

Pre-extension Demonstration and Evaluation of Improved Food Barley Technologies at Highlands of Guji Zone, Oromia, Ethiopia

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ABSTRACT

Food barley is a vital staple crop in the Ethiopian highlands, yet production remains constrained by a lack of high-performing crop technologies. This study evaluated the performance, profitability, and farmer acceptance of a newly released food barley variety, GABISA, against the standard check, HB-1307, in the Guji Zone, Oromia, Ethiopia. The evaluation was conducted across four kebeles in the Bore and Ana Sora districts using a participatory Farmers' Research Group (FRG) approach (11 trial farmers). Varieties were grown side-by-side on 10 × 10 m² plots with standard agronomic management (130 kg/ha seed rate; 100 kg/ha DAP). Capacity-building training and field days were conducted for 224 stakeholders. Data on grain yield, production costs, and farmer preferences were analyzed using descriptive statistics, independent t-tests, and net farm income (NFI) analysis. GABISA variety achieved a mean grain yield of 45.29 Qt/ha, demonstrating a highly significant ($p = .000$) yield advantage of 52.9% over the HB-1307 variety (29.62 Qt/ha). GABISA variety also exhibited a narrower technology gap (5.21 Qt/ha) and a superior technology index (10.3%), indicating excellent field feasibility. Economically, GABISA generated a Net Farm Income of 267,486 ETB/ha compared to 121,513 ETB/ha for the HB-1307 variety. It yielded a benefit-cost ratio of 4.46 and an incremental benefit-cost ratio of 32.44, proving that minimal added input costs yield massive financial returns. Qualitatively, farmers ranked GABISA as their top preference due to its high yield, lodging resistance, strong tillering capacity, appealing seed color, and high marketability. GABISA variety drastically outperforms the standard check biologically and economically while meeting local farmer preferences. The study strongly recommends the immediate pre-scaling up and wide distribution of the GABISA variety to enhance food security and income for highland farmers in the Guji Zone

INTRODUCTION

Barley (*Hordeum vulgare* L.) is the world's fourth most important cereal crop, after maize, wheat, and rice, with estimated area, production, and productivity of 48.94 million hectares, 145.62 million tons, and 2.98 tons/ha, respectively (FAOSTAT, 2023). According to recent global agricultural data (FAOSTAT; USDA, 2025), global barley production averages around 145 million metric tons. The European Union remains the world's leading producer, followed closely by the Russian Federation, Australia, Canada, and Turkey. While the Russian Federation has maintained a high volume of production (averaging roughly 19–20 million tons), Ukraine's barley infrastructure, farmable land, and export logistics have faced severe structural disruptions following the escalation of the conflict in 2022. This geopolitical crisis drastically reduced Ukraine's average annual output to under 5–6 million tons, shifting the dynamics of the world's top grain exporters and underscoring the volatility of global cereal supply chains.

Recent regional data (FAOSTAT, 2025) indicates that Morocco, Ethiopia, Algeria, Tunisia, and South Africa continue to lead Africa's barley production. However, North African yields have faced severe fluctuations due to recent multi-year droughts. On average, regional land allocation and production volumes have shifted, with Morocco and Ethiopia driving the continent's output. Morocco's area harvested has hovered around 1.1 to 1.3 million hectares, with highly volatile production yields (ranging between 1.0 and 2.2 million tons depending on rainfall). Concurrently, Ethiopia has emerged as a highly stable producer, utilizing approximately 0.95 million hectares to yield roughly 2.5 to 2.7 million tons, reflecting a superior average productivity of over 2.6 tons/ha. Algeria, Tunisia, and South Africa follow as the next largest producers, managing smaller harvested areas (averaging 0.45, 0.40, and 0.1 million hectares) and outputs (roughly 0.50, 0.35, and 0.38 million tons, respectively), with South Africa maintaining the highest localized technological yield efficiency at over 3.6 tons/ha."

In the 2020/21 main cropping season, more than 3.7 million smallholder household heads in most highland areas of Ethiopia grew barley for multiple purposes (food, feed, beverage, and roof thatching). During the same cropping season, Oromia and Amhara regions contributed about 81.2% and 83.8% of the overall barley production and area coverage of the country Ethiopian Statistics Service [ESS], 2022). According to the FAO (2023) estimate, from 2019 to 2021, the average per capita food use of barley in Ethiopia was 16.8 kg/ year, which was the second in the world next to Morocco (19.6 kg/year). Similarly, the total area coverage and production of Guji Zone were estimated at 19,847.01 ha and 200,493.23 Qt (ESS, 2022). Barley is an important food crop in Ethiopia, accounting for over 25% of the country's total cereal production (FAO, 2014). However, barley yields in Ethiopia are low, averaging around 15 Qt/ha (Agegnehu *et al.*, 2016). This is due to several factors, including poor soil fertility, drought, and disease (Alemu *et al.*, 2023; Megersa *et al.*, 2015). Improved barley technologies have the potential to increase barley yields in Ethiopia (Bakala *et al.*, 2022).

Demonstrations are a valuable tool for evaluating the effectiveness of improved technologies before they are widely disseminated to farmers. These demonstrations allow farmers to see the benefits of the technologies firsthand and to make informed decisions about whether or not to adopt them (Maake and Antwi, 2022). The demonstration method is an extension teaching method used to show a group of people how to carry out an entirely new practice or old practice in a better way. In the demonstration, the farmer is shown step by step. Food barley is an important crop in the Highland Guji, but its yield is below the national average due to different factors like soil acidity (Alemu *et al.*, 2023). Also, its potential productivity is limited by a lack of sufficiently improved food barley varieties. Moreover, low use of recommended full packages is also another yield-limiting factor. Therefore, demonstrating and evaluating high yielder, disease tolerant and stable varieties that can meet the increasing food demand of the growing human population and improve the income and livelihood of farmers is very important. Consequently, to fill the gap, the Bore Agricultural Research Center (Cereal Research Team) recently released an improved food barley (GABISA) variety with full recommended packages for production (Table 1). The introduction and release of new varieties alone is not sufficient to increase farmers' yields; these must be evaluated, and the recommended technologies must be shown on farmers' land (Kebede *et al.*, 2024). Thus, demonstration of newly released food barley variety through participation of farmers and other stakeholders for sustainable production and productivity of barley is vital.

Objectives

1. To evaluate the yield performance and profitability of food barley varieties under farmers' conditions in the Highlands of Guji Zone;
2. To create awareness on the importance of food barley varieties among farmers, Development agents (DAs), Subject matter specialists (SMSs), and other stakeholders.
3. To collect farmers' feedback on food barley varieties for further development of food barley technologies.

METHODOLOGY

Description of the study area

The study was conducted in Bore and Ana Sora districts of the Highland Guji Zone, Oromia Regional State, Ethiopia (Figure 2). Bore and Ana Sora districts are barley-producing potential districts in the Highland Guji Zone. The altitudes range from 1800 to 2900 and 1900 to 2350 m.a.s.l. for Bore and Ana Sora districts, respectively.

Demographics

The population density in the Highland districts of Guji Zone, particularly Ana Sora and Bore, is notably higher than the overall zonal average due to favorable climatic conditions and agricultural productivity. For instance, Ana Sora has a population of over 132,000 people with a high density of approximately 110.3 people per square kilometer, compared to the wider zonal average of 21.1 people per square kilometer (Beriso *et al.*, 2023). Based on

administrative data and official projections, the nearby Bore District is even more populous, with a baseline census population of 210,179 and an estimated total population reaching approximately 300,766 (ESS, 2022). Across both districts, the population remains overwhelmingly rural and agrarian, with less than 9% of the population residing in urban environments. Furthermore, the demographics reflect a consistent cultural landscape in which the Oromo constitute more than 86% of the population, with Afaan Oromoo as the primary language, alongside small minority communities, including the Amhara, Gedeo, and Sidama (Beriso *et al.*, 2023).

Socio-Economic Activities

Socio-economic life in the Bore and Ana Sora districts is thoroughly tied to rain-fed, smallholder mixed agriculture that effectively leverages the long highland growing seasons. Crop production heavily relies on *enset* (false banana) as a staple food insurance crop alongside major cereals like barley, wheat, maize, and teff, and farmers extensively cultivate high-yield highland pulse crops, specifically improved faba bean varieties such as *Gebelcho* and *Walki*, as well as field peas (Kebede & Korji, 2017). While predominantly subsistence-oriented, these highland areas serve as vital hubs for cash-generating agricultural projects, including the cultivation of improved malt barley for breweries (Kebede *et al.*, 2025) and specialized coffee in the lower-elevation fringes of the districts. Furthermore, livestock rearing of cattle, sheep, and goats acts as a primary economic asset by providing traction power, food, and financial security, which is complemented by a high potential for honey production (apiculture) supported by the diverse forest and flora canopy in the highlands (Kebede & Korji, 2017). Within these agricultural frameworks, gender dynamics play a significant role; women participate heavily in local agricultural labor, though systemic gender disparities persist, with studies estimating that roughly 58.6% of women in agricultural households experience socio-economic disempowerment (Beriso *et al.*, 2023).

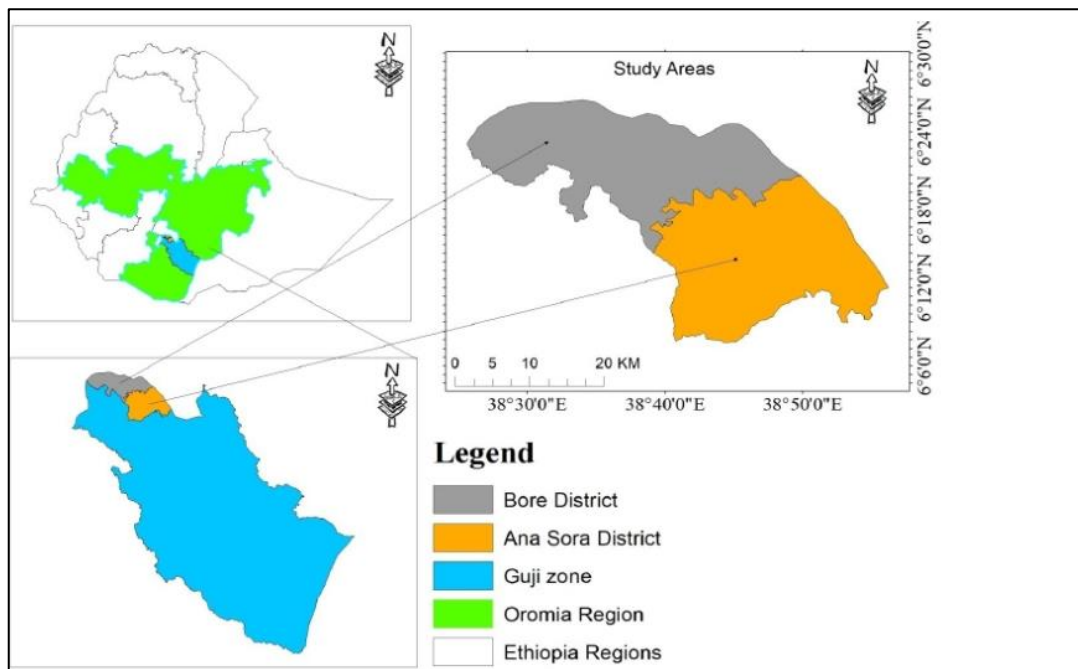
Land Use / Land Cover (LULC)

The landscape of the Bore and Ana Sora districts is profoundly shaped by sharp altitudinal transitions ranging from 1,200 to 2,900 meters above sea level. This topographic variance heavily dictates local Land Use/Land Cover (LULC) configurations (Beriso *et al.*, 2023). In the Bore district, which covers approximately 1,296 Km² the landscape is primarily divided between pasture or grazing land (33%), high-moist Afromontane forest (30%), arable or cultivated land (29%), and swampy or degraded areas (8%) (Ethiopian Forestry Development, 2020). Across both districts, croplands are heavily concentrated around flat valleys and gently sloping terrains where smallholders manage fragmented plots and homestead *enset* plantations to cultivate barley, wheat, corn, teff, and horse beans. Concurrently, grasslands and communal pastures distributed along valley floors and steep inclines remain vital for supporting local livestock pastoralism. Despite housing ecological havens like the diverse Bore-Anferara-Wadera forest ecosystems—which feature significant highland bamboo, shrublands, and moist evergreen forests—longitudinal LULC studies indicate that these natural forest covers are continuously declining, fragmented,

and undergoing edge-driven deforestation due to intense population and agricultural expansion pressures (Woldearegay and Woldu, 2020)

Hydro-Climatology

The hydro-climatology of the Bore and Ana Sora districts is profoundly shaped by their high-altitude topography, positioning them as humid-to-sub-humid moisture havens within the highland (*Dega*) agro-ecological zone of southeastern Ethiopia. Ranging predominantly between 1,400 and 2,932 meters above sea level, these districts experience a remarkably cool, temperate climate. Mean annual temperatures tightly span between 10.1°C and 21.0°C in Bore and approximately 15.0°C to 20.0°C in Ana Sora, shielding the region from the extreme heat profiles of the adjacent lowlands (Kebede and Bobo 2023). Due to their placement along the mountainous western escarpment of the Guji Zone, both districts capture high volumes of orographic precipitation; Bore receives an average annual rainfall fluctuating between 1,200 mm and 1,400 mm, while Ana Sora charts an extensive annual precipitation range stretching from 1,000 mm up to 1,750 mm (Grokikipedia, 2024).



Source: Own Sketch from GIS (2026)

Figure 1. Map of Study Area

Site and Farmers Selection

From each district, two kebeles (The smallest administrative unit in Ethiopia) were selected based on their barley production potential. In total, the trial was conducted in four kebeles. Trial farmers were selected in collaboration with the respective kebeles' development agents. The Farmers' Research Group (FRG) approach was used to select and organize farmers. One FRG per kebele, consisting of 15 farmers, was organized with attention to gender. From each FRG, 3 trial farmers were then selected for trial establishment, taking into

consideration their willingness to provide land, previous production history of the crop, and interest in participating in the group and sharing their experiences.

Planting material

One newly released improved variety, namely GABISA, was demonstrated with the standard check HB-1307 variety on selected trial farmers' land (Table 1).

Table 1. Description of Food Barley Varieties Used For Demonstration

S/N	Name of Varieties	Maintainer	Year of release
1	GABISA	Bore ARC	2023
2	HB-1307	Holetta ARC	2006

Experimental design and procedures

The newly released barley variety was demonstrated side by side with a standard check. The experimental field for each variety, including the standard check, was 10 x 10 m². Farmers were used as replication. Land was prepared by a farmer using an oxen plow. Seeds were sown at the recommended rate of 130 kg/ha⁻¹ in rows (20 cm between rows). The fertilizer rate of Diammonium Phosphate (DAP) 100 kg/ha was used. Plots were kept free of weeds using hand weeding.

Capacity development

After group formation, different capacity development activities were undertaken. Training was given for the FRG members, DAs, and SMS to improve their level of knowledge and create awareness about barley production. Field visits and a field day were organized for farmers to observe each other's fields and understand the difference between their experiences, and to create wider demand and further promotion of food barley in the highlands of Guji Zone.

Data collected and methods of data collection

Grain yield, costs of production, income gained, and farmers' feedback were collected through face-to-face interviews and FGDs. Grain yield, costs of production, and income gained from the production of barley were collected by preparing a checklist. Whereas farmers' feedback was collected through focus group discussions and interviews.

Methods of Data Analysis

Descriptive statistics using Statistical Package for Social Sciences version 24 (SPSS) were used to analyze agronomic and financial data. Feedback from the farmers was collected and analyzed qualitatively. Profitability of the variety was identified by using NFI (Net farm income). The technology gap implies researchable issues for the realization of potential yield, while the extension gap implies what can be achieved by the transfer of existing technologies (Dhaka *et al.*, 2010). Technology gap and technology index were calculated using the following formula;

Technology gap = Potential yield qt/ha – demonstration yield

Whereas the yield advantage of the demonstrated varieties was calculated using the following formula.

$$\text{Yield advantage \%} = \frac{\text{yield advantage of new variety} - \text{yeild advantage of sd; check}}{\text{yield advantage of standard check}} \times 100 \quad (1)$$

$$\text{Technology index \%} = \frac{\text{Potential yield} - \text{demonstrated yeild}}{\text{Potential yeild}} \times 100 \quad (2)$$

Finally, the benefit-cost ratio was used as it provides an added level of clarity and creates a look at the demonstrated varieties' overall economic feasibility. The incremental benefit-cost ratio was also used to show whether a unit addition in the production cost of a new variety is more profitable than a standard check.

$$\begin{aligned} &TR \\ &= Y \\ &* P \end{aligned} \quad (3)$$

where, TR = total revenue, Y = yield obtained in quintals per hectare (ha. ⁻¹) and P = farm gate price in ETB (Ethiopian Birr).

$$\begin{aligned} &NI \\ &= TR - TVC \\ &- FC \end{aligned} \quad (4)$$

NI = net income, TR = total revenue, TVC = total variable cost, and FC = fixed cost.

$$\begin{aligned} &BCR \\ &= \frac{NI}{TPC} \end{aligned} \quad (5)$$

where, BCR = benefit cost ratio and TPC = total production cost (TVC + FC). If BCR is > 1 profitable to accept the variety, but advisable to reject if it is < 1

$$\begin{aligned} &IBCR \\ &= \frac{NI \text{ of newly released variety} - NI \text{ of standard check}}{TPC \text{ of newly released} - TPC \text{ of standard check}} \end{aligned} \quad (6)$$

RESULTS AND DISCUSSION

Capacity Building on Food Barley Production

Development Agents (DAs), Subject Matter Specialists (SMSs), and a select group of Farmers Research Group (FRG) members received training on the importance and management of food barley varieties (Table 2). To improve farmer-to-farmer learning about the production and management of food barley, exchange visits and mini-field day were arranged. During the planned training, exchange visit, and field day, multidisciplinary teams are actively engaged by sharing their expertise and knowledge.

Table 2. Capacity Building Methods and Number of Participants For Demonstration and Evaluation of Newly Released Food Barley Variety

Capacity building methods	Participants	Number of participants		
		Male	Female	Total
A. Training	Farmers	36	14	50
	DAs	5	1	6

	SMSs	4	-	4
B. Field Day	Farmers	95	18	113
	DAs	15	1	16
	SMSs	16	3	19
	Others	15	1	16

Own Data Result, 2024

DAs = Development Agent, SMSs = Subject Matter Specialist

Role of Farmers and Other Stakeholders in the Technology Demonstration and Evaluation

The role of the farmers, extension workers, researchers, and other stakeholders during the technology demonstration is indicated in the table below (Table 3).

Table 3. Role of Farmers and Other Stakeholders' Participation in Technology Demonstration

Actors	Roles
FRG members	Involved in land preparation, sowing, management, yield evaluation, and providing feedback.
Trail farmers	Trail land provision, record-keeping, facilitating members' involvement, field monitoring, and reporting in the case of an emergency, and providing feedback.
Research teams	Provision of training for FRG members and other actors, and providing input, agronomic data collection, field monitoring, social data collection, analysis, and preparing extension materials.
Extension workers	Monitoring, feedback, and information transfer facilitate organizing the community.
Other stakeholders	Input supply, technical backup, community facilitation, and information dissemination.

Yield Performance of Demonstrated Food Barley Varieties

As shown in the following table 4, the mean grain yield obtained from the newly released GABISA variety was 45.29 Qt/ha, whereas 29.62 Qt/ha was gained from the standard check HB-1307 variety. The mean grain yield obtained from the GABISA variety was 52.9% yield advantage over the HB-1307 variety. The result of this demonstration was greater than previously conducted 38.62 Qt/hac by (Alemu *et al.*, 2023) and 42 Qt/hac on a farmer's field during registration of the GABISA variety (Aliyi *et al.*, 2025). The yield advantage of the GABISA variety over HB-1307 was highly significant, which was 52.9 %, this implies that producing the GABISA variety was more advantageous than that of the HB-1307 variety.

Table 4. Grain Yield Performance of Food Barley Varieties Was Demonstrated

Yield performance of food barley varieties in Qt/ha						
Variety	N	Min	Max	Mean	Std. Deviation	Yield advantage (%)
GABISA	11	38.00	54.25	45.29	5.97162	52.9
HB-1307	11	21.00	40.00	29.62	5.99268	

Independent sample t-test.

Table 5 shows that if the significance value for the Levene test is high (greater than 0.05), use the results that assume equal variances for both groups. Otherwise, use the results that do not assume equal variances for both groups. During the food barley demonstration, the equal variances are assumed ($p = .798 > .05$). A significance value of .000, which is $> .05$, indicates that there is a highly statistically significant difference between the two means yield of both varieties.

Table 5. Result of the Independent Sample T-Test

	Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	.067	.798	6.142	20	.000	15.67	2.55

Technology Gap and Technology Index

The technology gap indicates the gap between the demonstrated yield and the potential yield. The observed technology gap is attributed to dissimilarities in fertility, acidity, rainfall, and other natural calamities, and its contribution is to narrow down the gap between the yields of different varieties and to provide location-specific recommendations (Dhaka *et al.*, 2010). As indicated in Table 6, the technology gap is 5.21 qt/ha and 12.38 qt/ha for GABISA and HB-1307 varieties, respectively. The technology index indicates the feasibility of demonstrated variety on the farmer's land. This index should be lowered to be practicable on a farmer's land. The newly released GABISA variety (10.3) is more feasible than the standard check HB-1307 (29.47) variety

Table 6. The Result of the Technology Gap and Technology Index for Food Barley Varieties

Varieties	Potential yield (qt/ha)	Demonstrated yield (qt/ha)	Technology gap (qt/ha)	Technology index (%)
GABISA	50.5	45.29	5.21	10.3
HB-1307	42	29.62	12.38	29.47

Cost-Benefit Analysis

To evaluate the commercial viability and financial feasibility of the demonstrated food barley technologies on rented farmland, a comprehensive net farm income (NFI) and benefit-cost ratio (BCR) analysis was conducted based on the 2024 cropping season.

Driven by its massive yield advantage, the newly released GABISA food barley variety demonstrated clear financial superiority, generating a mean Total Revenue of 362,363.64 ETB/ha compared to 207,390.91 ETB/ha for the standard check, HB-1307 variety (Table 7). After accounting for variable expenses and fixed land rental costs (25,000 ETB/ha) during 2024 cropping season, the GABISA variety achieved a mean Net Farm Income of 267,486.18 ETB/ha – more than doubling the net returns of the HB-1307 variety (121,513.45 ETB/ha) (Table 7). Consequently, while both varieties proved highly profitable with benefit-cost ratios well above one ($BCR > 1$), the GABISA variety delivered an exceptional return on investment with a BCR of 4.46 compared to the HB-1307 variety, 2.19 (Table 7).

To evaluate the marginal value of shifting to the improved technology, the Incremental Benefit-Cost Ratio (IBCR) was calculated at 32.44 (Table 7). This exceptional metric proves that for every additional 1 ETB per hectare spent on the extra production costs required by the GABISA variety package, farmers receive an additional 32.44 ETB in net profit over the standard check (Table 7). This massive marginal return underscores that the minor extra cost of adopting the GABISA variety is highly economically justified, making it a lucrative, low-risk technology perfectly optimized for capital-constrained smallholders in the highlands of Guji.

Table 7. Cost-Benefit Analysis of Food Barley Demonstrated Varieties in Ethiopian Birr (ETB)/ha

Parameters	N	Minimum	Maximum	Mean	Std. Deviation
Yield of GABISA	11	38.00	54.25	45.30	5.97
Yield of HB-1307	11	21.00	40.00	29.63	5.99
Farm gate price of GABISA	11	80.00	80.00	80.00	0.00
Farm gate price of HB-1307	11	70.00	70.00	70.00	0.00
Total Fixed cost	11	25000.00	25000.00	25,000.00	0.00
Total Variable cost of GABISA	11	34416.00	36216.00	34,938.73	556.94
Total Variable cost of HB-1307	11	29916.00	31716.00	30,438.73	556.94
Total cost of GABISA	11	59416.00	61216.00	59,938.73	556.94
Total cost of HB-1307	11	54916.00	56716.00	55,438.73	556.94
Total Revenue of GABISA	11	304000.00	434000.00	362,363.64	47772.95

Total Revenue of HB 1307	11	147000.00	280000.00	207,390.91	41948.74
Gross margin of GABISA	11	268784.00	399584.00	327,424.91	48019.19
Gross margin of HB-1307	11	116884.00	249934.00	176,952.18	41971.24
NFI from GABISA	11	208568.00	340168.00	267,486.18	48270.61
NFI from HB- 1307	11	61768.00	194868.00	121,513.45	42001.10
Benefit-cost ratio of GABISA	11	4.46			
Benefit-cost ratio of HB-1307	11	2.19			
Incremental benefit-cost ratio	11	32.44			

Farmers' preference for demonstrated varieties

The newly released GABISA variety gave a higher yield than the standard check (HB-1307) variety. As it's not lodged, the color of the GABISA variety was preferred by farmers for both market and household consumption purposes. GABISA variety had better tillering status than that of the standard check (HB-1307), which farmers prefer. Not only based on yield and other traits that farmers preferred the GABISA variety, but also based on the farm getting income and marketability, farmers preferred the GABISA variety over the HB-1307 variety (Table 8).

Table 8. Farmers' preference for demonstrated varieties (N = 11).

	Rank	Preferred barley trait	Preference (n, [%])	Rank	
GABISA variety	1 st	Higher Yield	11(100%)	2 nd	HB-1307 variety
	1 st	Lodging status	11(100%)	2 nd	
	1 st	Marketability	11(100%)	2 nd	
	1 st	Tillering	11(100%)	2 nd	
	1 st	Seed color	11(100%)	2 nd	
	1 st	Overall rank of variety	11(100%)	2 nd	

CONCLUSIONS AND RECOMMENDATIONS

Higher yield with higher profit and farmers' preference can determine the production of food barley varieties. Demonstration of the newly released GABISA variety was conducted in the Highland districts of the Guji Zone. The result of the demonstration showed that the GABISA variety was a higher yielder than the HB-1307 variety, and with the application of recommended packages, the GABISA variety could improve further food barley production in the Highland areas; this ensures that the GABISA variety had the potential to solve barley demand in the study areas. The result of the net farm income revealed that production of the GABISA variety was profitable in the Highland areas of the

Guji zone. FRG members preferred the GABISA variety over the standard check (HB-1307) variety based on criteria like higher yield, lodging status, marketability, tillering, and seed color. Therefore, the pre-scaling up of the GABISA variety should be conducted in the Highland areas of Guji zone. Farmers of the Highland area should use the GABISA variety in their food barley production since it gives higher yield, no lodging status, and more returns.

Limitations and future research

This study only focused on demonstration of food barley at two highland districts. It should be conducted in all highland districts of Guji zone where barley production is possible. The study only focused on demonstration of barley, not on scaling up and the impact of barley on farmers' nutrition behavior, food security, and livelihood improvement. Hence, future research should focus on these limitations.

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Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of grammar and ChatGPT to assist with grammar checking, language refinement, and reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Author contributions

Conceptualization, G.A.; methodology, G.A.; validation, G.A., D.K. and B.K.; formal analysis, G.A.; investigation, G.A., D.K. and B.K.; resources, G.A.; data curation, G.A.; writing-original draft preparation, G.A.; writing-review and editing, G.A., D.K. and B.K.; visualization, G.A., D.K. and B.K.; supervision, G.A., D.K. and B.K.; project administration, G.A.; funding acquisition, G.A. All authors have read and agreed to the published version of the manuscript.

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Data availability: Data provided within the manuscript.

Clinical trial number: Not applicable.

Declarations

Ethics approval and consent to participate

Tilahun Geneti and Diriba Mengistu approved the protocol in accordance with the Oromia Agricultural Research Institute guidelines and regulations. All

farmers were asked for their informed permission before the research began. Throughout the research, participating farmers received respect and decency. This research was conducted based on farmers' interest to form Farmer Research Group (FRG) to grow barley and their willingness to provide land for barley production and farmers' willingness to share information related to yield obtained, income gained and production costs. We informed the farmers who took part in the study that the data collection from both the field and the farmers was just intended to indicate the study's completion and to share experiences for further research.

Consent for publication

The authors declare that this is the original study and it is not submitted for publication in any other journal.

Competing Interests Disclaimer

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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