Hindawi
Advances in Agriculture
Volume 2022, Article ID 1984478, 7 pages
https://doi.org/10.1155/2022/1984478

Research Article

Participatory Evaluation of Open Pollinated Maize (*Zea mays L.*) Varieties for Green Cob Production Under Irrigation in the North Shewa Lowlands, Ethiopia

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Received 24 June 2022; Revised 8 September 2022; Accepted 6 October 2022; Published 19 October 2022

Academic Editor: Othmane Merah

In the experimental area, there is a lack of improved maize varieties for green cob production. The experiment was conducted at Efratana gidim woreda Yimlo Kebele FTC-station in the North Shewa zone during the 2017 and 2018 experimental years under irrigation conditions. The objective of the study was to select adaptive, high-green cob yielders and farmers who preferred open-pollinated maize varieties for the lowland areas of North Shewa. The experiment was laid out in a randomized complete block design with three replications. Six nationally released open-pollinated maize, varieties including local check, were evaluated for two subsequent years. The combined analysis of variance showed highly significant ($p < 0.01$) differences for days to anthesis, days to silking, and number of cobs ha^{-1}. In each year, farmers participated and selected the top preferred varieties. During the 2017 experimental year, farmers used a number of cobs per plant, bear tip, cob length, uniformity, husk tip coverage, earliness, and stalk strength as selection criteria, and during the 2018 experimental year, farmers also used cob length, bear tip, earliness, lodging tolerance, and biomass as variety selection criteria. Varieties Melkasa-2 and Melkasa-6Q have been selected in both years. Analysis of variance revealed that both farmers preferred varieties that gave a high number of cobs, which is 46,914 and 41,358 cobs ha^{-1} for varieties Melkasa-2 and Melkasa-6Q, respectively. Based on this result, varieties Melkasa-2 and Melkasa-6Q were recommended for the North Shewa lowlands and similar agroecology.

1. Introduction

Maize is one of the oldest human-domesticated plants. It originated in Mexico and Central America and was introduced to Africa in the early 1500s by Portuguese traders [1]. Because of its greater adaptability, maize is cultivated in a wider range of environments than wheat and rice [2]. In Ethiopia, maize grows under a wide range of environmental conditions between 500 and 2400 meters above sea level. In this country, the midaltitude, subhumid agroecology is the most important maize-producing environment [3].

Maize is one of the most important cereal crops and serves as a staple food for many people in Ethiopia. In the major maize producing regions of the country, the majority of smallholder farmers depend on maize for their daily food throughout the year, and they have almost no access to protein sources like meat, eggs, and milk for their daily consumption [4]. In Ethiopia, maize has been used for the preparation of even-eyed flat bread, which is traditionally named injera, porridge, bread, and nefro. It is commonly consumed as roasted or boiled as vegetables at the green stage. It is also used to prepare local alcoholic drinks known as tella and arekie. The leaf and stalk are used for animal feed, and dried stalk and cob are used for fuel. Maize is also used as an industrial raw material for oil and glucose production. Maize is the lowest-cost calorie source among all major cereals; it accounts for 20.6% of daily caloric intake in the diet of major Ethiopian staple foods [5].

Participatory variety selection (PVS) refers to processes whereby farmers are involved in selecting lines that they judge to be most appropriate for their own uses from among a range of fixed (stable) lines that are being tested in their field [6]. It is a fast and cost-effective approach to selecting and promoting preferred crop varieties and a means to get feedback on the desired traits and priorities of farmers. The development of technologies through conventional agricultural research alone may not fulfill farmers' priorities and lead to low adoption of technologies. Through PVS, desirable varieties can be developed for end users [7]. In developing new varieties, traits considered undesirable to breeders may be highly desirable to farmers. As farmers are the ultimate beneficiaries of the maize varieties, there is a need to involve them in selecting suitable varieties under their socio-economic and agroecological circumstances at very early or advanced stages [8]. In order to meet farmers' demand for fresh market-oriented green cob production, there should be consideration of appropriate farmers' criteria by engaging them through the PVS approach. Since farmers have multiple criteria for evaluating maize varieties for green cob production, the incorporation of appropriate farmers' preferences may increase the adoption of the recommended varieties.

Production of green cobs is more profitable than grain production, and it is harvested in a short period of time as compared to the grain harvesting time [9]. Green cob is mainly produced for human consumption, either as a fresh cob, as a boiled or roasted condition, or as a processed product used as an ingredient in cakes, ice creams, and a number of other foods [9, 10]. Green cob is suitable for fresh consumption due to its sweet and delicious taste. In the experimental area, there is a tradition of maize cultivation for green cob as well as grain production under irrigation conditions. However, in the past, there was no research intervention in the target area for the improvement of farmers' varieties. As a result, in this area, small cob sizes and low-yielder local varieties are frequently used to produce for both fresh market green cob and grain consumption (an unpublished survey report). According to the national central statistical agency of agricultural sample survey report, there was low maize productivity and production coverage in the target area [11]. To alleviate this problem, the experiment was conducted as a new intervention in the area through a participatory variety selection approach so as to provide improved maize technologies, which have been released so far from the national maize improvement programs. Therefore, this experiment was conducted with the objective of selecting high-green cob yielders, and farmers preferred maize varieties to the lowland areas of North Shewa.

2. Materials and Methods

2.1. Description of the Study Area. The experiment was conducted in the lowland areas of North Shewa in the Amhara region, namely, Efratanagidim woreda (Figure 1), in the 2017 and 2018 experimental years. The experiment was conducted under irrigation during the off-season months from February to June. The site is located at 150 km North East of Debre Birhan town at 39° 54′27″ *E* longitudes, 10°17′27″ N latitudes, and 1514 m.a.s.l altitude. The mean annual rainfall, mean maximum, and minimum temperatures of the site are 822 mm, 27.7°C, and 11.5°C, respectively. The minimum and maximum temperatures, and total rainfall for the execution months are provided in Table 1. The general soil properties of the experimental location were predominated by heavy vertisol soil types.

2.2. Experimental Materials, Design and Trial Management. Seven open-pollinated maize varieties, including local check (Table 2), were evaluated for green cob production under irrigation.

The experiment was laid out in a randomized complete block design with three replications. Each variety was planted on a plot size of 3m × 3.6 m, and the spacing between plants, rows, plots, and replications was 0.3 m, 0.75 m, 1 m, and 1.5 m, respectively. The recommended 139 $kg{\cdot}ha^{-1}$ Urea and 121 $kg{\cdot}ha^{-1}$ NPS fertilizers were applied. The seed rate was 25 $kg{\cdot}ha^{-1}$. All NPS and half of Urea were applied at planting, and the remaining half of Urea was also applied at knee-height stages of the crop. Weeding management practices were implemented in a timely manner.

2.3. Data Collection and Measurements. Data were collected on a plant and plot basis. Data for sowing date, days to anthesis, days to silking, days to maturity, plant height at maturity, cob length, cob diameter, and the number of cobs were collected. Days to anthesis were taken as the number of days counted starting from the date of sowing when 50% of the plants flowered in a plot. The number of days to silking was recorded by counting the number of days from sowing when 50% of the plants in the plot emerge as silks. Days to physiological maturity were taken as the number of days after sowing when 90% of the plot stands' kernel forms a black layer at the base of the kernel. The above-ground plant height (cm) was measured from five randomly selected plants at physiological maturity. Cob length (cm) was measured from the base of the cob to the tip of the cob from five randomly selected plants at harvest. Cob diameter (cm) was measured from five randomly selected cobs by using a caliper. The number of cobs was determined by counting all the cobs on each plot at harvesting.

2.4. Farmers Preferences and Biological Data Analysis. Farmers freely put their selection attributes and made attribute comparisons. Farmers' preference data was analyzed using pair-wise and preference ranking matrix techniques. The pair-wise ranking method was used to analyze the position of each variety, and a weighted ranking matrix table was constructed. The group members were asked to compare and contrast each variety and to assign values for each variety based on identified attributes, and this procedure was repeated for all varieties. By counting the number of times each variety was chosen by each farmer and group, the aggregation was made to put scores for each variety. These aggregated scores are multiplied by a weight, and the result obtained from multiplication is summed up to represent the rank and position of the varieties [12]. According to Russell [12], farmers' preference data was analyzed using the formula: $\text{WFP} = \sum_{k=1}^{n} (\text{RVNF}/\text{TNPF})$; where RV = rank value, NF = number of farmers, and TNPF = total number of participant farmers.

For biological data, analysis of variance was computed using *R* 4.0.3 statistical software, and treatment mean separation was done using the least significant difference (LSD) at 5% level of

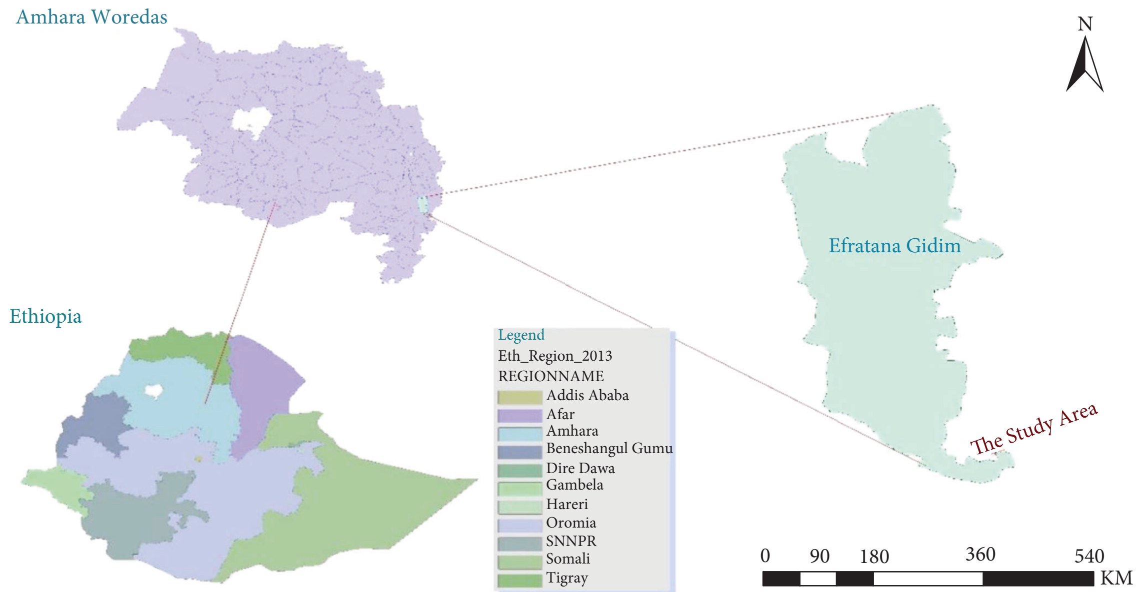

Figure 1: Location map of the study woreda.

Table 1: Monthly total rainfall, mean minimum and maximum temperature of the experimental area only for experimentation months.

Month	Rainfall (mm)		Temperature (OC)			
	2017	2018	2017 min.	2017 max.	2018 min.	2018 max.
February	134.0	47.5	16.2	29.2	15.7	30.7
March	78.4	53.8	17.3	32.7	18.4	33.5
April	32.1	122.3	17.6	33.4	17.9	33.2
May	136.4	137.5	19.2	32.5	17.4	34.3
June	2.7	23.6	19.7	36.4	17.7	35.7

Source: Ethiopian national metrology agency; min. = minimum, max. = maximum.

Table 2: List and passport data of improved open-pollinated maize varieties.

Varieties name	Year of release	Yield (Qt/ha)	Center of release '*	Days to maturity
Melkasa-2	2004	45–55	MARC/EIAR	130
Melkasa-5	2008	35–45	MARC/EIAR	125
Melkasa-6Q	2008	45–55	MARC/EIAR	120
Melkasa-7	2008	45–55	MARC/EIAR	115
Gibie-3	2015	65–75	BAKO/EIAR	145
Melkasa-4	2006	35–45	MARC/EIAR	105
Local check	—	—	—	—

Source: Ministry of agriculture, crop variety register. '* EIAR = Ethiopian Institute of Agricultural Research; MARC = Melkasa Agricultural Research Center; BAKO = Bako Agricultural Research Center.

significance. Model for analysis of variance: $Y_{ij} = \mu + t_i + r_j + \varepsilon_{ij}$; where μ = the overall mean; t_i = the i^{th} treatment effect; r_j = the j^{th} replication effect; ε_{ij} = the error term.

3. Results and Discussion

3.1. Analysis of Variance. During the 2018 experimental year, the analysis of variance showed a highly significant difference ($p < 0.01$) among open-pollinated maize varieties for days to anthesis, days to silking, and the number of cobs ha^{-1} (Table 3). This result is also supported by the finding of Aslam et al. [13], which stated that days to silking and days to tasseling showed significant differences only for genotypes, while the other parameters showed significant variations in the studied genotypes, treatments, and their interactions. In this experimental year, the highest number of cobs was obtained from variety Melkasa-2 (53,704 cobs ha^{-1}), followed by Melkasa-6Q (39,506 cobs ha^{-1}), and the lowest cob number was obtained from variety Melkasa-5 (24074 cobs ha^{-1}) (Table 3). Cob number is the major target for green cob production, which can result from the contribution of many related traits. During the 2017 experimental year, the majority of the parameters did not show a significant difference except for days to anthesis and days to silking, which showed a significant difference ($p < 0.05$) among tested maize varieties (Table 4). This result is in agreement with the findings of Gelaye and Kassie [14],

Table 3: Mean morphological and yield-related performance of open-pollinated maize varieties in 2018.

Varieties	Days to anthesis	Days to silking	Days to maturity	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	Number of cobs ha^{-1}
Melkasa-7	68^{a}	72^{a}	100	215	16	4.3	33951^{bc}
Melkasa-6Q	62^{c}	64^{cd}	99	171	15.4	4	39506^{b}
Melkasa-4	60^{c}	63^{d}	103	175	15.2	4	36420^{b}
Gibe-3	63^{c}	68^{bc}	105	184	15	4.3	38272^{b}
Melkasa-5	64^{b}	67^{bc}	98	175	14.5	4.1	24074^{d}
Melkasa-2	61^{c}	63^{d}	95	202	16	4.2	53704^{a}
Local	65^{b}	70^{ab}	104	201	14	4.4	29630^{cd}
Mean	63.3	66.7	100.6	189	15.1	4.2	36508
CV	1.8	3.2	1.7	10.8	16.9	7.8	10.2
LSD (0.05)	2.05^{**}	3.79^{**}	2.96	36	4.5	0.58	6634^{**}

CV = coefficient of variance; LSD = least significant difference at ($p = 0.05$); ** = highly significant difference at $p \leq 0.01$; significant values are assigned with different letters. Similar letters indicate no significant difference between varieties; the letters are ordered alphabetically from high to low scores.

Table 4: Mean morphological and yield-related performance of open-pollinated maize varieties in 2017.

Varieties	Days to anthesis	Days to silking	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	Number cobs ha^{-1}
Melkasa-7	49^{c}	52^{bc}	174	16	4.54	40482
Melkasa-6Q	58^{ab}	61^{a}	186	16	4.93	43210
Melkasa-4	54^{b}	$58a^{b}$	174	17	4.67	41975
Gibe-3	60^{a}	64^{a}	206	19	4.87	39638
Melkasa-5	44^{d}	51^{c}	162	16	4.53	42593
Melkasa-2	58^{ab}	62^{a}	203	18	4.76	40124
Local	58^{ab}	61^{a}	201	17	4.78	41315
Mean	54.4	58.4	186.6	17.1	4.7	41333
CV	4	6.5	10.3	7.8	4.2	3.6
LSD (0.05)	3.88^{*}	6.77^{*}	34.3	2.38	0.35	2737

CV = coefficient of variance; LSD = least significant difference at ($p = 0.05$); * = significant difference at $p \leq 0.05$; significant values are assigned with different letters. Similar letters indicate no significant difference between varieties; the letters are ordered alphabetically from high to low scores.

which stated that during the 2013/14 irrigation season only days to silking and days to anthesis showed significant differences; however, no statistical difference was observed among open-pollinated maize varieties for plant height, ear height, cob length, and cob diameter. Girma [15] also reported that there was no significant difference for most agronomic traits measured except days to 50% silking. From these significant parameters, the shortest days to anthesis (44 days) and days to silking (51 days) were obtained from variety Melkasa-5, and the longest days to anthesis (60 days) and days to silking (64 days) were obtained from variety Gibe-3 (Table 4).

Figure 2: Field performance of OPV maize.

The tested varieties showed better overall agronomic performance during both experimentation years (Figure 2). The combined analysis of variance exhibited highly significant differences ($p < 0.01$) for days to anthesis, days to silking, and number of cobs ha^{-1} between open-pollinated maize varieties (Table 5). Similar findings were also reported by Melkamu Elmyhun and Molla Mekonnen [14], which stated that the combined analysis of variance showed significant differences among open-pollinated maize varieties, including for days to anthesis, days to silking, and number of cobs ha^{-1}. The highest cob number was obtained from variety Melkasa-2 (46,914 cobs ha^{-1}), followed by Melkasa-6Q (41,358 cobs ha^{-1}), and the lowest number of cobs was obtained from variety Melkasa-5 (33,333 cobs ha^{-1}) (Table 5). This result indicated that the overall cob yield performance of variety Melkasa-2 is the best as compared with the rest of the tested varieties. Variety Melkasa-6Q also gave a high number of cobs ha^{-1}, which has been exceeded only by Melkasa-2. In addition to its high number of cobs ha^{-1}, variety Melkasa-6Q is also quality protein maize. This variety holds both a high cob yield and elevated levels of lysine and tryptophan. Similar results were also reported by [8], who stated that under the experimental study two maize varieties were obtained that combined high yields with elevated levels of lysine and tryptophan, and this could reduce food insecurity and malnutrition, especially in children, where protein deficiency among children is common because meat, fish, and eggs are beyond the means of the average family. The *o2*-based QPM contains nearly double

Table 5: Combined mean morphological and yield-related performance of open-pollinated maize varieties in 2017/18.

Varieties	Days to anthesis	Days to silking	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	Number of cobs ha^{-1}
Melkasa-7	58.5^{bc}	62^{ab}	194	16	4.4	37217^{cd}
Melkasa-6Q	60^{ab}	62.5^{ab}	179	15.7	4.5	41358^{b}
Melkasa-4	57^{c}	60.5^{b}	175	16.1	4.3	39413^{bc}
Gibe-3	61.5^{a}	66^{a}	195	17	4.6	38955^{bc}
Melkasa-5	54^{d}	59^{b}	169	15.3	4.3	33333^{e}
Melkasa-2	59.5^{abc}	62.5^{ab}	202	17	4.5	46914^{a}
Local	61.5^{a}	65.5^{a}	201	16	4.6	35473^{de}
Mean	59	62.6	187.8	16.2	4.4	38952
CV	3.2	4.9	12.2	12.3	5.9	7.2
LSD (0.05)	2.3^{**}	3.7^{**}	27.2	2.3	0.3	3355^{**}

CV = coefficient of variance; LSD = least significant difference at (p = 0.05); ** = highly significant difference at $p \leq 0.01$; significant values are assigned with different letters. Similar letters indicate no significant difference between varieties; the letters are ordered alphabetically from high to low scores.

the amount of lysine and tryptophan in the endosperm of normal maize. Such a balanced combination of amino acids in the endosperm results in a higher biological value, thereby ensuring the availability of better quality protein than normal maize [16]. Since QPM holds superior nutritional and biological value, it is essentially interchangeable with normal maize in cultivation and kernel phenotype [17].

Figure 3: Participant farmers at field day.

4. Farmers' Participation in Variety Evaluation and Selection

During the 2017 experimental year, 22 (5 female) and in the 2018 experimental year, 20 (4 female) farmers participated. The farmers who participated and were evaluated in the trial were well experienced in farming and representative of the area. In the meantime, farmers freely held group discussions to set their own selection criteria and select preferred open-pollinated maize varieties (Figure 3). During the 2017 experimental year, farmers' selection criteria were: the number of cobs per plant, bear tip, cob length, uniformity, husk tip coverage, earliness, and stalk strength (Table 6). During the 2018 experimental year, farmers also used cob length, bear tip, earliness, lodging tolerance, and biomass as variety selection criteria (Table 7). These selection attributes are also used by farmers with different socioeconomic and agro-ecological backgrounds. Melkamu Elmyhun and Molla Mekonnen [18] report that after a group discussion held with farmers, husk cover, cob number per plant, cob length, ear height, disease tolerance, and yield were identified as evaluation criteria.

By using the pair-wise ranking method, farmers' selection criteria were ranked to identify the most desired attributes, and the top ones were used (Tables 6 and 7). Each criterion was scored from 1 to 5 (1 = excellent, 2 = very good, 3 = good, 4 = average, and 5 = poor). Farmers' overall preference scores for each variety were averaged, resulting in a weighted mean score, which was used to rank the varieties. The weighted mean of selection attributes and variety rank was summarized using a preference ranking matrix summary sheet (Tables 8 and 9). The three top-ranked important selection criteria were a bear tip, cob uniformity, and cob length for 2017 and earliness, bear tip, and lodging tolerance for 2018 experimental years. Earliness is a highly important

Table 6: A pair-wise ranking matrix of attributes for the selection of open pollinated (OPV) maize varieties in 2017.

Attributes	NC	BT	UM	HTC	CL	ER	SST	Scores	Rank
NC		BT	UM	NC	CL	ER	SS	1	6
BT			BT	BT	BT	BT	BT	6	1
UM				UM	UM	UM	UM	5	2
HTC					CL	ER	SST	0	7
CL						CL	CL	4	3
ER							SS	2	5
SST								3	4

Best ranked farmers' selection attributes, bear tip, uniformity and cob length. Where NC = number of cobs, BT = beer tip, UM = uniformity, HTC = husk tip coverage, CL = cob length, ER = earliness, SST = stalk strength.

attribute that ranks as the best farmers' trait for the selection of maize varieties. This trait was also given high emphasis by Amzeri et al. [19], which stated that high production characteristics, early maturity, stability, and broad adaptation traits were used for the recommended varieties. This preferred trait is also supported by the finding of Kumar et al. [20], which stated that emphasis should be given to early-maturing hybrid maize, which performed better with respect to the magnitude of yield difference under optimal and stress conditions. As shown above, farmers also placed emphasis on the cob length trait used in the production of maize for the fresh green cob market. According to Chozin et al. [21], concurrent attention must be given to ear length in the selection practice for improving the ear yield of sweet corn.

Table 7: A pair-wise ranking matrix of attributes for the selection of open-pollinated maize varieties in 2018.

Attributes	Cob Length	Beer Tip	Logging Tolerance	Biomass	Earliness	Scores	Rank
Cob length		BT	LT	CL	ER	1	4
Beer tip			BT	BT	ER	3	2
Lodging tolerance				LT	ER	2	3
Biomass					ER	0	5
Earliness						4	1

Best ranked farmers' selection attributes: earliness, bear tip, and lodging tolerance.

Table 8: Farmers' preference ranking matrix summary sheet for OPV maize varieties in 2017.

Varieties	Weighted means of farmers selection attributes							Total	Mean	Rank
	NC	BT	UM	HTC	CL	ER	SST			
Melkasa-7	4.2	3.4	3.35	2.2	2.2	4.5	1.95	21.8	3.11	3
Melkassa-6Q	2.75	2.55	2.55	3.3	3.1	2.15	3.2	19.6	2.8	4
Melkasa-4	3.65	4	4	2.65	2.85	3.95	2.95	24.05	3.44	1
Gibie-3	2.7	2.5	2.5	4.2	4.25	2.5	4.2	22.85	3.26	2
Melkasa-2	2.15	2.65	2.65	2.7	2.9	3.1	2.85	19	2.71	5

Where NC = number of cobs, BT = beer tip, UM = uniformity, HTC = husk tip coverage, CL = cob length, ER = earliness, SST = stalk strength.

Table 9: Farmers' preference ranking matrix summary sheet for OPV maize varieties in 2018.

Varieties	Weighted means of farmers selection attributes					Mean	Rank
	Earliness	Beer tip	Logging tolerance	Cob length	Biomass		
Melkasa- 4	1.8	2.25	2.1	2.6	2.25	2.2	2
Melkasa- 2	2.25	1.8	1.6	2.0	2.0	1.9	1
Gibe-3	3.6	3.5	3.0	3.25	2.9	3.25	3
Melkassa-6Q	3.2	3.33	4.33	3.75	4.2	3.76	4
Melkasa-7	4.2	4.1	4.0	4.1	3.75	4.0	5

During selection, an agreement was made with farmers to compromise the farmers' recommendation with biological data and statistical analysis results. However; fortunately, farmers preferred materials that biologically fit with the statistical analysis results. A similar finding was also reported by Girma [15], which stated that there was matching between farmers' assessments and researchers' biological analysis results on grain yield and other agronomic traits. This author also reported a contradictory result for the same research in another replicated location, which stated that even though farmers eagerly participate in the selection of new varieties, but the performance of the selected variety is very different from that of the breeder's biological result. During the 2017 experimental year, farmers selected varieties Melkasa-4, Gibie-3, Melkasa-7, and Melkasa-6Q in their order of rank (Table 8). Also, during the 2018 experimental year, farmers selected varieties Melkasa-2, Melkasa-4, Gibie-3, and Melkasa-6Q in their order of rank (Table 9). Regarding the preference of variety Melkasa-2, similar findings were also reported by Aliyi et al. [22], which stated that after evaluating the tested varieties, farmers gave first preference rank to variety Melkasa-2. This variety gave the highest cob yield and was the top preference ranked one, which shows the stable performance of the variety. Its stability was explained both by its cob yield and rank performance. This result is also supported by the finding of Kumar et al. [23], which stated that stable hybrids were identified based on the ranking of genotypes.

5. Conclusion and Recommendation

In conclusion, participatory evaluation of improved maize varieties under irrigation is advantageous work as it helps to increase maize production under irrigation, which assures food security. Variety Melkasa-2 showed the best performance and gave the maximum cob number of 46,914 cobs ha^{-1}. Even though Melkasa-6Q became the second green-cob yielder (43,210 cobs ha^{-1}) next to Melkasa-2, it has an advantage in quality protein and nutritional value. To reduce the malnutrition problem of resource-poor farmers substituting normal maize with such kind of quality protein maize is a good opportunity. Varieties Melkasa-2 and Melkasa-6Q were also desired and selected by farmers. Based on farmer's selection and biological analysis results, varieties Melkasa-2 and Melkasa-6Q were recommended for the North Shewa lowlands and similar agroecology

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflict of interest.

Acknowledgments

The authors thank Amhara Agricultural Research Institute (ARARI) and Debre Birhan Agricultural Research Center (DBARC) for their technical and budget support.

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