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Research Article

Enhancing Farmers Maize Productivity and Profitability in Central Ethiopia: Insights from Participatory Demonstration and Evaluation of Maize Varieties

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Abstract

Despite its significance for food security and income, maize production in the Guraghe zone faces challenges like low yield and susceptibility to pests and disease. Cognizant of this fact, this study aims to determine the maize variety with optimal productivity and economic feasibility through active participation of farmer's in Abeshge district of Gurage zone and Kebena special districts. A participatory action research design was followed to demonstrate and evaluate maize technologies for two consecutive years in the study areas. A total of 124 purposively selected farmers were participated in the on-farm evaluation of the varieties. While a total of 24 demonstration has been made in both districts over the course of two years' time 2021/22-2022/23 main cropping seasons. Both quantitative and qualitative data were collected viz focus group discussion, key informant interview and formal data sheet. The analysis of collected data involved the application of descriptive statistics, including mean, median, and percentage, alongside inferential statistics like the Mann-Whitney U-test. Evaluation of demonstrated maize varieties utilized techniques such as pair-wise ranking matrix, technological gap index, and extension gap. Additionally, the economic feasibility of these varieties was assessed through partial budget analysis. BH-549 consistently outperforms BH-546 in grain yield and technological performance, with a mean grain yield advantage ranging from 4.49% to 14.6%. In addition, the Mann Whitney U-test result also reveals that BH-549 has a statistically significant (P=0.019) higher grain yield than BH-546 in 2021/22 and (P=0.026) in 2022/23. Farmers' preferences also align with BH-549, ranking it higher across various traits. Economically, BH-549 demonstrates superior profitability, highlighted by a higher Marginal Rate of Return (MRR) and MRR percentage (770), emphasizing its economic viability for smallholder farmers. As BH-549 exhibits a consistent superiority in yield, farmers preference and economic viability, the study recommends for further dissemination of BH-549 (Ilu) maize variety than BH-546 concerned bodies such as zonal and district level agriculture offices, NGO's and seed enterprises in the study areas.

Keywords

Central Ethiopia, Farmer Preferences, Maize Varieties, Participatory Demonstration, Productivity

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1. Introduction

Agriculture plays a vital role in Ethiopia's economy, contributing 37.64 percent of the national Gross Domestic Product (GDP), 80 percent of exports, and an estimated 75 percent of the country's workforce [1, 2]. The sector is predominantly marked by the prevalence of smallholder farming systems, confronting a host of challenges such as resource constraints, diminishing land sizes, declining soil fertility, and the profound influence of climate change [3]. Addressing these formidable challenges is paramount for ensuring sustainable food security and optimizing agricultural productivity. Thus, to achieve sustainable agricultural productivity growth, it is imperative to develop and disseminate improved agricultural technologies tailored to smallholder farmer's context. It involves improved seed varieties, irrigation systems and post-harvest technologies among others [4].

Maize (Zea mays L.) is one of the major staple crops in Ethiopia and serves as a crucial source of food, income, and employment for farmers. In the agricultural landscape of Ethiopia, maize stands as the primary cereal crop, excelling in terms of total production, acreage under cultivation, and the number of individual farm holdings. For instance, according to [5], it takes the second most extensively cultivated crop, following Tef, with a substantial production area covering 2.56 million hectares. Similarly, it holds a predominant position in both the Southern Nations, Nationalities, and Peoples' Region (SNNPR) and the Gurage zone, accounting for nearly 350 thousand and 32 thousand hectares of the total cultivated land in 2021, respectively [5]. It is noteworthy that amid this substantial maize cultivation, more than 30% of the total area was covered by unimproved varieties of maize seed.

Despite its significance, maize farming in the Guraghe zone has encountered persistent challenges, impeding the achievement of its full potential with productivity of around 53 quintal per hectare [6]. These challenges include low yield, susceptibility to pests and diseases, inadequate access to improved maize varieties, and suboptimal adoption of agronomic practices [7]. These factors, coupled with the effects of climate change, exacerbate the vulnerability of maize farmers and limit their ability to maximize their maize productivity. Moreover, the existing agricultural situation in Ethiopia underscores a significant gap between the yields achieved by farmers in practice and the yields observed in both on-farm and on-station trials.

According to [8], the productivity of maize in Ethiopia is 3.06 tons/ha. Which is operating below the maximum potential grain yield which ranges from 7–12 tons/ha [9]. Recognizing the importance of maize production for food security and income in the region, efforts have been made to introduce and evaluate improved maize technologies that have the potential to increase productivity and enhance farmers' profitability. Meanwhile, the introduction of improved maize varieties adaptable to local agro-ecological conditions by participating local farmers has been identified as a crucial intervention to overcome the limitations of old maize varieties and boost yields [10].

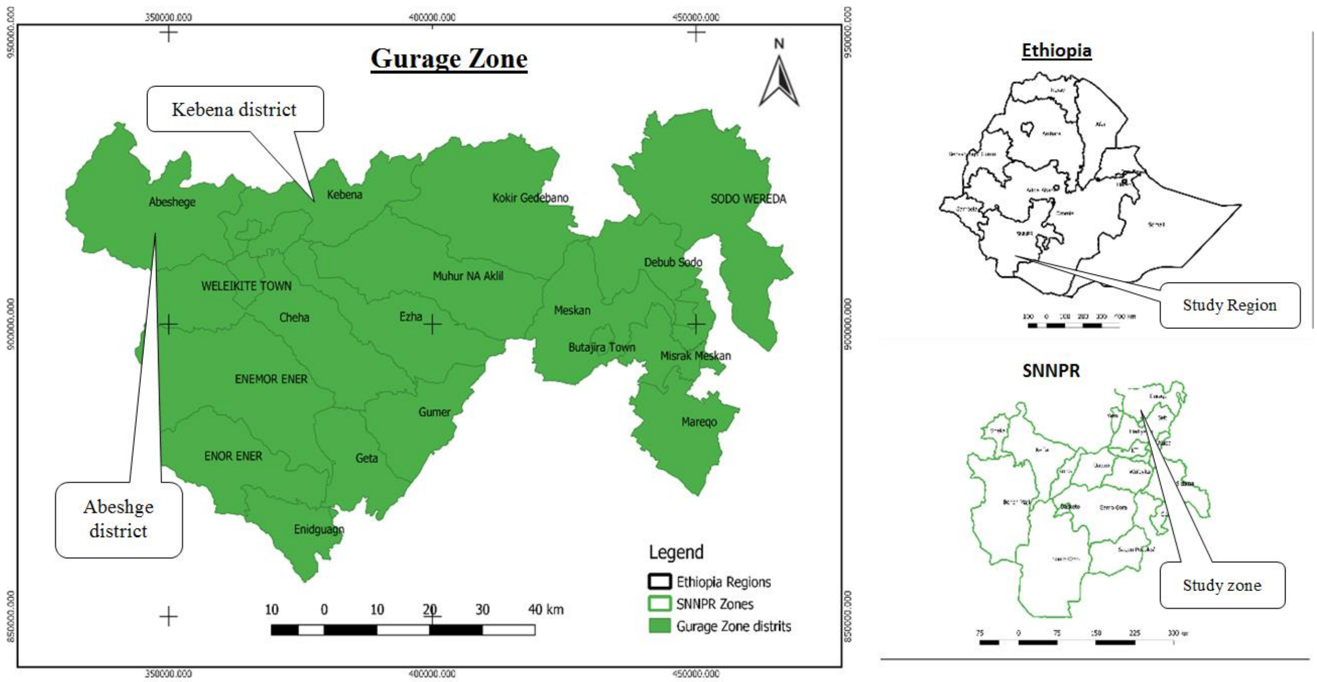
A participatory approach in crop technology evaluation and introduction can effectively be used to identify farmer-acceptable varieties and thereby overcome the constraints that cause farmers to grow old or obsolete varieties [11]. Therefore, the main aim of this study was to identify maize variety that has higher productivity and economic feasibility participating farmers to contribute valuable knowledge and practical recommendations for enhancing maize productivity and profitability in the study area. Furthermore, the findings of this study are expected to generate evidence-based insights and support decision-making in maize varietal choice and production in the study area.

2. Materials and Methods

2.1. Description of the Study Area

Abeshge and Kebena special districts are neighboring districts located in the Gurage zone of southern Ethiopia. Agriculture is the main source of livelihood for the majority of the population in both districts, with maize, Tef and beans being the major crops grown in the area. Abeshge district accounts for 44.3% of the total area cultivated for maize production in the Gurage zone while the two districts in combination occupies 53.6% of the total area of production in the zone [6]. Moreover, the mean productivity of maize in the two districts is found to be 7.25 tons/hectare. Livestock production is also an important economic activity in the area. Abeshge districts, which is located to the east of Kebena special district, predominantly characterized by mid-land. The altitude ranges from 1,500 to 3,000 meters above sea level, and the climate is generally characterized by a bimodal rainfall pattern, with the long rainy season occurring from June to September and the short rainy season from February to April. The mean annual rainfall in the area ranges from 800 to 1,200 millimeters. Kebena special district, likewise, is characterized by a mixture of mid-land areas [12].

The altitude ranges from 1,000 to 3,000 meters above sea level, and the climate is also characterized by a bimodal rainfall pattern, with the long rainy season occurring from June to September and the short rainy season from February to April. The mean annual rainfall in the area ranges from 800 to 1,200 millimeters [12]. Despite the agricultural potential of the area, the districts face several challenges, including soil erosion, low agricultural productivity, and limited access to clean water, education, and healthcare services. This study was conducted in five rural kebeles (lowest administrative units in Ethiopia) of Abeshge and Kebena special district, which are known for their large acreage of maize production in the zone.



Source: [13]: Ethio-GIS 2015

Figure 1. *Map of the study areas.*

2.2. Study Design

A farmer participatory action research design was followed conduct this study. It’s a research approach that use systematic inquiry in direct collaboration with those affected by the issue being studied for the purpose of action or change [14]. Moreover, researchers work alongside individuals or communities, fostering collective problem-solving and knowledge generation. Farmers in the study areas were actively participated in field demonstration and provide information on the different characteristics of the demonstrated maize varieties compared to local checks. The activity has been conducted for two consecutive years i.e. from 2021-2023 in the study areas. BH-549 (Ilu) variety of maize was demonstrated alongside the local check BH-546 in a single plot design with a total area of $100m^2$ for each varieties taking farmers as replication across different kebeles in the selected districts.

Table 1. *Description of maize varieties demonstrated in this study.*

Varieties’ name	Year of release	Days to maturity	Grain yield (q/ha)	
			Research field	Farmers field
BH-549 (Ilu)	2017	145	90-120	80-110
BH-546	2013	145	80-90	50-65

Source: [15]

2.3. Sampling and Data Collection Method

The study employed purposive a sampling method to select the study area and units. The activity was implemented in two maize growing districts of the Gurage zone. The districts were purposively selected based on their size of total area cultivation on maize and agro-ecological suitability for the demonstrated maize varieties. Out of the two districts, the activity was implemented in a total of seven rural kebeles over the two year period (2021-2023). Moreover, the study kebeles were also selected purposively for their agro-ecological suitability for the varieties as well as representativeness of the districts' agro-ecology. In addition, a convenience sampling method was used to select the 124 (97 male and 27 female) farmers to participate in the field evaluation of the demonstrated maize technologies through providing information. Participant farmers were selected in collaboration with Kebele level agricultural experts.

At the beginning, host farmers were also selected purposively based on their willingness to conduct the trial and accessibility of their respective farms for close follow up and monitoring. Training were given for 30 farmers, 9 experts and 18 development agents regarding maize production technologies. Varieties were evaluated using the participatory method. The demonstration was done on 16 farmers' fields; farmers as a replication using the treatment materials of improved maize variety and local one with the experimental plot size 10m*10m (100m^2) per each treatment over the course of two years.

The demonstrated maize varieties were planted on farmers' field and farmers, researchers, extension workers presented and evaluated the varieties at vegetative and maturity stage. Farmers who evaluated the trial were representative of the area and have long experience in farming. Before the beginning of the selection process, selected farmers from the villages were asked to set their selection criteria. Farmers observe the entire experimental plots by moving around one by one before they start selection. To avoid biasness, they were not allowed to discuss each other about the performance of the varieties.

2.4. Method of Data Collection

The data were collected by focus group discussion, field observation and key informant interview. Both primary and secondary data such as biological, social and economic were collected. Biological data including grain yield in kg/ha, economic data market price of output (grain), costs of inputs (fertilizer, labor, seed and chemical cost) and social data also attitudes and perception of farmers and other stakeholder's opinion. Both primary and secondary data sources were used to collect data for this study. The primary data sources were local farmers, development agents and experts. While the secondary data sources were local government report and published articles related to the topic. The collected primary data includes farmer's preference for maize varieties, traits, economic profitability and grain yield.

2.5. Method of Data Analysis

The collected quantitative data were checked for its completeness and entered into a computer program called Statistical Package for Social Science (SPSS) version. 24 for further analysis. Descriptive statistics such as mean, standard deviation, percentage, and frequency distribution were used to present the socio-demographic status. Moreover, an inferential statistic like Mann Whitney U test was used to compare median grain yield value among the varieties. Furthermore, was analyze using partial budget was used to analyze the economic data and determine the level of profitability of improved maize varieties over the local one.

The partial budget analysis method adopted from [16], is defined as:

$$NB = GB - TC \tag{1}$$

$$MB = NBIV - NBLC \tag{2}$$

$$MC = TCIV - TCLC \tag{3}$$

$$MNB = MR - MC \tag{4}$$

$$MRR = MB/MC*100\% \tag{5}$$

Where, NB= Net benefit; GB= Gross benefit; TC= Total cost; MB= Marginal benefit; MC= Marginal cost; MNB = Marginal net benefit; NBIV= net benefit of improved variety; TCIV= total cost of improved variety; TCLC= total cost of local cultivar; TR=Total revenue; MR=Marginal revenue; TVC= Total variable cost; MRR= Marginal rate of return.

On the other hand, pair wise ranking matrix was used to analyze perception of farmers towards the demonstrated maize varieties. It was used to identify the best varieties preferred by farmers using the following procedure. Thus, selection criteria were identified first, then ranking was given for each criterion and finally acceptability rank was determined. Data from both demonstrated improved maize varieties and local check underwent analysis to evaluate extension gap, technological gap, technological index, and benefit-cost ratio, following the methodology outlined by [17].

$$\text{Technology gap} = \text{Potential yield- Demonstration yield} \tag{6}$$

$$\text{Extension gap} = \text{Demonstration yield- Farmers yield} \tag{7}$$

$$\text{Yield advantage (\%)} = \frac{yield\ of\ new\ variety - yield\ of\ local\ (standard) check}{yield\ of\ local\ (standard)\ check} \text{ X } 100 \tag{8}$$

$$\text{Technological index} = \frac{Potential\ yield - \text{Demonstration}\ yield}{Potential\ yield} \tag{9}$$

3. Results and Discussion

3.1. Gender Composition of Participant Farmers

Table 2. *Gender composition of farmer's participated in evaluation of maize 2021-2023 (N=124).*

Districts	Year			
	2021/22		2022/23	
	Male	Female	Male	Female
	N (%)	N (%)	N (%)	N (%)
Abeshge	33 (44.6)	8 (10.8)	26 (52)	11 (22)
Kebena Special district	25 (33.8)	8 (10.8)	13 (26)	(0)
Total	58 (78.4)	16 (21.6)	39 (78)	11 (22)

Source: (Our own report, 2023)

The above table (Table 2) indicates a significant gender disparity in farmer participation in maize evaluation across the years 2021-2023. In the 2021/22 period, the total participation was dominated by males, accounting for 78.4% of the total, while females constituted only 21.6%. In the subsequent year, 2022/23, Abeshge experienced a shift with 26 males (52%) and 11 females (22%), while Kebena Special district the combined figures for 2022/23 reveal 39 males (78%) and 11 females (22%). The data suggests a notable male predominance, particularly in Abeshge. However, a positive trend is observed with an increase in female participation from 2021/22 to 2022/23 emphasizing the importance of gender-inclusive strategies in agricultural research and extension efforts.

3.2. Maize Varietal Performance and Technological Analysis in the Districts

The table below provides a comprehensive overview of the performance of maize varieties BH-549 (Ilu) and BH-546 (check) across two consecutive years, 2021/22 and 2022/23, in the study areas. Although there are fluctuations in grain yield, BH-549 demonstrates a consistent mean yield advantage over BH-546 with the highest and lowest mean grain yield advantage of 14.6% and 4.49% respectively (Table 3). This suggests that BH-549 outperforms BH-546 on average grain yield, showcasing its potential for higher grain yield in the study areas. The technology gap index reveal valuable insights into the efficiency of agricultural technology adoption. As also depicted in table 3 the highest technological gap index of BH-549 and BH-546 is found to be 23.7% and 23.6%. Moreover, the lowest technological gap index of BH-549 and BH-546 is found to be 22.47% and 9.4% (Table 3). A low technology gap index signify that farmers are performing above the mean, while a high index implies room for improvement in maize technology adoption.

The extension gap showed decreasing trends in each consecutive year of study, during demonstration years an average extension gap of -15.12 and 14.8 for BH-549 and BH-546 respectively (Table 3). It emphasizes there might be improvement in terms of educating the farmers through various means for adoption of improved maize production technologies to reverse the trend. A negative extension gap indicates that farmers are surpassing expected performance, while a positive gap suggests areas for improvement. This findings of the study relate with the idea and results of [18, 19]. The district-wise analysis showcases variations in performance between Abeshge and Kebena special district, a relatively higher yield was recorded from demonstrations in Abeshge district.

Table 3. *Technological analysis and performance of maize varieties in the study areas (N=24).*

Year	Districts	Variety name	Grain yield (t/ha) Mean ±SD	Mean yield advantage (%)	Mean Technology gap (t/ha)	Technology gap index	Extension gap
2021/22	Abeshge	BH-549 (Ilu)	8.46±1.66	4.49	2.45	0.23	-14.5
		BH-546 (check)	7.7±2.40		0.8	0.09	19.5
	Kebena	BH-549 (Ilu)	7.75±1.37	10.9	2.7	0.26	-17.5
		BH-546 (check)	6.99±1.90		2.0	0.23	12.4
2022/23	Abeshge	BH-549 (Ilu)	8.14±9.83	14.6	2.36	0.22	-13.6

Year	Districts	Variety name	Grain yield (t/ha) Mean ± SD	Mean yield advantage (%)	Mean Technology gap (t/ha)	Technology gap index	Extension gap
		BH-546 (check)	7.13 ±8.41		1.39	0.16	13.8
	Kebena	BH-549 (Ilu)	8.01 ±7.21	12.8	2.5	0.24	-14.9
		BH-546 (check)	7.1 ±9.40		14	0.16	13.5

Source: (Our own computation, 2023)

3.3. Grain Yield Comparison Among the Demonstrated Maize Varieties

A Shapiro-Wilk test for normality has been done and it revealed that there is a significant deviation from normal distribution with (p = 0.033). This implies the inappropriateness of parametric tests, necessitating consideration of non-parametric alternatives. The table below offers analysis of grain yield for two maize varieties, BH-546 and BH-546, over the course of two successive years, 2021/22 and 2022/23. In the initial year, BH-549 displayed a notably higher median (78.8) and mean rank of 15.88 compared to BH-546's median (72.2) and mean rank of 9.13, as evidenced by the Mann-Whitney U-test statistics with a U-value of 31.50 and a Z-value of -2.341, indicating a statistically significant difference (p = 0.019*) (Table 4). The Cohen's d effect size, calculated at 0.53, further emphasizes a moderate effect. In the subsequent year, 2022/23, a parallel trend was observed, with BH-549 maintaining a higher mean rank of 15.71 compared to BH-546's mean rank of 9.29 (Table 4). The Mann-Whitney U-test statistics continued to demonstrate a significant difference, with a U-value of 33.5, a Z-value of -2.224, and a p-value of 0.026 (Table 4). The consistent Cohen's d effect size of 0.53 reaffirms the moderate effect observed. These results underscore a substantial and consistent difference in grain yield between BH-549 and BH-546, favoring the earlier. The finding of the present study is in line with the findings of [20, 11].

Table 4. Comparative analysis of demonstrated maize varieties' mean grain yields (N=24).

Year	Variable	Maize varieties	N	Mean rank	Sum of rank	Mann-Whitney U-test			Cohen's d
						U	Z	P	
2021/22	Grain yield	BH-549 (Ilu)	24	15.88	190.50	31.50	-2.341	0.019*	0.53
		BH-546 (check)	24	9.13	109.50				
2022/23	Grain yield	BH-549 (Ilu)	24	15.71	188.50	33.5	-2.224	0.026*	0.53
		BH-546 (check)	24	9.29	111.50				

Source: (Our own computation, 2023)
Note: * and ** are significant association at P≤0.05 and P<0.01 respectively; the data are presented as median and compared using an Mann-Whitney U-test

3.4. Maize Variety Selection Traits Preference of Farmers in the Districts

The above diagram depicts farmer's maize variety selection criteria's that are pertinent to farmers in the study area. As it's presented in Figure 2 maize grain yield 32(25.8%), disease resistance 19 (15.3%) and cob husk cover 19 (15.3%) were found to be the main traits for selecting maize varsities in the study area. On the other hand, the trait lodging tolerance 8 (6.45%) was the least trait identified by the study participant farmers for selecting maize varieties (Figure 2).

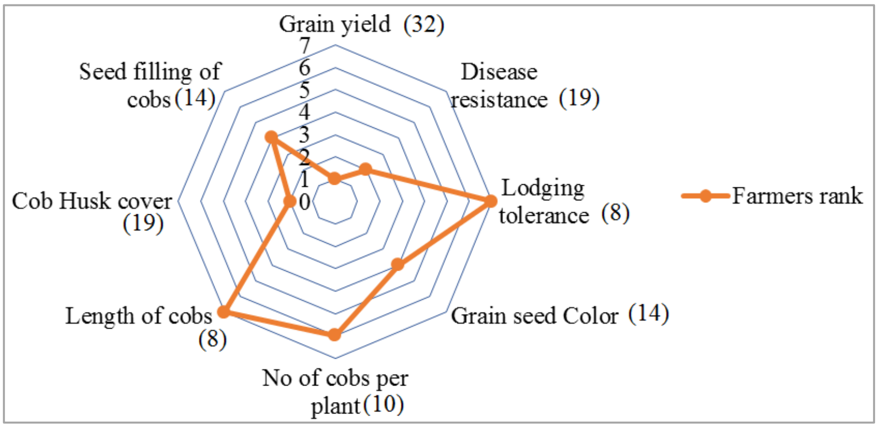


Figure 2. *Farmer's maize varietal trait preference in the districts (N=124).*

Source: (Our own report, 2023)
Note: numbers under braket represents the total number of farmers selected that specific trait

3.5. Ranking of Maize Varieties Based on Farmers Selection Criteria's

Table 5. *Direct matrix ranking of maize varieties in the selection criteria (N=124).*

Farmers selection criteria's	Weight	Varieties name	
		BH-549 (Ilu)	BH-546 (check)
Grain yield	0.258	1 (0.258)	2 (0.258)
Disease resistance	0.153	2 (0.153)	2 (0.153)
Lodging tolerance	0.064	1 (0.064)	1 (0.064)
Grain seed Color	0.112	1(0.112)	1(0.112)
No of cobs per plant	0.084	1 (0.084)	2 (0.084)
Length of cobs	0.064	1 (0.064)	1 (0.064)
Cob Husk cover	0.153	1 (0.153)	1 (0.153)
Seed filling of cobs	0.112	1 (0.112)	1 (0.112)
Total score	1	1.153	1.491
Rank		1	2

Source: (Our own report, 2023)
Note: farmers evaluate the demonstrated maize varieties based on their preferred trait using the rate 1-5; (1= very good; 2= good; 3 = moderate; 4 =poor and 5=very poor). numbers under braket represents the weight given for each criteria's by participant farmers during on farm evaluation of the varieties.

The presented table outlines the outcomes of a direct matrix ranking exercise conducted with 124 farmers, evaluating selection criteria for two maize varieties, BH-549 (Ilu) and BH-546 (check). Different weights assigned to various criteria, encompassing grain yield, disease resistance, lodging tolerance, grain seed color, number of cobs per plant, length of cobs, cob husk cover, and seed filling of cobs. Grain yield emerges as the most pivotal criterion, holding the highest weight at 25.81%, signifying its paramount importance in farmers' decision-making processes of maize variety preference. The rankings reveal a consistent preference for BH-549 across all criteria, positioning it as the top-ranked variety. The total score consolidates the weighted performance, resulting in a total score of 1.153 for BH-549 and 1.491 for

BH-546, culminating in BH-549 being ranked first and BH-546 second. The lower the rank index the variety was desirable by farmers. The finding of the present study is in line with the findings of [11]. This result is also further supported by an idea from key informant interviewee that states "Ilu has a vigorous standing and the roots are strongly attached with the soil, the husk doesn't open and fully covered the *cob*"

Figure 3. *During On-farm evaluation and performance of the demonstrated varieties.*

3.6. Economical Profitability of the Technologies

3.6.1. Partial Budget Analysis of Maize in the Study District

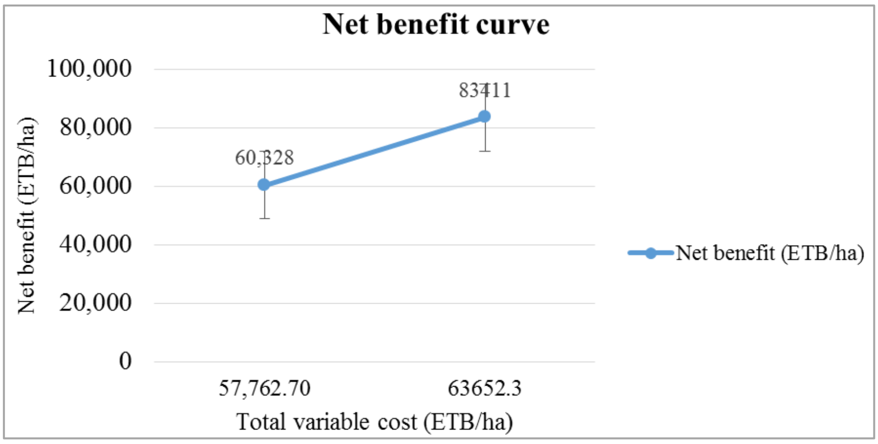
The partial budget analysis for maize production in the study district during the 2022/23 agricultural year reveals insightful economic metrics, with a particular focus on the Marginal Rate of Return (MRR) and MRR percentage. BH-546 (check) and BH-549 (Ilu) exhibit distinct economic performances, wherein BH-549 stands out with MRR of 7.70 (Table 6). This high MRR percentage underlines the economic viability and profitability of BH-549 in comparison to BH-546. The MRR of BH-549 is also found to be greater that the Acceptable Minimum Rate of Return (AMRR) which is 180%. Therefore, we recommend the production of BH-549 maize variety than otherwise in the study areas for optimum economic gain from maize production.

Table 6. *Partial budget analysis for maize in the study district in 2022/23.*

Parameter (ETB/ha)	BH-546 (check) (ETB/ha)	BH-549 (Ilu) (ETB/ha)
Gross benefit	161,415	182,740
Total variable cost	57,762.7	60,328
Total cost	97,762.7	100,328
Net benefit	63,652.3	83,411
Marginal net benefit	-	19768.7
Marginal cost	-	2565.3
Marginal rate of return		7.70
MRR%		770

Source: (Our own report, 2023)

3.6.2. Net Benefit Curve of the Maize Varieties in the Study Area



Source: (Our own computation, 2023)

Figure 4. *Net benefit curve of maize varieties.*

4. Conclusion and Recommendation

The study sheds light on critical aspects of maize technology promotion and varietal preferences among smallholder farmers in Abeshge district (Gurage zone) and Kebena special districts of Central Ethiopia region. Maize varieties BH-549 (Ilu) and BH-546 were evaluated over two consecutive years, revealing BH-549's consistent superiority in terms of grain yield and technological performance. The findings highlight a mean yield advantage of BH-549 over BH-546, ranging from 4.49% to 14.6%, indicating the consistent performance of BH-549 across both years. Furthermore, farmers participated in the evaluation reported a strong preference for BH-549, ranking it higher across various selection criterias. Particularly, 25.8% of farmers prioritized grain yield, 15.3% emphasized disease resistance, and 15.3% considered cob husk cover as crucial traits in maize variety selection. Moreover, the direct matrix ranking evaluation with 124 farmers further solidified BH-549's position as the preferred variety, outperforming BH-546 across all criteria and securing the top rank with a total score of 1.153 compared to BH-546's 1.491. Economically, the partial budget analysis underscores the superior profitability of BH-549 over BH-546, as evidenced by a higher Marginal Rate of Return (MRR) and MRR percentage. BH-549's MRR of 7.70 and a MRR percentage of 770% surpass the AMRR, reinforcing its potential for enhanced economic gains in maize production. Therefore, promoting the widespread promotion of BH-549 (Ilu) among farmers in the study area is recommended.

Abbreviations

AMRR	Acceptable Minimum Rate of Return
CSA	Central Statistics Agency
ETB	Ethiopian Birr
GDP	Gross Domestic Product
GZAO	Gurage Zone Agriculture Office
MRR	Marginal Rate of Return
PAR	Participatory Action Research
SPSS	Statistical Package for Social Science
SNNPR	Southern Nations, Nationalities, and Peoples' Region

Ethical Approval and Consent to Participate

Although no ethical approval was obtained, each participants were aware of the aim of the study and gave their consent to participate before starting the study.

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Author Contributions

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

Dirshaye Hailu: Data curation, Investigation, Project administration, Supervision, Validation, Writing – review & editing

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Data Availability Statement

The datasets used and/or analyzed during the current study will be available from the corresponding author on reasonable request.

Conflicts of Interests

The authors declare no conflicts of interest.

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