Participatory Variety Selection of Improved Mid-land Maize hybrids in the Gurage Zone, Ethiopia

Mohammed Hassen[1*], Mesfin Hailemariam Habtegebriel[1,2], Fetta Negash Gerura[1], Takele Zike[1], Tesfahun Fikre[1], Beyene Abebe[3] and Teshome Bekele

[1]Ethiopian Institute of Agricultural Research (EIAR), Wolkite Agricultural Research Center (WkARC), P.O. Box: 2003, Addis Ababa, Ethiopia; [2]Department of Microbial, Cellular and Molecular Biology, Addis Ababa University, Addis Ababa, Ethiopia; [3]Ethiopian Institute of Agricultural Research (EIAR), Bako Agricultural Research Center (BkARC), P.O. Box: 2003, Addis Ababa, Ethiopia

***Corresponding author: Mohammed Hassen:** mohahaff1438@gmail.com*

Abstract

Maize is a priority crop for farmers because of its reliable source for food and feed in many rural communities of the southern region of Ethiopia, particularly the Gurage zone. However, farmers in the area are still growing low yielding and obsolete maize hybrids. According to previous survey reports, farmers of the area have not been benefiting from recent maize improvement efforts. The objective of the study was to identify high yielding and adaptable maize hybrids through participatory variety selection (PVS) there by accelerating the replacement of obsolete hybrids with farmers-prefered newly released varieties. In this study, farmers in two woredas of the Gurage zone, Abeshge (Fitejeju and Wolkite on-station) and Misrak Meskan (Batilejano and Enseno-Ousmae), evaluated three newly released and one old hybrid varieties under four rainfed environments. The hybrids included for this study were obtained from the Bako National Maize Research Program, which considered the three hybrids (BH549, BH547 and BH546) as recent releases while BH540 as old hybrid check widely grown in the area. Combined analysis of variance (ANOVA) showed that the hybrids differed significantly ($p<0.01$) for all agronomic traits considered in this study. The highest mean yield was obtained from BH549 (8901.2 kg ha^{-1}) followed by BH546 (8560.7 kg ha^{-1}), while BH540 (6250.0 kg ha^{-1}) produced the lowest mean grain yield. Ranking was also used to identify the best hybrid(s) preferred by farmers. Accordingly, farmers identified the high-yielding maize hybrids (BH549 and BH546) that had good ranks from the participatory variety selection based on their selection criteria which is in harmony with the researchers' results. In conclusion, BH549 and BH546 hybrids were found superior and could be considered for extensive production in the tested areas as well as similar other agro-ecologies. It was also noted that farmers' preferences viz., yielding ability, husk cover, numer of seeds per cob and resistance to lodging need to be incorporated in maize breeding programs .

Keywords: Maize, Participatory, Productivity, Selection, Variety

Introduction

Maize (*Zea mays* L.) is the world's leading cereal in terms of production and is a versatile crop primarily used as a feed globally, but also important as a food crop, especially in sub-Saharan Africa and Latin America, besides other non-food uses (Erenstein *et al*., 2022). In Ethiopia cereals account for about 80% of the annual crop production and maize is the first in total production and yield per unit area and second in area coverage among all the cereals (ISSA, 2009; CSA, 2020/21; Wasihun and Desu, 2021). In addition, having the highest volume of total annual production and per hectare yield, maize recently emerged as the single most important food crop in Ethiopia in terms of the number of farmers engaged in cultivation (Geffersa *et al*., 2022). Maize became increasingly important in the food security of Ethiopia following the major drought and famine that occurred in 1984 (Tsedeke *et al*., 2015). Maize production in Ethiopia has been steadily increasing for more than four decades, but it declined in 2018 and 2019 and began increasing from 2020 (FAOSTAT, 2022; Wasihun and Desu, 2021). The decrease in production accounted to a number of factors including lack of high yielding maize hybrids, poor agronomic management, moisture stress, lack of complementary modern inputs, market imperfections as well as economic and management constraints, limited access to advanced technologies, planting density and pests (Tsedeke *et al*., 2017; Olasehinde *et al*., 2023; Sheahan *et al*., 2017 and Van Dijk *et al*., 2020). Ethiopia is a country having a highest population growth with the current population size of 116.5 million inhabitants that makes seconed most populous next to Nigeria in the Sub Saharan Africa which calls for development of high-yielding maize hybrids to feed the fast-growing global population and abrupt global climate change.

In Southern Nations Nationalities and Peoples Region (SNNPR) of Ethiopia, maize is the principal crop both in terms of productivity and production (CSA, 2020/21). Because it is a reliable source of food and feed in many rural communities in the region, the crop is a priority for the farmers. It is extensively cultivated throughout the region, from the lowlands to the mid-highlands. Thus, testing of newly released varieties has paramount importance prior to large-scale production (Loha, 2018; Simion *et al*., 2019).

The national maize breeding program in Ethiopia is framed in four major agro ecological zones including mid-altitude sub-humid, highland sub-humid, low-land sub-humid and low moisture agro ecologies characterized by contrasts in elevation, precipitation, temperature and relative humidity (Marenya *et al*., 2022).

Although the current maize hybrids' productivity falls of their potential, farmers are forced to pay inflated prices to purchase hybrid seeds from private seed companies. Gurage zone is one of the most top potential maize producer in SNNPR of Ethiopia (CSA, 2020/21). According to Dendir and Simane (2019), more than 60% of Gurage zone area is midland which is suitable for maize production, particularly, Abeshge, Misrak Meskan, Mareko and Sodo can be mentioned among the top maize-growing woredas (administrative unit equivalent to district). However, the released maize hybrids from public research institutes are blamed by the local farmers for their lower yield compared with hybrids of private seed companies.

According to Tadesse *et al*. (2018), maize varietal selections in Ethiopia have usually been dominantly based on grain yield. Large numbers of experimental lines and hybrids have been developed at various research centers and their performances evaluated across multi-location tests over several years for stability (Lalise *et al*., 2016). This approach, where only researchers involved on varietal evaluation and release, didn't lead to the development of quality hybrids with farmers required traits that hasten the adoption process. Meanwhile, a participatory variety selection is a strategy that gives farmers a wide range of varietal options to evaluate in their particular location. It improves farmers' access to alternative crop varieties, boosts output and speeds up the adoption of newly released varieties (Simon, 2019). It also enables cost-effective and timely varietal selection in specified locations (Loha, 2018).

Having a complex nature of agricultural research, it demands a coordinated effort among biological and social scientists for technology generation. Furthermore, it requires engagement of other stakeholders including extension agents, farmers, NGOs, farmers' cooperatives and seed enterprises to ensure appropriate technology is promoted. Recent findings have shown that Ethiopian farmers require multiple traits for their crop such as maize (Tadesse *et al*., 2018). In Ethiopia, efforts have been made to develop and popularize improved maize hybrids through Participatory Variety Selection (PVS) to ensure new released maize hybrids meet end user preferences because social and economic factors drive variety choices (Tadesse *et al*., 2018; Simon, 2019; Loha, 2018; Marenya *et al*., 2022). However, the farmers' selection criteria for improved varieties are not adequately assessed and well documented especially in Gurage zone (Bethel *et al*., 2020). Therefore, to improve maize production and productivity in the area, it's important to evaluate newly released midland maize hybrids for their adaptability and crop preferences with the participation of farmers of Gurage. The objective of the study were (1) to evaluate and recommend improved maize hybrids in the context of study area, (2) to identify farmers' criteria in selecting maize hybrids and (3) to assess socio-economic feasibility of the improved maize hybrids in the area.

Materials and Methods

Desription of the study area

Four maize growing locations in Gurage zone of SNNPR of Ethiopia were used for the study during the 2020/21 main cropping season. Abeshge, Misrak Meskan, Mareko and Sodo Woredas are among the top in terms of area coverage in maize production that cover nearly 80% of the zonal area coverage the rest 11 woredas cover 20% (GZANRD, 2020). For instance, in 2019/20 main cropping season, Abeshge Woreda alone takes the lion's share with area coverage of more than 44% of the total area covered by maize in the Gurage zone (Bethel *et al.*, 2020). The study locations fall in maize agro ecological frame of mid-altitude sub-humid category. The four locations included in the area described in Table 1 and Figure 1.

Table 1. Description of the experimental locations

Woreda	Kebele	Altitude (masl)	Coordinates
Misrak Meskan	Bati Lejano	1827	08^{0}102520 N , 38047639' E
Misrak Meskan	Enseno-Ousmae	1843	08^{0}4'20.46''N, 38^{0}28'13.15''E
Abeshge	Fite Jeju	1549	08^{0}322770 N , 37^{0}59290' E
Abeshge	Tatesa (WkARC)	1885	08^{0}17'06.75''N, 37^{0}50'49.54''E

masl = meters above seal level

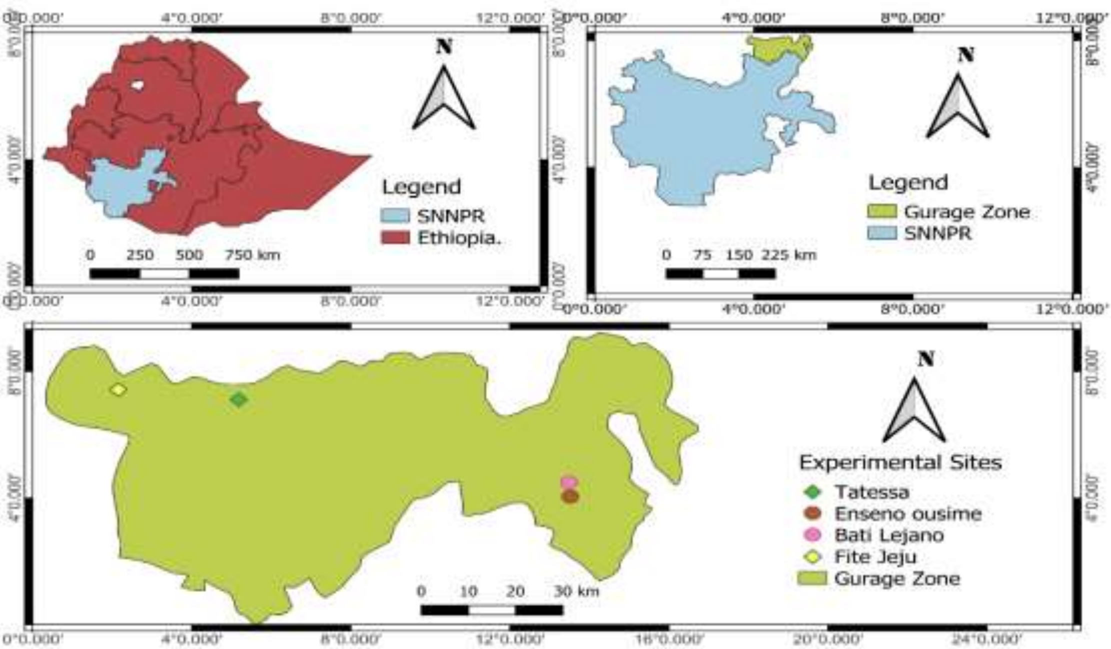

Figure 1. Map of the study area

Experimental materials, design and procedures

The experiment was set up in Randomized Complete Block Design (RCBD) with three replications. Following the agro ecological zone of the study area, maize hybrids suited to the selected agro ecologies were included in the study. Accordingly, four maize hybrids, namely: BH549, BH546, BH547 and BH540 were used in the trial. Out of these, three hybrids, *viz*., BH549, BH546, BH547 were released after 2013, whereas hybrid BH540 was old and used as a check (Table 2). The plot consisted of five rows with three harvestable rows having an area of 9 m^2 (2.25 m x 4 m) with 75 cm inter row spacing and 25 cm between plants. At planting, 121 kg ha^{-1} NPS and 100 kg ha^{-1} urea splitted 1/3 at planting and 2/3 at knee stage after weeding were applied. All other agronomic practices were performed in accordance with the recommended maize production package (Tesfaye *et al*., 2019).

The PVS trials were conducted in Misrak Meskan Woreda (Bati Lejano and Enseno-Ousmae kebeles, the smallest administrative unit), and Abeshge Woreda (Fitejeju kebele and Tatesa (WkARCOn station). Farmers evaluated the trials at maturity stages of the crop.

Table 2. Description of the experimental materials

Variety	Year of release	Altitude Range (masl)	Rain Fall (mm)	Yield on-station (Kg ha^{-1})
BH549	2017	1000-2000	1000-1200	Up to 12000
BH547	2013	1000-2000	1000-1200	8500-11500
BH546	2013	1000-2000	1000-1200	8500-11500
BH540 (Check)	1995	1000-2000	1000-1200	8000-9000

Source: Bako ARC

Data collection

All pertinent agronomic data such as grain yield, cob number, husk cover and plant height were taken from the three harvestable central rows by taking five random plants from each plot. Farmers' preference data *viz*., number of row per cob, number of seed per cob, lodging resistance, plant height, cob length, cob thickness and grain yield were collected using focus group discussion. The individual farmers selected purposively in consultation with local development agents based on their experience and knowledge on maize production in the locality. The perception data incorporates farmers' views and attitudes towards the tested hybrids. At physiological maturity, farmers from the three locations were invited to attend a field day. Maize cobs from the central rows of each plot were dehulled to allow farmers to evaluate hybrids based on cob and other crop parameters. They were then asked to justify their choice. Farmers' listed traits were considered field-based selection criteria. A total of 87 farmers (59 from Abeshge and 28 from Misrak Meskan Woredas and 11 development agents (DAs) nine from Abeshge and two from Misrak Meskan were participated during the on-farm evaluation. Farmers had given ranks to each hybrid with the respective parameters.

Grain yield of maize harvested from each plot was shelled, weighed, and the kernel moisture content (MC) was determined. The estimation of grain yield (kg ha^{-1}) at 12.5% MC was carried using the formula:

$$\text{Grain Yield (Kg ha}^{-1}) = \frac{GW(100-MC)}{87.5} x \frac{(10000)}{3.4X0.75X2}$$

Where, GW = the grain weight in kilograms of all ears harvested and MC = the grain moisture content after shelling (Owusu et al. 2021). According to Aslam *et al.*, (2022), % change was calculated for all the genotypes under each treatment by the following formula:

$$\%\ \text{Change for genotype} = \frac{\text{Mean of a treatment} - \text{Mean of control}}{\text{Mean of control}} x100$$

Data analysis

The data collected for quantitative traits were subjected to analysis of variance (ANOVA) using the R statistical software version 4.1.0 (R Core Team, 2017). Mean values were compared with LSD test at $P < 0.05$. To create a graphical representation of which hybrids were best suited to the testing location and agro ecology, Genstat software 18th version (VSN, 2015) was used. Direct matrix and pair wise ranking was applied to analyze perception of farmers towards maize hybrids. Moreover, partial budget analysis was carried out to compare the economic feasibility of the hybrids.

Results and Discussion

Agronomic traits of the maize hybrids

ANOVA revealed that the maize hybrids were significantly different (p<0.01) for all agronomic traits (Table 3). The hybrid BH549 (8901.2 kg ha^{-1}) produced the highest grain yield followed by BH546 (8560.7 kg ha^{-1}) and BH547 (7342.5 kg ha^{-1}). BH540 scored the lowest grain yield (6250.0 kg ha^{-1}). Hybirds BH549, BH546 and BH547 also scored the highest number of seeds per cob and cob length; whereas BH540 was the least (Table 3 and 4). Simmilar results were reported in the findings of perivious research observations that showed significant variations on plant height (Sharma *et* *al*., 2008; Simion *et al*., 2019), days to flower (Sharma *et al*., 2008), ear height (Sharma *et al*., 2008; Simion *et al*., 2019), grain yield (Sharma *et al*., 2008; Simion *et al*., 2019), cob length (Simion *et al*., 2019).

Table 3. Analysis of variance for yield and it's related traits of the maize hybrids over locations

Source of varataions	df	Mean Square			
		NSC	CL (cm)	PLH (cm)	YLD (Kg ha^{-1})
Genotype (G)	3	24909.6*	33.481**	5778.5***	14108140***
Environment (E)	3	400.2ns	11.338ns	1059.6**	1512534ns
Genotype x Environment (GEI)	9	9859	3.261	48.4	1502514
Env (REP)	8	4445.1	6.766	103.3	2178133
Residuals	24	5691.5	4.553	219	1646224
CV(%)		14.56	10.83	6.57	16.11
Grand Mean		517.94	19.70	225.34	7963.61

Where, df = degrees of freedom, PLH = plant height, CL = Cob length, NSC = Number of seeds per cob, YLD = yield, Loc = location, Rep = replication, Var = variety, CV(%)= coeffiecent of variation, * = Significant at P=0.05, ** = Significant at P=0.01, Rep=replication

Analysis of variance for locations revealed no significant difference for all the studied agronomic traits except plant height (Table 3). ANOVA also showed that non-significant variety by location interaction for all studied agronomic traits. These results differ from Simion *et al*. (2019), Anley *et al*. (2013) who detected significant variation due to environment and genotype by environment interaction.

Table 4. Combined mean of plant height, cob length, number of seed per cob and grain yield

Varieties	Plant height (cm)	Cob length (cm)	Number of seeds per cob	Yield (Kg ha^{-1})
BH540	200.5^{c}	16.3^{b}	441^{c}	6250.0^{c}
BH546	213.6^{b}	20.7^{a}	565^{a}	8560.7^{a}
BH547	242.7^{a}	19.9^{a}	507^{ab}	7342.5^{b}
BH549	245.5^{a}	20.9^{a}	540^{a}	8901.2^{a}
LSD (0.05)	12.5	1.8	63.6	1081.1

Where, Kg ha-1= kilo gram per hectar, LSD= least significant difference and cm=centi meter

As depicted from Tables 4 and Fig. 2, most of the traits showed a wide range of variability. Therefore, the presence of such a range of variations in the traits indicate the presence of genetic variation among the hybrids for the measured traits of interest.

Comparative yield advantages among varieties

As shown in Table 5, BH549 scored 4, 18 and 30 % yield advantages over maize hybrids BH546, BH547 and BH540, respectively. BH546, on the other hand, outperformed the other hybrids BH547 (14%) and BH540 (27%). Whereas BH547 had a yield advantage of 15 % over the check hybrid of BH540 (Table 5). Similarly, improved maize hybrids scored 38.7% (Olasehinde *et al.*, 2023) and 38.9% (Simion *et al.*, 2019) yield advantages over traditional varieties.

Table 5. Percentage yield advantage among tested hybrids

S/R	Yield (kg ha^{-1})	Yield advantages over the rest hybrids		
BH549	8901.2	4% (BH546)	18% (BH547)	30% (BH540)
BH546	8560.7	14% (BH547)	27% (BH540)	BH546
BH547	7342.5	15% (BH540)	BH547	
BH540	6250.0	BH540		

GGE biplots

The GGE biplot approach used in this study could help breeders to better decide what genotypes should be promoted: the visual combined assessment of performance and stability is a big advantage, and adds confidence in the decision to promote a superior genotype (Sharma *et al.*, 2008). The multivariate analysis in graphical visualization over location revealed BH546 and BH549 scored the highiest grain yield over the others, while BH540 scored the lowest (Fig.2). BH549 performed best at Bati Lejano, Enseno-Ousmae and Tatesa (WkARC onstation); while BH546 was best at Fitejeju (Fig. 2).

Combined mean yield of hybrids tested over location

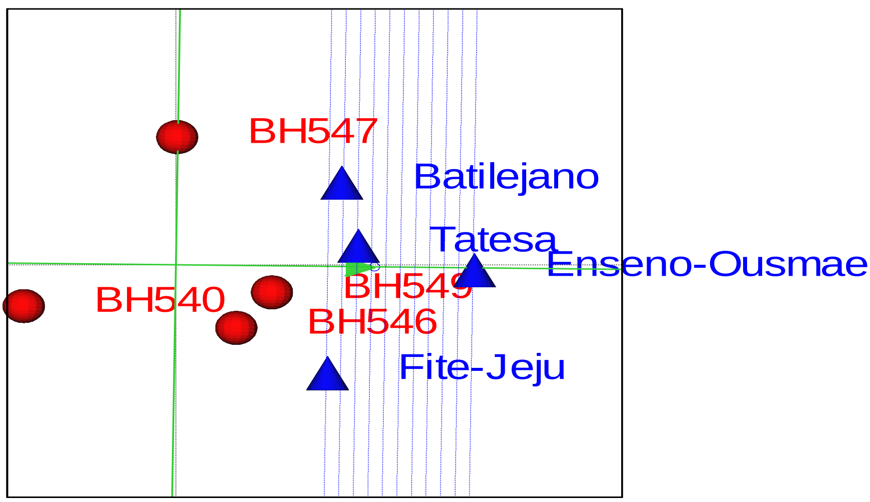

Figure 2. Adaptability of the hybrids over the tested locations

Farmers Participatory Evaluation

A regular stability analysis often does not provide relative ranking of superior entries in reference to an ideal genotype that results in making a subjective judgment in selecting a cultivar (Sharma *et al*., 2008). Farmers from the three locations set their priority selection criteria *viz*., husk cover, expected grain yield, number of rows per cob, number of seeds per row, cob length and thickness, lodging resistance and plant height (Table 6 to 11).

In the Enseno-Ousmae Kebele of Misrak Meskan Woreda, farmers prioritized number of seeds per cob, expected yield and lodging resistance; while, plant height and cob thickness received low priority (Table 6 and 9). Farmers of Batilejano Kebele gave priority to husk cover, number of rows per cob, lodging resistance and cob length (Table 7 and 10). In Fitejeju kebele of Abeshge Woreda, farmers prioritized husk cover, expected yield and number of seeds per cob; while, plant height and cob thickness ranked as lowest priority (Table 8 and 11). Comparison of the findings with those of other studies relatively confirms farmers' selection criteria with the number of cobs per plant, cob length, husk tip coverage, cob length and lodging tolerance as variety selection criteria (Chakle *et al*., 2022) and also a husk cover, cob number per plant, cob length, ear height, disease tolerance, and yield (Melkamu Elmyhun and Molla Mekonnen, 2016). On the other hand taste, long cobs, and big kernels, prolificacy, early maturity, retainability of seed and dark leaves (Chimonyo *et al*., 2019).

Table 6. Pair-wise ranking matrix of farmers' evaluation of maize hybrids at Misrak Meskan Woreda Enseno-Ousmae Kebele in 2020/21 main cropping season

Selection criteria	A	B	C	D	E	F	G	H	Score	Rank
Expected Yield (A)		A	A	D	A	A	A	A	6	1st
Husk cover (B)			B	D	E	B	B	B	4	4th
Number of rows per cob (C)				D	E	F	C	C	2	5th
Number of seeds per cob (D)					E	D	D	D	6	1st
Lodging resistance (E)						E	E	E	6	1st
Plant height (F)							G	H	1	7th
Cob length (G)								G	2	5th
Cob thickness (H)									1	7th

Table 7. Pair-wise ranking matrix of farmers' evaluation of maize hybrids at Misrak Meskan Woreda Batilejano Kebele in 2020/21 main cropping season

Selection criteria	A	B	C	D	E	F	G	H	Score	Rank
Expected Yield (A)		A	A	A	A	A	A	A	7	1st
Husk cover (B)			B	D	E	B	B	B	4	4th
Number of row per cob (C)				D	C	C	G	C	3	5th
Number of seed per cob (D)					E	D	D	D	5	2nd
Lodging resistance (E)						E	E	E	5	2nd
Plant height (F)							F	H	1	7th

Cob length (G)		G	2	6th
Cob thickness (H)			1	7th

Table 8. Pair-wise ranking matrix of farmers' evaluation of maize hybrids at Abeshge Woreda Fitejeju Kebele in 2020/21 main cropping season

Selection criteria	A	B	C	D	E	F	G	H	Score	Rank
Expected Yield (A)		A	A	D	A	A	A	A	6	2nd
Husk cover (B)			B	D	B	B	B	B	5	3rd
Number of rows per cob (C)				D	C	C	C	C	4	4th
Number of seeds per cob (D)					D	D	D	D	7	1st
Lodging resistance (E)						E	E	E	3	5th
Plant height (F)							F	H	1	6th
Cob length (G)								G	1	6th
Cob thickness (H)									1	6th

Table 9. Direct matrix ranking of the tested hybrids based on farmers' selection criteria at Misrak Meskan Woreda Enseno-Ousmae Kebele in 2020/21 main cropping season

Farmers' selection criteria	Weight	Maize Hybrid			
		BH540	BH546	BH547	BH549
Expected Yield	6	2(12)	5(30)	4(24)	5(30)
Husk cover	4	1(4)	5(20)	5(20)	5(20)
Number of row per cob	2	2(4)	4(8)	4(8)	5(10)
Number of seed per cob	6	2(12)	4(24)	4(24)	4(24)
Lodging resistance	6	1(6)	5(30)	4(24)	5(30)
Plant height	1	2(2)	5(5)	4(4)	5(5)
Cob length	2	2(4)	4(8)	4(8)	5(10)
Cob Thickness	1	3(3)	4(4)	4(4)	4(4)
Total		47	129	116	133
Average		5.9	16.1	14.5	16.6
Rank		4	2	3	1

Figures under columns of each tested maize hybrids are mean scores given by farmers to each hybrid with each evaluation criteria; (1= very good; 2= good; 3 = moderate; 4 =poor and 5=very poor). Numbers in the bracket are the product of the weight and rank given for each hybrids and traits.

Table 10. Direct matrix ranking of the hybrids based on farmers selection criteria at Misrak Meskan Woreda at Batilejano Kebele in2020/ 21 main cropping season

Farmers' selection criteria	Weight	Maize hybrids			
		BH540	BH546	BH547	BH549
Expected Yield	7	1(7)	3(21)	4(28)	5(35)
Husk cover	4	1(4)	5(20)	5(20)	5(20)
Number of row per cob	3	2(6)	3(9)	4(12)	5(15)
Number of seed per cob	5	1(5)	4(20)	4(20)	4(20)
Lodging resistance	5	1(5)	4(20)	4(20)	5(25)
Plant height	1	2(2)	5(5)	4(4)	5(5)
Cob length	2	2(4)	3(6)	4(8)	5(10)
Cob Thickness	1	3(3)	4(4)	4(4)	4(4)
Total		36	105	116	134
Average		4.5	13.1	14.5	16.8
Rank		4	3	2	1

Figures under columns of each tested maize hybrids are mean scores given by farmers to each hybrid with each evaluation criteria; (1= very good; 2= good; 3 = moderate; 4 =poor and 5=very poor). Numbers in the bracket are the product of the weight and rank given for each hybrids and traits.

Table 11. Direct matrix ranking of the tested varieties based on farmers selection criteria at Abeshge Woreda Fitejeju Kebele

Farmers' selection criteria	Weight	Maize hybrids			
		BH540	BH546	BH547	BH549
Expected Yield	6	2(12)	5(30)	3(18)	5(30)
Husk cover	5	1(5)	5(25)	3(15)	5(25)
Number of row per cob	4	2(8)	5(20)	4(16)	5(20)
Number of seed per cob	7	2(14)	5(35)	4(28)	4(28)
Lodging resistance	3	1(3)	5(15)	4(12)	4(12)
Plant height	1	2(2)	5(5)	3(3)	4(4)
Cob length	1	1(1)	4(4)	3(3)	5(5)
Cob Thickness	1	3(3)	5(5)	3(3)	4(4)
Total		48	139	98	128
Average		6	17.4	12.3	16
Rank		4	1	3	2

Figures under columns of each tested maize hybrids are mean scores given by farmers to each hybrid with each evaluation criteria; (1= very good; 2= good; 3 = moderate; 4 =poor and 5=very poor). Numbers in the bracket are the product of the weight and rank given for each hybrids and traits.

Based on the weighted farmers seletion criteria, among the tested maize hybrids in Enseno-Ousmae BH549 and BH546 were found to be most accepted by farmers. While Hybrids BH549 and BH547 were chosen in Bati Lejano. Whereas, in Fitejeju kebele of Abeshge Woreda, Hybrids BH546 and BH549 were ranked 1st and 2nd, respectively (Table 12). Overall, in majority of the testing locations BH549 was the most prefered.

Table 12. Summary of farmers maize variety preference over testing locations

Variety name	Misrak Meskan Woreda		Abeshge Woreda		Rank
	Batilejano	Enseno-Ousmae	Fitejeju	Tatesa (WkARC)	
BH549	1	1	2	-	1
BH547	2	3	3	-	3
BH546	3	2	1	-	2
BH540	4	4	4	-	4

It is critical to estimate the marginal rate of return (MRR) for maize production and productivity in the study area in order to recommend the appropriate technology (variety/ies). As a result, it is clear from the data presented in Table 13 that the mean total gross benefit and mean net benefit increased (in Ethiopian Birr) in assending order of the hybrids BH540, BH547, BH546 and BH549, respectively. Hybrids BH549 and BH546 yielded the highest mariginal rate of return of 16.3 and 15.54 than others (Table 13), respectively. Accordingly, as the result indicates, for better income gain from maize production in the study areas, it's recommeded to use the hybrid BH-549 than others.

Table 13. Partial budget analysis of maize hybrids

Parameters (ETB/ha)	Maize hybrids			
	BH540 (Check)	BH547	BH546	BH549
GB	128,125	146336	176177	189724
TVC	50762	51887	53672	54326
TC	75767	76887	78672	79326
NB	52,358	69,449	97,505	110,398
MNB	-	17091	45147	58040
MC	-	1120	2905	3559
MRR		15.259	15.541	16.307
MRR%		1525.9	1554.1	1630.7

Where: GB (gross benefit), TVC (total variable cost), MC (marginal cost), NB (net benefit), MNB (marginal net benefit) and MRR (marginal rate of return)

Conclusions and Recommendations

The current findings revealed that there is variability in the yield and yield-related traits of the hybrids. The mean grain yield and related traits across locations showed that BH549 and BH546 were superior hybrids over the others. Based on the criteria set by farmers, BH549 and BH546 were the preferred hybrids in Misrak Meskan and Abeshge Woredas, respectively. Moreover, as the marginal rate of return (MRR) perentage of BH549 (1630.7%) and BH546 (1554.1%) were greater than the acceptable minimum rate of return (AMRR~184%), we recommend BH549 and BH546 hybrids for optimum economic return from maize production in the study area over BH540. Farmers mostly preferred hybrids that combined high yield, disease resistance, more number of seeds and resistance to lodging as variety selection criteria. Therefore, it is recommended that engagement of farmers in a maize improvement program from the start and exploit their local knowledge and criteria to develop farmer-preferred varieties and the two selected hybrids BH549 and BH546 could be used as an alternative hybrid varieties in the study areas and other similar agro-ecologies in order to boost production and productivity.

Declarations

Ethics approval and consent to participate

The experiments did not involve endangered or protected species. The data collection of plants was carried out with permission of related institution, and complied with national or international guidelines and legislations.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

Mohammed Hassen: Planned the experiment, Conceived, designed and performed the experiments; collected, analyzed, interpreted the data and wrote the article. **Mesfin Hailemariam Habtegebriel, Fetta Negash Gerura** and **Takele Zike:** Conceived, designed, performed the experiments, data collected and analysed, and wrote the article. **Tesfahun Fikre:** analyzed farmers' perception data, and edited and improved the article. **Beyene Abebe**: provided working materials and access the budget and **Teshome Bekele**: Conceived, designed, and performed the experiments.

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