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Global impacts of sorghum anthracnose disease on sorghum production and its management option: A review

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ABSTRACT

Sorghum [*Sorghum bicolor* (L.) Moench] is an important staple food crop for most communities in the developed and under-developed countries.Global sorghum production and productivity is affected by various stresses notably by biotic factors such as diseases, weeds and insect pests. Among which sorghum anthracnose caused by the fungal pathogen *Colletotrichum sublineola* is an important one which is now considered as destructive disease of sorghum. Sorghum anthracnose occurs in epidemic proportions under high temperature and humidity conditions causing yield losses reaching up to 80% in susceptible varieties which can cause significant losses in grain yield and quality. This review provides the status of sorghum production, important production constraints with emphasis to anthracnose disease and its management options. Information presented in this paper may guide future breeding of sorghum varieties incorporating farmer needs and preferences.

Keywords: Desi Chickpea, Adaptation, Grain yield, Variety.

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Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is an annual C4 naturally self-pollinating and a short-day cereal crop belonging to the family Gramineae and grown in over 100 countries with uses ranging from animal feed, food and recently as a potential source of biofuel (Doggett,1988; Ng'uni *et al*., 2011; Burrell *et al*., 2015). Sorghum adapts to grow in divese agro-ecologies including in dry lowlands, intermidate and high altitudes of the world and is relatively tolerant to harsh growing conditions. Sorghum is tolerant to heat and drought stress making it an ideal crop under limited rainfall and high temprature conditions in arid and semi-arid regions (Sharma *et al*., 2012; Billot *et al.,* 2013)

Ethiopia is believed to be the center of origin and diversity of sorghum due to the presence of diverse genetic pool and wild sorghum types and these genetic resources have been widely used globally in various breeding programs (De Wet and Huckabay 1967; Doggett 1988; Smith and Frederiksen 2000).

In the country, wild types of sorghum are prevalent. The four sorghum races are domesticated in Ethiopia except kafir (Mann *et al.,* 1983; Doggett 1991).

Sorghum production and productivity in the world including Ethiopia is affected by various biotic and abiotic constraints among which sorghum anthracnose caused by the hemibiotrophic fungal pathogen *Colletotrichum sublineola* is an important one which is now considered as destructive disease of sorghum in most sorghum growing areas of the globe (Thakur and Mathur, 2000). Most notably, anthracnoseis prevalent in the warm and humid climates (Perumal *et al.*,2012; Prom LK *et al.*, 2012), causing yield losses reaching up to 80% (Tesso*et al*., 2012)

Therefore, this review article highlights global impacts anthracnose disease on sorghum production and management options which is helpful to policymakers interested in promoting sustainable sorghum production in the future and for researchers interested in focusing on specific critical factors affecting sorghum production on the basis of farmer's needs and preferences.

Sorghum Genetic diversity:

Sorghum is a genus of about 25 species of flowering plants in the grass family Poaceae. Some of these species have grown as cereals for human consumption and some in pastures for animals. One species, Sorghum bicolor, was originally domesticated in Africa and has since spread throughout the globe. Seventeen of the 25 species are native to Australia, with the range of some extending to Africa, Asia, Mesoamerica, and certain islands in the Indian and Pacific Oceans. One species is grown for grain, while many others are used as fodder plants, either cultivated in warm climates worldwide or naturalized in pasture lands. Sorghum is in the subfamily Panicoideae and the tribe Andropogoneae.

Sorghum is a very genetically diverse crop both in cultivated and wild species. The genus Sorghum consists of three widely known species S. halapense, S. propinquum and S. bicolor (Sun *et al*., 1994; Berenji and Dahlberg 2004). Sorghum bicolor is the cultivated species (Smith and Frederiksen 2000; Berenji and Dahlberg 2004). Sorghum bicolor comprises three subspecies; S. bicolor subsp. bicolor, S. bicolor subsp. drummondii, and S. bicolor subsp. verticilliflorum (Berenji and Dahlberg 2004). Sorghum bicolor has the following five basic races: bicolor, guinea, caudatum, durra, and kafir (Harlan and De Wet 1972; Harlan and Stemler 1976; Doggett 1991; Smith and Frederiksen 2000). The races guinea and caudatum are predominantly cultivated in west and east Africa extending to Tanzania, Malawi, eastern Sudan and Uganda. Durra is the dominant race widely cultivated in India, Ethiopia, Sudan and Egypt, while Kafir is widely grown in eastern and southern Africa including in South Africa (Mann *et al*., 1983; Doggett 1991).The Sorghum bicolor ssp. bicolor as the majority bearer of commercial varieties. The greatest variation within the sorghum genus is found in Ethiopia-Sudan (northeast Africa) where it is likely to have originated (OECD, 2016).

Global sorghum production:

Sorghum (Sorghum bicolor) is the fifth most cultivated cereal crop in the world after maize, wheat, rice and barley. It is cultivated both in tropical and temperate climates (Dahlberg *et al*., 2011). In wetter regions, its production is lower than that of more lucrative crops such as Oryza sativa (rice) and Zea mays (maize). Sorghum is a particularly essential crop in Africa, second to maize, as the staple grain for millions of people. The four leading sorghum producers in Africa are Nigeria, Ethiopia, Burkina Faso and Niger. About 74% of sorghum in Africa is used for food (Acquaah, 2012). Although the production varies widely among countries, sorghum remains an important food constituent in the diet of many rural households. Traditionally providing food, feed, and fodder, but more recently also fermentable sugars for the production of renewable fuels and chemicals (Mofokeng *et al*., 2017).

In 2019/2020, the United States was the largest producer of sorghum worldwide, producing about 8.6 million metric tons of sorghum followed by Nigeria 6.7 million metric tons .That year, Ethiopia, is the third largest sorghum producer, produced about 5.2 million metric tons of sorghum(Shahbandeh,2020). In Ethiopia sorghum is the third largest cereal crop in area coverage preceded by tef and maize. Fourth in total grain production is preceded by maize, teff and wheat. In the country sorghum is produced by 5 million smallholder farmers with an estimated total grain production of 5.2 million tonnes, 52,655,800.59 quintals, from an estimated area of 1,828,182.49 hectares of land. This provides a national average grain yield of around 2.8 t ha-1. Sorghum covers 14.21% of the total area allocated to grain crop production (cereals, pulses, and oil crops) and 15.71% of the area covered by cereals in Ethiopia (CSA,2020).

Sorghum production constraints:

Production and productivity of sorghum is affected by both biotic (diseases, insect pests, and weeds) and abiotic (nutrient deficiency, aluminium toxicity, drought, high salinity, water logging and temperature stress) constraints (Tari *et al*., 2013). Important sorghum diseases include anthracnose, grain mold, leaf blight, rust and smut. Insect pests (stem borer, weevils, shoot fly, termites and birds) and the parasitic weed, Striga, are important biotic constraints of the crop (Ekeleme*et al.*, 2011).

Anthracnose and its Symptom on sorghum:

Since 1985, sorghum anthracnose, caused by a fungus, *Colletotrichum sublineolum* is one of the most devastating diseases in sorghum which poses a serious threat to sorghum production and profitability.The disease is commonly found in tropical and subtropical environments where warm, humid climatic conditions enhance the development and spread of the disease(Thakur and Mathur, 2000).The disease occurs in four phases: seedling root rot, leaf (foliar), stalk rot and seed mold. All these phases may occur within a single growing season. The seed rot is mainly due to planting of infected seed or infection of the seeds as they germinate in infested soil. The foliar anthracnose is the most destructive disease phase and it appears 30-40 days after emergence during growth stage 4.0 or later. It occurs from the true leaf through the emergence of the panicle from the boot. The leaf phase of anthracnose begins to develop very quickly near the end of the vegetative stage of the plant and near the beginning of the heading stage. The fungus survives as mycelium, conidia and microsclerotia up to 18 months in crop debris or above the soil surface. In alternative hosts it survives as mycelium in infected seeds. Manifestation of the symptom on the leaves will depend on the cultivar and environmental conditions and may appear as small circular to elliptical spots or elongated lesions, and fruiting bodies (acervuli) appearing as black spots in the center of the lesions. Premature defoliation in highly susceptible cultivars which may result in a death of a plant before seed development. The foliar infection occurs at any stage of plant development and may cause yield losses from 20% up to 80% (Ali *et al.* 1987; Marley *et al*., 2005; Tesso*et al*., 2012). It can also cause reduction in kernel number and size. Stalk anthracnose develops from spores produced in the foliar phase, and is spread throughout the field by splashing rain and/or wind. The spores germinate and infect the stalk above the uppermost leaf and rot the interior of the stalk. If the head and stalk are split lengthwise, a banded or marbled pattern of dark red to purple lesions interspersed with white pith tissue are seen. In severe cases, infection of the panicles can hinder grain filling. The infected heads generally mature earlier than uninfected and they are smaller and lighter in weight and the movement of nutrients to the grain is also limited. The stalk rots and leads to yield losses due to lodging of susceptible cultivars. The infection on the panicle can cause yield reduction of 30-50% (Thakur and Mathur, 2000). The infected seeds appear dark brown or black with streaks encircling the seed. Additionally, the infected seeds can cause reduced germination and new introductions/pathotypes of the disease in new regions (Cardwell *et al.,* 1989; Marley *et al*., 2004). Further sorghum anthracnose, can reduces photosynthate accumulation, which is detrimental to maximizing yield and harvestable biomass(Perumal*et al*.,2012; Prom LK *et al*., 2012).

Survival mechanisms of sorghum anthracnose:

Colletotrichum sublineolum pathogen overwinters in the soil through different mechanisms. The fungus is harbored in plant residues as mycelium, acervuli, melanized hyphopodia, sclerotia and microsclerotia infected seeds of sorghum. Johnson grass is an alternative host of the pathogen. The pathogen survives in sorghum seed for 2.5 years at room temperatures (Crouch and Beirn 2009)

Economic importance of anthracnose disease:

Sorghum anthracnose is one of the most important diseases which cause significant yield and quality losses (Sharma *et al*., 2012; Tesso*et al*., 2012).

Management Strategies to control anthracnose:

aimed at reducing disease damage to the crop.

Several control measures have been recommended, all aimed at reducing disease damage to the crop. The anthracnose is managed by the use of fungicides, cultural practices and resistant cultivars (Singh *et al*., 1989).

Cultural control:

Cultural practices such as weed and residue management, planting disease free seeds and crop rotation and host resistance In west and central Africa, proper crop residue management assisted in minimizing anthracnose disease (Marley *et al*., 2005 ;Silva *et al*., 2015). Crop residue management in the form of cleaning of fields after harvest is found to significantly reduce the level of anthracnose infection in fields. Crop rotation will also help minimizing the buildup of sorghum anthracnose in the same field.

Chemical control:

Seed dressing with fungicide is one of the cheapest and the most effective means of controlling seed and soil borne sorghum diseases of smut and anthracnose. They are convenient for farmer's use, improve stands and seedlings raised from treated seeds are healthier than those from un-treated seeds. Different seed treatment fungicides such as Apron-plus (a mixture of methalaxyl, carboxin and furathiocarp) and foliar fungicides such as carbendazin and maneb and mancozeb applications controlled sorghum anthracnose in Nigeria (Akpa *et al.,* 1992).

However, this method is not environmentally friendly and it is not economically feasible for small-scale farmers.

Breeding sorghum for host resistance:

Breeding sorghum for anthracnose resistance is the most sustainable, economic and environmentally friendly option to control anthracnose disease (Marley *et al*., 2005; Singh *et al*., 2006; Chala*et al*., 2010; Li *et al*., 2013; Cuevas *et al.,* 2014).Deployment of naturally occurring resistance genes is the most effective management strategy for limiting pathogen impact. However, the pathogen exhibits a variability that allows its rapid adaptation to the genetic resistance found in commercial varieties of sorghum (Costa *et al.,* 2003; Silva *et al.,* 2008). This hyper-variability of *C. sublineola* requires continuous evaluation of sorghum germplasm to identify new and diverse resistant sources (Prom LK*et al*.,2012).

Conclusion

Sorghum is the fifth most cultivated cereal crop in the world, traditionally providing food, feed, and fodder, but more recently also fermentable sugars for the production of renewable fuels and chemicals. It is one of the main staple food crops for millions of subsistence farmers in Africa including Ethiopia. This review highlighted the status of sorghum production, important production constraints with emphasis to sorghum anthracnose disease and its control options. The low productivity is aggravated by biotic and abiotic stress factors. Among the biotic factors, anthracnose is the most important and rank first reducing grain yield and quality which causes economic losses to farmers. A number of investigations have been done to control anthracnose disease such as chemical control, cultural practices and resistant cultivars. Crop residue management in the form of cleaning of fields after harvest is found to significantly reduce the level of anthracnose infection in fields. However, developing sorghum anthracnose resistant varieties through resistance breeding is environmentally feasible, economically sustainable and beneficial to smallholder sorghum farmers is a way to protect sorghum against this pathogen that lower input costs while reducing economic losses due to diseases. These advances will increase future sorghum production in new and existing growing regions for both human consumption and biofuel. Thus, priority on research should focus on the identification, incorporation and promotion of anthracnose resistant varieties. Future breeding activities should give considerations to untapped resistant genetic material and marker assisted selection to facilitate the screening of the large numbers of germplasm.

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