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Participatory Variety Selection of Maize (*Zea mays* L.) Varieties in the Low Lands of Eastern Amhara, Ethiopia

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ABSTRACT

Background: Maize (*Zea mays* L.) is the most important staple food in the lowland of North Shewa, Ethiopia. However, the crop is less researched in this area. Thus, the objective of this study was to assess the performance of improved open pollinated variety maize with the participation of farmers' using their selection criteria for cultivation in the lowland areas of North Shewa.

Methods: Fourteen open pollinated maize varieties including local were evaluated in the lowland of Eastern Amhara at Eferatana Gedim district, Yimlo research station in 2016 and 2017 main cropping season. The experiment was conducted in randomized complete block design (RCBD) in three replications. Five agronomic and yield traits were collected in both cropping years. In addition, maize small holder farmers were participated to evaluate and score varieties using the matrix ranking method based on the farmers' selection attributes.

Result: The combined analysis of variance across years showed that highly significant ($p<0.01$) difference for days to anthesis, grain yield. The highest grain yield was obtained from Melkassa-4 (5243 kg/ha) and Melkasa-2 (5115 kg/ha) while the lowest yield was recorded from Rare-1 (3294 kg/ha). The overall yielding ability of Melkasa-4 was higher as compared with the tested varieties. In addition, this variety was highly appreciated by maize farmers in both cropping years. Based on farmer's selection and yield potential, therefore, Melkassa-4 has recommended for the lowlands of North Shewa and similar agro ecologies in Ethiopia. Support is needed to scale-up and deliver such improved variety through involving farmers in the selection and dissemination of varieties that are adapted to their needs, as it incurred income, good in crop rotation and animal feed.

Key words: Farmer's trait, Grain yield, Lowlands, Open pollenated variety.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important staple crops in the world. It is a popular crop having a wide adaptability to different agro climatic conditions. The crop is one of the most important annual cereal crops in the world (Tandzi and Mutengwa 2019). Maize is globally known as the queen of cereals because of its high yield potential amongst other cereal crops. It is cultivated on about 150,000,000 hectares in over 160 countries with a broader diversity of climate, soil, biodiversity and management practices contributing to 36% of the global grain production. The USA is the global leader in maize production, with 377,500,000 metric tons of maize (World Atlas 2016) and 36% of the world total in 2014 (Statista 2015). Maize is the most grown crop in many developing countries, especially Sub-Saharan Africa (SSA), contributing immensely to the SSA economy (Gebre et al., 2019). The crop occupies more than 33 million ha of sub-Saharan Africa's estimated 200 million ha of cultivated land. Due to the low average maize grain yields that are still shown in farmers' fields, satisfying the projected increase demand for maize grain in Africa presents a challenge (Harold, 2015).

In Ethiopia, maize grows from moisture stress areas to high rain fall areas and from lowlands to highlands. It is the most widely grown crop from lowland to highland agro-ecologies. Among cereals, maize accounts for the largest share in the country's crop production and is grown more than any other crop by farmers. It is largely produced in Western, Central, Southern and Eastern parts of the country. Nationally maize is the largest cereal commodity in terms of total production and yield (CSA 2021). In Amhara region, maize is fourth in area coverage next to tef, wheat and sorghum and first in volume of production. In North Shoa Zone, maize is fifth in area coverage and production next to tef, wheat, sorghum and barley (CSA 2021).

Maize is an important carbohydrate source for human diets in developing countries and animal feed in developed countries (Undie *et al*., 2012). Maize is processed and consumed in various forms, varying from region to region or from one ethnic group to another. For instance, maize grains are prepared by boiling, roasting, or as paste in Nigeria and Ghana, or as popcorn consumed all over West Africa (Abdulrahman and Kolawole, 2006). Maize provides about 1,400 Kcal/100 g of energy on a dry weight basis (Shikha *et al*., 2019). Maize is consumed as Injera, Porridge,

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Bread and Nefro. It also consumed roasted or boiled as vegetables at green stage. In addition to the above, it is used to prepare local alcoholic drinks known as Tella and Arekie. It is also used as industrial raw material for oil and glucose production. Maize is the cheapest source of calorie, providing 16.7% of per capita calorie intake nationally (Rashid *et al*., 2010).

Open-pollinated maize varieties are genetically diverse and developed by selecting open-pollinated maize ears that are desirable to the breeders or farmers. This causes a variation within plant populations that allow the varieties to adapt to local growing conditions and climates. Open-pollinated variety (OPV) seeds can be saved for future planting without losing vigor or yield (Frank Kutka 2011). Open-pollinated maize varieties are more appropriate to peasant farmers since the seeds obtained from the harvest can be used as planting materials for subsequent cropping season (Iken *et al*., 2001). Research reported showed that open-pollinated maize varieties yield higher than local varieties because they are more effective in transferring assimilates to their ear sink (Worku and Zelleke 2007).

Participatory variety selection (PVS) is the selection of new varieties by farmers on their own fields of finished or near-finished products from plant breeding programs. These include released cultivars, varieties in advanced stages of testing and well characterized material such as advanced non-segregating lines in inbreeding crops, or advanced populations in outbreeding crop under different target environments. It is increasingly being used to select and promote new crop breeding materials in most African countries (Eileen 2021) .It provides an opportunity of getting large number of varietal choices to farmers, enhances farmer's access to crop varieties and increase in diversity, increases production and ensures food security, helps to disseminate the adoption of pre and released varieties in larger areas, allows doing varietal selection in targeted areas at cost-effective way and also in a lesser time and helps seed production at community level (Yadaw *et al*., 2006).

Even if maize has multiple uses, but there is low production even no significant production coverage in the low lands of North Shoa Zone. Poor stand establishment results in reduced yield and/or complete crop failure if drought occurred at the seedling, flowering or grain filling stages, which coincide with the beginning and end of the growing season (Sacks *et al*., 2010). Therefore, the low yield in these areas is mainly faced due to poor productivity of their local variety, lack of improved maize varieties, recurrent drought, low levels of fertilizer use and shortage of hybrid seed, incase if hybrid seed available the price of seed is too expensive that farmers unable to afford furthermore; farmers in the study areas habitual to re-use hybrid seed which they produced last year for this year which have problem of segregation and yield reduction. To combat this problem, varied maize varieties haves been released from Melkassa Agricultural Research Center for moisture stress areas which are tolerant to drought. However, most of the varieties were not evaluated for moisture stress areas of North Shewa Zone especially on farmers land. Hence, the objective of this study was to evaluate improved Open Pollinated Variety Maize with the participation of farmers using their selection criteria and compare this with the researchers' eye and recommend for cultivation in North Shewa lowlands.

MATERIALS AND METHODS

Descriptions of the study areas

The experiment was conducted in the low land areas of North Shewa, Efratanagidim district, Yimlo research station in 2016 and 2017 main cropping season. The site located at about 130 km north eastern of Debre Birhan. Its coordinates is 10° 17′ 27″ N and 39° 54′ 27″ E in DMS (Degrees Minutes Seconds). The experimental site lies at an altitude of 1,514 meters above sea level. The study area average temperature is 25.4°C; June is the hottest month of the year. December is the lowest average temperature of the year. The climate is characterized by bimodal rainfall consisting of the long rainy season (June-September), short rainy season (February-May) and dry season (October-January). The mean annual rainfall is 1085 mm Fekadu (2015).

Plant material

Fourteen nationally released open pollinated maize varieties including local check were evaluated for phenological, agronomic and grain yield traits (Table 1).

Treatment arrangements

The experiment was carried out using randomized complete block design (RCBD) replicated three times at each site. Each variety was planted in row planting two seed per hole and thinned after full emergence on a plot size of 3 m × 3.6 m (10.8 m^2) with spacing of 30cm between plant and 75 cm b/n rows. The path between plots and blocks were 1 m and 1.5 m respectively. Harvestable net plot area was 1.5*3.6=5.4 m^2. Fertilizer was applied at the recommended rate of 139 kg/ha for urea and 121 kg/ha for NPS, respectively. All the recommended NPS and half of nitrogen applied during planting whereas the remaining half of nitrogen was applied during knee height stages of the crop. The seed rate was 25 kg/ha. Weeding was performed two times at crop reach nee height and before flowering.

Data collection and analysis

Phenotypic data were collected for days to anthesis (DTA) days to silking (DTS) and plant height (PH) days to physiological maturity (DTM), grain yield (GY). The collected agronomic and phenological data were subjected to SAS computer software version 9.1 (SAS institute 2002) and treatment mean separation was done using Duncan's new multiple range test (DMRT) at 5% level of significance (Gomez and Gomez, 1984).

Selection of participants was done in a participatory manner with the district pastoral office experts working on crop production. The selection of participants was based on the interest they had on technology, model farmers and managing the field as required. During the farmers' field days, a total of 69 farmers (55 male and 14 female) were selected and involved to list their major selection attributes of maize variety. Farmers' preferences were collected and analyzed by using formula described by De Boef and Thijssen (2007). The formula of ranking method used was:

$$\text{Rank} = \sum \left(\frac{N}{n}\right)$$

Where

N = Value given by group of farmers for each variety based on the selection criteria.

n = Number of selection criteria used by farmers.

RESULTS AND RISCUSSION

Performance of agronomic and grain yield traits

Analysis of variance showed that a highly significant (P<0.01) and significant variations among tested maize varieties for all measured traits in each year except PH in 2017 cropping season (Appendix Table 1 and 2). Mean values of measured traits ranged from 50 (Melka-5) to 58.67 (Rare-1) for days to anthsis in days, 8 (Rare-1) to 62 (Melka-4, Melka-5) for days to silking in days,78(Melkasa-1q) to 117 (Gibe-3) for day to maturity in days,153 cm (Melkasa 1q) to 279 (Local) for plant height in cm and 4448 (Melka-5) to 7532 (Gibe-3) for grain yield in kg/ha in 2016 cropping season (Table 2). In 2017 cropping season, mean values of agronomic and yield traits ranged from 54.3(Alemya composite) to 64 (Rare-1) for days to anthsis in days, 57 (Alemya composite) to 66 (Gibie -2) for days to silking in days, 118 (Melkasa-4 and Melkasa-6Q) to 123 (Gambela composite, Rare-1) for days to maturity in days, 190 (Melkasa-4) to 245 (Melkasa-2) for plant height in cm and 1768 (Rare-1) to 4449 (Melkasa-4) for grain yield in kg/ha (Table 3).

The analysis of variance combined over two years

Table 1: Descriptions of Ethiopian low lands maize varieties used for the experiments.

Variety name	Variety type	Year of release	Maintainer	Altitude (m)	Seed color
Melkassa 5	OPV	2008	MARC	1000–1700	White
Mellkassa 4	OPV	2006	MARC	1000–1600	White
Mellkassa 2	OPV	2004	MARC	1200–1700	White
Melkassa 7	OPV	2008	MARC	1000–1750	Yellow
Melkassa 1	OPV	2001	MARC	1000–1750	Yellow
Melkassa 1Q	OPV	2013	MARC	1000–1750	Yellow
Melkassa 6Q	OPV	2008	MARC	1000–1750	White
Gibe-1	OPV	2001	EIAR/BNMRC	1000–1700	White
Gibe-2	OPV	2011	EIAR/BNMRC	1600–1800	White
Gibe-3	OPV	2013	EIAR/BNMRC	1600–1800	White
Alemeya composite	OPV	1973	Hara. University	1600–2200	White
Gambela composite	OPV	2002	EIAR/BNMRC	300–1000	White
Rare-1	OPV	1997	Hara. University	1600–2200	White

Source: MoARD (2004-2016).

Table 2: Performance of maize varieties evaluated for grain yield and yield related traits at Ataye in (2016).

TRE	DTA	DTS	DTM	PH(cm)	GY (kg/ha)
Melka-5	50abc	62a	94.6	222.5cd	4448de
Melka-4	51.67abc	62a	82.7	224cde	6036b
Gibe-3	55.67ab	61.3a	117.3	259.5abcd	5941b
Melka-6q	51abc	60.3a	98.7	217.7de	5981b
Gibe-2	55.67ab	59ab	103	222.5cde	7532a
Melka-1	56.67ab	59.3ab	86	170cde	4928cd
Melka-1q	45.3c	50ef	78.7	153.5fg	4180e
Melka-7	47.6bc	54.3cd	82	202.4ef	5190c
Gibe-1	57.00a	55.3bc	99	264.9abc	5905b
Ga .comp	57.3a	53.3cd	108	245.3abcd	5136cd
Melka-2	51.3abc	50.6de	97.7	233bcde	6485b
Rare-1	58.67a	48.6f	84.3	251.2abcd	4821de
Ale.comp	58.3a	54.3cd	99.3	273ab	4996cd
Local	56.67a	59f	103	279a	4676de
Mean	53.8	56.4	95.4	227.9	5447
C.V	8.75	1.98	23.9	9.7	7.5

DTA = Days to anthesis; DTS = Days to silking; DTM = Days to mature; PH = Plant height and GY = Grain yield; CV = Coefficient of variance, * Significant at (p<0.05), ** Highly significant at (p<0.01), NS = Non-significant.

showed that a highly significant (p< 0.001) and significant (p<0.05) differences among varieties for plant height, grain yield, days to anthesis and silking (Appendix Table 3). The significant difference observed among varieties showed the genetic difference of the varieties. Similarly, Bassa and Goa (2016) reported a significant difference among maize genotypes in grain yield in their study of maize performance evaluation at Southern Ethiopia Hadiya zone. Research reported showed a significant difference in grain yield and agronomic traits in the high land maize genotypes evaluated at Bule Hora in Ethiopia (Taye *et al*., 2016). Year showed significant difference for days to anthesis ,days to silking, days to mature and grain yield (Appendix Table 3). Variety by year interaction showed significant differences for all traits except days to maturity (Appendix Table 3).

In combined data, days to anthesis ranged from 51 (Melkasa -1Q, Melkasa-7) (to 61 (Rare-1(), days to silking ranged from 54.5 (Melkaasa-7) to 64 (Rare-1), days to maturity ranged from 99 (Melkasa-1Q) to 119 (Gibe-3), plant height ranged from 252 (Local) to (190) Melkasa -1Q and grain yield ranged from 3294 (Rare-1) to 5243 (Melkasa-4) (Table 4). Variety Melkasa-4, Gibe-2 and Gibie-1 were found to be the most promising variety in the study areas. This result is in agreement with the previous findings reported by Husain *et al.* (2011). The highest yield obtained from varieties Melkasa - 4 (5243 kg/ha) (Table 4). In recent trials, yields of better-performing OP cultivars were often over 4400 kg/ha (Smith *et al*., 2003).

Comparison of farmers' preference traits

Maize smallholder farmers were asked to list the main criteria to be considered in the selection of improved seed in their local condition. The major selection attributes identified by farmers were number of cob/plant (NCPP), bear tip (BT), earliness (ER), plant height (PH) and biomass (BM) (Table 5). Farmers identified grain yield, cob size earliness as the most important criteria for adoption of maize varieties in the low-lands of North Shewa. Farmers prioritized and ranked bear tip, earliness, plant height, number of cob per plant and

Appendix Table 1: Summary of ANOVA for grain yield and other agronomic traits of OPVM in 2016.

SV	DF	SS	MS	F-Value	Pr>F
DTA	13	796.5	61.3	10.6	<0.0001
DTS	13	828.3	63.7	12.1	<0.0001
PH	13	52613.6	4047.2	8.1	<0.0001
TSW	13	34647.9	2665.2	8.2	<0.0001
GY	13	37.5	2.89	3.8	<0.001

Appendix Table 2: Summary of ANOVA for grain yield and other agronomic traits of OPVM in 2017.

SV	DF	SS	MS	F-Value	Pr>F
DTA	13	455.9	35.0	26.0	<0.0001
DTS	13	465.7	35.8	18.3	<0.0001
PH	13	5735.0	441.2	0..82	<0.64
TSW	13	11398.5	876.8	1.4	<0.21
GY	13	17.8	1.37	2.16	<0.04

Appendix Table 3: Performance grain yield and other agronomic trait across year.

Source of variation	DTA	DTS	PH	DTM	TSW	GY
Rep	NS	NS	NS	NS	NS	NS
Year	***	***	NS	***	NS	***
Variety	***	***	***	NS	***	*
Yr*Variety	***	***	***	NS	***	**

NB: *** indicate significance at 0.01 probability levels.

Table 3: Performance of maize varieties evaluated for grain yield and yield related traits at Ataye in (2017).

Trt	DTA	DTS	DTM	PH(cm)	GY (kg/ha)
Melkasa-5	54.67hg	58.67de	119.33bc	205.93	3430.1ab
Melkasa-4	55.67efgh	58.67de	118.67c	190.80	4449.1a
Gibe-3	62.00bc	65.00b	122.33ab	220.53	3434.6ab
Melkasa-6Q	56.33defg	58.00e	118.33c	208.20	3237.3ab
Gibe-2	63.33ab	66.67ab	122.00ab	212.20	2744.3bc
Melkasa-1	61.33c	64.67b	122.33ab	219.13	3232.2ab
Melkasa-1Q	57.33de	61.00cd	119.33bc	227.53	3694.3ab
Melkasa-7	55.00fgh	58.33e	119.00bc	205.67	2716.0bc
Gibe-1	56.00defgh	59.33cde	119.00bc	209.20	4207.9a
Gambela.Comp	61.67bc	64.33b	123.00a	219.80	3587.2ab
Melkasa-2	56.67def	60.00cde	120.67bc	245.00	3745.6ab
Rare-1	64.00a	67.67a	123.00a	224.00	1768.1c
Alemaye.Comp	54.33h	57.67e	118.68c	209.53	3561.1ab
LocalCheck	57.67d	61.67c	120.00bc	226.33	3959.3ab
Mean	58.29	61.55	120.4	215.99	3411.93
CV (%)	1.99	2.27	0.86	10.52	14.1

DTA = Days to anthesis; DTS = Days to silking; DTM = Days to mature; PH = Plant height and GY = Grain yield; CV = Coefficient of variance, * Significant at (p<0.05), ** Highly significant at (p<0.01), NS = Non-significant.

biomass in their order of importance (Table 5). In 2016 cropping season, a total of 29 farmers (male 24 female 5) were involved in maize participatory varieties selection trial and farmers evaluated fourteen open pollinated maize varieties and they selected five best varieties based on their preference criteria. Farmer's top preferred variety was Melkasa-4 followed by Melkasa-5 (Table 6).

In 2017 cropping season, a total of 40 farmers (31 male and 9 female)evaluated fourteen maize varieties and they selected five varieties based on their selection attributes such as beer tip (BT), earliness (ER), plant height (PH), number of cob per plant (NCPP) and Biomass (BM). Farmers prioritized and ranked bear tip, earliness, biomass, number of cob per plant and plant height, in their order of importance (Table 7). This finding is in line with Chimonyo *et al*., (2019).

Table 4: Mean performance of grain yield and other agronomic trait of traits of 14 maize varieties combined over two years.

Varieties	DTA	DTS	DTM	PH(cm)	TSW(gm.)	GYLD(kg/ha)
Melkasa-5	52.33d	56.0cd	107.00	214.20cdefg	210.00e	3939e
Melkasa-4	53.67cd	57.0cd	100.67	207.43efg	267.50abc	5243a
Gibe-3	58.83ab	62.2ab	119.83	240.00abc	255.67abcde	4688bc
Melkasa-6Q	53.67cd	56.2cd	108.50	212.94defg	246.83bcde	4609bcd
Gibe-2	59.50ab	62.8ab	112.83	217.10bcdef	280.83a	5138ab
Melkasa-1	59.00ab	62.3ab	104.17	194.73fg	226.83ef	4080de
Melkasa-1Q	51.33d	54.8d	99.00	190.51g	250.17bcde	3937e
Melkasa-7	51.33d	54.5d	100.50	204.04fg	246.33cde	3953e
Gibe-1	56.50bc	59.8bc	109.17	237.05abcd	267.83abc	5057ab
Gambela Compo	59.50ab	62.8ab	115.50	232.53abcde	230.67def	4362cde
Melkasa-2	54.00cd	57.3cd	109.17	239.01abcd	280.67a	5115ab
Rare-1	61.33a	64.8a	103.67	237.61abcd	258.00abcd	3294f
Alemaya-Compo	56.33bc	59.8bc	109.00	241.42ab	276.00ab	4278cde
Local Check	57.00bc	60.3bc	111.50	252.67a	259.83abcd	4318cde
Mean	56	59	107.9	222.9	254	4429
CV (%)	6	6.3	15	10	10	10.6

Trt= Treatments. DTA = Days to anthesis; DTS = Days to silking; DTM = Days to mature; PH = Plant height; TSW = Thousands seed weight (gm); GYLD = Grain yield (kg/ha). CV = Coefficient of variance, *Significant at (p<0.05); **Highly significant at (p<0.01; NS = non-significant.

Table 5: Pair wise ranking matrix of selected criteria's for maize varieties in 2016.

Attributes	NCPP	BT	ER	PH	BM	Scores	Rank
NCPP		BT	ER	PH	NC	1	4th
BT			BT	BT	BT	4	1st
ER				ER	ER	3	2nd
PH					PH	2	3th
BM						0	5rd

Table 6: Farmers' preference ranking matrix summary sheet of maize in 2016.

Varieties	Farmers selection attributes						
	Number of cob/plant	Bear tip	Earliness	Plant height	Biomass	Mean	Rank
Melkasa 5	3.53	3.24	3.35	3.65	3.35	3.42	2nd
Melkasa 6Q	3	3.29	3.35	2.94	3	3.12	3rd
Melkasa 4	4.24	3.71	2.76	3.94	3	3.53	1st
Melkasa 2	2.29	1.71	2.35	1.88	2.82	2.21	5th
Melkasa 7	1.94	3.06	3.18	2.59	2.82	2.72	4th

Table 7: Pair wise ranking matrix of selected criteria's for maize varieties in 2017.

Attributes	BT	ER	PH	NCPP	BM	Scores	Rank
BT		BT	BT	BT	BT	4	1st
ER			ER	ER	ER	3	2nd
PH				NCPP	BM	0	5th
NCPP					BM	1	4th
BM						2	3rd

Table 8: Farmers' preference ranking matrix summary sheet of maize in 2017.

Varieties	Farmers selection attributes						
	BT	ER	BM	NCPP	PH	Mean	Rank
Alemaya - composite	2.1	2.75	3.9	3.05	3.4	3.04	4th
Melkasa - 5	2.1	2.55	3.0	3.0	3.1	2.75	2nd
Melkassa - 4	2.35	2.6	2.95	2.7	2.8	2.68	1st
Melkassa - 1	4.1	4.4	2.1	2.4	1.35	2.87	3rd
Gibe - 1	4.25	2.7	3.4	3.85	4.35	3.7	5th

Fig 1: Pictorial presentation of Melkasa 4 maize variety and farmers' preference 2017 main cropping season at grain filling stage (Ataye, September, 2017).

Traits desired by farmers, from the most to the least preferred, were short to medium plant height, long cobs, a large number of kernel rows (= 12), prolificacy, good cob filling, big kernel size, flint kernels and early maturity. Finally farmers preferred variety Melkasa-4 followed by Melkasa-5 (Table 8).

In both cropping seasons farmers were actively participated and selected variety Melkasa-4 as first preferred variety (Fig 1). Similarly, farmers were actively involved and play a great role in selecting top preferred varieties in finger millet (Andualem and Desalew 2017). In general, variety Melkasa-4 was not only high yielder but also early maturing and highly preferred by maize farmers which was ranked first during both years and this variety is also relatively early maturing as compared with the tested varieties. Research report showed that earliness trait is considered as an important criterion because early maturity allows the crop to escape drought and ensure early and quick provision of cash and food to households to bridge the hunger gap (Badu-Apraku *et al*., 2009).

CONCLUSION AND RECOMMENDATION

Incorporating farmers' selection criteria and farmer evaluation in the development of new open pollinated maize variety is important under the changing maize-growing environments in Ethiopia, to recommended and to increase the varietal turnover of improved maize and to improve the production system in the study areas. Our results show that farmers had a wide range of criteria they used in evaluating maize varieties. This clearly shows farmers can distinguish their desired trait at mid-season. The combined analysis of variance across years showed that highly significant ($p<0.01$) difference for days to anthesis, plant height and grain yield. The highest yield was obtained from Melkassa-4 (5243 kg/ha) and Melkasa-2 (5115 kg/ha) while the lowest yield was recorded from Rare (13294 kg/ha). The overall yielding ability of Melkasa -4 was higher as compared with the tested varieties. In addition, this variety was highly appreciated by maize farmers. Based on farmers' selection, yield potential, Melkassa-4 has recommended for the lowlands of North Shewa and similar agro ecologies in Ethiopia. Support is needed to scale-up and deliver such improved variety through involving farmers in the selection and dissemination of varieties that are adapted to their needs, as it incurred income, good in crop rotation and animal feed.

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REFERENCES

Abdulrahman, A. and Kolawole, O.M. (2006). Traditional preparations and uses of maize in Nigeria. Ethnobot Leaflets. 10: 219-27.

Andualem, W. and Desalew, F. (2017). Participatory on-farm variety selection of improved finger millet (*Eleusine coracana*) varieties in North Western Amhara Region of Ethiopia. Journal of Biology, Agriculture and Healthcare www.iiste.org ISSN 2224-3208 (Paper) ISSN 2225-093X. (Online) Vol.7, No.5,

Badu-Apraku, B., Menkir, A., Onyibe, J.E., Buah, S., Yallow, C.G., Coulibaly, N. and Crossa J. (2009). Results of the 2008 Regional Maize Trials in West Africa. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Chimonyo, V.G.P., Mutengwa, C.S, Chiduza, C. and Tandzi, L.N. (2019). Participatory variety selection of maize genotypes. The Eastern Cape Province of South Africa Journal of Agricultural Extension. 47: 103-117. http://dx.doi.org/10.17159/2413-3221/2019/Vol.

CSA (Central Statistical Authority) (2021). Agricultural Sample Survey. Vol. IV, Report on Area and Production of Crops. Addis Ababa Ethiopia.

De Boef, W. and Thijssen, M.H. (2007). Participatory Tools Working with Crops, Varieties and Seeds. A Guide for Professionals Applying Participatory Approaches in Agrobiodiversity Management, Crop Improvement and Seed Sector Development. Wageningen, Wageningen International. 83 p.

Eileen B.N., Cosmas, K.L., Odhiambo, C.A.. David, K. and Eliezah, K. (2021). Gender-responsive participatory variety selection in Kenya: Implications for common bean (*Phaseolus vulgaris* L.) breeding in Kenya. Sustainability https://doi. org/10.3390/ su132313164.

Fekadu, K. (2015). Ethiopian seasonal rainfall variability and prediction using Canonical Correlation Analysis (CCA). Earth Sciences. 4(3): 112-119.

Gebre, G.G., Isoda, H., Rahut, D.B., Amekawa, Y., Nomura, H. (2019). Gender Differences in the Adoption of Agricultural Technology: The Case of Improved Maize Varieties in Southern Ethiopia.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research (2nd Edn.). John Wiley and Sons, New York. pp. 680.

Harold, M. (2015). Feeding Africa IBM SPSS Stastics (Version 20.). (pp. 36).

Husain, N., Khan,M.Y. and Baloch,M.S.(2011). Screening of maize varieties for grain yield at Dera Ismali Khan. The Journal of Animal Plant Science. 21(3): 626-628.

Iken, J.E., Anusa, A. and Obaloju, V.O. (2001). Nutrient composition and weight evaluation of some newly developed maize varieties in Nigeria. Journal of Food Technology. 7: 25-28.

Kutka, F. (2011). Open pollinated vs. hybrid maize cultivars. Sustainability3. doi: 10.3390/su3091531.

Kutka, F., Conway, P., Christensen, J. (2004). The Heritage Maize Project (FNC00-301) Study of Open-Pollinated Corn: Final Report to the North Central Region Sustainable Agriculture Research and Education Program, US Dept. of Agriculture SARE Program.

Rashid, S., Kindie, G. and Solomn, L. (2010). Maize value chain potential I Ethiopia: constraints and opportunities for enhancing the system. International Food Policy Research institute. 64 p.

Sacks, W.J. Deryng, D., Foley, J.A., Ramankutty, N. (2010). Crop planting dates: an analysis of global patterns. Glob. Ecol. Biogeogr. 19(5): 607-620.

SAS (2002). SAS/STAT user's Guide, Version 9. SAS Institute.

Shikha, B., Manpreet, J., Ramanjit, K. (2019). Nutritive value, maize-production and use, Akbar Hossain. In tech Open. doi: 10.5772/intechopen.8 8963.

Smith, M., Seiter, S. Mt, Pleasant J., Kutka, F. (2003). Performance of Open-pollinated Corn Varieties for Grain and Silage Production. In: Proceedings of the 58th Northeast Corn Improvement Conference, Ottawa, ON, Canada, 13-(14 February; Reid, L., Ed.; Agriculture and Agri-Food Canada: Ottawa, Canada.

Statista. Distribution of Global Corn Production in (2015) by Country. (2016). Available online at: www.statista.com/market/ (accessed July 20, 2021).

Tandzi, L.N., Mutengwa, C.S. (2019). Estimation of maize (*Zea mays* L.) yield per harvest area: Appropriate methods. Agronomy. 10: 1-18. doi: 10.3390/agronomy10010029.

Taye, T., Bekele, N., Shimalis, Y. (2016). Evaluation of highland maize at Bule hora District of Southern Oromia, Southern Ethiopia. Africa Journal of Agriculture Research. 11(34): 3178-3181.

Undie, U.L., Uwah, D.F., Attoe, E.E. (2012). Effect of intercropping and crop arrangement on yield and productivity of late season maize/soybean mixtures in the humid environment of South Southern Nigeria. Journal of Agricultural Science. 4: 37-50. doi: 10.5539/jas.v4n4p37.

Worku, M., Zelleke, H. (2007). Advances in improving harvest index and grain yield of maize in Ethiopia. East African J. Sci. 1(2): 112-119.

World Atlas (2016). World Leaders in Corn (Maize) Production, By Country. Available online at: https://www.worldatlas.com/articles/world-leaders-incorn-maize-production-by-country.html (accessed July 24, 2021).

Yadaw, R.B., Khatiwada, S.P., Chaudhary, B., Adhikari, N.P, Baniya, B., Mudwari, A. and Tripathi, B.P. (2006). Participatory Variety Selection (PVS) of rice varieties for rain fed condition. International Rice Research Institute. (IRRI).