Journal of
Innovative Agriculture

Research Article
DOI: https://doi.org/10.37446/jinagri/rsa/10.2.2023.27-35

Cluster-based large-scale demonstration of improved sorghum cultivation technology

Melkachew Hailemariam*, Asmera Adicha, Kassahun Kabata

Southern Agricultural Research Institute, Jinka Agricultural Research Center, P.O.Box 96, Jinka, Ethiopia.

Cluster-based large-scale demonstration of improved sorghum technology through irrigation was done with the objective of demonstrating and popularizing improved sorghum technology in the Bena-Tsemay district of the South Omo zone. A total of 17 agro-pastoralists participated in the demonstration, and one pastoral and agro-pastoral research and extension group containing 27 members was established. The demonstration took place on a 10-hectare plot of land in a cluster base. Participatory training was given to all participants on important agronomic practices and management measures. Researchers applied all the recommended agronomic and management practices with close supervision and follow-up. Both qualitative data like agro-pastoral perception and agronomic data, and quantitative data like grain yield were collected and analyzed. Cost-benefit ratio was also calculated to see the economic feasibility of sorghum production. The result indicated that the mean grain yield of sorghum production was 2.65 tons per hectare and the net gain (profit) from sorghum production was 55975 Birr per hectare which is an initiative for producers to continue the production. And also, the benefit to cost ration of 1.6:1 indicates that sorghum production is an economically feasible activity in the area. Pastoral perception and feedback were also collected from participants. Most participants indicated the sorghum (Melkam) variety performed better than their local in terms of yield, early maturity, disease resistance, seed color, and seed size. Thus, further expansion and seed supply by district and zone stakeholder groups to that area is necessary to enhance sorghum productivity and thereby ensuring food security.

Received: 15 January 2023
Accepted: 22 April 2023
Published: 30 June 2023

***Correspondence**
Melkachew Hailemariam
melkachewhailemariam@gmail.com

Volume: 10
Issue: 2
Pages: 27-35

Key words: *cluster, demonstration, cost-benefit, production, sorghum, yield, Ethiopia*

INTRODUCTION

Food security has been severely constrained by climate change variability in various forms, which also substantially impacts agriculture productivity (Assefa et al., 2021). Diversifying climate change-resilient crops can help to overcome food insecurity by augmenting household consumption and creating new market opportunities for smallholders (Kushabo et al., 2019). Sorghum is a climate change-resilient crop and mostly grows in arid and semi-arid areas that offer opportunities for vulnerability adaptation while other major food crops face challenges (Jarvis et al., 2012; Adicha et al., 2022; Mahdi et al., 2012). In the southern region of Ethiopia, mostly arid and semi-arid areas, namely, south omo, Konso, and others, mostly grow sorghum as the main food security crop (Habte et al.,2021) and about 112,193 hectares of land were covered by sorghum, with productions and productivity of 2852, 640.8 quintals, and 25.43 Q/h, respectively (CSA, 2017/2018). The lowland areas of the South Omo zone are dominated by the rearing of animals and parallelly sorghum is grown by farmers, agro-pastoral, and pastorals in the south omo zone as a climate change adaptation crop and one of the favorite food items (Amjad et al., 2009; Abebe et al., 2016; Kusse et al., 2021). However, the productivity of sorghum is declining over time as they follow traditional production and they do have less technology access (Adicha et al., 2022). In response to this productivity decline, Jinka Agricultural Research Centre undertook adaptation trials and recommended highly performed improved varieties with associated agronomic practices. The result of the experiment indicated that improved varieties had given yield as compared to the local variety and the yield obtained by the adaptation trial at the Jinka Agricultural Research Centre was (31.5Q/h, 50Q/h, and 29Q/h for Melkam, Teshale, and Dakaba, respectively). Thus, demonstrating these recommended varieties with agronomic practices enhances the production and productivity of sorghum in the area. Therefore, this activity was carried out to demonstrate the proven sorghum technology through cluster-based large-scale demonstration in the South Omo Zone research site.

MATERIALS AND METHODS

Description of the study area

Bena-Tsemay District is one of the ten districts in the South Omo Zone of Southern Ethiopia, with a total land coverage of 254,905 hectares. The district is about 483 kilometers from the regional center, Hawassa, and 42 kilometers from the zonal administrative city, Jinka. It is bordered to the south by Konso, to the north by Ari, to the west by Hammer, and to the east by Malle. Agro-ecologically, the district is predominantly semi-arid. The agro-climate zone of the district consists of Kolla (78%), Dry Woyina Dega (19%), and Bereha (3%). The district is located at an altitude range of 526–1800 meters above sea level. As reported by Adicha et al. (2022), the district is covered with different varieties of vegetation, mainly indigenous trees, shrubs, and bushes. The major crops grown in the midland areas of Bena-Tsemay district are cereals (maize and sorghum), pulses and oils (common bean, pigeon pea, and ground nut), roots and tubers (sweet potato, cassava, taro, Irish potato, and yam), fruits (banana, mango, avocado, papaya, and citrus), coffee and spices (coffee, turmeric), and vegetables (cabbage, hot pepper, onion, and tomato).

The site and Agro-pastorals selection

A cluster-based large-scale demonstration of improved sorghum technology was carried out in the Bena-Tsemay district of the south Omo Zone. From the district, Duma kebele was chosen for its high population density, access to irrigation, access to roads, and access to suitable farmland in clusters within the kebele for production. Totally, 17 pastoral and agro-pastoral producers participated in the cluster-based large-scale demonstration of improved sorghum technology conducted in the district. Also, a PAPREG containing 27 members was established. Based on the area of land that was covered and access to suitable farmland, all the pastoral and agro-pastoral farms had farmland nearby each other. Researchers from the Jinka Agricultural Research Center, agricultural experts from the Zonal and respective districts, and the administrator actively participated in selecting participants and the host kebele.

Implementation design

Improved sorghum technologies such as improved seed, seed rate, spacing, fertilizer rate, chemicals and irrigation watering or crop water requirement were applied and used for the demonstration of each agro-pastoralist. The technology was planted on agro-agro-pastoralists' in Belg 2013 cropping season with full recommended management packages. For the demonstration trial, the row planting method was used, with a spacing of 75 cm between rows and 15 cm between plants, and thinning was implemented. The recommended seed rate of 15 kg/ha was used for drilling. The recommended rates of 100 kg/ha UREA (at planting and knee height) and 50 kg/ha NPSB were used to conduct the demonstration. Totally, 10 hectares of land were covered.

Training and skill developments

Different disciplines of researchers prepared training and provided for both experts and beneficiaries. To enhance the effectiveness of sorghum production field-based training while planting, weeding and chemical application times are very critical and at each time the training was provided by respective researchers. As per the training provided, beneficiaries tried to apply both theory and field training at the ground and it helped the beneficiaries to update their productions skills and change their perception of the productions associated challenges.

Data collection and analysis

Agronomic data and Agro-pastoralists' perception, yield, price and input data were collected and analyzed by using descriptive statistics like maximum, minimum, mean, frequencies, and percentage. Using direct matrix ranking the agro-pastorals perception on improved variety was analyzed. And also benefit-cost ratio was used to calculate the feasibility of sorghum production technology under agro-pastoral management in the research site.

RESULTS AND DISCUSSION

Achievements or demonstrations through field day

A field day was conducted to demonstrate improved sorghum technologies to agro-pastoralists, development agents, and key stakeholders. As a result, a field day was held at Bena-Tsemay district on Duma Kebele to demonstrate cluster approaches at crop maturity.

Model pastoral and agro-pastoral participants, development agents, and administrative bodies from three kebeles with sorghum productions potential and nearby kebeles, key stakeholders from districts, and the South Omo Zone stakeholders were invited to visit crop field performance and share experiences on the field day. A total of 121 agro-pastoralists, 6 development agents, 3 kebele administrators, and 6 key stakeholders from districts and zones attended the field day. During the field day, a discussion section was organized to raise awareness of pastoral and agro-pastoral issues through experience sharing and brochures, Debub radio, and television, mass media were also used to increase the technology's popularity.

Yields and yield component of sorghum

The study's findings showed that the new sorghum (Melkam variety), with its technological packages produced more yield per hectare than the local variety under the existing agro pastoralists' practices. Thus, in comparable production years in the research area, the mean grain yield of new sorghum was 26.5 quintals ha-1 while the mean yield of local variety was 10 quintals ha-1. This suggests that the new sorghum had a greater yield advantage over the indigenous variety. The right application of suggested technology packages, including the use of the new variety, suitable fertilizer, chemicals, seed rates, and sound management practices, allowed for the achievement of this higher yield advantage (Abady et al. 2017; Kinfe and Tesfaye, 2018; Birhane et al. 2019) all reported a comparable yield result. The outcome is also in line with (EIAR, 2016), which stated that superior technology demonstrations over traditional farmer practices could increase sorghum yields and improve yield characteristics. The mean yield was 15.64 quintals, while the minimum and maximum yields for each agro pastoral were 11.44 and 19.84 quintals from a plot area of 0.59 hectares, respectively (Table 1).

Table 1. Yield data of the field experiment

Beneficiary	Land (ha)	Mean yield Q/ha	Total yield
17 agro pastorals	10	26.5	265
Per agro pastorals	0.59	15.64	15.64
Per agro pastorals plot of 0.59ha	Min (Q) 11.44	Max (Q) 19.84	Mean (Q) 15.64

Source: own result, 2022

Agro-pastoralists' perception and feedback

At the end of the activity, feedback was collected from participant agro-pastoralists to know their perception level of sorghum cultivation technology. Accordingly, they revealed their interest on the variety with regard to performance of grain yield, early maturity, disease tolerance, and medium height enabling the variety to resist logging & good for bird keeping, seed color, and seed size. Seven men and ten female evaluators were lumped together during the evaluation. The selection criteria suggested by agro-pastoralists were early maturity, disease tolerance, high-yielding ability, stalk palatability, panicle length, seed size, seed color, plant height, and disease /pest/ resistance were the main traits listed (Table 2). Direct matrix ranking was used to identify the prioritization order of the agro-pastorals selection criteria. Melkam variety was preferred by agro-pastoralists because of its high-yielding ability, early maturity, stalk palatability, and seed color and disease resistance traits. This is in line with the findings of (Hailemariam et al., 2021), who found the same selection criteria as the most important farmers' criteria for rice varieties.

Table 2. Preference of agro pastorals on improved sorghum (Melkam) Variety

		Improved				Local			
No	Preference criteria	Preferences of PAPREGs			Rank	Preferences of PAPREGs			Rank
		Male	Female	Total		Male	Female	Total	
1	Grain yield	7(4)	10(4)	17	1	7(1)	10(1)	17	2
2	Panicle length	7 (3)	10(3)	17	1	7(1)	10(1)	17	2
3	Seed colour	7(4)	10(4)	17	1	7(1)	10(1)	17	2
4	Seed size	7(4)	10(4)	17	1	7(2)	10(2)	17	2
5	Plant height	7(3)	10(3)	17	1	7(2)	10(2)	17	2
6	Early maturity	7(4)	10(4)	17	1	7(1)	10(1)	17	2
7	Bird infestation	7(0)	10(0)	17	0	7(0)	10(0)	17	0
8	stalk palatability	7(4)	10(4)	17	1	7(2)	10(2)	17	2
9	Disease/pest/ resistance	7(4)	10(4)	17	1	7(1)	10(1)	17	2

Score for criteria 0 up to 4, 0=similar 1=poor, 2=good, 3=better, 4= Best

Cost-benefit analysis

Return components (Biomass and yield)

In this research site, agro pastoralists exploited the sorghum production for both human and animal feed. However, converting the biomass of sorghum to money is a difficult task. As agro pastorals produces various quantities of biomass and uses it in different ways, it is difficult to evaluate. In this study, the return of sorghum production did not include the financial value of biomass. Moreover, researchers observed and monitored agro pastoral fields frequently during the demonstration season, which inspired them to actively monitor, weed, and irrigate their sorghum plot. According to the suggested agronomic practices for the particular location, planting and weeding were carried out at the appropriate times of the season. The melkam variety's average grain yield was 26.5 quintals per hectare, which was significantly higher than the local variety's grain yield of 10 quintals per hectare (Table 3). This difference was mostly caused by the melkam variety's early maturation period and productivity advantage.

Table 3. Cost benefit analysis of sorghum productions

Costs per hectare	Measurement	Amount	Unit cost (Birr)	Total cost (Birr)
Seed	Kg	15	50	750
Fertilizer	Kg	150	28.5	2100
Chemical	Liter	5	1800	3600
Tractor	Operator & fuel	1	12000	12000
Labour	Labor per hectare	120	100	12000
Total variable cost				30450
Fixed cost	Land cost per ha	1	5000	5000
Total cost				35450
Benefits (Birr/ha)				
Grain yield	Quintal (Average)	26.5	3450	91425
Total return				91425
Gross margin				60975
Profit (Birr/ha)				55975
Benefit to cost ratio				55975/35450=1.6:1

Source: own calculation field experiment, 2022

Cost of inputs used

The most important production inputs of sorghum are seed, fertilizer, chemicals, labour and tractor operation. The cost of all inputs used is recorded by the researcher using a data sheet provided for that purpose. Accordingly, the cost of seed per hectare was 750 birr which amounted to 15k per hectare as per recommended rate. The fertilizer used was NPSB and Urea which costed total of 2100 Birr per hectare. As per recommendation for sorghum productions, 50kg NPSB and 100kg urea per hectare were used with a total cost of 3600 Birr per hectare. The land was prepared by tractor for plantation and the cost of fuel for tractor and labour cost of the operator totaled 12000 Birr per hectare. The labour cost items identified are plantation, thinning, irrigation, weed control, harvest and separating/threshing. Thus, the cost of labour from planting to harvesting and threshing was 12000 Birr per hectare. The overall cost which varies with productions was 30450 Birr per hectare. Whereas land cost as an opportunity cost if the rent for other purposes is 5000 Birr per hectare in the current market value of land in the research site. To sum up, the total cost of sorghum production in the research site is 35450 Birr per hectare.

Return

Return is the difference of gross return which is price multiplied by yield gained and variable inputs costs. Thus, the return from sorghum production was 91425 Birr per hectare. The higher gross return encourages the agro-pastorals to participate in sorghum production and enhance their income through increased productivity. Any modifications to technologies or practices often depend on the financial benefit obtained. Agro-pastoralists who are prone to not understanding new technologies are aware of the potential financial risk involved in making investments in any kind of commercial setting. The gross margin of Melkam variety was 60975 Birr per hectare which indicates the economic feasibility of new technology-based sorghum productions.

Net gain (profit)

Net gain (profit) is just the variance between total costs (total variable and fixed costs) and the total net value of the produce at current market prices. The estimated current market cost of inputs (variable and fixed) equals 35450 Birr per hectare. The total return obtained from (sorghum) production was 91425 Birr per hectare. So, the net gain (profit) was 55975 Birr per hectare which is initiative for producers to continue the production.

The ratio of benefit to cost

The result of benefit to cost ratio indicated that the sorghum production in the study is economically feasible. The average return obtained from the sale of seed was 91425 Birr per hectare which is sound income with respect to the cost of production which is 35450 Birr per hectare in the area. Furthermore, the ratio indicated that the benefit from sorghum production exceeds the cost by one and a half than the cost of the production. This implies that the 1.6 (net return) to 1 (total cost) provokes emerging agro-pastoralists to twitch with sorghum productions.

Lessons learned and suggestions forward

It is true that sorghum cultivation in the area was being practiced by the pastoral and agro-pastoral research and extension group, and the chosen area for sorghum production at the time was unusual. However, they are forced to collaborate and learn from one another in the forms of the pastoral and agro-pastoral research and extension groups. This made it easier for the pastoral and agro-pastoral research and extension group members to carry out all the crop management tasks. The employment of more advanced technologies, such as improved seed, fertilizer and row planting needs group efforts to easily demonstrate and familiarize the technologies for agro-pastorals. As a result, a sense of competitiveness developed among group members due to the teamwork within the pastoral and agro pastoral research and extension group and the group members 'influence on one another. Therefore, one of the primary strategies for technology adoption in the region is the creation of the pastoral and agro-pastoral research and extension group. Members of PAPREGs were now increasing production, and other adjacent agro pastorals were implementing the technology. Sorghum is grown in agro-pastoral areas for both human use and as a high-yielding source of animal feed. Therefore, productions should be scaled out extensively at all times as it is irrigation based and rainfed, and skill gap training in using the technology should also be provided for better production of sorghum and to enhance the economy of producer households.

CONCLUSION

The findings of this study demonstrated that the improved variety of sorghum (Melkam) had shown better grain yield as compared to agro pastorals' practice and it improves agro-pastoralists' income as it was used for additional seed productions, home consumptions, and income generations by selling seed and biomass for animal feed. The net gain (profit) was 55975 Birr per hectare from sorghum production which is an initiative for producers to continue the production. And also, the benefit to cost of 1.6:1 indicated sorghum production is the economically feasible activity in the area. Thus, it can be concluded that the income from sorghum production enhances further production and expansion of sorghum for multiple purposes. Additionally, each household who participated in the improved sorghum productions could have known how on the uses seed for further expansion and consumption for household purpose. The outcome also supported that enhanced sorghum varieties have increased yields over local varieties compared to agro-pastoralist practices who didn't use improved sorghum production technology. The large-scale demonstration's host agro-pastoralists also played a crucial role as a source of knowledge and high-quality seeds for spreading the enhanced sorghum variety (Melkam) among other agro-pastoralists in the area. It is concluded that a large-scale demonstration is an effective instrument for boosting sorghum production and productivity by expanding agro-pastoralists' knowledge, attitude, and abilities. As a result, the offices of agriculture and rural development in each district should spread and expand the Melkam variety to numerous agro pastoralists with comparable agro-ecologies. In order to continually and consistently increase sorghum production and provide the seed of this variety for further production, it needs strong efforts by respective stake-holders on seed producer cooperative establishment or organizing agro-pastoral improved seed producing groups.

ACKNOWLEDGMENTS

The authors would like to appreciate the southern agricultural research institute Jinka agricultural research center for financial support and vehicle arrangement during field experiments and monitoring. And we highly appreciate the Bena-Tsemay district agricultural office experts and kebele development agents for their valuable support during fieldwork.

AUTHOR CONTRIBUTIONS

Mr. Melkachew H/Mariam wrote the proposal, secured the budget, conducted the field demonstration and field day events, collected all field data, analyzed, and interpreted the result, and wrote the manuscript. Mr. Asmera Adicha secured land, conducted the field demonstration, arranged the field day, collected data, and wrote the manuscript. Mr. Kassahun Kabata conducted the field demonstration field day events and collected all field data.

COMPETING INTERESTS

The authors declare that there is no conflict of interest among each other.

ETHICS APPROVAL

Not important for this work

REFERENCES

Abady, S., Liku, G., & Yadeta, D. (2017). Participatory varietal selection and evaluation of twelve sorghum (Sorghum bicolor (L.) Moench) varieties for lowlands of Eastern Hararghe. *International Journal of Plant Breeding and Crop Science, 4*(1), 281-285.

Abebe, H., Asmera, A., & Shimelis, T. (2016). Economic Analysis of the Effect of Nitrogen and Phosphorous Fertilizer Application for Sorghum Productions at Alduba, South Omo, South Western Ethiopia. *International Journal of Agricultural Economics, 1*(2), 26-30.

Adicha, A., Dawit, D., Gedion, E., & Kutoya, K. (2022). Assessment of possibilities to establish a model agricultural technology village in Southern Ethiopia. *Journal of Innovative Agriculture,* 9(1), 49-61.

Amjad, M.A., Niaz, S., Abbas, A., Sabir, W., Jabran, K. (2009). Genetic diversity and assessment of drought tolerant sorghum landraces based on morph physiological traits at different growth stages. *Plant Omics Journal, 2*(1), 214-227.

Assefa, B.T., Chamberlin, J., van Ittersum, M.K., & Reidsma, P. (2021). Usage and Impacts of Technologies and Management Practices in Ethiopian Smallholder Maize Productions. *Agriculture*, *11*(1), 938.

Birhane, G., Belay, F., Gebreselassie, T., & Desta, D. (2019). Enhancing sorghum yield through demonstration of improved sorghum varieties in Tanqua-Abergelle Wereda, Central Zone of Tigray, Ethiopia. *Journal of Agricultural Extension and Rural Development*, *11*(1), 11-16.

CSA (Central Statistical Agency) (2017/2018): Agricultural Sample Survey. Report on Area and Productions of Major Crops. Volume I, VII, and VIII. Statistical Bulletin 586. Addis Ababa, Ethiopia; April 2017/2018.

EIAR. (2016). Cereal crop productions and management manual. http://www.eir.gov.et.

Habte, A., Worku, W., Gayler, S., Ayalew., D., & Mamo, G. (2020). Model-based yield gap analysis and constraints of rainfed sorghum productions in Southwest Ethiopia. *The Journal of Agricultural Science, 158*(1), 855–869.

Hailemariam, S., Fistum, M., Amare, S., & Chalachew, E. (2021). Promotion of Improved Sorghum Technologies through Large-Scale Demonstration in Gololcha District, Arsi Zone of Oromia Regional State, Ethiopia. *American Journal of Plant Sciences*, *12*(1), 366-375.

Jarvis, A., Ramirez-Villegas, J., Navarro-Racines, C., Herrera V., & Ramirez-Villegas, J. (2012). Is cassava the answer to African climate change adaptation? *Tropical Plant Biol*., *5*(1), 9–29.

Kinfe, H., & Tesfaye, A. (2018). Yield Performance and Adoption of Released Sorghum Varieties in Ethiopia. *Edelweiss Applied Science and Technology*, *2*(1), 46-55.

Kushabo, A., Solomon, A., & Derege, T. (2019). Climate change and variability impacts on rural livelihoods and adaptation strategies in Southern Ethiopia. *Earth Systems and Environment*, *7*(1), 1- 12.

Kusse, K., Ermias, G., Darcho, D. (2021). Major Cereal Crops Productions in South Omo Zone, Southern Ethiopia. *J. Geo Nat. Disast*., *11*(1), 493.