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Research Article

Sorghum Production in Ethiopia: An Overview of Advances, Successes, and Challenges

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Abstract

Sorghum is an essential crop, particularly significant in semiarid areas with minimal precipitation. It is the fifth most important grain crop globally and originated in Ethiopia, where it underwent diversification. In Ethiopia, sorghum serves multiple purposes, including as a food staple in forms such as popped grain, beer, malted beverages, cooked gruel or porridge, chips, and enjera. It also provides fuel, making it a vital resource for local communities. Sorghum is a critical crop for Ethiopia, contributing significantly to food security, agricultural livelihoods, and the economy. Advances in agronomic practices, breeding programs, and technology adoption have led to improved yields, disease resistance, and drought tolerance, enhancing the crop's resilience in the face of climate variability. Successes in government initiatives, research collaborations, and farmer engagement have facilitated increased sorghum production and diversification of its uses. However, sorghum production faces challenges, including biotic, socioeconomic, and abiotic factors such as diseases, pest insects, drought, and the parasitic weed striga. Soil degradation, limited access to improved seed varieties, inadequate infrastructure, and the ongoing impacts of climate change further hinder productivity. Coordination in Ethiopia is managed by the Melkassa Agricultural Research Center of the Ethiopian Agricultural Research Institute, which oversees the national sorghum breeding program. Through regional and national sorghum improvement initiatives, Ethiopia now has access to a wide variety of open-pollinated and hybrid sorghum varieties suited to diverse agro-ecological settings. This paper discusses these advancements, successes, and challenges in-depth, emphasizing the need for sustained investment in research, policy support, and capacity building to overcome barriers and ensure the long-term sustainability of sorghum production in Ethiopia.

Keywords

Sorghum, Production, Yield, Challenges, Advances, Successes

1. Introduction

Sorghum is one of Ethiopia's most dependable and varied food crops [*Sorghum bicolor* (L.) Moench; 2n = 20]. Sorghum ranks as the world's fifth most important cereal crop, behind maize, rice, wheat, and barley [1]. In terms of production and acreage, it is the third most important crop. As it provides raw materials for expanding enterprises and construction projects and feeds an increasing number of cows, its value as a food source for rural communities is growing. Due to its C4 status, sorghum is also the cornerstone of dry land agriculture in the current scarcity scenario. Depending on the type of panicle,

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spontaneous cross-pollination can occur at levels of 5 to 30% in sorghum, which is mostly a monocotyledon crop that pollinates itself [2].

Compared to other food crops, sorghum is ideal for dry land farming due to its high degree of adaptability and resilience to harsh environments [3]. According to Mindaye et al. [4], Ethiopia is the sixth-largest producer of sorghum worldwide and the third-largest grower of sorghum in Africa, behind Nigeria and Sudan [5]. It is the third most important crop, behind maize and teff, in terms of overall production and area covered. Data from the CSA shows that in 2018, the entire area under grain crops was 81.31% (10,358,890.13 hectares), the total cover of sorghum was 14.13% (1,829,662.39 ha), and the total production was 15.70% (50,243, 68072 kg). Sorghum is cultivated and farmed practically everywhere in the country. Sorghum is one of the most important commodities for the world's poorest and most vulnerable populations [6].

Sorghum is one of the most significant food crops in the world. It is lower in carbohydrates and higher in iron, protein, and vitamin B3 than rice and maize. Sorghum is suitable for a specific nutritional diet due to its low glycemic index and gluten content [7]. The grain is consumed in Africa as chips, bread, boiled gruel or porridge, beer, malted beverages, and injera [8]. Ethiopia is the core of sorghum genesis and diversification, according to Vavilov [9]. After the United States, Mexico, Nigeria, Sudan, and India, the country ranks sixth globally in terms of sorghum production.

About 1.83 million hectares of agricultural area are used to grow Ethiopian sorghum, which produces 4.34 million tons a year [41]. Local bread, injera, and other drinks like tela and areke are frequently made using sorghum. According to [42], it is the third most important food crop in Ethiopia, after tef and maize, in terms of total number of farmers, area covered, and grain production. It is also eaten as a roasted vegetable and boiled grain. Additionally, sorghum stalks are utilized as fence posts, animal fodder, and building materials.

Abiotic, social, and biotic factors all affect sorghum crop production. The parasitic weed Striga hermonthica and the stem borer (*Chilo partellus*) are the most detrimental biotic restrictions [10, 11]. According to several authors, Ethiopia has not been able to achieve optimal crop production and productivity because of a number of socioeconomic barriers, including a lack of funding, a lack of improved seed systems, a lack of farmer-preferred varieties, a lack of market linkage, a lack of value addition, a lack of extension service support, and a lack of storage facilities [10]. The primary abiotic factors influencing sorghum productivity, including in Ethiopia, are salt, drought, and low soil fertility [10, 12].

The nation's sorghum breeding program (EIAR) is managed by the Melkassa Agricultural Research Center (MARC) of the Ethiopian Agricultural Research Institute. In terms of overall responsibility for the creation and execution of national sorghum research projects, the Melkassa Agricultural Research Center (MARC) is the house of sorghum development or the center of excellence for sorghum research. The sorghum breeding program operates, including multi-location variety trials, at several federal and regional research and testing facilities, higher education institutions, and farmers' fields under the protection of this institutional architecture [13]. For Ethiopia's lowland regions that don't receive enough moisture, national and regional sorghum development initiatives have produced a large range of open pollinated and hybrid sorghum cultivators [14]. The primary goal of this review is to describe the developments, achievements, and important problems in Ethiopia's sorghum production.

2. Review Literature

2.1. Ethiopian Sorghum's Origins and Growth Regions

According to Doggett [2] and Vavilov [9], sorghum originated in Africa and was first domesticated there. Sorghum [*Sorghum bicolor* (L.) Moench] is thought to have originated and been domesticated in Ethiopia, among other African countries. The initial domestication of farmed sorghum took place in northeastern Africa. Given the vast variation of sorghum, Vavilov proposed Ethiopia as the crop's middle of origin [9]. Sorghum is cultivated in 41 of Ethiopia's 49 sub-agro-ecological zones and 13 of the country's 18 major agro-ecological zones [15].'As seen by the diverse variety of morphological variants cultivated there and the crop's extensive agro-ecological coverage, Ethiopia has a richness of genetic variation because it was one of the original countries to cultivate sorghum [2]. Ethiopia cultivates it in a variety of climates and rainfall conditions. Sorghum is grown in many of the hot, arid lowlands, and some varieties are even cultivated at elevations of 2,700 meters in the cooler, wetter highlands. Sorghum typically grows alone when there is little rainfall and the ground is dry [16].

2.2. Ethiopia's Sorghum Production Situation and Economic Importance

Based on statistics from the CSA [17], cereals are the most significant food crop in the total grain crop in terms of planted area and production volume. They are produced in higher quantities than other crops since they are the main staple crops. Everywhere, cereals are grown in different amounts. Approximately 81.19% (10,538,341.91) of Ethiopia's land was planted with grains in general. Of those, 12.94% (1,679,277.06 hectares) were devoted to sorghum cultivation. A total of 302,054,260.58 quintals, or 88.36% of the grain produced, came from cereals. 13.22% (45,173,502.18 quintals) of the grain produced were sorghum. The three regions that generate the most of it are Oromia, Amhara, and Tigray, with respective area coverage of 676,075.00 ha, 597,440.83 ha, and 232,636.49 ha.

More than 500 million people, primarily in developing countries, rely on sorghum as their primary source of carbs, vitamins, protein, and minerals [18]. The top producers of sorghum worldwide are Ethiopia, the US, Mexico, Nigeria, Sudan, and India. In Ethiopia, sorghum is produced on about 1,679,277.06 hectares of agricultural land annually, yielding 45,173,502.18 quintals of grain [1]. Sorghum is Ethiopia's third-most important food crop, behind tef and maize, in terms of total growers; area covered, and grain production, according to data from the CSA [17]. It is usually used to make the two indigenous drinks, areke and tela, as well as the bread known as injera. In addition, sorghum is utilized as a building material, animal feed, and industrial raw material.

2.3. Sorghum Breeding from a Historical Perspective

The collection, investigation, and assessment of sorghum germplasm marked the beginning of a scientific sorghum research study in Ethiopia in 1953 at Jimma Agricultural Technical School (JATS), which is now Jimma University College of Agriculture [19]. After that, it was relocated, and formal research at what is now Alemaya University—formerly known as Haramaya College of Agriculture and Mechanical Arts—began in 1957. One of the major turning points in the history of official sorghum research in Ethiopia was the creation of the Ethiopian Sorghum Improvement Project (ESIP) in 1972, which received large subsidies from the International Development Research Center (IDRC). Research on sorghum was taken over by EIAR, the former EARO, which included ESIP as one of its national projects in 1982.

Ever since, EIAR has been organizing nationwide sorghum research from the Melkassa Research Center. National, regional, and worldwide research institutes and universities are partners in the national sorghum research program these days. Based on end-users' requirements for each of the four primary sorghum agro-ecologies, stakeholders, and sorghum growing farmers' attention to detail, the breeding program has currently identified six product kinds (PC1–PC6). The pipeline development's resource allocation and efforts matched the market segment's significance for the product categories mentioned. The first three product categories catered to the dry lowland environment, making up 72% of the total production area. The remaining three product categories, on the other hand, are responsible for 8%, 11%, and 9% of the production area, respectively, for humid lowland, highland, and intermediate altitude agro-ecologies.

2.4. Sorghum Breeding Method

By improving the diet, feed, and malting quality of sorghum for industries, the breeding method of sorghum is primarily used to improve the livelihoods of smallholder sorghum farmers through the development and promotion of enhanced sorghum technologies and information/knowledge for increased production and productivity. The generation of sorghum varieties is mostly dependent on germplasm enrichment, exploitation, and preservation of existing variety, or the creation of new variation, due to the importance of genetic variation in inbreeding. Sorghum breeding pipelines consist of several stages, the first of which is the collection of working collections (parents) for desired features, followed by planned hybridization and generational segregation management. Multi-location trials will be conducted to assess the trait of interest once it has been fixed, and a farmer-preferred variety will subsequently be released for production [20].

2.4.1. Principal Accomplishments

In spite of the crop's vital relevance, Ethiopia started a scientific research project on sorghum enhancement in the late 1950s with the goal of increasing productivity and yield through proper cultural practices and genetic advancement. Knife & Tesfaye [21] state that since the outset, more than fifty improved cultivars with agronomic suggestions have been made available for production by a number of national and regional research agencies and colleges across the nation. Difficulties in improving and producing sorghum: A wide range of biotic and abiotic variables have reduced sorghum's potential yield. Two of the most common abiotic stresses are drought and low soil fertility, or nutrient deficiencies. A few significant biotic restrictions are the parasitic weed Striga (Striga species), shoot flies, foliar and panicle diseases, and stem borers [11].

2.4.2. Drought

Across the world, one of the most significant problems affecting crop productivity is drought. Climate change will make droughts more frequent, particularly in parts of Africa that are prone to them. It is projected that by 2050, water-related issues will impact 67% of the global population [22]. Towards the start and finish of the growing season, drought is more common in the dry and semi-arid tropical regions. Early in the growing season, drought stress has a significant effect on plant establishment; later in the growing season, drought stress may result in decreased establishment, lower yield, or crop failure [23].

Due to insufficient rainfall and/or its uneven distribution, many of Ethiopia's sorghum-growing regions frequently experience droughts. In locations where sorghum is grown, rain either arrives later or ends earlier than usual, causing crops to develop too quickly and failing. An irregular rain pattern coupled with a year-round subsistence agricultural system has rendered drought-prone regions of the nation susceptible, leading to acute malnourishment and famine [24].

Low yields and subpar crop performance are hallmarks of Ethiopia's traditional lowland agricultural techniques, which are fully dependent on a rain-fed food production system. The following factors contribute to low yields: Striga hermonthica, low soil fertility, moisture stress, and limited access to better seed and efficient production techniques.

The main factor influencing crop productivity in the area is the erratic patterns of rainfall. There is not enough rain, it is not evenly distributed, and it doesn't always start when it should [22].

Especially in water-stressed areas like eastern and southern Africa, drought is a serious constraint on the production of sorghum crops worldwide and is thought to be the primary cause of yield decline in agricultural plants [25]. The biggest effect on productivity can be caused by drought, which can occur at any stage of growth, including seedling, pre-flowering, and post-flowering [26]. Plant establishment will be greatly impacted by drought stress when the plants are still in the seedling stage [27]. Reduced yields or possibly crop loss may result if it occurs during the pre-flowering, blooming, or grain filling stages [28]. The response of genotypes to pre- and post-flowering stressors, such as drought tolerance, is varied and regulated by numerous genetic mechanisms [29].

To enhance crop genotypes for drought-prone regions, scientists are currently examining a variety of growth traits as well as the physiological, biochemical, and agronomic performances of various stay-green sorghum accessions. Ethiopian sorghum landraces possess innate genetic diversity resistant to drought, which has not been utilized to generate sorghum cultivars resilient to these extreme circumstances [30]. Ethiopia's breeding strategy has largely focused on screening landraces and varieties in drought-prone areas because the country has such a huge genetic pool of drought-tolerant landraces. For instance, before drought-tolerant landraces or cultivars were published, arid lowland areas like Werer, Kobo, and Miesso were used to confirm them [14].

2.4.3. Weeds

Weeds are a difficulty in agricultural output. They could result in lower crop production. They can harbor pests and diseases that are detrimental to agriculture, and they can compete with crops for resources like as light, space, nutrients, and moisture [31]. The increased incidence of herbicide-resistant weeds, rotational crop restrictions that follow the use of some herbicides allowed for use in grain sorghum, and growers' limited access to herbicides make managing weeds in grain sorghum difficult [32].

High yields and effective harvesting in sorghum depend on weed control; yet, obtaining adequate weed control in sorghum is usually difficult. After sowing, small-seeded sorghum grows slowly over the first few weeks. Furthermore, several herbicides that are effective on maize are ineffective on sorghum. Weed management is hampered by the sluggish growth of sorghum seedlings as well as the low rates and limited amount of herbicides that must be applied [33].

2.4.4. Insects

Sorghum productivity is affected by pest and insect damage. Insect pests target seeds, seedlings, whorls, blooming structures, and mature grain at various phases of growth. More than 100 of the more than 150 insect species that have been identified as sorghum pests worldwide are found in Africa. In the past decade, entomologists have focused their attention on 29 important insect groups [34]. Serious insect pests that can cause up to 85% of damage in some circumstances include head bugs, midges, shoot flies, and stem borers in Africa [35]. It is estimated that sorghum production losses in West Africa will range from 11 to 49 percent, in East Africa from 15 to 88 percent, and in Southern Africa from 50 to 60 percent due to stem borer infections alone.

Insect damage causes an estimated $1.1 billion in losses annually in Asia and Africa [36]. The grasshopper, green bug, sorghum aphid, shot fly, sorghum midge, sorghum borer, and other related insects are among the most frequent insect pests of sorghum. General integrated management for sorghum insect pests includes resistant cultivars, biological control (using the natural enemies of the pests), cultural approaches (planting date, crop rotation, fertilizer), and appropriate chemical control.

2.4.5. Disease

The primary productivity restrictions were found to be sorghum anthracnose, ergot, smut, and grain mold [37]. Anthracnose is one of the causes of foliar disease resistance identified by the national sorghum enhancement initiative. Sorghum landraces from the country's west and south exhibited resistance to anthracnose and other leaf diseases. As part of the national sorghum improvement program, these areas are used for sorghum screening in natural settings (hot spot sites), particularly for breeding disease resistance [38, 39].

Essentially, the national sorghum development program verifies varieties prior to distribution by using the Western and South-Western parts of the country as disease testing hotspots. The Ethiopian national sorghum research program and various regional research centers have been breeding sorghum in these agro-ecologies, with a focus on breeding for resistance to leaf and grain mold. For instance, Bako Agricultural Research Center (BARC), Asosa Agricultural Research Center (AARC), Pawe Agricultural Research Center (PARC), and Jimma Agricultural Research Center (JARC) have all conducted extensive sorghum breeding to combat grain and leaf mold infections. The only cultivars from BARC, AARC, and JARC that have been released and put into production are the foliar and grain disease-resistant cultivars (Chemeda, Gemedi, Lalo, Dano, Adukara, Asosa-1, and Aba melko) [40, 41].

2.4.6. Striga

The biggest challenges in Ethiopia's north and northeast have been identified as striga weed and drought [42]. Due to Striga infestation, 40 percent of Africa's fertile land has lost 30 to 50 percent of its agricultural productivity [43]. Striga infections lead to large production losses, generally causing a considerable output decline that often surpasses 65% in places with high infestation levels. [44] Note that severe levels of

Striga infestation can result in up to 100% reductions in grain yield on vulnerable sorghum varieties.

Ejeta States that while 65–100% losses are typical in heavily infested parts of Ethiopia and Sudan, complete loss may happen if drought exacerbates the Striga infection [29]. Losses of 65–100% are common in strongly infested areas of Ethiopia and Sudan; however, if the Striga infection intensifies due to drought, total loss may occur [29].

In order to harm host plants, striga causes parasitism, reduced photosynthesis, and increased photosynthetic partitioning to the roots. Due to allelopathy, competition for nutrients, and inhibition of the full expression of sorghum plants' genetic potential, the weed reduces agricultural productivity. It clings to the roots of the host plant and drains the crop plant of nutrients, water, amino acids, and carbon assimilations [45]. The crop is particularly vulnerable to drought since striga also decreases the efficiency of water utilization [46] and has a substantial impact on the host plant's water economy due to its high transpiration rates. Often associated with striga infestation is low soil fertility, which leads to poor harvests and famine [29].

3. Summary and Conclusion

Ethiopia's national sorghum development seems to be going quite well. Research is taking notice of it. It is an essential crop for food, fuel, feed, construction, and other purposes, especially in areas of the country that are sensitive to moisture stress. Sorghum production and productivity are hindered by a number of biotic (insects, birds, disease) and abiotic (nutrient deficit, drought, etc.) issues. As of right now, around fifty-two sorghum cultivars with distinct sorghum traits and further agronomic advice have been made available for various ecologies. Ethiopia's population is expected to grow at an alarming rate in the future. To feed this growing population, a quick and less costly method of variety enhancement will save time and money.

The National Agricultural Research System should concentrate on molecular breeding methods, which allow varieties to be enhanced with desirable features in a shorter amount of time, in order to feed the country's growing population. Better released materials should be introduced, evaluated globally, and then made available to farmers in order to address the food issue brought on by this growing population.

Abbreviations

MARC	Melkassa Agricultural Research Center
JATS	Jimma Agricultural Technical School
BARC	Bako Agricultural Research Center
AARC	Asosa Agricultural Research Center
PARC	Pawe Agricultural Research Center
JARC	Jimma Agricultural Research Center
IDRC	International Development Research Center

Author Contributions

Dinku Atnafu Anega is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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