectare with production 670.87 million tons and productivity of 3117 kg/ha. India is second largest producer of wheat after China with an area of 29.90 million hectare with production of 94.88 million tons and productivity of 3173.24 kg/ha covering 12 per-cent of world production (FAO Statistics Division 2015) [19]. Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar and Maharashtra are the major (80%) wheat growing states in the country from the point of both area and production. Bihar has 6.00 million ton production from an area of 2.17 million hectare with productivity of 2766 kg/ha (Directorate of Statistics Evaluation, Dept. of Agriculture, Govt. of Bihar 2014) [14].

Wheat crop is affected by many fungal diseases. Spot blotch disease of wheat caused by *Bipolaris sorokiniana*, a hemibiotrophic, phytopathogenic fungus is one of them and prevalent in warmer and humid wheat growing regions of the world (Joshi *et al.* 2007) [25]. *B. sorokiniana* usually induce symptoms on the leaf, sheath and stem (Chand and Joshi, 2004) [27-28]. Severe infection may also reach the spikes, resulting in low weight shrivelled grains (Kiesling, 1985) [29] with black point at the embryo end of kernels (Chand and Joshi, 2004) [27-28]. The symptoms of spot blotch appear as small, light brown lesions which are scattered throughout the leaves and increase in size with stage advancement. Later, these lesions coalesce and change to large spots (oval to oblong and measuring 0.5 to 10mm long and 3 to 5 mm wide) after a week of infection (Chand *et al.* 2002) [11].

Annual yield loss of wheat due to this disease in South Asia is estimated to 15-20% (Duveiller and Sharma, 2009) [17].

The disease severity affects more than 10 million ha. of wheat in gangetic plains (Nagarajan and Kumar, 1998) [41] and reduce grain yield up to 25% in the affected areas (Saari, 1998) [46]. In eastern India, the yield losses can reach up to 100% under severe conditions (Pandey *et al.* 2005) [44]. In the Trans-Himalayan Ladakh region of India yield loss of 6% to 53% have been estimated (Vaish *et al.* 2011) [61].
The area under North Eastern Plains of India is extremely affected by spot blotch disease (Chand *et al.* 2002) [11]. The productivity of region is not at par with national and international level due to biotic stress. In changed climatic scenario, hot and humid condition favours spot blotch disease. Due to the increasing food demand from limited agricultural land, an effective control of spot blotch needs to be achieved.
The warmer parts of the world are mainly affected by many diseases and among these diseases, spot blotch or foliar blight caused by *Bipolaris sorokiniana* (Sacc. in Sorok). Shoem is one of the most concerning disease in warm and humid regions of India and other South Asian countries due to its wide spread prevalence and increasing severity (Joshi *et al*., 2002) [26, 11]. It is an important disease in that mega environment which is characterized by high humid conditions around and after heading stage. According to Duveiller and Sharma, 2009 the wide spread use of conservation tillage practices may be favorable for spot blotch incidence in the South East Asia.
It is the major biotic constraint in wheat in the gangetic plains, especially in the rice-wheat cropping system and is the main limiting factor to growing wheat in South-East Asia (Duveiller *et al*., 1998) [15-16]. At present spot blotch of wheat is a major pathogen at national level in India and its frequency is highest in north eastern plains zone amongst six agro climatic zones due to prevalence of hot and humid weather conditions.

Symptoms
The dark brown necrotic spots (boat shaped) occur on the coleoptiles, leaves, crowns, stems, and roots with or without yellow halo around these. Darkening of the sub crown internode is a characteristic symptom. Lesions on the leaves start as a few mm that extend as elongated dark brown spots greater than 1-2 cm (Chand *et al.*, 2002) [11]. Later such spots coalesce each other thus result blight on large leaf portion. As the disease progresses the spots join together forming large blotches that cover the leaves and eventually killing it. On leaves, conidia develop readily under humid conditions and spread over several centimeters before coalescing and inducing the death of the leaf tissue. An abundant production of conidia can be observed on old lesions under humid conditions and chlorotic streak is sometimes seen diffusing from the border of the lesion as a result of toxin production (Mercado Vergnes *et al*., 2006 and Bockus *et al*., 2010) [39, 89].

Pathogen and host range
Spot blotch is caused by *Bipolaris sorokiniana* (Sacc.) Shoem. Syn. *Drechslera sorokiniana (Sacc.) [Syn. Helminthosporium sativum,* teleomorph *Cochliobolus sativus]* Subram., and Jain, *Cochliobolus sativus*, *Drechslera* ex Dastur [anamorph *Bipolaris sorokiniana* (Sacc.) Shoem.] and several synonyms of the anamorph have been used like *Helminthosporium sorokinianum*, *Drechslera sorokiniana* and *Helminthosporium sativum* (Maraite *et al*., 1998) [37]. *Bipolaris sorokiniana* is characterized by thick-walled, elliptical conidia (60- 120μm ×12-20μm) with 5-9 cells. In axenic culture, the mycelium is composed of hyphae interwoven as a loose cottony mass and appears as white or light to dark grey depending on the isolates (Kumar *et al.*, 2002).
B. sorokiniana belongs to the division- *Eumycota*, subdivision-*Deuteromycotina*, class-*Hyphomycetes*, subclass-*Sporomycetidae*, order-*Moniliales* and family-*Dematiaceae*. It is considered as a semi-biotrophic fungus and has worldwide distribution. A key for distinguishing species of *Bipolaris* has been reported (Subramanian, 1971) [59].
Prem Naresh *et al.* (2009) reported that Richard media supported best growth, excellent sporulation occured at pH 6.5 and optimum temperature for growth and sporulation was 28 ºC. The host range study revealed that *Bipolaris sorokiniana* can infect oat barley, maize, rice and wild canary grass and linseed plant indicated that it had wide range hosts.
Acharya *et al*. (2011) [1] reported that conidiophores of *Bipolaris sorokiniana* were unbranched, brown to dark brown, erect, single or clustured, septate and conidia were brown to olivaceous brown color, straight or slightly curved 50-70μ long 15-20μ wide and variation in septation from 3-7.

Pathogen variability and aggressiveness
Historically, the spot blotch pathogen *B. sorokiniana* has been described as a variable fungus with many morphological (Christensen, 1925) [13] and physiological (Tinline, 1962) [60] variants. Variability in the isolates of *B. sorokiniana* have been reported at morphological (Chand *et al.*, 2003; Maraite *et al.*, 1998, Mishra, 1981) [10, 37] and pathological (Nelson, 1960, Hetzler *et al*., 1991 and Jaiswal *et al.*, 2007) [43, 23, 24] levels. The PCR based molecular markers RAPD has been successfully used to identify strains (Guzman *et al*., 1999) [21], to characterize races (Malvic *et al.*, 2001) [35] and to analyse virulence (Chen *et al.*, 1995) [12] in this pathogenic fungi.
On the basis of morphological characters various isolates of *Bipolaris sorokiniana* have been identified.(Aminuzzaman *et al.*, 2010 and Chand *et al*., 2003) [4,10].

Epidemiology
The severity of the disease is directly influenced by tillage option, irrigation scheduling, soil fertility level, sowing density, crop growth stage, occurrence of late rains during crop cycle, heat stress during grain filling, late planting, high temperature and high relative humidity causing more than 12 hours duration of leaf wetness (Sharma and Duveiller, 2003) [49]. In field, infected seeds and soil serve as an important source for primary inoculum of spot blotch pathogen. Spot blotch pathogen may infect wheat right from first leaf stage and susceptibility of plants increases after flowering.
Ideal conditions for spot blotch development on the leaves are high relative humidity with high temperature and long periods (more than 12 to 18 hours) of leafs wetness caused by rainfall, irrigation, fog or dew. The most important factor, temperature plays a key role coupled with high humidity. Moderate to warm temperature range (18˚C to 32˚C) favours the growth of *B. sorokiniana*. There are various cycles of conidia production during the cropping season which lead to secondary infections after spreading through wind and water drops. Many scientists reported that disease was more severe at 28°C than at lower temperatures. Epidemiological studies have shown that timely sowing avoids the physiological stress that often coincides with the flowering stage which in turn reduces spot blotch (Duveiller *et al*., 2005) [18].
Acharya *et al.* (2011) [1] concluded that spot blotch of wheat emerged as serious concern for wheat cultivation in warmer and humid regions of world. Disease severity was said to be

directly related to humidity, temperature and soil nutrient condition. The greatest yield loss occurred when the flag leaf and leaf below the flag leaf becomes infected before emergence of head.

Disease assessment

The most effective system consists of using a double-digit scale (00-99) developed as a modification of Saari and Prescott's severity scale (Saari and Prescott, 1975) [47]. The first digit (D1) indicates disease progress in the canopy height from ground level; the second digit (D2) refers to measured severity based on diseased leaf area. Both D1 and D2 are scored on a scale of 1-9. For each score, the percentage of disease severity is estimated based on the following formula:

Severity (%) = (D1/9) × (D2 /9) × 100

Because the disease evolves very rapidly in areas affected by the spot blotch, it is often necessary to record several individual disease scores per plot at 3 to 7 day intervals over a 3 to 4 week period between anthesis and the dough stage, depending upon the seedling date (Duveiller and Sharma, 2009) [17].

Yield losses

Yield losses due to foliar blights are variable and in last two decades spot blotch has emerged as serious concerns for wheat cultivation in the developing world. In India, losses due to diseases may be 10-50 per cent which can be devastating for farmers in the Eastern Gangetic Plains (EGPs) and depends on the level of resistance in a cultivar against leaf blight and weather conditions. Spot blotch has been considered as a major constraint to wheat yields in South Asia due to reduction in 1000-grain weight and grain yield (Singh *et al.*, 2007) [25].

Diseased wheat plots in Mexico without fungicides yielded 43 per cent less (Villareal *et al*., 1995) [62]. In farmers' fields in Bangladesh, the average losses due to these foliar blights were estimated to be 15 per cent (Alam *et al*., 1998) [3].

Earlier studies on wheat diseases have reported impressively high yield losses and suggested that sizable area of wheat is at risk to specific diseases or pests. Grain infections by this fungus in years that were favorable for the disease were detected to be as high as 70 per cent (Sharma *et al.* 2005) [54]. In Nepal, it was shown that spot blotch induced grain yield losses of 52 per cent under soil nutrient stress comrade with 26 per cent under optimum fertilization and spot blotch continues to causes substantial grain yield reductions under resource limited farming conditions (Sharma and Duveiller, 2006) [50].

Saari (1998) confirmed through pathogenicity test that *Bipolaris sorokiniana* cause very dire disease foliar blight/spot blotch of wheat and was able to reduce yield losses upto 16-23%.

Disease management

Identification of high yielding and spot blotch resistant genotypes offers opportunity to further increase the yield of the commercial cultivars by improving resistance through selective breeding.

Kumar *et al.*, (2013) [32] observed that Chirya 3, Chirya 7 and Chirya 1 were resistant both at seedling and adult plant stage and two genotypes *viz*., Milan/Shanghai 7 and Shanghai 4 were moderately resistant when tested at different locations of India. Dubin *et al.*, (1998) [15-16] reported that the leading commercial wheat cultivars of South Asia in early 1990s had much higher spot blotch severity than K 8027, which showed good level of resistance.

In South Asia, moderate success in breeding for spot blotch and foliar blight resistance has been reported (Bhandari *et al*., 2003, Sharma *et al*., 2004, Joshi *et al.,* 2004a, Siddique *et al*., 2006, Singh *et al*., 2007, Kumar *et al.,* 2013) [6, 52, 55, 25, 32]. Conventional breeding of wheat for selection of genotypes resistant for spot blotch has made limited progress in the past (Sharma *et al*., 2004 & 2007, Singh *et al.,* 2008) [51-52]. Joshi *et al.* (2007) [25] evaluated Seven hundred twenty-nine lines of diverse wheat germplasm lines in eight locations of three countries (India, Nepal and Bangladesh) of South Asia for 5 years (1999–2000 to 2003–2004) and promising 25 lines have been listed as sources of strong resistance, with 9 lines better yielding than the best resistant check PBW 343 in fewer days to maturity.

Lia Tukas and Ruzgas (2011) [34] studied a total of 99 modern European winter wheat cultivars and breeding lines for resistance to four *Bipolaris sorokiniana* isolates, obtained from wheat straw and grain, under laboratory conditions using a detached leaf technique.

Agronomic practices

Information from different countries on managing foliar blight through manipulation of agronomic practices suggests that different mineral nutrients may reduce foliar blight (Krupinski and Tanaka, 2000, Singh *et al.*, 1998) [31, 58]. Although soil moisture and soil nutrient stress occur together in the wheat fields of South Asia, little quantitative information is available on the effect of low soil moisture and poor soil fertility on foliar blight severity. There are some reports to indicate the role of potash in reducing spot blotch severity (Regmi *et al*., 2002) [45]. Good crop husbandry and optimum agronomy may also reduce spot blotch disease severity up to certain level (Sharma *et al.*, 2006) [50]. Singh *et al*. (1998) reported that late-sown (30 December) wheat fields suffered more from foliar blight than plots sown on the optimal date (30 November). Duveiller *et al*. (2005) [18] showed that timely sowing avoids the physiological stress that often coincides with the flowering stage which in turn reduces spot blotch. Sharma *et al.* (2006) [50] found that the balanced application of nitrogen, phosphorous and potassium reduced spot blotch severity by 15 and 22% respectively

Seed treatment

Seeds are one of the important sources of primary infection. Therefore, seed treatment with a suitable fungicide reduces the carry over inoculum potential, but unless soil inoculums are reduced, seed treatment alone offers no benefit. Seed lots with less than 20 per cent infection should only be treated if there is a shortage of seed (Mehta, 1993) [38]. Seed treatment with Vitavax 200 B and Bavistin increased seed germination by 43 per cent and reduced seedling infection in Nepal (Sharma *et al*., 2005) [18]. The seed treatment of a newly developed fungicidal formulation Vitavax 200 WS (Carboxin + Thiram 1:1) @ 2.0, 2.5 and 3.0 g per kg seed gave good results in reducing seedling mortality, incidence of foliar diseases at multi location of India (Singh *et al*., 2007) [25].

Biological and chemical control

Bio-control of spot blotch has been attempted by several scientists with mixed responses. Successful antagonists against seed borne *B. sorokiniana* were *Chaetomium* sp., *Idriella bolleyi*, and *Gliocladium roseum* (Knudsen *et al.*, 1995) [30].The antagonistic potential of *Chaetomium globosum* against *Drechslera sorokiniana* was first observed by Mandal *et al*., (1999) [36] which was further confirmed (Biswas *et al*., 2000). Agarwal *et al*., (2004) [2] has highlighted the potential antagonism of an antifungal metabolite produced by *Chaetomium globosum* against *C. sativus* both *in vitro* and *in vivo* conditions.

Despite the harmful effect of fungicides to human and environment, it has proved useful and economical in the control of spot blotch. Non systemic and systemic foliar fungicides belonging to the dithiocarbamates (*viz*; Mancozeb) and Triazoles (*viz*. Propiconazole, Tebuconazole, Flutriazol, Procloraz, and Triadimenol) and dicarboxymides (*viz*. Iprodione) are known to be effective. Foliar applications especially with systemic fungicides such as Tebuconazole, Epoxiconazole, Flutriazol, Cyproconazole, Flusilazole, Epoxiconazole and Metaconazole applied between heading and grain filing stages, have been proved to be cost effective. Duveiller *et al*. (2005) [18] observed that Triazole group (e.g.-Tebuconazole and Propinazole) especially have proven to be very effective against spot blotch disease.

Bahadar *et. al.* (2016) [5] have evaluated the inhibitory effect of essential oil of flowering buds and potential extracts of *Eucalyptus camaldulensis* Dehn (leaf, Bark and Flowering Buds) on the most aggressive isolate of *Bipolaris sorokiniana.* Hasan *et al.* (2012) [22] evaluated five botanical extracts namely garlic, onion, ginger, neem and black cumin at different concentrations (5%, 10% and 15%) and five fungicides namely Hexaconazole, Carbendazim, Mancozeb, Difenoconazole + Propiconazole and Propiconazole at different concentrations (100 ppm, 200 ppm, 300 ppm, 400 ppm and 500 ppm) against *Bipolaris sorokiniana* in laboratory.

Carbendazim, Propiconazole and Hexaconazole were almost equally effective against spot blotch of wheat and may be used as an alternative to each other for management of disease (Yadav *et al*, 2015) [63]. Singh *et al.*, 2008) [57] proposed that three foliar application of Propiconazole @ 0.1% after appearance of the disease significantly reduce the disease and increase yield tested over several locations of India. The efficacy of some newly synthesized organotin compounds against *B. sorokiniana* has also been reported (Sarkar *et al.*, 2010) [48].

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