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Reseacrh Article

MAJOR ACHIEVEMENTS AND CHALLENGES OF SORGHUM (*SORGHUM BICOLOR* [L.] MOENCH) BREEDING AND PRODUCTION IN SOUTHWESTERN PART OF ETHIOPIA-REVIEW ARTICLE

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ABSTRACT

Sorghum (*Sorghum bicolor* [L.] Moench, Poaceaea family) (2n = 20) is the 5th most important cereal crop and is the dietary staple of more than 500 million people in 30 countries. In Ethiopia, sorghum is the third largest cereal crop in area coverage and total production preceded by tef and maize. In Ethiopia, South and Southwestern part of Ethiopia were one of major coffee growing regions and have climatic and edaphic factors that combine well to meet the requirements of both coffee and cereals. In collaboration with sorghum improvement program, Jimma research center was conducting different sorghum experiments at Omonada, Kersa, Yem special wereda, and Shebe sombo to identify adaptable technologies for agro-ecologies of southwestern part of Ethiopia. Jimma research center conducted adaptable and high yielding technologies for mid altitude and lowland areas of southwestern part of Ethiopia. Major challenging factors for sorghum improvements were lack of varieties with specific trait and adaptatibility, diseases and insects' threat, drought and limited availability of quality seed and instability of researchers, dieases, weeds, and birds were major breeding and production threat of Southwestern Ethiopia.

Keywords: Challenges, Production, Sorghum, Southwestern, Varieties.

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INTRODUCTION

Sorghum (*Sorghum bicolor* [L.] Moench, *Poaceaea* family) (2n=20) is the 5th most important cereal crop and is the dietary staple of more than 500 million people in 30 countries (FAO, 2011). It is grown on 40 million hectare in 105 countries of Africa, Asia, Oceania, and the Americas. Africa and India account for the largest share (>70%) of global sorghum area while USA, India, Mexico, Nigeria, Sudan, and Ethiopia are the major producers (FAO, 2011). Sorghum plays an important role as dietary staple for millions of people, especially in arid and semi-arid countries of Africa and Asia.

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 (Smith and Frederiksen, 2000). In the country, wild types of sorghum are prevalent. The four sorghum races are domesticated in Ethiopia except kafir (Doggett, 1991). Sorghum genetic resources from Ethiopia have been widely used globally in various breeding programs (Doggett, 1991).

Cereals are the most important food crops in the overall grain crop, according to the CSA (2020) data, both in terms of planted area and production size. Because they are the primary staple crops, they are produced in greater quantities than other crops. Cereals are grown in varying quantities in all places. In general, in Ethiopia around 81.19% (10,538,341.91) hectares) was under cereals. Sorghum is the third largest cereal crop in area coverage and total production preceded by tef and maize. From those sorghum took up 12.94% (1,679,277.06 hectares) and of the grain crop area. As to production, the cereals contributed 88.36% (about 302,054,260.58 quintals) of the grain production. Sorghum made up 13.22% (45,173,502.18 quintals) of the grain production. It is primarily produced in Oromia, Amhara, and Tigray region with their area coverage of 676,075.00 ha, 597,440.83 ha, and 232,636.49 ha, respectively.

The production of sorghum in Jimma zone and Yem special district of southwestern Ethiopia was 1,899,716.78 and 17,562.18ha with productivity of 30.11qt and 24.8qt, respectively (CSA, 2020). The productivity of sorghum in southwestern part of Ethiopia high comparing to national average 26qt and due to favorable conditions. Jimma research center conducting different sorghum experiments in collaboration with sorghum improvement program to identify high yielding, adaptable and stress resistant sorghum technologies. Sorghum production and productivity are affected by many factors such as lack of improved varieties, diseases, weeds, and insect pest's worldwide. Therefore, the objective of the review is to summarize major achievements and challenges of sorghum breeding and production in southwestern part of Ethiopia.

METHODS

Site description

Jimma research center conduct different sorghum trials at South and Southwestern part of Ethiopia such as Kersa, Omonada, Yem special district for intermediate trials and Gojeb for lowland sorghum breeding. In all sites, the experiment was conducted during main cropping seasons.

Kersa site located on latitude 7° 42' N and longitude 36° 59' E and laid at an altitude of 1750 m.a.s.l. The average minimum and maximum temperature are 6°C and 25.5°C, respectively, and reliably receives good rains 1712 mm/annum during cropping season.

The Omonada site was located on 7° 46' N and 36° 00' E and laid at an altitude of up to 1753 m.a.s.l. with soil type of the area is Upland: Chromic Nitosol and Combisol. The average maximum and minimum temperature are 9°C and 28°C, respectively, and reliably receive good rains 1561 mm/annum cropping season. The farming system of the study site is coffee and cereal crops dominated with coffee, maize, tef, and sorghum also has warm and cold climate, also convenient topography is very suitable for all agricultural practices. It was situated in the tepid to cool humid-mid highlands of southwestern Ethiopia. The soil type of the experimental area was Eutric-nitisols (reddish brown).

Shebe Sombo district is located at a distance of 375 km, South West of Addis Ababa. The major town is Shebe. It is situated at an altitude ranging from 1350–2800 m above sea level and with an estimated

area of 121.5 km. The area receives an average annual rainfall ranging from about 900 to 1300 mm. The minimum and maximum daily temperatures of the area are 20°C and 28°C, respectively. The livestock potentials of the district are cattle, sheep and poultry and equines, and goats, respectively. The major crops grown in the district are sorghum, maize, wheat, barley, haricot beans, pea, and enset in addition to these, backyards vegetables, and root crops (Potatoes, Carrot, and Cabbages, etc.) are also produced in the district.

Yem special district, elevation ranges from 1967 to 2859 m.a.s.l. Yem special district is one of the districts in the Southern Nations, Nationalities, and Peoples' Regions (SNNPR) of Ethiopia. Yem special district is situated in the northwestern apex of SNNPR and is located between 7° 57′ N to 8° 02′ N latitude and 37° 40′ E to 37° 61′ E longitude. The topography of the district is characterized by rolling mountains, long gorgeous land, steeply sloppy areas, and flat to undulating plateaus. In general, the physiographic features of the district are framed by Laba peaks in central part and by Gibe river in the east part of the district

Major achievements of sorghum breeding

History of sorghum breeding at Southwestern Ethiopia

A scientific sorghum research study in Ethiopia was started in 1953 at Jimma Agricultural Technical School (JATS) now Jimma University College of Agriculture through the collection, exploration, and evaluation of sorghum germplasm (Adam *et al*., 2019). Then it was moved and formal research was started in 1957 at Alemaya College of Agriculture and Mechanical Arts now Haramaya University with the subsequent initiation of Ethiopian Sorghum Improvement Program (ESIP) with the fund from International Development Research Centre (IDRC), Canada. As of then, sorghum breeding activities were done in the different ecological parts of the country by different national and international organizations. The collection, evaluation, characterization, and conservation were one of the primary activities. Closer to 8000 indigenous collections were made (PGRC/E, 1986). Various types of crossing programs were undertaken to solve sorghum production problems.

In Ethiopia, South and Southwestern part of Ethiopia was one of major coffee growing regions and have climatic and edaphic factors that combine well to meet the requirements of both coffee and cereals (Paulos, 1994) thereby strengthening the linkage between the two crops. This linkage has, in turn, enhanced the role of cereals in diversifying the coffee based farming system and the coffee industry as well.

Sorghum breeding is focusing on developing varieties for low and mid altitude areas, depending mainly on introduction and evaluation of germplasm from exotic sources due to low genetic diversity in the local germplasm. For the highland, where there is immense diversity, emphasis has been placed on evaluation of local germplasm. Sorghum research is nationally coordinated from Melkassa Research Center in collaboration with different higher learning institutions and federal and regional centers carrying out research in their respective agro-ecologies. Accordingly, Cereal crops improvement has been collaborating with National Sorghum Research Project in identifying improved sorghum varieties suitable for the southwestern part of Ethiopia.

The major activities focused on evaluation of intermediate elevation high rainfall sorghums, which are obtained from different breeding programs. So far, the collaborative efforts among federal and regional centers have released about 19 varieties, which are on the current recommendations list (Leta and Habte, 2008). Agronomic characters and yield potential of released sorghum varieties with better adaptation to different agro-ecologies of the high potential coffee growing regions are indicated in Table 1. The first four are high land varieties selected from indigenous collections for different merits. Alemaya 70 is the best improved variety ever known in Ethiopia for its injera making quality (Girma *et al*., 2007).

Unlike, the other highland varieties, "chiro" has special character of sugary stalk which can be chewed like sugarcane and is excellent for animal feed. IS9301 and "Baji" were released for the mid altitude coffee growing areas of western Oromia. Despite their attractive performance and yield potential in research plots, these varieties were found to be low yielding in pre extension demonstration conducted on farmer's field. This was mainly because of higher severity of leaf and head diseases under the humid and hot environments of Southwestern Ethiopia (Girma, 1995). Birds were the other biotic constraints that caused significant damages. Due to earliness in maturity the improved varieties could not compete with the long maturity local types, which are disease and bird resistant. As a result, there has been no acceptance of the varieties by the farming community (Leta and Habte, 2008).

Recognizing the problem, sorghum breeders based at Jimma Agricultural Center (JRC) changed the strategy in sorghum breeding in 1995. The new approach has been focusing on evaluation of local sorghum collections besides the improved varieties that are sent from the coordinating center. A variety which has been purified through pure line selection from accession named SAR-2 collected from Tobba/Agaro area of Jimma zone has been found yielding higher than local and standard checks with better resistance to diseases and birds. The variety was officially released in 2001 by the name "AbaMelko" which means the father of Melko, referring to the center where it has been developed.

AbaMelko produced mean grain yield of 9.6 t/ha on research plots and 5t/ha in on farm trials. It has yield advantage of 3 t/ha over Baji in both cases (Leta and Habte, 2008). AbaMelko was recommended specifically for Melko, Kersa, and Omonada areas of Jimma and similar areas below 1800 m. In addition to higher yield potential and better resistance to birds and diseases, Aba Melko has the merits of being early in maturity and shorter compared to the local variety. Hence, its yield level can be further increased by planting at higher density. AbaMelko is highly responsive to management especially early weeding and fertilizer application. Under good management, its yields up to 10 t/ha at Melko (Leta and Habte, 2008; Girma *et al*., 2007). AbaMelko variety was demonstrated and popularized at Omonada, Kersa, Limuseka, Limu Kosa, Sekoru, Yem special woredas of South and Southwestern part of Ethiopia. At the demonstration site (demonstrated with Dagim and Geremew), the variety was superior in different traits, especially in grain yield (Tegegn and Nesiriya, 2020). Due to its high yielding and competitive nature, the variety was included as standard check in different sorghum trials. The variety was popular in south and southwestern part of Ethiopia (Table 2). The cereal crops improvement has recently launched community-based seed production of diseases and bird resistant and high yielding sorghum variety, Aba Melko, in collaboration with Bureau of Ministry of Agriculture and Natural Resources of Omonada and Limu Seka Weredas in Jimma zone. This work has shown itself in accelerating the adoption of Aba Melko in these weredas.

Food crops having high anti-nutritional content may not be good for food consumption, due to its negative impact on nutrient availability and digestibility unless processed very well. Besides, the sensory of the food product may not be accepted due to bitterness characteristics. Tannin is the most abundant anti-nutritional factor in sorghum (Deosthale *et al*., 1971). Multiple phenolic hydroxyl groups of tannins may form stable complexes with protein, metal ions, and other macromolecules like polysaccharides (Choct and Hughes, 1999) and will reduce the digestibility of the proteins and the availability of the nutrients in the gut. Masresha and Belay (2020) reported Aba Melko had Moisture (10.41), ash (1.5100), fat (3.5625), fiber (5.601), protein (8.98), carbohydrate (75.536), and tannin (2418.9) of mg/100 g. In the demonstration sites, the feedback from end users and agricultural sector are that the technology was good and high yielder, but not palatable and digestible. So that most of the time we use technology as feed for cattle and poultry. By identifying the problem, the cereal crops breeding team based at Jimma in collaboration with sorghum breeding program aimed to improve the grain quality especially tannin content of Abamelko sorghum variety.

Table 1: Agronomic characters and yield potential of released sorghum varieties with better adaptation to different agro-ecologies of the high potential coffee growing regions of Ethiopia

Varieties	Year of release	Plant height (cm)	Days to maturity	Grain yield (t)	Specific areas
Alemaya 70	1970	250-384	175-190	3.0-5.5	Highlands of haraghe
ETS2752	1978	234-285	190-205	3.0-5.5	Highlands
Chiro	1996/97	185-257	175-190	4.2-5.8	Highlands
ETS1176	2004	250-410	181-207	2.9-6.3	Arsi Negele, East and West Hararghe highlands
IS9302	1981	100-180	150-180	3.0-6.0	Mid altitude agro-ecologies
Baji	1996/97	139-164	150-180	3.1-5.6	Bako, Jimma, and similar areas
Gambella	1976	120-200	110-130	2.0-5.0	Moist lowlands similar to Gambella
Aba Melko	2001	230-280	160-170	6.0-9.0	Specifically adapted to mid altitude of Jimma area

Source: Girma *et al*., 2007

Table 2: Performance of adaptable and high yielding sorghum varieties (qt/ha) at south and southwestern parts of Ethiopia

Omonada						Yem special district			Overall mean
Sorghum Varieties	2015	2016	2017	2018	Mean	2016	2017	Mean	
Dagim	33.6	33.3	35.9	46.3	37.3	33.5	41.5	37.5	37.4
Geremew	35.4	30.6	31.6	51.8	37.3	24.8	20.8	22.8	30.05
Baji	28.4	20	47.4	18.7	28.6	32.5	45.1	38.8	33.7
AbaMelko	44.5	27.3	45.2	27.1	36.1	36.9	48.3	42.6	39.35
Mean	35.5	27.8	40	36	34.8	31.9	38.9	35.4	35.1

Table 3: Description of lowland sorghum varieties used in the experiment

S. No.	Sorghum varieties	Year of release	Maturity group	Days to flowering	Plant height (cm)	Yield (qt/ha)	Seed color
1.	Gambella	1976	Medium	80-90	150-200	30-50	White
2.	Melkam	2009	Medium	70-80	109-140	30-45	White
3.	Dekeba	2012	Early	-	-	40	White
4.	Meko	1998	Early	61-92	157-177	22-33	White
5.	Abishir	2000	Early	83	110-140	14-24	White
6.	Gobiye	2000	Early	80	110-140	14-27	White
7.	Teshale	2002	Early	65-76	169-200	26-52	White

Lowland sorghum breeding

Sorghum is grown in Ethiopia in 12 of the 18 major agro-ecological zones. It is one of the important indigenous food crops and is only second to *tef* as *injera* (leavened local flat bread) making cereal. In the dry land areas of Ethiopia which covers 66% of the total area, it is the major cereal crop grown. In these areas crop production is mainly rain-fed. Because of the low amount, uneven distribution and erratic nature of the rainfall crop production are seriously affected in these areas. The cereal crops improvement conducted adaptation trial of released lowland sorghum varieties at lowland areas of Jimma zone. Seven early maturing sorghum varieties, namely, Gambella, Dekeba, Melkam, Meko, Abishir, Gobiye and Teshale were obtained from national sorghum breeding program based at Melkassa research center (Table 3). By conducting the experiment the team identified high yielding and stable varieties for lowland areas of jimma zone (Table 4).

Table 4: Mean performance of adaptable and high yielding lowland white Sorghum varieties evaluated at Gojeb

S.No.	Sorghum varieties	PH (cm)	DH	DM	GY (qt/ha)
1.	Meko	180	76	141	35.07
2.	Melkam	175.7	80	138	51.05
3.	Gambella	205	72	143	48.59
4.	Teshale	176	78	144	42.69

CHALLENGES OF SORGHUM BREEDING

Diseases

Southwestern part of Ethiopia was hot spot area for different sorghum diseases. Major production restrictions were identified as sorghum anthracnose, grain mold, smut, and ergot. Under the national sorghum improvement program, southwestern part of Ethiopia are used for sorghum screening in natural conditions (hot spot areas), particularly for disease resistance breeding.

Weeds

Weeds compete with crops for resources such as moisture, nutrients, space, and light, and they can also harbor pests and diseases that harm crops (Tibugari *et al.*, 2020).

Birds

Damage of sorghum by bird infestation is a worldwide problem in grain production and productivity. These birds cause damage in sorghum fields more especially when the sorghum plants are at soft dough stage crushing the juice out of sorghum grains (Tipton *et al*., 1970). The birds can cause damage to crops and a loss to the farmers from sowing and planting till harvesting. The yield loss of birds causes vary from 10 to 80% as they flock in large numbers. Many losses were observed during early flowering and late flowering of the sorghum varieties. Other major challenging factors for sorghum improvements were lack of varieties with specific trait and adaptability, diseases and insects' threat, drought and limited availability of quality seed and instability of researchers (transfer to other centers and long term training).

FUTURE LINE OF WORK

1. Developing sorghum varieties broadly adapted and tolerant to biotic and abiotic stresses
2. Popularization and dissemination of the improved technologies
3. Conducting more research on making quality injera and beverage products

4. Research on crop protection and management
5. Capacity building
6. Creating more linkages at national and international.

SUMMARY

In Ethiopia, sorghum is the third largest cereal crop in area coverage and total production preceded by tef and maize. In the country sorghum is produced by 5 million smallholder farmers. In Ethiopia, South and Southwestern part of Ethiopia was one of major coffee growing regions and have climatic and edaphic factors that combine well to meet the requirements of both coffee and cereals. In collaboration with sorghum improvement program. JRC was conducting different sorghum trials at Omonada, Kersa, Yem special wereda and Shebe sombo to identify adaptable technologies for agro-ecologies of southwestern part of Ethiopia. The cereal crops improvement identified adaptable and high yielding technologies for intermediate and lowland areas of southwestern part of Ethiopia. Sorghum national breeding program released many Sorghum varieties for highland, intermediate and lowland agro-ecologies of Ethiopia. These varieties were showed yield reduction due to high severity of leaf and heads under the humid and hot environments of southwestern Ethiopia. By identifying these problems, JRC breeding team identified new variety referred to as AbaMelko, from local sorghum collection through pure line selection. Abamelko has merits of high yielding potential and better resistance to birds and diseases. The variety was demonstrated and popularized at Omonada, Kersa, Limuseka, Limu Kosa, Sekoru, Yem special districts of South and Southwestern part of Ethiopia. At the demonstration site, the variety was superior in different traits, especially in grain yield. The variety had some drawbacks and the team planned to improve this drawbacks. Major challenging factors for sorghum improvements were lack of varieties with specific trait and adaptatibility, diseases and insects' threat, drought and limited availability of quality seed and instability of researchers, diseases, weeds and birds were major breeding and production threat of southwestern Ethiopia.

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