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Research Article

Improved Sorghum Technologies Are Vital in Ensuring Food Security: The Case of Benishangul Gumuz Region, Ethiopia

Habtamu Alemu*, Fekadu Begna, Desta Bekele

Assosa Agricultural Research Center, Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia

Abstract

Sorghum is the vital food security crop in semi-arid region of the world including Ethiopia. This activity was conducted to demonstrate improved sorghum technologies in Assosa zone by involving 479 male headed and 57 Female headed households. The average age of the participant was 40 to 46 years with mean farming experience 22-30 years. The participant farmers provide 0.125 to 1 hectares of land and a total of 314.5 ha of land were used. The training was given for all farmers, Regional and district experts, and concerned development agents at Kebeles were the trial conducted. The field day was organized at physiological maturity involving 713 participants. Mean grain yield of improved Assosa-1 sorghum variety at demonstrated areas were 26.8 qt.ha^{-1} at Assosa, 29 qtha^{-1} at Bambasi, and 32 qt.ha^{-1} at Homosha. The technological gap in the study area ranges from 6 to 11.2 qt.ha^{-1}, with an average technological yield gap of 8.73 qtha^{-1}. The highest technological yield gap 11.2 q.ha^{-1} was observed in Assosa district and the lowest technological gap 6 q.ha^{-1} was observed in Homosha district. Similarly, the extension yield gaps were ranged from 12.8 to 20 qt.ha^{-1} with an average yield of 15.6 qtha^{-1}. The result further showed that the highest extension gap of 20 qt.ha^{-1} was observed at Homosha district and the lowest extension gap was observed at Assosa districts with 12.8 qt.ha^{-1}.

Keywords

Demonstration, Stable Food, Assosa-1, Extension Gap, Technology Gap, Yield

1. Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is widely cultivated cereal crop in Ethiopia. It is extensively grown across various regions, including the Americas, Asia, and Africa. It ranks as the second most significant crop, following maize, in regions where sorghum or millets are the primary cereals in Africa. In many developed nations, sorghum has emerged as a crucial industrial crop, offering a valuable alternative in arid environments where the cultivation of other crops is challenging. Sorghum is a highly suitable option for agriculture in Africa due to its adaptability to low input farming practices, particularly in regions facing water scarcity. Across the continent, sorghum ranks as the second most significant cereal crop following maize, covering 22% of the total cereal cultivation area [2] while in Ethiopia; it is the third most important cereal crop after tef and maize in terms of area coverage and total production [14].

Sorghum plays a crucial role in ensuring food security in drier regions of the world [1]. About 74% of Sorghum grain

*Corresponding author: habtamualemu2005@gmail.com (Habtamu Alemu)

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from the total of production is estimated to be consumed at the house level while the remaining part used for sale and seed purposes at local level [7]. Moreover, it serves as a vital crop for food and nutritional security, supporting over 100 million individuals in the Eastern Horn of Africa [3]. Sorghum in Ethiopia is grown in different agro-ecologies. As it is grown in diverse environment, the productivity of sorghum is constrained by several biotic and abiotic factors. Sorghum production in arid regions is mainly challenged drought, striga, poor crop yield, and insect infestations [4]. Throughout Africa, Sorghum is utilized and consumed in diverse range of appealing and nutritious traditional foods, including bread, porridges, fermented and non-fermented products. It serves as the cornerstone of thriving food and beverage sectors, with the leaves and stalks used as animal feed, fuel wood, and even as a source of income through selling it as fuel in urban areas [8].

High temperatures and high rainfall are characteristic features of the humid lowland and intermediate sorghum growing regions, which encourage the growth of several bacterial and fungal diseases. Sorghum anthracnose caused by fungal pathogens *colletricum sublineolum* Henn. (Previously known as *C.graminicola* [Ces] G. W. Wilson) is among the most important disease due to which 50-70% of grain yield loss has been reported in susceptible sorghum varieties in the Ethiopian humid agro ecologies. Sorghum anthracnose is an important foliar disease and various studies have stated that annual rainfall is an important factor affecting foliar disease severity ([9-11]). Grain yield losses due to disease problem are commonly related with a decrease in seed size [12] and it accounts from 30% to 67% of yield loss [12, 13]. Sorghum production in the study area was mainly constrained by low soil fertility which leads to high fertilizer costs, lack of tractor for plowing, shortage of larger farm plot of land allocation followed by lack of thresher were the major constraints to sorghum production [15].

For the last several years there was research works done to release adapted sorghum varieties to the intermediate and humid lowland area particularly for western Ethiopia that characterized by long duration and high intensity rainfall with higher humidity. Most of released sorghum varieties in Ethiopia were fail to adapt under humid lowland, intermediate and highland agro-ecology of the country because most of the released varieties targeted for dry lowland areas where early maturity is apriority. Since, it became difficult to get a variety well adapted to this agro-ecologies due to early maturity of released varieties that fail to adapt in environment having longer duration of rainfall that have created favorable condition for bird attack and fungal disease development. The basic problem of such region was lack of improved sorghum varieties which are potential in terms of production, quality and ease of mechanization. However, with strong effort and endeavor genetically potential sorghum varieties that can suit this agro ecology were released for production in 2015 G.C by Assosa Agricultural research center of Ethiopian Agricultural Research Institute. These varieties can give higher yield and adapted to the environment. So, demonstrating and popularizing these varieties is of paramount importance to the area.

Objectives

1) To showcase and familiarize the recently released sorghum variety to sorghum producing farmers,
2) To create awareness of improved sorghum technology (the packages)

2. Materials and Methods

2.1. Description of the Study Area

This experiment was undertaken at Assosa Zone of Benishangul Gumuze regional state. Assosa town is the capital city of the zone as well as the region, which locates at 670 km far from capital city of Ethiopia, Addis Ababa. Assosa located on altitude and longitude of $10^0$04'N34^{0}31'E/10.067^{0}N34.517^{0}E. The altitude of the study area is 1570 meters above sea level. Sorghum is the major food crop produced in almost all parts of the zone along with crops like Maize, Finger millet, Teff, Soya bean, Sesame, Groundnut, Rice and horticultural crops. The mean annual rainfall of the area was 1300 mm during the main rainy season of May to October. The study area was also characterized with soil type of predominantly Nitosol with the soil texture of clay loam.

2.2. Information About Assosa-1 Sorghum Variety

After a prolonged period of research endeavors, the Assosa Agricultural Research Center has successfully released an improved sorghum variety in 2015 G.C. Subsequently, this improved variety was named "Assosa-1" in recognition of the research center (Assosa) and as the premier improved sorghum variety released by the center (1). The variety was introduced through the collection, characterization, and purification of landraces from western Ethiopia. The crop is suitable for wet lowland and intermediate agro-ecologies found in various regions of the country such as Benishangul Gumuz, Western Oromia, Southwestern Oromia, Gambella, and the newly formed Southwestern Ethiopia regional states. Additionally, it can also thrive in other areas that share similar agro-ecologies with the aforementioned regions. This particular variety is characterized by its white-colored seeds and a manageable plant height of 210 cm. It takes approximately 139 days for the Assosa-1 variety to flower and 180 days to reach physiological maturity. On a research field this variety can produce a yield as high as 38 quintals per hectare. However, when implemented by farmers with their own practices, it can yield up to 34.5 quintals per hectare. To achieve these results, it is recommended to use a fertilizer rate of 100 kg/ha of NPS and 50 kg/ha of Urea. Additionally, this variety thrives in well-drained clay loam soil.

2.3. Site and Farmer's Selection

In the present era, the cluster-based or group approach proves to be more effective than dealing with individuals, particularly in our specific circumstances where the majority of farmers are smallholders and distinct socio-economic disparities exist. This approach promotes the advancement, widespread acceptance, distribution, and implementation of enhanced agricultural technologies tailored for our farmers. Moreover, it facilitates the supervision of a larger expanse of lands and users. The activity was conducted for the last three cropping season starting from 2020 G.C to 2022 G.C. Based on this, Assosa, Homosha and Bambasi districts from Assosa zone were purposively selected with the collaboration of district experts and kebele development agents in cluster based approaches for the implementation of the activity based on the potential for sorghum production.

Representative kebele's were selected from each districts based on their willingness, interest and accessibility for field inspection and evaluation taking in to consideration their ability to implement the activity. Based on these criteria 536 (Male 479, Female 57) farmers were involved implement the demonstration on 314.5 hectares of land (Table 1). In selected kebeles of each districts, each farmer contribute 0.25 to 1 hectare of land for demonstration of the improved variety. The training were given for all stakeholders involved on due process on all agronomic practice like ploughing, sowing, fertilizer application, weeding, harvesting, threshing and storage mechanisms by a team from agricultural extension and communication and sorghum breeder.

Table 1. *Selected districts, Kebeles, Area coverage and input distributed.*

Year	Woreda /districts	Kebele	Hectare	Minimum	Maximum	Seed distributed (qt.)
		Amba-13	18	0.25	0.5	1.8
		Nebar-komoshiga	12	0.5	1	1.2
	Assosa	Amba-12	5	0.25	0.5	0.5
		Enzi-Shederiya	5	0.25	0.5	0.5
2020		Agusha	5	0.5	0.75	0.5
	Bambasi	Mender-48	50	0.25	0.5	5
		Nebar-Keshmando	7	0.25	0.5	0.7
	Homosha	Shula	24	0.5	1	2.4
	Year Total		126			12.6
	Bambasi	Mender-44	45	0.25	1	4.5
		Mender-45	24.75	0.25	1	2.5
		Mender-40	20	0.5	1	2
		Eshen Almetama	27	1	3	3
2021	Assosa	komoshga 28	23.75	1.25	2.5	2.5
		Shedriya	2	0.5	1	0.2
	Beghi	Beghi	20	1	2	2
	Total		162.5			16.7
2022	Bambasi	Selama Dabus	30	0.25	2	3.0

Assosa Agricultural Research center provided improved Assosa-1 Sorghum variety seed for the involved farmers in the demonstration activity. The selected farmers were provided with 40 quintals of improved Assosa-1 sorghum variety seed (Table 1). Farmer prepared inorganic (NPS and Urea) fertilizers by themselves for their allocated land based on recommended fertilizer rate for sorghum production in the area. To keep the optimum plant population per hectare, the row to row spacing of 75 cm and between plants of 15 cm respectively were used.

For this popularization activity the technology gap and extension gaps were calculated for each district at which the demonstration was conducted using the formula stated by [5].

Technology gap was calculated by;

$$\text{Technology gap } (qt \cdot ha^{-1}) = \text{potential yield } (qt \cdot ha^{-1}) - \text{Demonstration yield } (qt \cdot ha^{-1})$$

Extension gap was calculated by;

$$\text{Extension gap } (q \cdot ha^{-1}) = \text{Demonstration yield } (qt \cdot ha^{-1}) - \text{Farmers yield } (qt \cdot ha^{-1})$$

$$\text{Technology index } (\%) = [\text{Technology gap } (qt \cdot ha^{-1}) / \text{potential yield } (qt \cdot ha^{-1})] \times 100$$

2.4. Data Collection and Analysis

Qualitative and quantitative data were gathered by conducting field observations and engaging in focus group discussions with experts and farmers. The data collected encompassed various aspects such as input distribution, total number of farmers, participation of experts in training and field day events, gender distribution of participants in clusters, area coverage in hectares, yield data, income, and feedback from farmers. Subsequently, the collected data subjected to analysis using descriptive statistics.

3. Result and Discussion

3.1. Characteristics of Participants

Within the group of farmers involved, there were 479 Male headed households and 57 led by women. The average age of these farmers participating in the sorghum technology demonstration and promotion across all districts ranged from 40 to 46 years, with an average farming experience of 22 to 30 years. This indicates that they were in their prime years for agricultural production, making them receptive to new technologies. Similar result was also reported by other researchers [6]. Each participating farmer owned between 0.125 and 1 hectare of land for the project.

3.2. Training

Assosa Agricultural Research Center (AsARC) multidisciplinary team gave participatory training from Agricultural Extension Communication and sorghum breeder researcher for selected participants each year for the selected participants of the selected kebeles. The training were given for different stakeholders and farmers on agronomic practice of improved sorghum production techniques and managements, site clearance, ploughing, planting, clearing the weed, disease and insect management, harvesting, threshing and storing. The participants of the training were regional, zonal, district experts, development agents (DAs) and farmers. Totally 479 Male and 57 Female farmers, 53 Regional, Woreda experts, and Development agents (DA's) attend the practical training (Table 2).

The farmers who took part in the program received hands-on training on the enhanced techniques for sorghum production. This includes giving insight on selecting suitable sites, preparing the land, and properly planting the sorghum seeds while maintaining the appropriate spacing between plants and rows. The training also covered the application of fertilizers and the process of drilling the seeds. Additionally, the farmers were instructed on thinning the seedlings to ensure a 15 cm spacing between plants, as well as the timing and methods for conducting the first and second weeding. They were also educated on when and how to apply the second urea fertilizer, and were provided with comprehensive guidance on managing the field as a whole.

Table 2. *Number of Participants, districts and kebeles involved in promotion of improved sorghum technologies from 2020 up to 2022 G.C.*

Year	Woreda /districts	Kebele	Participants	
			Male	Female
2020	Assosa	Amba-13	73	-
		Nebar-komoshiga	4	-
		Amba-12	11	-
		Enzi-Shedriya	5	-
		Agusha	4	-
	Bambasi	Mender-48	35	2
		Nebar-Keshmando	7	-
	Homosha	Shula	19	5
	Total		158	7
2021	Bambasi	M/44	62	13

Year	Woreda /districts	Kebele	Participants	
			Male	Female
		M/45	81	6
		M/40	30	4
		Eshen Almetama	26	2
	Assosa	komoshga 28	59	11
		Shedriya	3	1
	Beghi		21	3
	Total		261	37
2022	Bambasi	Selama Dabus	60	13

3.3. Farmer's Field Visit

Field day serves as a means to inspire individuals to embrace novel approaches by showcasing the accomplishments already attained under real-world circumstances. Essentially, its purpose is to demonstrate the effectiveness and profitability of innovative practices and persuade others of their practicality. Consequently, field day events are arranged when the crop reaches its physiological maturity stage. A totally of 713 stakeholders (farmers 630, DA, experts and other stakeholders 83,) were participated on the field day events. At the field day event, attendees discussed their top experiences related to sorghum production. They talked about implementing demonstrations in a cluster-based approach, organizing with other farmers for large-scale production, using fertilizers, sowing sorghum in rows, and managing weeds effectively. These practices were shared with invited farmers and stakeholders. During the events, invited experts and farmers expressed an interest to use the technologies by next cropping year to their kebele's and share the experiences to extend using this sorghum technologies (improved sorghum variety "called Assosa-1" and "sorghum thresher") to their districts. For the first two cropping seasons, 2020 G.C and 2021 G.C, the improved sorghum variety called "Assosa-1" was demonstrated at the unaddressed kebeles of Assosa zone. During the last cropping season, 2022 G.C, the improved sorghum variety was demonstrated along with the postharvest technology specifically with sorghum thresher at Bambasi woreda. The demonstration and popularization events were covered by regional media such as Begu TV and Radio, which disseminated knowledge and experience on sorghum technology production for other undressed area (Figure 1).

Figure 1. *Photo taken at the farmers' field day. December, 2020.*

3.4. Yield Potential and Yield Gap Analysis

Yield gap of improved sorghum variety was computed based on the implementation of appropriate improved sorghum technologies and the normal farmer's practices used to produce sorghum in the area. The average grain yield of the improved Assosa-1 sorghum variety was 26.8 qt.ha^{-1} in Assosa, 29 qt.ha^{-1} in Bambasi and 32 qt.ha^{-1} in Homosha (Table 3). The difference in grain yield was mainly due to environmental difference. The utilization of recommended agronomic practices, along with proper training and field management, resulted in a higher potential yield compared to traditional farming methods. The findings clearly show that the Assosa-1 variety outperformed the farmers' practices. This research highlights the significant difference in grain yield between traditional farming methods and large-scale production. Therefore, promoting the adoption of enhanced sorghum varieties through large-scale demonstrations is crucial in areas suitable for sorghum cultivation. This indicates that the technologies showcased in specific districts hold promise for improving production and productivity, ultimately contributing to food security for local farmers.

The comparison of grain yield from the large-scale demonstration in the form of cluster in each district with the potential yields of the variety was conducted to determine the technology and extension yield gap. The technology gap varied from 6 to 11.2 qt.ha^{-1} with an average technology yield gap of 8.73 qt.ha-1. Similar result was reported by [6]. The district with the highest technological yield gap of 11.2 qt.ha^{-1} was Assosa, while the district with the lowest technological gap of 6 qt.ha^{-1} was Homosha (Table 3). Discrepancies in yield may be attributed to differences in the environment, soil fertility, and management practices.

Table 3. *Sorghum grain yield gap analysis of Assosa-1 variety during 2019/2020 cropping season.*

Woreda	Area (ha)	Potential yield (q.ha-1)	Demonstration yield (q.ha-1)	Farmers practice yield (q.ha-1)	Technology gap yield (q.ha-1)	Extension gap (q.ha-1)
Assosa	45	38	26.8	14	11.2	12.8
Bambasi	57	38	29	15	9	14
Homosha	24	38	32	12	6	20
Mean	42	38	29.26	13.66	8.73	15.6

In a similar way, the discrepancy in yield between different areas ranged from 12.8 to 20 qt.ha^{-1}, with an average yield of 15.6 qt.ha^{-1}. The findings also revealed that the Homosha district had the highest extension gap of 20 qt.ha^{-1}, while the Assosa district had the lowest extension gap of 12.8 qt.ha^{-1}. This variation in extension gaps could be due to differences in soil fertility, extension services, weather conditions, and management issues. Consequently, the significant extension gap in the Homosha district highlights the urgent need to motivate farmers to adopt improved technologies instead of relying solely on traditional practices. Furthermore, the implementation of advanced production techniques and high-yielding crop varieties will ultimately contribute to narrowing the extension gap.

Figure 2. *The stored sorghum heads after harvest until threshing by farmers, 2020 at Bambasi (left) and Assosa (right).*

Once the sorghum crop reaches its physiological maturity, farmers proceed with harvesting and storing the crop in the field. During this process, the harvested heads are exposed to sunlight for a period of few days or weeks (Figure 2). This practice allows the crop to dry adequately, preventing any undesirable moisture that could potentially compromise the quality of the harvested sorghum seed. To ensure proper storage conditions, farmers utilized locally available materials that facilitate sufficient aeration and prevent contamination.

Farmer’s suggestion highlights the issues surrounding the technology showcased, particularly emphasizing the benefits of the "Assosa-1" sorghum variety with all improved recommended practices. Feedback was gathered from households led by both men and women who participated in the demonstration. In the demonstration site, the community had been relying on traditional methods to cultivate local sorghum varieties due to the unfamiliarity with improved technology and the influence of agro-ecology. Each farmer cultivated sorghum individually on separate plots of land, leading to low yields and productivity over an extended period. All participant farmers were very interested on this improved Assosa-1 variety and organized in cluster based approach.

In addition to using local sorghum varieties, the farmers stated that they were used to use traditional means of “hitting by stick” or using livestock for threshing the sorghum grain. These results in quality deterioration and wastage of the crop produced. So, the participants stated that by using this demonstrated sorghum thresher, we will produce a quality grain without wastage. Using improved sorghum variety has given a good impact over the farming community as they were encouraged by recommended technology applied in the demonstration fields. Generally farmers describes that Assosa-1 sorghum variety stem strength high resistant to lodging, large seed size and white seed color is good for “injera-making”, disease resistant, stalk is used as fuel, has ecologically and economic importance and used for food and income source and attractive for market price food security. The other point’s farmers raised during the events is the problem of sustainability of using this improved sorghum variety for the future and unavailability of improved seed in the area due to lack of farm machinery that ease to the burden and difficulty to harvest and threshing (labor intensive). Beside, clustering and group approach were enhanced the working culture of farmers. Good awareness and confidence were created among different stakeholders about Assosa-1 variety and sorghum thresher.

4. Conclusions and Recommendations

Improved "Assosa-1" sorghum variety was demonstrated in a cluster and individual based approaches in selected districts of Assosa Zone of Benishangul gumuz region during 2020-2022 G.C. This demonstration created awareness among farmers about the improved Assosa-1 sorghum variety. From the demonstration, participated farmers appreciated the potential of Assosa-1 variety and excited to use it as their primary variety for sorghum production. The researcher strongly recommends that Assosa-1 sorghum variety with its full technology packages including sorghum thresher should further scale out to other similar agro ecologies. From the demonstration interventions, it can be concluded that, there are wider possibilities to greatly support the government efforts toward enhancing food security and livelihood of poor households and contribute to it. Therefore, based on this result the researchers recommend farmers and other development practitioner to use "Assosa-1" improved sorghum variety and sorghum thresher to thresh the produce in a wider proportion.

Abbreviations

Qt.ha-1	Quintal Per Hectare
G.C	Gregorian Calender

Author Contributions

Habtamu Alemu: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation , Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

Fekadu Begna: Conceptualization, Data curation, Investigation , Methodology, Project management, Software, Supervision, Visualization, Writing – original draft

Desta Bekele: Data curation, Supervision, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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