Chapter 14
Current Status and Management of Foxtail Millet [*Setaria italica* (L.) Beauv.] Blast Disease

Rajesha G, I. K. Das, Sakthivel Krishnan, and Vilas A. Tonapi

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14.1 Introduction

Foxtail millet [*Setaria italica* (L.) Beauv.] [(synonym: *Panicum italicum* L.)] is one among the small millets commonly called as Italian millet, German millet, and Hungarian millet. It is an important ancient crop of dryland agriculture, grown since 10,500 years ago in China (Yang et al. 2012). This crop is mainly cultivated for food purposes in Asia, whereas in the United States and Europe as fodder for animal feed (Seetharam et al. 1989). Foxtail millet ranks the second position in the total world production among the millets and is an essential staple food crop for millions of

R. G (✉) · I. K. Das · V. A. Tonapi
ICAR-Indian Institute of Millets Research, Rajendranagar, Hyderabad, Telangana, India
e-mail: rajesha@millets.res.in

S. Krishnan
ICAR-Indian Institute of Oilseed Research, Rajendranagar, Hyderabad, Telangana, India

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people residing in southern Europe and Asia (Marathee 1993) and extensively cultivated in the developing countries in semiarid and arid regions of Africa, Americas, and Asia (Lata et al. 2013). In India, the crop is cultivated in an area of 0.98 lakh ha with the production of 0.56 lakh tons of grain and average productivity of 565 Kg/ha (Hariprasanna 2017). In India it is mostly cultivated in Karnataka, parts of coastal Andhra Pradesh, Uttarakhand, Tamil Nadu, and some pockets of northeastern states (Sharma et al. 2014). Generally, this millet is cultivated all over the world at present, and is most important in China, India, Indonesia, Korean, south-eastern Europe, the United States, and Australia (Sheahan 2014; Taylor 2018).

This crop generally requires short duration, and is highly resilient to drought, physiologically very efficient, and reliable for harvest. In some parts, it is grown as a catch crop when the main crop is failed to utilize the remaining season. The grains are highly nutritious and even well superior to rice and wheat with respect to certain constituents (Upadhyaya et al. 2011) because of its lushness in dietary fiber content, antioxidants, phytochemicals, and polyphenols that are beneficial to human health (Muthamilarasan et al. 2016). The grains contain a greater amount of protein, minerals (calcium, iron, potassium, magnesium, and zinc), and vitamins (Rai 2002). Seetharam et al. (1983) reported 4.0–7.3% of seed oil content in various foxtail millet germplasms. The protein present in foxtail millet is also used as a food component to fight type 2 diabetes and heart diseases (Choi et al. 2005). Hermuth et al. (2016) reported that essential amino acids (threonine, valine, methionine, isoleucine, leucine, and phenylalanine) present in grains of foxtail millet are 65%, 51.1%, and 41% higher as compared to wheat, corn, and rice, respectively.

Climate change is one of the undesirable phases which may intensely affect agricultural production in the coming days. The most serious threats that occur due to climate change are biotic and abiotic stress. Among the biotic stress, diseases play a risk factor for its production, *viz*. blast (*Pyricularia setariae*), rust (*Uromyces setariae-italica*), smut (*Ustilago crameri*), brown spot (*Drechslera setariae*), downy mildew (*Sclerospora graminicola*), udbatta (*Ephelis* sp.), and bacterial leaf blight (*Pseudomonas avenae*) that have been reported in foxtail millet (Das 2017). Among the diseases, the blast caused by *Pyricularia setariae* Nishikado is of moderate importance in India but it may become a major constraint for the production of foxtail millet especially in northern China and India (Nakayama et al. 2005) distressing the production of both forage and grains. During the favorable environmental condition, the disease occurs in severe form and may cause grain loss of up to 60% (Nagaraja et al. 2007; Karthikeyan and Gnanamanickam 2008).

14.2 Distribution

Initially, the blast pathogen was reported by Kawakami (1901–1902) as *P. oryzae* Cav. But this blast pathogen was first reported by Nishikado from Japan in 1917 and identified as *Pyricularia setariae*. In India, this pathogen was reported by McRae (1922) for the first time from Tamil Nadu. Again, Thomas (1940) reported that *P. oryzae*, the cause of paddy blast, could infect *S. italica*, but *Pyricularia* species from *S. italic* is unable to infect rice. The fungus is seed-borne and to some extent soilborne (Palaniswamy et al. 1970). The spread of this pathogen occurs due to the accomplishment of the pathogen in seeds. Later, several countries have reported the occurrence of disease in foxtail millet. In Iran the first report of blast disease was reported by Adel Pordel in 2016 (Pordel et al. 2018).

14.3 Symptoms

The symptoms of blast disease appear on different parts of the plant, viz. leaf, sheath, node, neck, stem, and head. Lower leaves are the most severely affected parts (Gaikwad and D'Souza 1986). The seedling blast is also observed at the seedling stage (Sharma et al. 2014). Symptoms of the disease appear as circular spots with straw-colored centers on leaf blades (Das et al. 2016). The spots are small and scattered, 2–5 mm in diameter, and surrounded by a dark brown margin. The spots coalesce and make the leaves to dry up. When the disease appears in severe form during humid weather conditions, especially with a dense plant stand, the leaves wither and dry as shown in Fig. 14.1.

14.4 The Causal Organism and Host Range

The mycelia of *P. setariae* is thin, hyaline, and straight in young culture whereas as culture becomes old, the mycelium becomes thicker, attains slightly brownish tinge, and swells (Ramakrishnan 1948). The conidiophores emerge through epidermal cells or stomata. Several conidia are formed one after another from the apex of each conidiophore. The production of conidia occurs during high relative humidity and it is released under wind pressure. They are subhyaline, three-celled pyriform, and measure 19–30 μ × 9–15 μ (Kulkarni 1969). Germ tubes are formed from the end cells on germination. Thick-walled, brown, globose chlamydospores are developed at the tips of the germ tubes. The fungus grows well on agar media and host leaf extract.

Fig. 14.1 Foxtail millet sowing leaf blast symptoms

The Pyricularia species has a wild host range belonging to the graminaceae family. These species of Pyricularia were categorized into different species by several authors based on the comparative studies on their pathogenicity factors, host range, mating ability, and isozyme patterns of the extracellular enzyme of pathogens (Kato and Yamaguchi 1980; Matsuyama et al. 1977). In addition to these traditional characteristics, molecular markers such as restriction fragment length polymorphisms (RFLPs) of ribosomal RNA gene (rDNA) and mitochondrial DNA (mtDNA), DNA fingerprints with repetitive DNA, and random amplified polymorphic DNA have been applied to elucidate genetic similarities of *Pyricularia* isolates (Ko et al. 1993; Borromeo et al. 1993; Huff et al. 1994; Valent and Chumley 1991). These studies proposed that *Pyricularia* isolates could be classified into several host-specific groups.

The occurrence and infectivity of this pathogen were not reported in any other crop species as cross infectivity was reported in other species. Many researchers reported that *P. oryzae*, the cause of paddy blast, could infect *S. italica*, but *Pyricularia* species from *S. italica* failed to infect rice crop (Thomas 1940; Ramakrishnan 1948; Wallace 1950). It shows that the pathogen infecting foxtail millet is genetically different from the species infecting other crops. *Pyricularia setariae* pathogen is highly host specific in nature. Showed that *Pyricularia* from *S. italica* resembled *P. setariae* rather than *P. oryzae*. Since *P. setariae* is not associated with the rice, much work on *Pyricularia* from *S. italica* was not done, as compared to *P. oryzae*.

Nishikado (1917) compared host ranges and morphological characters of 16 *Pyricularia* isolates from six host species, and proposed the scientific name *P. setariae* for the three Setaria isolates, mainly because of their specific pathogenicity to foxtail millet. Kato et al. (2000) classified 85 isolates of pathogens into different pathotypes based on the RFLP analysis. He recognized the three isolates from green foxtail that were included and were only pathogenic to foxtail millet among their differential plants. Therefore, pathogenic isolates of foxtail could be classified as in separate pathotypes and named as Setaria pathotypes. Viswanath and Seetharam 1989) reported that *P. setariae* was also found to infect finger millet, pearl millet, and wheat. Furhter Doust, and Kellogg et al. (2002) and Yamagashira et al. (2008) reported that isolates of foxtail millet also infect bristle grass but distinct from *P. grisea*. Whereas, Sharma et al. (2014) reported that *M. grisea* strains from rice or any other hosts do not infect foxtail millet and vice versa.

14.5 Survival and Spread

The pathogen mainly survives in the previous crop residue leftover in the main field and on other cereals including weeds present on the bunds as well as in and around the field. The primary source of inoculum comes from weeds or collateral hosts which belong to Poaceae; when the sporulation occurs on these hosts, the conidia are liberated and spread by wind.

14.6 Disease Cycle and Epidemiology

The blast of foxtail millet is polycyclic in nature and infects all parts of the plant. This fungus produces both sexual spores (ascospores) and asexual spores (conidia). In asexual reproduction, airborne pyriform conidia liberate from conidiophore, land on the surface of the leaves of the plant, and adhere to the surface by producing sticky mucilaginous substance. Later the spore germinates when it gets sufficient moisture especially in the presence of dewdrops, leading to the formation of a germ tube. The germ tube becomes swallow and forms the appressorium which enters the plant through natural openings. The fungal hyphae penetrate into the plant tissue, grow, and eventually produce lesions. The blast lesions become apparent between 72 and 96 h after infection (Agrios 2005). Under higher relative humidity, sporulation of pathogen is high and liberated. Again these conidia start infecting the other plants to continue the next disease cycle. Like this, asexual cycle can be repeated many times during each growing season based on the availability of suitable environmental condition. In the case of sexual reproduction, the production of sexual spores is found inside the specialized fruiting body called perithecium. The asci containing ascospores released from perithecium and hyphal formation after ascospore germination lead to the production of airborne conidia (Fig. 14.2).

14.6.1 Epidemiological Requirements

Many factors influence the development of blast epidemics; mainly it depends on the susceptibility of a variety, availability of primary inoculum load to initiate the disease development, excessive application of nitrogen fertilizer, cloudy and drizzling weather or dew resulting in continuous leaf wetness for more than 10 h, night temperature between 15 and 24 °C, and relative humidity above 90%.

14.7 Integrated Disease Management Approaches

Adaptation of integrated approaches is an effective means to combat the disease. In the practical and majority of cropping systems today, the combination of suitable management practices is the holistic strategy for effective and sustainable management of disease instead of a single method.

14.7.1 Host Plant Resistance

Among the methods of disease management, host plant resistance is one of the simplest, practical, effective, and economical for plant disease management. The use of resistant varieties can not only ensure protection against diseases but also save the

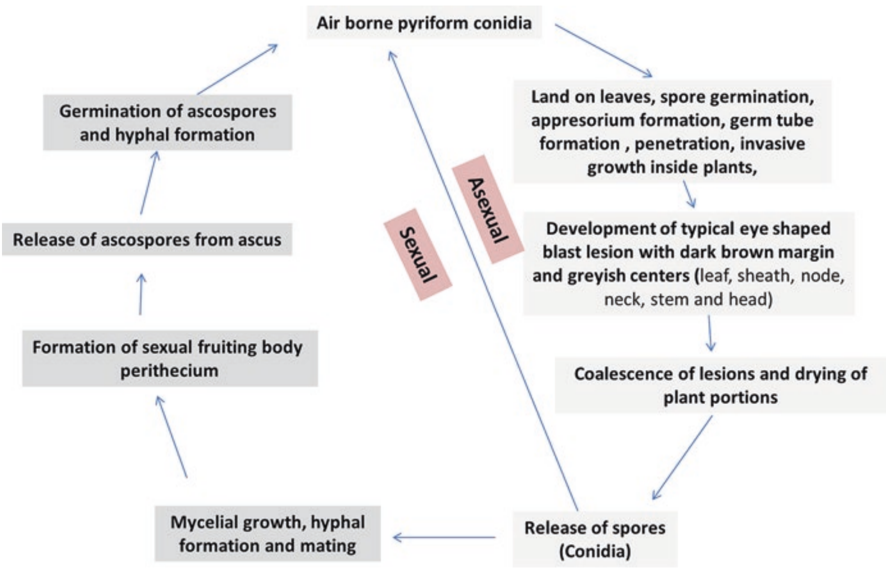

Fig. 14.2 Life cycle of blast fungus *Pyricularia* spp.

time, energy, and money spent on other measures of control. It is very much practical in such cases where chemical control is very expensive and impractical. Breeding for improved blast-resistant varieties is an important goal of foxtail millet improvement programs. Singh et al. (1976) found the varieties SR 118, SR 102, ISc 709, 701, 703, 710, 201, JNSc 33, 56, RS 179, and ST 5307 as resistant to blast in India. Later Sharma et al. (2014) reported that multiple pathotype-resistant accessions identified in the core collection could be used in breeding programs. Among blast-resistant accessions in his study, ISe 376 was found resistant to three of the four foxtail blast isolates tested out of 155 core collections evaluated. Adaptation of integrated approaches is an effective means to combat the disease. Varietal resistance offers one of the most effective means of controlling this disease. Hence, it is necessary to have information on genotypes resistant against the disease. Regarding this, many field screenings have been conducted and have identified the resistant source against the disease in India. But further utilization of unique blast-resistant source in breeding programs is not yet taken up and this needs to be concentrated in future breeding programs on disease resistance.

14.7.2 Cultural Methods

Cultural control methods are very important as it helps the crops to escape from initial pathogen inoculum and the further infection and spread of disease. It involves mainly good agricultural practices right from sowing of seeds to harvest of crop. The important cultural practices include use of disease-free good-quality seeds, proper date of sowing, removal and destruction of weeds and collateral hosts regularly, selection of resistant cultivars, avoiding the use of excess nitrogenous fertilizer, application of N fertilizers in split doses, and crop rotation, all of these singly or in combination.

14.7.3 Chemical Methods

When initial blast spots are seen immediate spraying with effective fungicides like carbendazim 50 WP @ 1 g/L, edifenphos 50 EC @ 1 mL/L, or a combination product of carbendazim + mancozeb @ 1 g/L of water has to be resorted to intercept further development of the disease (Konda et al. 2016). Chemical methods for disease management are followed in high-disease-pressure-prone areas. Seed treatment with captan or carbendazim or thiram or tricyclazole at 2.0 g/kg seed can be used to reduce initial disease incidence at nurseries. During low infection at tillering stage, systemic fungicides such as pyroquilon and tricyclazole are possible chemicals for controlling the disease. Spraying of tricyclazole at 1 g/L of water, edifenphos at 1 mL/L of water, or carbendazim at 1.0 g/L is useful. For successful control 2–3 sprays of chemicals may be used from seedling to booting stage of crop.

14.7.4 Biological Control

Biological control of plant pathogens using antagonistic and beneficial microbes has been found promising in recent days. Many fungal and bacterial diseases have been successfully controlled through biocontrol agents worldwide. Many of the beneficial bacterial genera like *Bacillus* spp. (Chen et al. 2019) and *Pseudomonas* spp. (Sakthivel and Gnanamanickam 1987; Gnanamanickam 2009), and also few yeast species, like *Streptomyces* spp. (Law et al. 2017), were found effective in the management of rice and finger millet blast diseases caused by *Pyricularia oryzae* and *Pyricularia grisea*, respectively. In case of foxtail millet blast, few studies showed *in vitro* potential of *Trichoderma* spp. and *Bacillus* spp. against *P. setariae*; however, not many studies have been reported on the field performance. Hence further studies are needed to strengthen the recommendations on biological control of blast disease in foxtail millet.

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