Participatory Evaluation of Maize Cultivars under Conservation Agriculture and Conventional Practice for Moisture Deficit Areas of Southern Ethiopia

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ABSTRACT

Maize is the main staple food and the dominant cereal in low moisture stress areas of Boricha and Loka Abaya districts of southern Ethiopia. The objective of this study was to test the adaptability and suitability of improved maize varieties under conservation agriculture (CA) and conventional farming practice (CP) and to recommend for further use by farmers. Seven improved maize varieties of which four were hybrids and the other three were open pollinated (OPV) tested using Participatory Varietal Selection (PVS)in the first year under CP whereas in the second year all the genotypes tested were hybrid varieties in the same districts. In addition, at Hawassa on station in CP, each variety was sown on an area of 22.95 m 2 replicated three times. In the first year under CP, hybrid variety Shala gave the highest yield (3.59 t/ha), followed by the OPV Gibe2 (2.72 t/ha) under farmers' conditions. In the second year under CA conditions, varieties Shala and SC-403 gave highest yields 3.94 and 3.87 t/ ha, respectively. In researcher managed conditions, varieties Shala, BH-543 and MHQ-138 gave highest yields 9.21, 9.08, 8.81 t/ ha, respectively and ranked from first, second and third under CP. In both seasons variety Shala ranked first in yield under CA and CP which shows the variety's good stability in favorable and unfavorable years. This variety was also farmers' first choices in both years and locations based on their evaluation criteria.

Keywords: *Participatory varietal selection, Conventional farming practice, Conservation agriculture, Farmers selection criteria, Moisture deficit.*

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1. INTRODUCTION

In subSaharan Africa, maize is the main staple crop; accounting for an average of 32% of consumed calories (Cairns *et al.*, 2012) in Ethiopia 93% of the farmers in the lowlands are maize growers (Girma *et al.*, 2005). Maize grain is used for food, for sale and for making local brewery and the stalk is used for construction, animal feed and domestic fuel (Girma *et al.*, 2005; Mosisa *et al.*, 2011). It is the main staple food and the dominant cereal in Boricha and Loka Abaya districts. In Ethiopia among cereals, maize ranks second in area coverage and first in total production having over 2million hectares and 6.1 million tons, respectively (CSA., 2013). Even though maize productivity has increased by 30% from 1990s to the 2000s (Mosisa *et al.*, 2011) the average national grain yield 3.0 t ha^{-1} (CSA., 2013) is still very low as compared to the world average yield 5.2 t ha^{-1} (FAOSTAT, 2012).

The use of conventional farming practices based on extensive tillage, especially when combined with removal all biomass or *in situ* burning of crop residues, has accelerated erosion while the soil resource base has been steadily degraded. Conservation agriculture (CA) has been proposed as a set of management principles that assures a more sustainable agricultural production and reducing productions costs while increasing profitability (Cairns *et al.*, 2012). It combines reduced tillage, retention of adequate levels of crop residues maintaining soil surface cover and crop rotations. Conservation agriculture, based on minimum tillage, crop residue retention and crop rotation, can improve infiltration and reduce evaporation compared to practices involving conventional tillage, and zero tillage without retention of adequate levels of crop residue (Verhulst *et al.*, 2010).

Sustainable agronomic and resource management practices can effectively contribute to climate change mitigation (Cairns *et al.*, 2012). In areas where maize is the dominant crop it is mainly mono-cropped but farmers fail to attain the yield potential of the improved varieties due to the decline in soil fertility (Mosisa *et al.*, 2011). Unless mono-cropping is replaced by maize–pulse rotation and/or the soil is conserved and managed well, maize production in these areas will be endangered.

As CA is new practice for Ethiopia the improved varieties were not tested by comparing both in CA and conventional practice (CP) to see all the advantages of CA especially in low moisture stress areas of Borecha and Loka Abaya districts of southern Ethiopia. Hence, this work was done with the objective to test the adaptability and suitability of improved maize varieties under CA and CP and to recommend for further use by farmers.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

Borecha and Loka Abaya are in southern mid-altitude dry lands districts in Sidama Zone, SNNPR. They are 50 and 70 Km far from Hawassa town to the south direction, respectively. The intervention of Sustainable Intensification of Maize-Legume cropping systems for food security in Eastern and Southern Africa (SIMLESA) expansion program identified these sites representing that are drier and more prone to drought than the main program sites. The expanded activities was address the issues of fodder shortages for livestock that impact directly and severely on the adoption of CA strategies whereby livestock compete for crop residues as a feed source (the forage parts will not be discussed in this paper as it was tested separately in participatory varietal selection).These farming systems are characterized by chronic poverty and food insecurity resulting from low productivity of maize based mixed crop-livestock systems which support livelihoods for the majority of the small-scale farmers. Before the intervention 10 focused group discussions with key informants were held in the two districts by multidisciplinary team, one in each community and identified their soil types (Table 1).

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Table-1. Altitude and major soil types of the community

Woreda	Community	Latitude	Longitude	Altitude (masl)	Major soil types
Borecha	Shelo Abore	$06^0$57.120 N	038^0 13.376 E	1809	Sandy loam
	Shelo Elancho	$06^0$56.203 N	038^0 14.407 E	1836	Verti soil
	Shelo Belela	$06^0$57.120 N	038^0 13.957 E	1826	Clay loam
	Shamena Godo	$06^0$59.579 N	038^0 15.858 E	1927	Verti soil
	Sadamo Chala	$06^0$56.192 N	038^0 16.627 E	1914	Verti soil
Loka Abaya	Baretu	$06^0$41.976 N	038^0 14.870 E	1780	Verti soil
	Rudie	$06^0$43.088 N	038^0 14.941 E	1765	Sandy loam
	Segeno	$06^0$44.438 N	038^0 15.989 E	1771	Sandy loam
	DansheGambela	06^0 38.088 N	038^0 15.681 E	1682	Clay soil
	Areda Gale	06^0 42.491 N	038^0 14.978 E	1761	Clay soil

2.2. Genotypes Studied

In the first year of SIMLESA expansion 2012 seven improved maize varieties of which four were hybrids (Abaraya, Shala, BH-540, BH-543,) the other three were Open pollinated varieties (OPVs)*viz* Melkasa-2, Melkasa-4, Gibe-2 sown under CP in 10 Kebeles (one host farmer in each kebele, five kebeles per woreda) and Hawassa Center. In the second year 2013 all the genotypes tested were hybrid varieties (Abaraya, BH 540, BH 543,Shala,SC403, MH130 and MHQ138) those were collected from Seed Co, (Abaraya and SC403), Pioneer Hybrid Company (Shala) , public seed enterprise (BH 540 and BH 543), and Melkassa Agricultural Research Center (MH130 and MHQ138) . Among the hybrid varieties Abaraya, BH 540, BH 543, Shala were tested in both seasons but the rest three were only in 2013 cropping season.

2.3. Experimental Design and Cultural Practices

In the first year in Borecha and LokaAbaya districts the Participatory Varietal Selection (PVS) constituting 10 un replicated trials tested in single large plots under CP conventional farming practice and one replicated trial at Hawassa on station. Among 10 PVS, four were in good condition and harvesting was done in those fields while the others have failed due to moisture stress that lasted for a month after sowing. In the second year the PVS were conducted under CA in Loka Abaya (four kebeles) and Borecha (two kebeles) in each kebele the maize PVS were sown with an area of 100 m^2 under CA practice and in addition at Hawassa on station (conventional way) each variety was sown with an area of 22.95 m ^{2} replicated three times. For the CA farming practice non selective herbicides glyphosphate (round up) 3liter /ha was used 10 days before sowing to control both broad and grass weeds. Traditional hoe (*Tike*) was used to slightly open the furrow for planting. Phosphorous fertilizer was applied at the rate of 100 kg DAP ha $^{-1}$ at planting and as source nitrogen urea was applied at the rate of 100 kg ha^{-1}when it attains at knee height stage(i.e $P_2 0_5$= 46 and N= 64 kg/ ha).

2.4. Data Collected

Agronomic and yield data were collected on the researchers side and farmer perception towards the varieties based on their criteria was evaluated. Varietal evaluation and selection was conducted by farmers who considered the following traits: no barren plants, stay green at maturity, early maturing, adapted to the area and tolerant to moisture stress, big cob size, no rotten cobs/ no insect damage, big seed size, heavy seed weight, white seed color, not open its tips at maturity, high yielder at moisture stress condition. Farmers ranked each genotype for all traits. Scoring was based on the number of genotypes tested and the relative performance of each genotype and finally put overall ranks for each genotype based on their preferences.

2.5. Data Analysis

For analysis each farmer was considered as replication for the on farm demonstration and analysis was done using (SAS Institute Inc, 2002) and the mean separation was done in Least Significant Difference (LSD). In the second year among the tested genotypes MHQ138 tested only in two farmer's field because of shortage of seeds then not considered in the analysis.

3. RESULT AND DISCUSSION

In the first year under conventional farming practice comparison was among hybrid and OPVs consequently the hybrid variety Shala gave higher yield (3.59 t/ha) and followed by the OPV Gibe-2 (2.72 t ha^{-1}) under farmer conditions (Table 2). Even though the yield was low as compared to the potential of the varieties in optimum condition, relatively good yield was obtained as severe moisture stress occurred that lasted for a month after sowing which caused failures of most of the PVS. Among the tested maize varieties, Abaraya, Gibe-2 and Shala with their deep root able to anchored the soil and were resistant to root lodge as compared to Melkasa-4 and shown minimum root lodge (Table 2). In the second year under CA conditions Shala and SC 403 gave higher yields 3.94 and 3.87 t ha^{-1}, respectively (Table 3).

Thapa *et al.* (2009) reported that PVS has been shown to diversify range of varieties in farmers' fields and allow plant breeders to demonstrate, train and disseminate appropriate technologies to farmers in the target environment. In agreement to these authors, among the tested maize PVS in 2012 in Borecha and Loka Abaya districts the hybrid variety Shala and OPV variety Gibe 2 were preferred by farmers and scaled out in conventional farming practice because farmers were participated in the PVS and build up confidence and trusted the technologies. In addition it increased varietal diversity and most effective within complex farming community.

Table-2. Mean agronomic and yield (t ha^{-1}) of OPV and hybrid maize varieties under CP in Borecha and Loka Abaya 2012

Genotypes	Grain yield (t ha^{-1})			PH (cm)	EH (cm)	RL (%)	SL (%)	EPP
	Borecha	Loka Abaya	Combined					
Abaraya	1.52	2.74	2.13	155.8	85.7	4.6	4.4	1.08
Gibe-2	1.58	3.86	2.72	142.3	75.1	8.1	5.8	1.68
BH-540	1.45	3.32	2.39	144.6	79.3	22.5	7.4	1.32
Melkasa-2	1.39	3.47	2.43	148.3	76.5	24.5	5.8	1.42
BH-543	1.74	2.45	2.09	161.1	90.2	14.9	5.2	1.11
Melkasa-4	1.66	3.26	2.46	134.5	68.5	41.1	7.1	1.69
Shala	2.16	5.02	3.59	151.7	75.5	8.8	3.6	1.53
Mean	1.64	3.44	2.54	148.3	78.7	17.8	5.6	1.40

PH= Plant Height, EH= Ear Height, RL= Root Lodge, SL=Stalk Lodge, EPP= Ears per Plant, EPP= Ears PerPlant

Table-3. Mean agronomic and yield (t ha^{-1}) of hybrid maize varieties under CA in Borecha and Loka Abaya 2013

Genotypes	Grain yield (t ha^{-1})			PH (cm)	EH (cm)	RL (%)	SL (%)	EPP
	Borecha	Lokabaya	Combined					
Abaraya	3.50	3.49	3.49	157.4	67.1	4.2	15.0	0.83
BH-540	3.65	3.35	3.45	174.8	67.4	6.2	31.3	0.81
BH-543	3.48	3.22	3.31	178.4	83.1	4.3	28.2	0.86
Shala	4.10	3.86	3.94	147.9	51.0	1.1	15.6	0.93
SC 403	4.51	3.55	3.87	172.8	62.4	0.8	23.5	0.93
MH130	3.74	2.75	3.08	126.9	48.0	1.8	21.2	0.88
Mean	-	-	3.52	159.7	63.2	3.1	22.4	0.87

PH= Plant Height, EH= Ear Height, RL= Root Lodge, SL=Stalk Lodge, EPP= Ears per Plant, At Hawassa on station condition most of the characters showed significant difference except root lodge (%) and number of barren plants. All the hybrid varieties gave higher yield ranged from 7.63 to 9.21 t/ha even though there was significant difference among them. In researcher managed PVS Shala, BH-543 and MHQ138 gave higher yield 9.21 , 9.08, 8.81 t ha^{-1}, respectively and ranked from one to three at CP (Table 4). Hawassa on station was better than the other two stressed districts and Borecha was the least. In both seasons Shala ranked first in yield under CA and conventional farming practice which shows stable in worse and good years.

Table-4. Mean agronomic and yield (t ha^{-1}) of hybrid maize varieties under CP at Hawassa on station, 2013

Genotypes	Grain yield (t ha^{-1})	DT	DS	PH (cm)	EH (cm)	RL (%)	SL (%)	EPP
Abaraya	8.07	77	78	190.7	88.8	16.7	22.3	1.10
BH-540	7.76	77	80	221.7	112.1	52.5	53.6	0.98
BH-543	9.08	79	85	208.5	126.8	23.0	18.0	1.04
Shala	9.21	73	77	192.5	84.1	11.7	15.2	0.96
SC 403	8.37	69	73	201.8	80.0	25.8	17.7	1.05
MH130	7.63	75	70	158.5	64.8	23.2	11.2	1.13
MHQ138	8.81	77	77	192.4	84.2	31.6	26.7	1.18
Mean	8.42	74	77	195.1	91.5	26.4	23.5	1.06
CV	7.1	0.7	0.9	5.8	11.3	59.8	20.5	10.88
LSD	1.07	0.9	1.3	20.2	18.4	28.0	8.6	0.21
Signifi.	*	***	***	***	***	NS	***	NS

*= Significant at 0.05; **= Significant at 0.01; ***=Significant at 0.001; NS=Not significant, DT= Days to Tassel, DS= days to Silking, PH= Plant Height, EH= Ear Height, RL= Root Lodge, SL=Stalk Lodge, EPP= Ears per Plant,

3.1. Farmer Selection Criteria

The farmers considered a number of criteria in evaluating the performance of the different maize varieties in the field right from germination to harvest time (Table 5 and 6). The farmers criteria in both season were somewhat similar across many varieties *viz* no barren plants, stay green at maturity, early maturing, adapted to the area and tolerant to moisture stress, big cob size, no rotten cobs/ no insect damage, big seed size, heavy seed weight, white seed color, not open its tips at maturity, high yielder at moisture stress condition. From the above criteria high yield, early maturing, stay green at maturity and no rotten cobs were the most important criteria set by farmers to evaluate the varieties. According to Girma *et al.* (2005) and Buah *et al.* (2013) farmer's preferences in some cases coincided with the breeders' selection as it was the case with similar order of ranking of Shala , Abaraya and SC403 by both researchers and farmers in the second season. The hybrid, Shala was ranked first because of its stay green characters at maturity, big cob size, big seed sizes, heavy seed weight and high yield potential. This hybrid variety was selected by farmers in their overall criteria both under CA and conventional farming practice of the two seasons (Table 2 and 3). Farmers revealed that besides many smart characters of this variety it has also defects such as open its tips at maturity (not good husk cover) and has red seed color which was not their first options. Farmers afraid of when rainfall coincides at maturity it becomes easily deteriorate and they gave assignment to researchers to improve its uncover tips. In relation to this, study conducted in South Africa shown that farmers prefer maize varieties with good husk cover which is important in against storage pests and ear rots (Derera *et al.*, 2006). In the first year among several criteria of farmers' high yield, stay green at maturity and no rotten cobs (insect tolerant) was the most important criteria accordingly Shala was their first choice. But in overall criteria Shala, BH 540 and Abaraya was ranked respectively from one to three (Table 5). In the second year among the criteria due attention was given high yield, early maturing and no rotten cobs, in this case Shala was first in yield but both in early maturing and no rotten cobs their first option was MH130 and in overall criteria Shala, Abaraya and SC 403 ranked by farmers from one to three(Table 6).In agreement to this study Obaa *et al.* (2005)

stated that early maturity allows the crop to escape drought and ensure early and quick provision of cash and food to the households to alleviate hunger in low-moisture stress areas.

Table-5. Farmers selection criteria for comparison of OPVs and hybrid maize varieties in Borecha and Loka Abaya districts, 2012

Selection criteria	Maize varieties ranked by farmers criteria						
	Abaraya	Gibe-2	BH-540	Melkasa-2	BH-543	Melkasa-4	Shala
No barren plants	6	4	7	2	5	1	3
Stay green at maturity	2	3	5	7	4	6	1
Big cob size	2	3	4	6	5	7	1
No rotten cobs	4	2	7	5	6	3	1
Big seed size	2	4	3	7	5	6	1
Heavy seed weight	2	3	5	6	4	7	1
White seed color	1	3	2	4	6	5	7
Not open its tips at maturity	1	2	3	4	6	5	7
High yielder at moisture stress condition	2	3	5	5	4	6	1
Over all rank of farmers	3	4	2	7	5	6	1

Table-6. Farmers selection criteria for comparison hybrid maize varieties under CA in Borecha and Loka Abaya districts, 2013

Selection criteria	Maize varieties ranked by farmers criteria					
	Abaraya	BH-540	BH-543	Shala	SC 403	MH130
Early maturing	4	5	6	3	2	1
Adapted to the area and tolerant to moisture stress	3	6	5	2	4	1
Big cob size	2	4	5	1	3	6
No rotten cobs/ no insect damage	3	6	5	2	4	1
Big seed size	3	4	5	1	2	6
Heavy seed weight	3	4	5	1	2	6
White seed color	1	2	4	6	3	5
Not open its tips at maturity	2	1	5	6	3	4
High yielder at moisture stress condition	2	6	3	1	4	5
Over all farmers rank	2	5	6	1	3	4

4. CONCLUSION AND RECOMMENDATIONS

Results of this study showed that farmers have a multiple of criteria for evaluating maize varieties apart from yield, even though yield was the major parameter for selecting varieties they grow. Incorporating farmers' preferences in selection of varieties in PVS process facilitates the scaling out of the varieties and also increases the rate of adoption of the maize varieties by farmers.PVS approach in the study area would contribute in food security through increases diversification and productivity of maize varieties. Conservation agriculture has many advantages over the conventional farming practice *vis* increased water infiltration, reduced moisture evaporation, less water run-off and soil erosion, reduction in labor and energy use and increase soil organic matter. Besides its advantage it is friendly with nature but slow and seen as cumulative effects. In order to promote to scaling out this technologies awareness creation and demonstration of the technologies in the farmers field is important with participation of farmers from the very beginning of planning up to harvesting as it was done in this study. As the CA was done only for one year it requires repeating the evaluation to see all its effect and advantages over the conventional farming practice.

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