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Highland Maize Technology Demonstration: Evidence from Three Maize Growing Districts of West and Southwest Ethiopia

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Abstract: Maize is Ethiopia's most important crop in terms of production, and it contributes significantly to the country's economic and social development. The study was conducted in Wonchi, Ejere, and Kersa Malima districts of South West Shewa and West Shewa zone of Oromia region, Ethiopia, to evaluate and identify adaptable improved maize varieties and familiarize farmers with highland maize production techniques. The districts were selected purposively based on their production potential and accessibility for maize production. In this study, a participatory extension approach is employed as part of the methodology to select a demonstration site and host farmers. A total of 54 host farmers were chosen, and the trial was conducted on selected farmers' fields, with three varieties planted side by side on equal-sized plots size ($10m^2$ x $15m^2$) from each district. Highland maize namely Jibat and Hora varieties along with a standard check (BH-661) were demonstrated and evaluated for grain yield and other parameters across tested sites. In the course of the implementation phase, different levels of field days at different growth stages of the crop were organized for respective potential Kebeles, and during the event stakeholders including host farmers and surrounding farmers, researchers, development agents, agricultural experts, and administrators attended to share experience, evaluate performance, and communicate the activity's progress. The variety selection process was carried out from different dimensions including both pre-harvest and post-harvest assessments. Using these criteria, the farmers identified varieties that are appropriate for their specific locations. Accordingly, host farmers showed special interest in Jibat and Hora varieties respectively. Overall grain yield performances of Jibat and Hora varieties on farmers' fields were 5.1 and 3.8 t/ha-^{1}, respectively. Furthermore, the yield advantage of the two preferred varieties over the standard ones ranged from 54.9% to 15.1% in the three tested districts as compared to the standard checks. Beside this research intervention made impact to improving food security, livelihood, and knowledge and skill of host farmers in the study area. Hence, Based on the study's findings, it is recommended that the Jibat maize variety should be scaled up in the farming community to improve the maize production and productivity of the area, thereby improving their livelihood.

Keywords: Demonstration, Highland Maize, Technologies

1. Introduction

Agriculture is the backbone of the Ethiopian economy. This particular sector determines the growth of all other sectors and consequently the whole national economy. It constitutes over 50% of the gross domestic product (GDP), accounts for over 85% of the labour force and earns over 90% of the foreign exchange [1].

Maize is originated in Central America and was introduced to West Africa in the early 1500s by the Portuguese traders. It was introduced to Ethiopia during the 1960s to 1970s. Today, maize is one of the most important food crops worldwide. It is grown in most part of the world over a wide range of environmental condition, ranging between 50° latitude north and south of equator. It also grows from sea level to over 3000 m above sea level [2].

Maize is Africa's most widely grown and consumed staple crop, with over 300 million Africans relying on it as their primary food source. It is the staple food for 24 million households in East and Southern Africa, and 15.5 million hectares are planted each year. Research into maize improvement practices to optimize grain yields is a priority for governments in the region because of the critical role the crop plays in ensuring food security [3].

In Ethiopia, maize grows from moisture stress areas to high rainfall areas and from lowlands to the highlands. It is largely produced in Western, Central, Southern and Eastern parts of the country. In 2017 cropping season, 2,135,571.85 ha of land was covered by maize with an estimated production of 784.7 tons [4].

Among cereals, maize is the most main crop in terms of production and contributes significantly to the economic and social development of Ethiopia [3]. In the country out of the major cereal crops, maize ranks second to teff in the area and first in production, and per capita consumption of maize is 60 kg/year, in Ethiopia. As a result, improved highland maize production is critical for Ethiopians' short- and medium-term food security, as well as GTP growth [5].

Although a substantial quantity of maize is produced in the lowland areas, predominantly maize is grown in the most productive agricultural lands in the mid and highland areas of the country [5]. The high altitude, sub-humid maize agro-ecology (1800-2400 m.a.s.l) in Ethiopia is estimated to cover 20% of the land devoted to annual maize cultivation. More than 30% of small-scale farmers in this agro-ecology depend on maize production for their livelihoods [6]. To satisfy the need of increasing maize production in the highlands of Ethiopia, the Highland Maize Breeding Program was established at the Ambo Plant Protection Research Center (APPRC) of the Ethiopian Institute of Agricultural Research (EIAR) with the support of the International Maize and Wheat Improvement Center (CIMMYT), [7].

It is aimed at developing and popularizing improved Highland maize cultivars and enhancing their crop management technological packages. From 1999 to 2011, the breeding program released five superior Highland maize hybrids including AMB02SYN1-'Hora', AMH800- 'Arganne', AMH850-'Wenchi', AMH851-'Jibat', and MH760Q-'Webi', for large-scale production [5]. AMH760Q was identified as a quality protein maize (QPM) hybrid, which was developed from the most popular, top-yielding non-QPM hybrid 'BH660'. Over 5.8 million hectares of potentially suitable land were identified for the highland maize hybrids in the country [3].

Holetta agricultural research center is working on a highland maize program in collaboration with Ambo agricultural research center. Highland maize materials are a new entry in the highland part of Ethiopia in general and Oromia in particular.

In most parts of highland areas particularly in the east, west, and southwest Oromia region small-scale maize production gradually becomes a permanent activity for different purposes. In Ethiopia, maize is produced mainly for food, especially in major maize producing regions particularly for low income groups; it is also used as staple food. Maize is consumed as "Injera," porridge, bread and "Nefro." It is also consumed roasted or boiled as vegetables at green stage. In additions to the aforementioned, it is used to prepare local alcoholic drinks known as "Tella" and "Arekie." The leaf and stalk are used for animal feed and also dried stalk and cob are used for fuel. It is also used as industrial raw materials for oil and glucose production [2].

However, the production and productivity are very low and there is strong interest from farmers to replace the currently growing low-yielding variety with an improved maize variety. Most studies witnessed the clear contributions of agricultural technologies to the welfare of smallholder farmers and other poor households who benefited from the enhanced adoption of technologies and improved agricultural productivity and production over time [8].

As a result, demonstrating and evaluating newly released highland maize varieties for adaptability and agronomic performance is critical to addressing the issue of low maize production and productivity, as well as food insecurity, in the study area [9].

Therefore, this activity was conducted to demonstrate the various improved highland maize varieties with their production package to farmers in major maize growing areas in the Oromia region, particularly, in kersa Malima, Ejere, and Wonchi districts.

2. Methodology

2.1. Description of the Study Area

The study is executed under three woredas of the west and southwest shewa zone of Oromia region. Kersa Malima district is located, in the southwest Shewa zone of Oromia Regional State, in the eastern part of the zone. Geographically the district is located between latitudes of 8.36° N to 8.71° N and with longitudes of 38.34° E to 38.71° E. The district is located 60 Km southwest of Addis Ababa with a total area of 58613 hectares (586 Km^2). The land under cultivation accounts for nearly 86% of the woredas' total area. The climate of a year is characterized by two rainy seasons, mainly summer and spring. The summer season lasts for five months (June to October) while the spring season lasts for three months (March to May) bimodal rainfall pattern prevails [10]. Elevation varies from 1839 to 3568 m.a.s.l. It is bounded by S.N.N.P. national regional state to the southwest, East Shewa Zone to the east, Sodo Dachi, Alemgena, and Tole Woredas to the south, northeast, and Northwest, respectively, and the total length of the boundary line is about 220 km [10].

Wonchi is the second district located southwest of Addis Ababa the capital city of Ethiopia. It is one of the administrative regions under the Southwest Shewa Zone of Oromia regional national state. Wonchi district is 155 km from Addis Ababa. The topography of the study area ranges from gently sloping to hilly lands with ridges and valleys in between. The district lies at a latitude of 8°40′ N and 37°55′ E and an altitude ranges from 1700 to 3380 meters above sea level. The rainfall is bimodal, with long periods from June to September and short periods from March to April, with the peak period usually occurring in July and August. The average annual rainfall ranges from 1650 to 1800 mm, with average low and high temperatures of 10°C and 30°C, respectively. The study district has a total surface area of 475.6 km^2 and a population of 1, 19736 people, with 58,671 males and 61065 females [11]. In the Wonchi district, two agro-ecological zones have been identified. These are highland (Dega) which accounts for 40% and mid-highland (weynadega) which covers 60% of the district. The major soil types found in the district are black soil 11%, red soil 46%, and mixed soil 43%. The main crops cultivated in the district are teff (Eragrostis teff), barley, wheat, maize, sorghum, chickpea, bean, pea, lentil, and haricot bean.

Ejere is the third district in Oromia Regional State's West Shoa Zone, with the capital 50 kilometers west of Addis Abeba. It is bounded in the South by the Southwest Shoa Zone, in the west by the Dendi District, in the northwest by the Jeldu District, in the north by the Meta Robi District, in the northeast by the Adda Berga District, and in the east by Welmera district [12].

The district's elevation ranges from 2,060 to 3,185 meters above sea level [13]. The district's soil types are predominantly red (58%), black (32%), and mixed (10%). The district is distinguished by a subsistence mixed farming system in which crop and livestock productions are common economic activities. The district's total land area is estimated to be 56,918 ha, of which 40,985 ha cultivated land is, 4,446 ha is grazing land, 4,456 ha is forest, and 7,031 ha is covered by other lands [12]. The district is well-known for its high crop and livestock production potential. Crop production accounts for the majority of household consumption and income generation. Cereal crops grown in the area include teff, wheat, barley, and maize; pulse crops grown include chickpeas, haricot beans, faba beans, and noug.

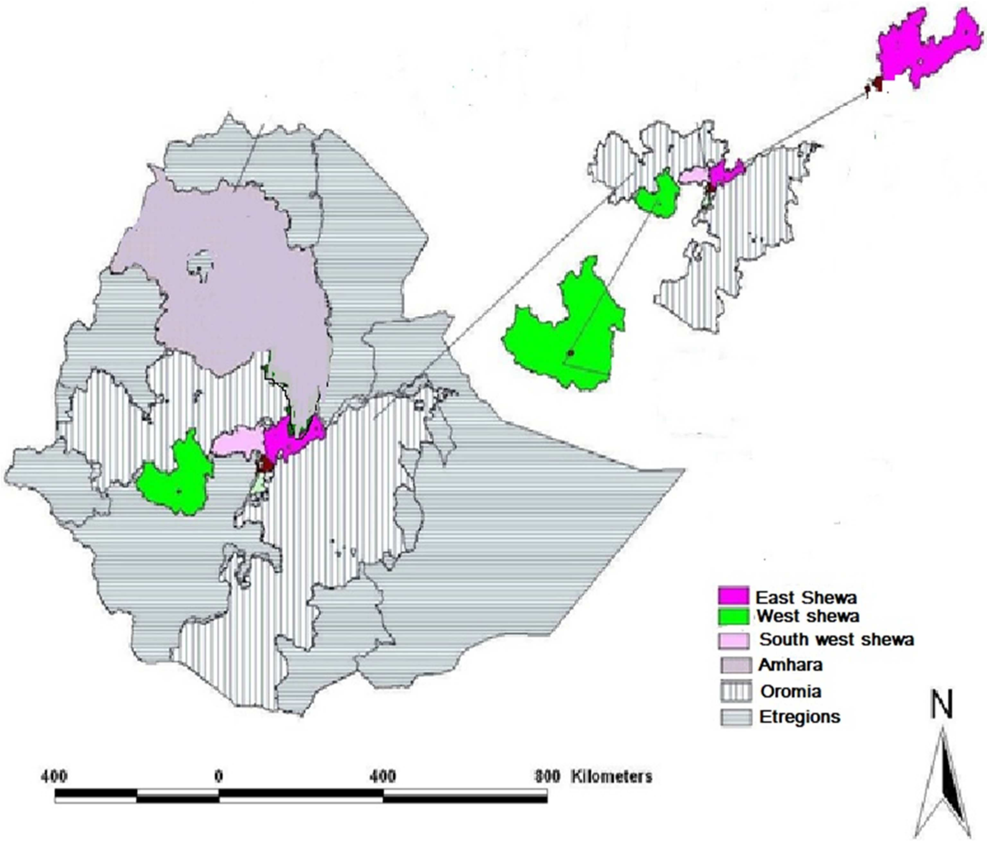

Figure 1. *Map of Ethiopia indicating Oromia zones and the study sites East, West, and South West Shewa Zone.*

2.2. Site and Farmers' Selection

The activity was carried out in the Oromia region's kersa Malima, Ejere, and Wonchi Districts, which were selected purposively based on maize production potential and representativeness for the study. 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. It experiment was executed for two consecutive years (2017/18-2018/19).

2.3. Experimental Design and Procedures

The experiment was carried out on 54 farmers' fields; farmers as a replication using the treatment materials of improved maize variety with improved management practices with the experimental plot size 10m*10m (100m^2) per treatment. Two different maize varieties namely Jibat and Hora were used along with a standard check (BH-661). On the selected farmers' fields the three varieties (two improved and one standard check) were planted side by side on equal-sized plots 10m*10m (100m^2) per each treatment replicated by the number of participant farmers. A seed rate of 25 kg/ha and 150 diammonium phosphate (DAP) kg/ha and 250 urea kg/ha were used with a line spacing of 75 and 25 cm between plants and rows, respectively. All Agronomic practices were employed as per the recommendation. The improved varieties used were the ones ranked first and second by bio-physical researchers during the on-station adaptation trial process.

2.4. Technology Evaluation and Demonstration Methods

The demonstration of the trials was implemented in farmers' fields to create awareness about the maize varieties. The demonstration of the trials followed the process demonstration approach by involving Development agents and experts at the different growth stages of the crop. The activity was jointly monitored by researchers, experts, and development agents.

2.5. Data Collection

The data was gathered through focus group discussions, field observations, and the use of a formal data sheet. Primary and secondary data were collected, which included biological and social information. Biological data such as grain yield in ton/ha and social data also attitudes, training, and perception of farmers and other stakeholders' opinions.

2.6. Data Analysis

The collected data were analyzed using simple descriptive statistics for yield and yield-related traits. According to the research [7]. partial budget analysis was employed to determine the level of profitability of improved technologies over conventional practice, as shown in Table 7. The partial budget analysis method used in this study is stated as follows:

Total revenue was calculated by multiplying the price by the yield obtained (TR= Y x P), growth marginal rate by subtracting total variable cost from total revenue (GM = TR-TVC), and final profitability by subtracting total fixed cost from total growth marginal rate (Profit= GM-TFC).

Pair-wise ranking, on the other hand, was used to examine farmers' attitudes toward maize varieties. The following procedure was used to rank the best varieties preferred by farmers. Thus, the selection criteria were identified first, followed by a ranking of each criterion, and finally, the acceptability rank was determined.

The technology gap indicates issues that need to be researched to realize potential yield, whereas the extension gap implies what can be accomplished through the transfer of existing technologies [14]. The following formula was used to calculate the technology gap and technology index:

Technology gap = Potential yield qt/ha – demonstration yield

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

$$\text{Yield advantage\%} = \frac{Average\ demo\ plot\ yield - standard\ check\ average\ plot\ yield}{standard\ check\ average\ plot\ yield}\ x\ 100$$

$$\text{Technology index\%} = \frac{Potential\ yield - demostrated\ yield}{Potential\ yiels}\ x\ 100$$

3. Results and Discussion

The data in Table 1 compares the research practice to farmer practices, and it was revealed that the research package/practices significantly outperforms interims of grain yield gain and yield-related attributes than framer practice.

Table 1. Comparison between the demonstrated package and existing farmers' practice of Maize production.

S/N	Interventions made	Demonstrated Packages	Farmers Practice
1	Farming Situation	Rainfed	Both irrigation and rainfed
2	Varieties	(Improved) Jibat, Hora, and BH-661	Local
3	Seed treatment	Seed treated with thiram 75%WP@3g/kg	Nil
4	Time of sowing	Onset of rain (5th to 15th of May)	May 15th to early June
5	Method of Sowing	Row planting with a space of 75 b/n rows and 25 b/n plants	Broadcasting
6	Seed rate	25 kg/ha	>30kg/ha
7	Fertilizer dose	Dap 150 and 200 urea kg/ha	Blanket recommendation
8	Plant protection	Need-based applications like roundup and the like chemical and good agricultural practice	Nil
9	Weed management	Pre-emergency herbicide (S-metolachlor 290g/l + atrazine 370 g/l), 2 seeds per hill and later thin to 1 seedling	Three-hand weeding in three phases (early, mid, and late stage of the crop)

3.1. Training of Farmers and Other Stakeholders

Full package training on maize production and management practices was given during the 2017 and 2018 cropping seasons (Table 2). This includes both theoretical and practical types of training. The following table illustrates the number of farmers, Das, and experts who participated in the training.

Table 2. *Training of Farmers and other Stakeholders on maize production.*

Participants (N=64)						
Year	Experts (DA + SMS)			Farmers		
	Male	Female	Total	Male	Female	Total total
2017/18	8	3	11	22	7	29 40
2018/19	2	0	2	20	5	25 27
Total	10	3	13	42	12	54 67

N: Implies number, DA: development agents, SMS: subject matter specialists

3.2. Field Day Organized

At the physiological maturity stage of the improved maize varieties, a mini field day was jointly organized with other relevant stakeholders such as districts level agricultural development offices and participated farmers in the district to create awareness about the importance of using improved maize variety and its agronomic and management practices and boosting the dissemination of the varieties through farmers to farmers linkage. A total of 106 participants (80 farmers from trial and non-trial, 11 agricultural experts, 2 Administrators, 9 development agents, and 4 researchers participated in the mini-field day. The participants shared their experiences and discussed the condition of improved variety with trial farmers in the district (Table 3).

Table 3. *Mini-field day organized on maize production.*

Year	Participants	Male	Female	Total
2017/18 &2018/19	Administrators	2	0	2
	Agri. Experts	10	1	11
	DAs	8	1	9
	Farmers	68	12	80
	Researchers	3	1	4
	Total	91	15	106

3.3. Agronomic and Yield Performance

The varieties ranked from first to second in respective trial sites (Figure 1) were evaluated for their field performance. Similarly, the varieties selected just by using pre-harvest assessments like disease resistance, cob size, stay green, and better grain hold per spike exhibited outstanding field performance as well.

3.4. Yield Advantage

In three Districts the varieties were tested with fifty-four trial farmers (54) using Jibat, Hora, and standard check (BH-661) varieties. As shown in (Figure 1) Jibat had the highest (54.9%) yield advantage over the standard check followed by Hora (15.2%). Although both varieties were appreciated for being high-yielders, their susceptibility to Fally army worm was expressed as a concern by the farmers. The standard check variety was comparatively found low in yield in every tested district. There was visible variation among farmers' plots, mainly due to differences in management (plowing frequency and weeding). The land of some farmers was plowed once while that of other farmers was not properly weeded and followed up. Thus, the occurrence of the outbreaks of the Fally army worm and poor management practices in some host farmers resulted in yield reduction in one way or another.

3.5. Technology Gap and Index

The technology gap indicates the disparity between the demonstration yield and the potential yield. The observed technology gap is due to variations in fertility, acidity, rainfall, and other natural calamities, and its contribution is to narrow the yield gap between different varieties and provide location-specific recommendations [15].

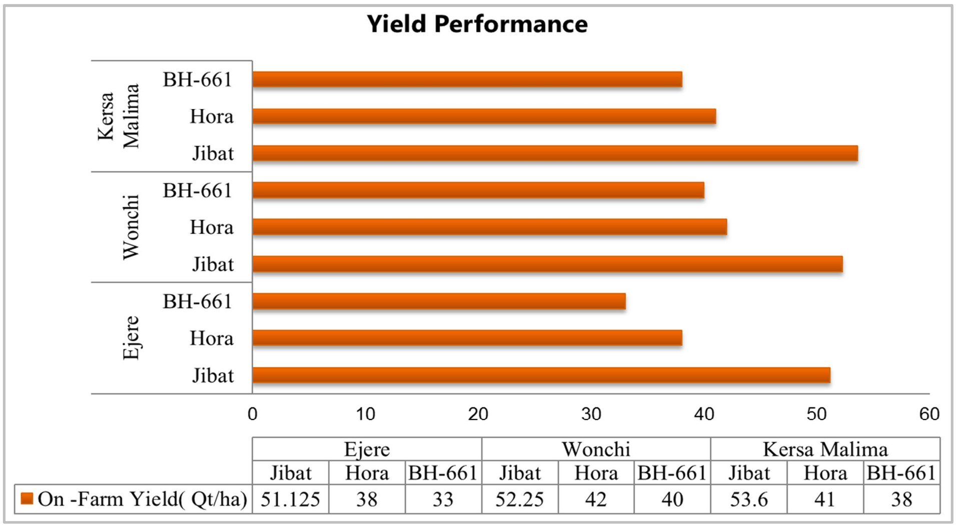

Figure 2. *The average yield of maize varieties across tested sites, 2017/18 and 2018/19.*

***Table 4.** The mean result of the technology gap and technology index for Maize varieties.*

Varieties	Potential yield (Qt/ha)	Demonstrated yield (Qt/ha)	Technological Gap (Qt/ha)	Technological Index (%)
Jibat	80	52.3	27.7	34.6
Hora	45	40	5	11
BH-661	95	37	58	61.1

NB. Qt implies quintal unit and 1Qt=100kg

3.6. Yield Increase and Advantage

According to Table 5, the Jibat variety has a 15.3 qt/ha yields increase and a 42.2% yield advantage over the BH-661 variety, while the Hora variety has a 3.3 qt/ha yield increase and a 9.4% yield advantage over the BH-661 variety. Jibat and Hora both show positive yield advantages and increases over standard checks (BH-661 variety).

***Table 5.** Mean Grain Yield Advantage and Yield Increases across the tested site.*

Location	Yield in (Qt)			Yield Increase (Qt/ha)		Yield advantage (%)	
	Jibat	Hora	BH-661	Jibat	Hora	Jibat	Hora
Ejere (N=18)	51.1	38	33	18.125	5	54.92	15.2
Wonchi (N=18)	52.25	42	40	12.25	2	30.6	5
Kersa Malima (N=18)	53.6	41	38	15.6	3	41	7.9
Mean	52.3	40.3	37.0	15.3	3.3	42.2	9.4

NB. Qt implies quintal unit and 1Qt=100kg

3.7. Farmers' Opinion/Perception

Based on the criteria established by the farmers, three different maize varieties were used: Jibat, Hora, and standard check varieties. These varieties were ranked in order of preference from most to least preferred. The ranking process was done by identifying farmers' responses (from most preferred/very good (score 1) to least preferred/poor (score 3) against each one of the selection criteria. Based on discussion with the host farmers the following selection criteria were identified.

These include pre-harvest selection criteria farmers identified as disease resistance, cob size, stay green, and better grain hold per spike while post-harvest selection criteria marketability, seed size, seed color, yield, and biomass yield were identified by the participant farmers. Based on these selection criteria farmers in each site ranked the maize varieties as indicated in (table 6).

***Table 6.** The rank of different maize varieties as evaluated by the farmers.*

Wonchi, Ejere, and Kersa Malima Farmers (N=54)								
Maize Varieties	Grain color	Cob Size	Disease resistance	Market preference	Biomass Yield	Stay green	Grain Yield	Rank
	No.	No.	No.	No.	No.	No.	No.	
Jibat	35	25	28	40	24	32	50	1
Hora	15	15	18	12	20	4	4	2
BH-661	4	14	8	2	10	18	0	3

The major variety selection criteria of farmers in the trial sites were almost similar except in very few cases where they vary in level of emphasis to a particular criterion. The farmers have identified, using the above criteria, the varieties that suits their respective location. Accordingly, The Results revealed that the variety Jibat preferred over the other candidate Hora and the check (BH-661) in most of the tested districts. The host farmers have now developed a better capacity in identifying the best varieties and management practices of maize as well. Demand was also created in the area for further scaling out of the technologies in the unaddressed areas.

3.8. Cost Benefit Analysis

In the demonstration experiment, a partial budget analysis shows the economic impact of changing from one treatment to another. The gross net benefit for the three treatments was calculated based on the input and output prices as shown in Table 7 below. Improved and standard maize varieties with improved management produced a net benefit of 29,761.78 ETB/ha, 21,783.1 ETB/ha, and 20,218.00 ETB/ha respectively, in the study area. For partial budget analysis, the mean grain was adjusted by 10% to account for the yield penalty.

In general, using the improved maize variety Jibat with an improved production package provided the highest net benefit, followed by the Hora variety, and lastly the standard check (BH-661) variety (Table 7). So, in the study area, adopting improved maize technology in general, and the Jibat variety in particular, with an improved production package, is economically feasible.

Table 7. *Result of cost-benefit analysis of highland maize demonstrated varieties.*

S/N	Parameters	Varieties		
		Jibat	Hora	BH-661
1	Average yield kg/ ha (Y)	5233	4035	3800
2	Adjusted yield (-10%)	4709.7	3631.5	3420
3	Price (P) per quintal	740	740	740
4	Total Revenue =TR=Y*P	34,851.78	26,873.1	25,308.00
5	Variable costs			
6	Seed Cost (birr/man/day/ha)	740	740	740
7	Fertilizer cost (birr/kg/ha)	2350	2350	2350
8	Labor cost (birr/man/day/ha)	1200	1200	1200
9	Total variable cost (TVC)	4290	4290	4290
10	Fixed costs			
11	Land cost (birr/ha)	800	800	800
12	Total fixed costs (TFC)	800	800	800
13	Total costs (TVC+TFC)	5090	5090	5090
14	Gross Margin (GM)=TR-TVC	30,561.78	22.583.1	21,018.00
15	Profit=GM-TFC	29,761.78	21,783.1	20,218.00

4. Conclusion and Recommendations

In Ethiopia, it is impossible to increase production and productivity, ensure food security and improve the livelihoods of smallholder farmers, where conventional farming is dominant with the use of improved varieties with best management practices. Thus, much is expected from stakeholders to increase the production and productivity of small-scale farmers. Cognizant of this fact, Holetta agricultural research center has conducted the pre-scaling up of improved highland maize technologies in Ejere, Wonchi, and Kersa Malima districts for two consecutive years. Generally, the result of this study revealed that the improved Jibat maize variety gave the highest yield followed by the Hora variety. Accordingly, many farmers built their awareness on the newly introduced Jibat variety and understood that it can give a reliable yield and improve their production and productivity which in turn will improve their livelihoods and ensure food security. Moreover, the knowledge and skill of Development agents (DAs) and agricultural experts were also improved through training and exchange visits. Better access to Jibat variety, Improving farmers' skills, knowledge, and attitude of the host farmers on the importance and application of all recommended packages were the impacts attained during the pre-scaling up activity. Furthermore, the partial budget analysis revealed that using improved maize variety Jibat with an improved production package provided the highest net benefit, followed by the Hora variety.

Therefore, based on the findings of this study, improved Jibat maize varieties with recommended production packages should be popularized in study areas and districts with similar agro-ecology for the benefit of the larger community. This would boost maize production and productivity in the study area as well as the surrounding areas in general. Farmers, research institutions, and zonal and district agricultural offices should also work together to develop capacity for long-term dissemination of highland maize technology to the general public in the study area and other similar agro-ecology regions.

Author Contributions

The first author designed the study, analyzed the data, and wrote the paper. The co-author supervised data collection. Finally, all authors read and approved the final manuscript.

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Availability of Data and Materials

The authors want to declare that they can submit the data at any time based on the publisher’s request. The data sets used and/or analyzed during the current study will be available from the authors upon reasonable request.

Consent for Publication

Not applicable.

Competing Interests

The authors declare that they have no competing interests.

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