

 RESEARCH PAPER

Pre-scaling up of early maturing sorghum (*Sorghum bicolor* L.) technologies in moisture-deficient areas of eastern Amhara, Ethiopia

Abere Haile¹, Nigussie Siyum¹, Mesfin Bahta¹, Mekonnen Assefa¹

¹ Amhara Agricultural Research Institute, Sirinka Agricultural Research Center, P.O. Box 74, Woldia, Ethiopia

Corresponding author: Abere Haile (Aberehaile15@gmail.com)

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Abstract

Sorghum is one of the major staple crops grown in Ethiopia's poorest and most food-insecure regions. In the Amhara region, sorghum covered a significant amount of cultivated land following tef. However, sorghum production is predominantly based on local landraces with limited recommended agronomic practices, which means that productivity and production are low due to associated problems. This study aimed to pre-scale up improved early-mature sorghum technologies conducted at Kobo, Habru, Kalu, and Dawa chefa districts to create wider demand for improved sorghum technology, enhance technology dissemination, and strengthen linkage among stakeholders. A total of 273 farmers, of which, 50 female-headed households with a total of 80 ha of adjacent farms were purposively selected and clustered accordingly. The result of descriptive statistics indicated that Sorghum variety Girana-1 gave a mean grain yield of 4.57-ton ha⁻¹, 3.5-ton ha⁻¹ and 3.65-ton ha⁻¹ at Raya kobo, Habru, and Dawa chefa districts, respectively. The melkam variety also gave a mean grain yield of 3.98-ton ha⁻¹, 4.80-ton ha⁻¹, and 4.15-ton ha⁻¹, and 2.80-ton ha⁻¹ in Raya Kobo, Habru, Kalu, and Dawa chefa districts, respectively. In addition to this focus group discussion also showed that farmers were very attracted to their earliness and high-yielding traits of varieties as compared to the local variety in the respective districts. Therefore, early mature sorghum varieties with recommended production packages should be further scaled out to other sorghum-growing areas in collaboration with agricultural wings.

Keywords

Girana-1, Melkam, Scale Up, Sorghum, Technology

Introduction

Sorghum (*Sorghum bicolor* L.) ranks as the fifth most important cereal crop globally, after maize, rice, wheat, and barley, and is a crucial food-security crop in sub-Saharan Africa (Pixley et al. 2023). It is well adapted to drought-prone and marginal environments, making it particularly valuable in semi-arid regions where other staples often fail. In Ethiopia, sorghum is the second most important staple crop after maize, ranking third in productivity per hectare and cultivated across nearly all regions, covering approximately 1.8 million hectares (CSA 2020).

Despite its importance, sorghum production faces significant constraints. In eastern Africa, drought, low soil fertility, Striga weed, insect pests, quelea birds, and weeds have been identified as major limiting factors (Wortmann et al. 2006). In Ethiopia, low soil fertility, recurrent drought, Striga infestation, reliance on local landraces, and limited access to improved agronomic practices are particularly severe in the northern and northeastern lowlands (Gebretsadik et al. 2014; Anega 2024). Moisture stress during critical growth stages, establishment, flowering, and grain filling can significantly reduce yields or cause total crop failure (Simane et al. 1998; Tumwesigye

and Musiitwa 2002). Erratic rainfall, characterized by late onset, early termination, and uneven distribution, further limits productivity in rain-fed systems (EARO 2001; Tadesse and Tesfahun 2001).

Sorghum grain plays the first role in the daily diet of the people in such areas, which has been used as food, and local beverages, and its stock is used as a fodder and source of fuel. The average yield of sorghum for the period 1993–2000 at the national level was only 1.3 tons ha⁻¹. (FAO 2006) but now it has reached 2.3-ton ha⁻¹ (CSA 2014/15). Currently, the average productivity of sorghum in North, South Wollo, and Oromia special zones is 2.5-ton ha⁻¹, 2.4-ton ha⁻¹, and 2.7-ton ha⁻¹ respectively; these are above the national productivity, which indicates that there is a production potential in the area. The total arable land is 4.4 million hectares covered by field crops in the Amhara region, sorghum covers about 14% (650000 hectares), contributing 16% (14 million quintals) production share.

The Yeju-Kewet Sorghum cluster, running from Kobo-Alamata plain to Kewet, is the major sorghum-producing area in Eastern Amhara. Particularly, the lowland areas of Wollo are affected by moisture stress and recurrent drought. Because of its genetic make-up and biochemical and physiological profiles, sorghum is a drought-tolerant cereal crop and is considered a climate-smart crop. Moreover, due to its high photosynthetic efficiency, sorghum ranked second in productivity next to maize and is regarded as a food security crop in moisture-stressed areas. The lowland areas of Eastern Amhara are food insecure and hence, rely on food aid and safety net support. Of the total safety net users in Amhara Regions, 77% come from the food-insecure areas of Eastern Amhara. Hence, to improve the livelihood of the farming community in the lowland and moisture-stressed areas of Eastern Amhara, introducing and promoting improved sorghum technologies is crucial. Moisture stress, low soil fertility, poor crop management practices, parasitic weeds, diseases, and insect pests are the major sorghum production constraints (Asfaw et al. 2010).

In Eastern Amhara, the rainfall pattern is erratic and characterized by late onset and early termination. Hence, growing of late-maturing sorghum varieties (that require 7–8 months) is becoming unlikely. Recognizing such production constraints, several improved early maturing sorghum varieties with recommended agronomic packages were developed and released from the regional and federal research institutes. On-station and on-farm demonstration of improved sorghum technologies in the lowland areas of Eastern Amhara has a remarkable productivity (3.5–4.2 ton ha⁻¹) over the local sorghum landraces and farmers' practices (1.8–2.5 ton ha⁻¹), resulting in a yield advantage of 70–90%. Sorghum varieties Girana-1 and Melkam were demonstrated in the lowland areas of eastern Amhara.

Even though these varieties have higher grain yield, early maturing, white and bold-seeded, have acceptable stock biomass, and are outfitted with adaptability to semi-arid agro-ecologies (IDRC 2023), adoption of these improved varieties has been constrained by limited seed availability,

weak extension linkages, insufficient farmer awareness, and gender-related barriers to technology access (Kombi et al. 2024; Melesse et al. 2023). Therefore, scale-up of the newly demonstrated early maturing sorghum varieties Girana-1 and Melkam with their agronomic packages should be popularized for wider demand creation. Therefore, this study aims to increase farmers' awareness and demand for improved sorghum varieties and associated agronomic technologies, enhance the dissemination and seed multiplication of early-maturing varieties, and strengthen linkages among key stakeholders involved in sorghum production, marketing, and utilization.

Material and methods

Description of the study area

The study was conducted in four districts of Kobo, Habru, Kalu, and Dawa chefa located in the North Wollo, South Wollo, and Oromia Special Zones of the Eastern Amhara Region, Ethiopia. These districts are well known for the production of sorghum, Mung bean, Haricot bean, and other lowland crops.

Kobo district is situated at 12°09'60.00"N, 39°38'59.99"E, with an altitude of 1,500 meters above sea level (m.a.s.l.). The district receives an average annual rainfall and temperature of 617.3 mm and 22.3 °C, respectively. Habru district lies between 11°32'58.00"N, 39°48'58.89"E, at altitudes ranging from 1,150 to 1,825 m.a.s.l. The district experiences a mean annual rainfall of 750–1,000 mm and temperatures ranging from 15 to 29 °C. Kalu district is located at 11°00'00.00"N, 39°83'59.99"E, with altitudes ranging from 1,895 to 1,954 m.a.s.l. The district receives an average annual rainfall of 750–900 mm, and the mean temperature varies between 25 and 35 °C. Dawa chefa district is situated at 10°55'49.30"N, 39°47'47.59"E at an altitude of 1,424 m.a.s.l. It has a mean annual rainfall of 895.2 mm and an average temperature of 26.2 °C (Woreda office of agriculture 2022).

The study districts are characterized by a lowland agro-ecology with short and erratic rainfall patterns, typically extending for not more than three months from late June to early September. Consequently, crop production in these districts is often challenged by low soil fertility and high moisture stress, resulting in frequent crop failures.

Sampling procedure and farmers' selection

A multi-stage sampling technique was employed to select participant farmers for the study. In the first stage, three sorghum-producing zones in moisture-deficient areas of the Eastern Amhara Region were purposively selected. In the second stage, four districts representing high sorghum producing districts Kobo, Habru, Kalu, and Dawa Chefa were identified. In the third stage, seven kebeles were selected in consultation with the respective Woreda Offices

of Agriculture: Adisalem and Aradom from Kobo, Gorarba from Habru, Arabo from Kalu, and Gerbi, Shekla, and Gur from Dawa Chefa. Finally, farmers with a minimum of 0.25 ha of cultivated land were identified and clustered within each district to facilitate crop management, monitoring, and evaluation.

Host farmers in each kebele were selected in collaboration with agricultural experts and key informants familiar with the local communities. Selection criteria ensured representation across different social segments, including variations in age, gender, and wealth status, to capture a diverse spectrum of farmers. Researchers facilitated timely action plans for technology promotion in collaboration with agricultural experts and other stakeholders, ensuring organized implementation and effective dissemination of improved sorghum technologies.

Technology dissemination and capacity-build- ing activities

The dissemination of improved sorghum technologies in the study area involved a series of structured activities, including a planning workshop, package training, mass media, field days, and field visits aimed at enhancing farmers' knowledge, skills, attitudes, and adoption behavior.

Workshop

Before initiating the pre-scale-up activities, the researchers organized a launch workshop to establish an operational platform. The workshop aimed to create awareness among stakeholders and identify responsible parties for specific tasks throughout the project. Following the workshop, a Memorandum of Understanding (MoU) was signed among the stakeholders to formally delineate roles, responsibilities, and collaboration throughout the implementation of the activities.

Training

The effectiveness of technology dissemination was measured by changes in participants' knowledge, skills, attitudes, and adoption behavior rather than merely by physical achievements (Winterton 2006). Training addressed gaps in knowledge, skills, and attitudes (KSAs) and was provided to farmers, development agents, and agricultural experts. Farmers attended a two-day program comprising theoretical and practical components on basic agronomic practices and improved sorghum technology packages.

In this study, training was provided to farmers, development agents, and agricultural experts on improved sorghum production techniques. Farmers received a two-day training program that combined both theoretical and practical components, focusing on basic agronomic practices and technology packages. The researchers were responsible for organizing the training, providing technical backstopping, and overseeing data collection, while farmers carried out the practical activities.

The scale-up involved two improved sorghum varieties, Girana-1 and Melkam, with the following recommended agronomic practices: a seed rate of 12 kg ha⁻¹; application of 100 kg ha⁻¹ NPS fertilizer and 50 kg ha⁻¹ urea (with 39 kg urea applied at the knee-height stage), planting techniques 75 cm between rows and 15 cm between plants, thinning after 20 days of planting, and moisture conservation practices such as tie-ridges, were used. Farmers implemented all recommended management practices under the guidance of researchers, who provided technical backstopping and supervised data collection. The key stakeholders, including zone and district-level agricultural development offices, cooperatives/unions, private service providers, and agricultural input regulation and quarantine experts were participated in the training sessions to ensure coordinated support for technology adoption.

Extension communication and mass media

a combination of appropriate extension approaches and teaching methods, including individual, group, and mass contact methods, was employed according to the situation. Additionally, print materials such as leaflets, pamphlets, and flyers, posters in Amharic and English versions were used to raise awareness, enhance knowledge and skills, and promote positive attitudes toward the adoption of improved sorghum production packages.

Field days and field visits

Field days were organized to motivate farmers and stakeholders by demonstrating the performance, profitability, and practical applicability of improved sorghum technologies under field conditions. These events facilitated mass mobilization, stakeholder engagement, and knowledge sharing. Discussion sessions and result-sharing forums were conducted during the field days to communicate outcomes and lessons learned, strengthening linkages among relevant actors.

Field visits were arranged to raise awareness, allow farmers to share experiences, and reinforce knowledge and practical skills on improved sorghum practices. Regular joint monitoring and evaluation were conducted at different crop growth stages to provide follow-up actions and technical advice based on emerging needs.

Field day participants

Field days were conducted in North Wollo, South Wollo, and Oromia Special Zone, as indicated in the table below. Many stakeholders, including farmers, experts, development agents, researchers, and unions and cooperatives, participated in these events. During each field day, participants provided their own opinions on the improved early-maturing sorghum technologies. They evaluated various attributes such as earliness, seed color, seed size, and suitability for intercropping, uniformity, thresh ability, and other parameters identified by farmers themselves. The opinions were collected from different stakeholders to capture a comprehensive assessment of the technologies (Table 1).

Table 1. Field days conducted in North Wollo, South Wollo, and Oromia Special Zone.

Location	Field day participants									
	Farmers		Experts		Researchers		Other Stakeholders		Grand Total	
	M	F	M	F	M	F	M	F	M	F
Dawa chefa	78	13	81	40	9	0	33	12	201	66
Raya kobo	9	1	29	4	10	0	11	7	59	12
Total	87	14	110	44	19	0	44	19	260	78

*Other stakeholders include cooperatives, unions, Media agencies, and administrative staff.

Exit strategy

At the end of the study, a closing workshop was held to define and share roles and responsibilities among stakeholders for the sustainable management of formal and informal seed systems. This included organizing seed producer cooperatives and promoting farmer-to-farmer seed exchange using quality seed. Market linkages were established through unions and seed enterprises to facilitate information sharing among stakeholders and promote the production and marketing of quality-declared seeds. Moreover, experience sharing through success stories facilitates the engagement of relevant stakeholders such as research centers, agricultural offices, farmers, cooperatives, unions, private seed dealers, NGOs, and others, for the sustainable supply of seeds.

Methods of data collection

Data were collected from a selected sample using a structured data sheet to record both biological and socio-economic information. Participatory Rural Appraisal (PRA) tools such as focus group discussions, individual interviews, and field observations were used for data collection. Biological data included grain and straw yields, while economic data encompassed market prices of outputs and costs of inputs. In addition, farmers' preferences and perceptions of the technologies were measured using a five-point Likert scale, and feedback from other stakeholders on the technologies was also recorded.

Data analysis

Yield-related data were analyzed using simple descriptive statistics, while preference rankings and Likert scale responses were evaluated using the Relative Importance Index to capture perceptions. The results were presented through graphs, tables, and narrative descriptions to effectively convey qualitative insights.

Results and discussions

Input distribution

The amount of inputs distributed and the total number of project participants are summarized in Table 2 below. During the project period, a total of 1230 kg of seed was

distributed. The initial seed served as a revolving seed to reach additional farmers in the area. A farmer-to-farmer seed exchange mechanism was established to improve access to early-maturing sorghum seeds. This system provided a relatively low-cost approach to ensure adequate seed quantity, maintain quality, and deliver seed at the right time and place at an affordable price.

Yield performance and yield advantage across locations

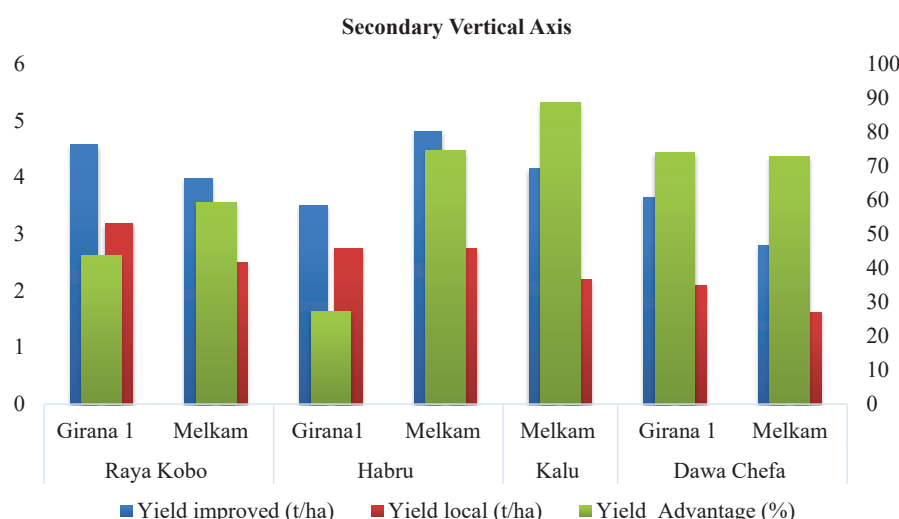
The results presented in Fig. 1 show clear differences in yield performance between the improved sorghum varieties (Girana-1 and Melkam) and the local varieties across the four districts. The mean grain yield of Girana-1 was 4.57 t ha⁻¹, 3.50 t ha⁻¹, and 3.65 t ha⁻¹ at Kobo, Habru, and Dawa Chefa districts, respectively. These yield levels represent substantial improvements over the local varieties, corresponding to yield advantages of 43.45% at Kobo, 27.27% at Habru, and 73.8% at Dawa Chefa under comparable management conditions. This reveals that Girana-1 performs consistently well across varied agro-ecological conditions, particularly in moisture-stressed areas where early-maturing varieties are advantageous.

Similarly, the Melkam variety also showed superior performance, with mean grain yields of 3.98 t ha⁻¹, 4.80 t ha⁻¹, 4.15 t ha⁻¹, and 3.80 t ha⁻¹ at Kobo, Habru, Kalu, and Dawa Chefa, respectively. Compared to the local varieties, Melkam exhibited even larger yield advantages of 59.2%, 74.54%, 88.63%, and 73.37% across the respective districts. The exceptionally high yield advantage in Kalu (88.63%) suggests that Melkam is particularly well-suited to the environmental conditions of this district, possibly due to better soil moisture availability or improved compatibility with local management practices. These results are consistent with earlier findings indicating that Melkam is one of the high-yielding, stable, and widely adaptable sorghum varieties recommended for dryland areas (Tesfaye et al. 2021; Seyoum et al. 2019).

Although both improved varieties showed high grain yield performance, Melkam showed a relatively lower stalk yield advantage compared to the local variety. This is mainly because Melkam has a shorter plant height, which reduces total biomass yield; however, farmers reported that its stalk is more palatable and easier to utilize as animal feed. This aligns with

Table 2. Implementation of improved early matured sorghum varieties.

Districts	Crop	Variety	Distributed seed-kg	Area covered ha ¹	Participants		
					M	F	T
Raya Kobo	Sorghum	Girana-1	600	38	123	43	166
	„	Melkam	75	5	14	2	16
Habru	„	Girana-1	75	5	9	0	9
	„	Melkam	75	5	7	0	7
Kalu	„	Melkam	75	5	14	3	17
Dawa chefa	„	Girana-1	150	10	18	1	19
	„	Melkam	180	12	38	1	39
Total			1230	80	223	50	273


Figure 1. Mean yield and yield advantage of improved early maturing sorghum varieties. Note: Local varieties used for comparison: Raya Kobo↔Wodehagr, Habru↔Jigurti, Kalu↔Gorade and Dawa chefa↔Esmael.

recent observations that improved varieties often trade off biomass quantity for grain yield but provide better feed quality (Berhanu et al. 2025). The dual-purpose value of sorghum grain for food and stalk for livestock remains an important factor for farmer preference, and improved varieties like Melkam can still be valuable where feed quality is prioritized over bulk biomass.

Overall, the findings indicate that both Girana-1 and Melkam offer substantial yield benefits and agronomic improvements over local varieties. Their consistent performance across locations highlights their potential for wider scaling, contributing to increased food security, resilience to drought, and improved household income in the sorghum-growing areas.

Demand creation and stakeholder linkage

Early-maturing sorghum technologies were previously unfamiliar in the moisture-stressed areas of eastern Amhara due to limited access to improved sorghum varieties and associated production packages. However, this situation has now improved as farmers have begun producing improved sorghum varieties after obtaining seed from research centers and NGOs, along with adequate training

on full production practices. Farmers frequently compare the improved varieties with their local counterparts and consistently note advantages such as uniform crop stand, compact and well-filled heads, better tolerance to moisture stress, and other desirable agronomic traits.

The clustering approach used for pre-scaling up sorghum technologies has played an important role in facilitating field observation, improving weed management, reducing wild animal damage, and enhancing disease, insect, and pest control. It has also contributed to the development of stronger market linkages within the production areas. As a result, there is now a high demand for improved sorghum technologies, with farmers seeking seed either by borrowing or purchasing from neighboring farmers.

The involvement of experts and the creation of linkages among key actors, including research centers, agricultural offices, cooperatives, unions, and NGOs, have been instrumental in technology generation, adaptation, demonstration, and promotion. These collaborations have helped introduce new ideas, improve production practices, and ensure farmers' access to improved early-maturing sorghum seeds. This support enhances production and productivity at the woreda, zonal, regional, and national levels.

Early-maturing sorghum varieties are in high demand locally, nationally, and internationally because they are essential food security crops for rural households. Stakeholders share roles and responsibilities to ensure sustainable production and productivity improvements. The long-term sustainability of the seed supply system depends on coordinated participation through a multi-stakeholder extension approach, strengthening seed production and marketing cooperatives, and reinforcing farmer-to-farmer seed exchange systems within communities.

Feedback provided by farmers and other stakeholders

Farmers expressed strong appreciation for the performance and uniformity of the improved sorghum varieties. Many farmers indicated their willingness to further scale out the technologies through farmer-to-farmer seed exchange. They also reported that early-maturing sorghum varieties are well-suited for intercropping with crops such as mung bean, haricot bean, and various forage species. Some farmers noted that they plan to cultivate additional forage crops to compensate for feed shortages, particularly when adopting the Melkam variety. Melkam was also favored for its short plant height, which enhances its tolerance to wind damage. Both improved varieties were reported to be highly thresh-able and free from health problems known as “*qinqn*”, making them more convenient for post-harvest handling.

Stakeholders emphasized the need to strengthen market linkages to support the sale of improved seed produced at the community level. They also highlighted the importance of conducting further research on the management of major insect pests and diseases, including fall armyworm, stalk borer, and other emerging threats.

Additionally, they recommended that technology promotion efforts be expanded to other sorghum-producing areas in collaboration with local agricultural offices to achieve broader coverage. Food science research was identified as necessary for assessing the food quality attributes of early-maturing sorghum varieties along the value chain. Cooperative organizations were encouraged to actively participate in the establishment and strengthening of seed producer cooperatives to address recurring seed shortages and ensure a sustainable community-based seed supply system.

Farmers' perception of early maturing sorghum varieties

Fig. 2 illustrates farmers' perceptions of early-maturing sorghum varieties using the Relative Importance Index (RII). The RII value greater than or equal to 0.5 (closer to 1) indicates a high level of preference for both positive and negative statement parameters, whereas an RII value closer to 0.1 (zero) reflects low perception or low preference for a given attribute. As shown in the figure, the Melkam variety is highly preferred by farmers across most of the evaluated parameters. Girana-1 is also generally preferred, although not to the same extent as Melkam across all traits. Overall, farmers noted that Melkam has a uniform crop stand, is suitable for intercropping, and matures early; however, it has lower stalk yield and is more susceptible to bird damage due to its white seed color and short stalk height. Girana-1, on the other hand, is appreciated for its grain color, desirable grain size, better stalk palatability, and marketability, as well as its suitability as livestock feed. These perceptions highlight the distinct advantages of both varieties and reflect farmers' practical evaluation of the varieties under their local production conditions.

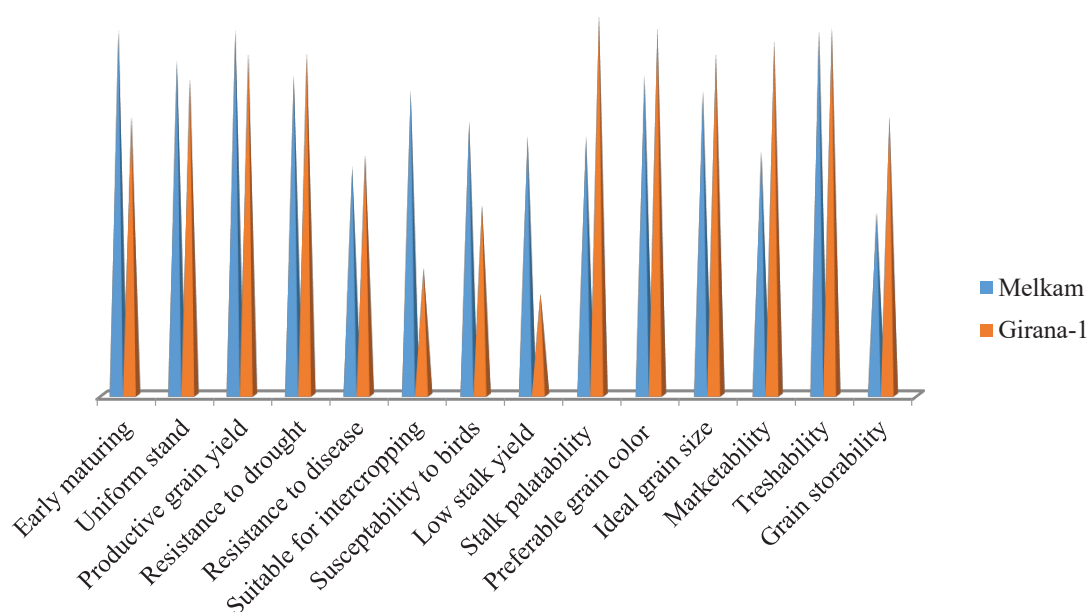


Figure 2. Farmers' perception and preference evaluation of early maturing sorghum varieties.

Food-related sensory evaluation of early mature sorghum varieties

The results presented in the graph show farmers' perceptions of the food quality attributes of the Melkam and Girana-1 sorghum varieties based on the Relative Importance Index (RII). Overall, both varieties were considered suitable for a range of traditional food products, but each exhibited different strengths. Melkam received the highest preference for porridge quality for a common household dish. It was also highly rated for injera taste and injera color, reflecting its favorable sensory characteristics in common staple food preparation. In contrast, Girana-1 performed better in attributes related to fermentation and baking, including local beer quality, injera baking quality, and injera lusciousness, suggesting that farmers found this variety more appropriate for products requiring desirable fermentation behavior and good baking performance. Girana-1 also scored highly for injera color and water-holding capacity of flour powder, traits important for dough handling and final product appearance. Although Melkam was slightly less preferred for these fermentation-related traits, it remained valued for its versatility and good taste profile. Overall, the findings indicate that Melkam is particularly preferred for porridge and flavorful injera, while Girana-1 is more suitable for fermented foods and high-quality injera, highlighting the complementary food-use advantages of the two early-maturing sorghum varieties (Figs 3, 4).

Conclusion and recommendation

Sorghum production in the moisture-stressed areas of eastern Amhara is constrained by recurrent drought, late onset rainfall, early termination of rainfall, and the widespread use of late-maturing local varieties. Besides, limited access to improved seed, low adoption of recommended agronomic practices, and a fragile extension system

reduce productivity. To address these challenges, a pre-scaling-up intervention of two early-maturing sorghum varieties, Girana-1 and Melkam were implemented in the Kobo, Habru, Kalu, and Dawa Chefa districts. A total of 1,230 kg of seed (825 kg Girana-1 and 405 kg Melkam) was distributed, covering 80 hectares of clustered farmland over 273 participating farmers, including 50 female-headed households.

The results clearly proved the superior performance of the improved sorghum varieties over local. Girana-1 achieved mean grain yields of 4.57 t ha⁻¹, 3.50 t ha⁻¹, and 3.65 t ha⁻¹ in Kobo, Habru, and Dawa Chefa, respectively. Melkam produced mean yields of 3.98 t ha⁻¹, 4.80 t ha⁻¹, 4.15 t ha⁻¹, and 2.80 t ha⁻¹ in Kobo, Habru, Kalu, and Dawa Chefa, respectively. Both varieties showed significant yield advantages over the local varieties under farmer-managed conditions.

Farmers and experts expressed strong satisfaction with the improved sorghum varieties due to their superior performance, early maturity, resilience, and other important traits. The intervention of scaling early maturing sorghum technologies can significantly enhance productivity, strengthen food security, and reduce climate-related risks in moisture-stressed farming systems, confirming the strong potential of Girana-1 and Melkam for wider scaling across similar agro-ecological zones. To sustain seed supply and support large-scale adoption, a coordinated multi-stakeholder approach is essential, strengthening community-based seed systems, marketing cooperatives, and farmer-to-farmer exchange networks. Collaboration among research institutions, agricultural offices, cooperatives, unions, seed enterprises, NGOs, and the Bureau of Agriculture is crucial for effective dissemination. Continuous training on agronomy, pest and disease management, and post-harvest handling should be provided, alongside efforts to establish strong market linkages that enhance grain and seed marketing. Further research on major pests such as fall armyworm and stalk borer is needed, and supportive policies must be promoted to enable rapid, sustainable scaling of early maturing sorghum technologies.

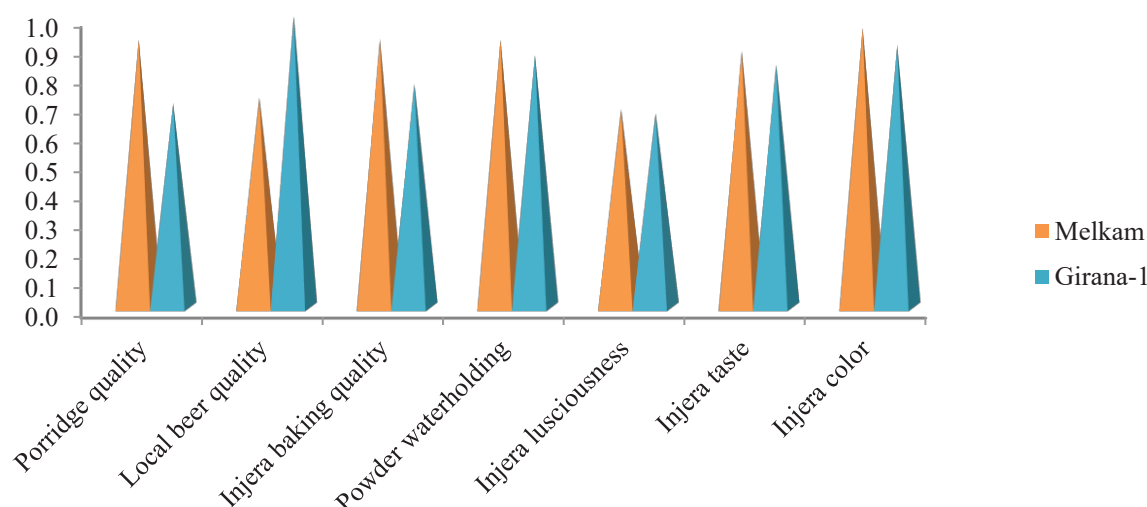


Figure 3. Farmers' food processing evaluation of early mature sorghum varieties.



Figure 4. Field performance of early maturing sorghum varieties.

Author contributions

Writing - original draft: AH.

Artificial Intelligence (AI) use

The authors accept full responsibility for the content of the manuscript, including the disclosure of any use of AI. No AI tools were used in the preparation of this manuscript.

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