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Research Article

Participatory Evaluation and Demonstration of Improved Sorghum [*Sorghum bicolor (L) Moench*] *Varieties* in Argobba District, Afar Region

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Abstract

A study was carried out to improve agro-pastoral awareness and enhance the adoption of full-package sorghum production technologies. Participatory on-farm demonstration and evaluation of sorghum varieties were conducted with their full packages at Zone 3 of Argobba district, Afar region, Ethiopia. A gender-inclusive pastoral and agro-pastoral research extension group member (PAPREGs) was formed in the study kebele before the start of demonstration work. Capacity-building training on sorghum agronomic practices was delivered to PAPREG members and extension agents. A single plot design was used for the area's 10 m × 10 m size for each variety on each selected agro-pastoral land. This experiment contains five improved sorghum varieties: Melkam, Argiti, Tilahun, Dekeba, and Meko, and one local variety as a check. A PAPREG group with 30 members was formed to facilitate active participation and enhance awareness of improved sorghum production. Yield data and agro-pastoral perception were collected. Simple descriptive statistics were used to examine the quantitative data, such as the amount of grain yield produced, whereas pair-wise and direct matrix ranking were used for qualitative data, such as agro-pastoralists' perceptions. Based on the analysis of agro-pastoral preference and other physiological data, improved sorghum technologies, Kekeba and Melkam, can be promoted in the respective districts of the study area. These varieties were preferred by agro-pastoral because of their earliness, good palatability, drought tolerance, and disease-tolerant traits. Therefore, it could recommend further promotion and large-scale production of sorghum using the Kekeba and Melkam varieties in the study area and similar agroecological zones.

Keywords

Participatory, Trait Preferences, Perception

1. Introduction

Sorghum [Sorghum bicolor (L.)] Moench [2n = 20] is the world's fifth most important cereal crop, after maize, rice, wheat, and barley [1]. It is a stable food crop for the poor and the most food-insecure people, living mainly in tropical and subtropical regions [2]. Sorghum is a highly versatile crop in terms of adaptation to varied agroecologies, with good resilience to both drought and waterlogging [3]. The crop requires relatively less water than other important cereals, such as maize and wheat. In Ethiopia, Sorghum is the third most important crop produced next to maize and teff [4]. In many

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regions of the country, the rain falls late or stops early, making the crop-growing period very short and leading to crop failures. The irregular rain pattern, coupled with an age-old subsistence farming system, has made areas of the country vulnerable to drought, leading to malnutrition and hunger. Little sorghum varieties were adapted previously by the Pastoral and Dry-land Agriculture Research Center (Melkassa, Debreberhan, and Sirinka) to address the technology gap that fills both the market and consumption demand [5]. Nevertheless, those technologies were not sufficiently introduced to all potential production sites. Recently adapted and high-yielding sorghum varieties (Adukara, Melkam, Girana1, Chare, Serdo ESH1, etc.) were also found to have potential for small-scale agro-pastoral in dryland areas. The varieties were good yielders (up to 50-55 Qt/ha at the research site and 35-43 Qt/ha on the farm site) compared to previously released ones and also had a short maturity cycle. They pose an opportunity for the agro-pastoralists who, at times, hardly wait too long to feed the family, especially in the Afar region, where moisture is a limiting factor for crop production.

The study area is characterized by erratic, low, and unpredictable rainfall. Occasionally, high temperatures during the rainy season exacerbate soil moisture stress. As a result, the moisture deficit is the most pressing problem, causing frequent crop failures in the area. So, agro-pastoral and private sales are now opting for the production of sorghum under supplemental and/or full irrigation. Irrigation is one of the approaches taken as a countermeasure to the unpredictability of rain. In most of the study areas, agro-pastoralists do not have enough knowledge about site selection, land preparation, agronomic management like variety selection, actual field management for sowing, appropriate seed rate and row planting, fertilizer (dose and time) application, and pest protection methods for sorghum crop production. Agro-pastoralists in the study areas have a knowledge gap about sorghum production techniques and lack appropriate varieties for the area. Thus, to have sustainable and improved sorghum production and enhance the adoption of technologies, evaluating and demonstrating sorghum varieties that are released at the national level and determining and introducing their production techniques in the Argobba districts are very important. Therefore, these technologies will be evaluated and demonstrated under agro-pastoral field conditions to create a forum for effective communication of information and create a dialogue among pastorals and agro-pastorals, researchers, and extension workers to empower pastorals and agro-pastoral capacity and to bring pressure to bear on the public sector research system.

OBJECTIVES

1) To evaluate improved sorghum varieties for agro-pastoralists in major sorghum-growing areas, particularly in the Afar region, Argobba district.
2) To evaluate the agropastoral preference for improved sorghum varieties techniques in the area.

Expected outputs

1) High-yielder sorghum varieties were identified for further demonstration and scaling-up endeavors.
2) Awareness of the pastoral and agro-pastoral research extension group members (PAPREG) created for improved sorghum varieties.

2. Methodology

Description of the test environment

The study area is found in the northwestern parts of the Afar region, 222.46 km away from Addis Ababa. It has an altitude of 475 m.a.s.l and possesses fertile alluvial soil. The Afar region is generally characterized by an arid and semi-arid climate with low and erratic rainfall. The temperatures vary from 20°C in higher altitudes to 50 ℃ in lower elevations (northern parts of the region). Rainfall throughout the region is bimodal, with a mean annual rainfall of around 500 mm in the semi-arid western escarpments and 150 mm in the arid zones (eastern and northern parts). Argobba special district (zone 3, Afar region), situated between Aliyu-Amba (North Shewa) and Dulecha woreda (zone 3, Afar region), is the only non-Afar woreda within the Afar region 4. This district is remote and isolated between North Shewa and the Afar Region due to poor road conditions linking Aliyu Amba to Dulecha. With a population estimated to be some 18,632 people, 85% are agro-pastoralists, depending on rain-fed agriculture, producing mainly cereals [6].

PAPREG Establishment

PAPREG members were selected within the selected community in collaboration with the DA, researchers, Kebele, and clan leaders during the community meeting. The selection criteria were active participation during the community meeting, interest in being involved in the adaptive research work, etc. The participatory sorghum variety trial was conducted in the Argobba district with the active participation of male and female agro-pastorals (husband and wife).

Experimental design and data collection

Trial site selection

The selection of the potential district was carried out from which was a beneficiary of the Lowland Livelihood Resilient Project; in collaboration with district experts from the Livestock and Fishery Resources, Agriculture and Natural Resources, Pastoral and Agro-pastoral Affairs, the Lowland Livelihood Resilient Project, and researchers from the Werer Agricultural Research Center. The Kebele used for PAPREG establishment was selected by the Argobba district administration office based on their selection criteria that were suitability for sorghum production.

Treatments and materials used

Five improved sorghum varieties, along with local checks, were used for variety adaptation and evaluation trials (Table 1). The required hand tools and materials were rope, meter, weighing balance, wooden peg, hessian sacks, sorghum seed, pesticides, and fertilizer. The participatory variety selection

trial was evaluated using an RCBD experimental design in two agro-pastoral fields (each agro-pastoral used as a replication). This experiment contains five improved sorghum varieties, namely: Melkam, Argiti, Tilahun, Dekeba, and Meko, and one local variety as a check. The total area used for the experiment was 10 m x 10 m (100 m^2). The seed was drilled by hand at a seed rate of 10 kg/ha with 0.2 m and 0.75 m spacing between planting rows and plots, respectively, and after 21 days of sowing, the seedling was thinned. The middle rows were used for agronomic data collection, and the other two end rows served as a border. The source of the sorghum seed was the Melkassa Agricultural Research Center (MARC). Around 50 kg of urea fertilizer was applied in splits, that is, half at the seedling stage and the remaining half as top dressing before heading to the knee stage of the crop. One hundred twenty-five (125 kg/ha NPS) fertilizer, on the other hand, was applied at sowing time. A continuous inspection of disease and insect pests was made at an interval of 3 days. Weeding and all other agronomic practices were done for each treatment equally at the recommended time.

Table 1. *List of improved sorghum varieties used for the experiment.*

S/N	List of Varieties	Center Released	Year of Release	Yield (Q/Ha) On Station	Yield (Q/Ha) On-farm
1	Melkam	MARC/EIAR	2009	37-58	35-43
2	Argiti	MARC/EIAR	2017	37	21
3	Tilahun	MARC/EIAR	2019	38-60	35-45
4	Dekeba	MARC/EIAR	2012	37-45	26-37
5	Meko	MARC/EIAR	1998	22-33	17

Data Collection

Data were collected through supervision and follow-up of the activity with the joint action of the stakeholders and analyzed. A data record sheet was developed to collect the data according to the International Board for Plant Genetic Resources (IBPGR) and ICRISAT descriptors [7]. Thus, field observation, contacting the target agro-pastoralist, and focus group discussion during the field visit were the data collection methods. The number of agro-pastoral participants in training and field day, the number of locations addressed, the number of seeds distributed, and the number of agro-pastoralists benefited from the demonstration process were major types of data collected during the activity.

Roles of agro-pastoralists, extension workers, and researchers

1) *Agro-Pastoralists (PAPREGs):* Participate in problem identification and prioritization, site selection, land preparation, sowing, weeding, trial evaluation, data collection, harvesting, etc.
2) *Researchers:* Problem identification and prioritization, proposal writing, sowing as per design, training of agro-pastorals during the trial management period, trial evaluation and guidance, overall research work monitoring, data collection and analysis, research report writing.
3) *Development agents:* Participate in problem identification, trial management, trial evaluation, data collection, monitoring of agropastoral records, and facilitating short meetings among PAPREG members.

Data analysis

Finally, the collected data were analyzed using descriptive statistics, gap analysis, and preferences were analyzed using narrations and tables. The collected data were subjected to analysis using both inferential and descriptive statistics. The preference ranking method was used to examine agro-pastoral perceptions of sorghum cultivars. The ranking was used to identify the best varieties preferred by the agro-pastoral. Selection criteria were identified first, then ranking was given for each criterion, and finally, the acceptability rank was determined. Gross margins of each crop will be analyzed on a per-hectare basis as per [8].

3. Results and Discussion

Awareness creation, training, and field days

Practically, on-farm training was given to agro-pastoralists, members of PAPREGs, and development agents of kebeles to create awareness and improve the associated skill gap on improved sorghum production. The training was delivered to pastoralists, agro-pastoralists, experts, and development agents (Figure 2), which is believed to be one of the prominent inputs to improve the adoption of high-yielding varieties and their agronomic practices [9]. (Thirty (30) PAPREG members (25 males and 5 females), development agents (3 males), and other experts attended the training. At the end of the field activity (crop maturity stage was conducted to further promotion of the sorghum production technology was conducted. A field day is a means of agricultural extension events to accelerate the popularization of new or improved agricultural technologies

to agro-pastoralists, development agents, and key stakeholders. Agricultural events are the mechanism for accelerating technology transfer for the beneficiaries in the farming system by generating the opportunity to share responsibilities and provide feedback in the process [10]. Finally, at the end of the field day, a group discussion was held to grasp the agro-pastoralists' feedback on the strengths and weaknesses of the improved sorghum varieties.

Figure 1. *Field day training program.*

Field visits and field day

Aside from field days, experience sharing occurred at experimental sites. During the field day, agro-pastoralists shared their opinions on the advantages and disadvantages of each variety. At the end of the field day, stakeholders agreed to share responsibilities for promoting the selected sorghum varieties. Field day visits and different trainings are shown in the figures below.

Table 2. *Number of participants in the evaluation of the sorghum varieties.*

Participants	Gender	Locations	
		PTC	Melka Oda
PAPREG Members	Male	25	25
	Female	5	5
Development Agents	Male	3	3
	Female	-	-
Researchers	Male	2	2
	Female	-	-
Total Participants		35	35

Figure 2. *Field visit program.*

Performance of improved sorghum varieties across study sites

The mean results showed that the sorghum variety Dekeba, followed by Melkam, had a significantly higher mean yield, and a low yield was recorded for the local check variety at both locations (Figure 1). Of many others, yield is one of the major parameters for a given crop variety, which determines its acceptability by the agro-pastoral community. The positive effects of demonstrations over the existing agro-pastoral practice towards enhancing the yield of sorghum and its positive effect on yield attributes were previously reported [11].

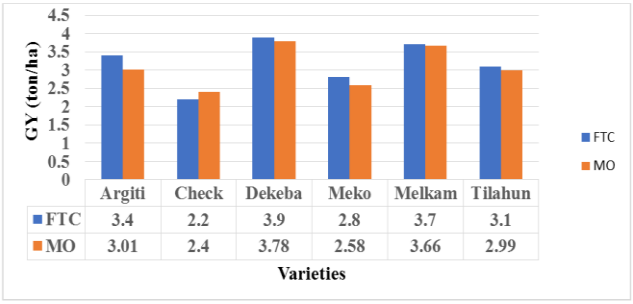

Figure 3. *Grain yield differences among the varieties across locations.*

Agro-pastoral Perception towards the Sorghum Varieties across

Participation of agro-pastorals in farm-level technology testing might improve information feedback regarding the technologies and reveal existing restrictions [12]. In this context, agro-pastoralists' participation in the variety selection process is critical in finding agro-pastoral preferred features and promoting sorghum varieties. For this study, a total of 30 participants were presented to evaluate sorghum varieties of agro-pastoral fields across locations. The detailed description of participants in the evaluation process is depicted below in Table 3. The discussion was held with the agro-pastoralists to help them identify selection criteria. Accordingly, the criteria were identified in Table 4 with their justification. The next step was to rank the criteria to easily prioritize each criterion for the selection process. Following the procedures, the Dekeba variety was preferred by the agro-pastoralists at both locations, the farmers training center (FTC) and Melka Oda. A detailed description of the ranking is stated in Tables 5, 6, and 7.

Table 3. *Number of participants in the evaluation of the sorghum varieties.*

Participants	Gender	Locations	
		FTC	Melka Oda
PAPREG Members	Male	25	25
	Female	5	5
Development Agents	Male	3	3
	Female	-	-
Researchers	Male	2	2
	Female	-	-
Total Participants		35	35

Table 4. *Identified agro-pastoral selection criteria.*

No.	Criteria	Justification
1	Earliness	Cultivating early maturing varieties is one of the best strategies for double cropping, which is identified by agro-pastoral systems.
2	Plant Height	Apart from grain yield, sorghum is the source of feed for animals, fuel consumption, and raw materials for building houses or fences.
3	Seed Size	Used as a proxy measure for marketability and grain yield.
4	Panicle	Used as a measure of panicle weight, panicle yield, and grain yield.
5	Compactness	Birds, unless protected timely manner, can bring significant damage to the yield of sorghum. Therefore, the variety with a compacted head can relatively tolerate bird damage.
6	Marketing	Besides consumption in different foodstuffs, agro-pastoral have the experience to sell sorghum as grain and seed. Hence, this criterion highly depends on the variety's preference.

Table 5. *Agro-pastoral trait preference ranking.*

No.	Criteria	Earliness	Height	Seed Size	Panicle Length	Compactness	Marketing	Total	Rank
1	Earliness	X	Earliness	Earliness	Earliness	Earliness	Earliness	5	1
2	Plant Height		X	Seed Size	Productive	Plant Height	Height	3	3
3	Seed Size			X	Seed Size	Earliness	Productive	2	4

No.	Criteria	Earliness	Height	Seed Size	Panicle Length	Compactness	Marketing	Total	Rank
4	Panicle Length				X	Panicle Length	Panicle Length	4	2
5	Compactness					X	Seed Size	1	5
6	Marketing						X	1	4

Table 6. Variety VS agro-pastoral trait preference ranking at FTC.

Varieties	Earliness (1)	Plant Height (3)	Seed Size (4)	Panicle Length (2)	Compactness (5)	Marketing (4)
Melkam	1	3	8	4	30	4
Argiti	4	12	12	6	20	12
Tilahun	3	15	16	8	15	20
Dekeba	5	6	4	2	5	8
Meko	2	9	24	10	25	24
Check	6	18	20	12	10	16

Table 7. Variety VS agro-pastoral trait reference ranking at Melka Oda.

Varieties	Earliness (1)	Plant Height (3)	Seed Size (4)	Panicle Length (2)	Compactness (5)	Marketing (4)
Melkam	1	6	8	6	30	8
Argiti	4	12	16	4	20	12
Tilahun	3	15	12	8	15	20
Dekeba	5	3	4	2	5	4
Meko	2	9	24	10	25	24
Check	6	18	20	12	10	16

Agro-pastoral trait preference

Trait preference was done separately for male and female households. A total of thirty agro-pastoralists have participated in trait preference. Agro-pastoral described that early maturity, drought tolerance, high yielding ability, marketability, stalk palatability, and quality food making were the main traits listed [13]. Accordingly, the Dekeba variety was preferred by agro-pastoralists because of its high-yielding ability, consumption quality, early maturity, palatability, and drought-tolerant traits.

Table 8. A summary of specific feedback was given for each variety.

No.	List of Varieties	Likes	Dislikes
1	Melkam	Early maturing, good seed size	The head is not compact
2	Argiti	Have better stalk and seed color	The head is not compact
3	Tilahun	Have better stalk and seed size	Less uniformity
4	Dekeba	Have a very good panicle shape	Late maturing and short

No.	List of Varieties	Likes	Dislikes
5	Meko	Relatively early maturing type	The threshing ability problem
6	Check	Compact head (gooseneck type)	Poor head size and Late

The Combined Mean Cost and Returns of Sorghum Varieties

Table 9 presents the revenue and cost analysis to produce improved sorghum varieties and the local variety across the two locations. The largest cost share to produce improved varieties and the local variety was incurred by labor costs for different farm operations, followed by fertilizers and oxen power costs in the area. The result indicates that the production of sorghum using improved varieties in both areas is quite profitable. The share of each operational cost of sorghum variety was slightly varied among the cost items to produce improved varieties and local varieties of sorghum crops. The average current market price for improved sorghum varieties is 45 ETB/kg, while the price for a local check is 36 ETB/kg.

Table 9. *Cost and return for improved sorghum varieties and the local variety.*

No.	Description of Cost and Revenue of Items	List of the varieties and their production cost per hectare					
		Melkam	Argiti	Tilahun	Dekeba	Meko	Local
1	Seed cost (ETB/ha)	450	450	450	450	450	360
2	Fertilizer's cost (ETB/ha)	4800	4800	4800	4800	4800	4800
3	Labor cost (ETB/ha)	6000	6000	6000	6000	6000	6000
4	Oxen power cost (ETB/ha)	3000	3000	3000	3000	3000	2000
5	Total cost/TVC (ETB/ha)	14350	14350	14350	14350	14350	13060
6	Gross revenue (ETB/ha)	150,229.8	132,675.8	124,306.9	156,761.5	109,814.7	93,893.4
7	Benefit-cost ratio (BCR)	10.5	9.25	8.7	10.9	7.6	7.2
8	Break-even yield (Kg/ha)	318.9	318.9	318.9	318.9	318.9	290.2
9	Break-even price (ETB/Kg)	4.31	4.87	5.21	4.22	5.88	6.23

The cost and return analysis indicated that Dekeba has more benefits than the other improved sorghum varieties and the local variety. The results of the break-even analysis (TVC/Sale price) (Kg/ha) indicated that the break-even price can cover all variable costs under the current cost of production. On the other hand, the break-even yield (TVC/Total production) (ETB/kg) was analyzed to know the variable costs covered to produce the varieties. Therefore, to minimize risk (loss), the smallholder farmers should produce at least a break-even yield per hectare and/or the minimum price of sorghum varieties above break-even on average price to cover the variable costs [14].

4. Conclusion and Recommendation

Participatory evaluation and demonstration of improved sorghum varieties is a process where agro-pastoral actively participates in evaluating and demonstrating new and improved sorghum varieties. This approach involves agro-pastoral in the selection and testing of sorghum varieties to ensure that they meet their specific needs and preferences. By actively involving the agro-pastoral in the evaluation and demonstration process, the program aims to increase the adoption and uptake of improved sorghum varieties, ultimately leading to improved productivity and livelihoods for the agro-pastoral. Through this participatory evaluation and demonstration process, agro-pastoralists became aware of the importance and quality of technologies as compared to the local ones. The demand for the improved variety was also created. The demonstration results showed that most of the studied varieties showed higher yields than local varieties. Mostly, the Dekeba variety was preferred by participants for its better agronomic performance. Based on these facts, this variety was recommended for further scaling up in these areas.

Important lessons drawn

Participatory evaluation and demonstration of improved sorghum varieties offer valuable insights for both growers and researchers. Agro-pastoralists actively participate in evaluating different sorghum varieties under their management conditions. By observing yield, disease resistance, lodging, and other traits, they gain firsthand knowledge about which varieties perform best in their specific context. Agro-pastoral preferences play a crucial role in variety selection. Criteria such as seed color, marketability, home consumption, and yield influence their choices. Researchers and extension agents learn from these preferences to promote varieties that align with agro-pastoralists' needs [15]. Joint evaluations involving agro-curators, experts, and researchers facilitate collaborative decision-making. By considering multiple perspectives, the process becomes more inclusive and effective.

Future Focus

Promote the adoption of successful varieties by scaling up their cultivation in all demonstration sites and similar agroecologies. Explore and document Agro-pastoral indigenous knowledge related to sorghum. Understanding local practices and traditional wisdom can inform future sorghum research. Provide training and awareness-building sessions for stakeholders, including Agro-pastorals, extension agents, and experts. This helps enhance their understanding of improved sorghum technologies and management practices.

Emerging challenges

After suitable varieties are identified, ensuring the timely availability of quality seeds is a challenge. Seed production and distribution systems need to be efficient. Addressing issues related to seed storage, handling, and transportation is critical to successful adoption.

Opportunities

Besides the availability of land, water, and technology, participatory evaluation and demonstration facilitate knowledge sharing among different stakeholders. One can learn from others' experiences and gain insights into effective sorghum management practices. By demonstrating improved sorghum varieties, agro-pastoralists become familiar with their characteristics and advantages. This encourages adoption and promotes sustainable agricultural practices.

Abbreviations

PAPREG	Pastorals and Agro-pastorals Research Extension Group
FTC	Farmer's Training Center
MARC	Melkassa Agricultural Research Center

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Author Contributions

Ambesu Tiliye: Formal analysis, Methodology, and Full writeup

Hailu Mengistu: Original draft, Reviewing, and Editing

Shimelis Alemayehu: Funding acquisition, Resources, and Supervision

Conflicts of Interest

The authors declare no conflicts of interest.

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