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Participatory evaluation of the adaptability of released maize varieties to moisture stress areas of Dugda Dawa, Southern Oromia

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Maize is an essential food crop in Ethiopia. The experiment was conducted to establish and select adaptable maize variety with better agronomic performance and to familiarize farmers with improved agronomic practices for moisture stress within the study area. The experiment was conducted on agro-pastoralists' land by the researcher together with some selected members of agro-pastoralists. Three maize varieties that included MH140, MHQ138 and MH130 were used for the experiment on selected pieces of land. A total of twenty-five farmers were selected from the following Peasant Association for this experiment for both years based on their interest. Five groups were formed based on their closer areas. Each group planted all maize varieties on 10 × 10 m plot size for each variety with a gross area of 100 m^2 after the land was prepared in good manner with the help of expert. Recommended spacing of 75 and 25 cm between rows and plant, respectively was used. Analysis of variance showed significant difference among varieties in days to physiological maturity, plant height, biomass, grain yield, and harvest index. The highest grain yield was obtained from MH130 (6.55 ton/ha) followed by MHQ138 (5.88 ton/ha), while the lowest grain yield was recorded for MH140 (5.02 ton/ha). Based on agro pastoralists perception and selection criteria, MH130 was the first followed by MHQ138. This study states how the pastoralist perceptions were obtained. Therefore, since MH130 is relatively a high yielder and early maturing variety, it is recommended for adoption in Dugda Dawa district and other areas with the same agroecology.

Key words: Participatory, agro-pastoralist, Dugda Dawa, maize variety, perception.

INTRODUCTION

Maize (*Zea mays* L) is one of the most important cereal crops grown world-wide with a global leader in total cereal production and is ranked third most important food crop after wheat and rice (FAOSTAT, 2012). Maize is also an important staple cereal crop sub-Saharan Africa. The crop fits well in farming systems across agro-

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ecological zones in the region, meeting the nutritional needs of people with varying socio-economic circumstances (Macauley and Ramadjita, 2015). It is a versatile crop grown over a range of agro climatic zones. In fact, the adaptability of maize to diverse environments is unmatched by any other crops. It is grown from 58°N to 40°S, within latitudinal ranges of 0 to 3000 masl and in areas with 250 mm to more than 5000 mm of rainfall per annum (Dowswell et al., 1996). Maize is one of the most important cereal crops in Ethiopia, ranking second in area coverage following tef and first in total grain production followed by tef, wheat and sorghum and first in area coverage (FAO, 2015). The popularity of maize in Ethiopia is partly because of its high value as a food, feed and source of fuel for rural families. Approximately 88% of maize produced in Ethiopia is consumed as food, both as green and dry grain (CSA, 2015).

Maize growing areas in Ethiopia are mostly classified into four agro-ecological zones based on altitude and annual rainfall. These are the high altitude moist zone, which lied between altitudes of 1700 to 2400 masl, and receive 1200 to 2000 mm annual rainfall. The mid altitude moist zones lies between an altitude of 1000 and 1700 masl and receives 1200 to 2000 mm annual rainfall. The low altitude moist zone lays an altitude less than 1000 masl and receives 1200 to 1500 mm annual rainfall. The moisture stress zones lie between an altitude ranging from 500 to 1800 masl and receives rainfall amount of less than 800 mm per year (Kebede et al., 1993). About 40% of the total maize growing area is located in lowland (moisture stress areas) and contributes less than 20% of the total annual production (CSA, 2015). This is because rainfall in this region is unpredictable both in terms of distribution and amount (may start early or very late in the season), quantity (sometimes less than 600 mm/annum) and in its distribution.

Annual maize yield loss of about 15% has been attributed to drought in sub-Saharan Africa and biomass production generally decreases with decreasing moisture availability (Blackwell et al., 1985). The yield reduction of 70 to 90% has also been reported under mild to severe water stress condition (Vicente, 1999). Drought stress at silking, tasseling and grain filling has been reported to be more drastic on grain yield in maize than stress during vegetative phase (Westgate and Grant, 1989). 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 attributed to recurrent drought, low levels of fertilizer use and low adoption of improved varieties. 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 western Guji zone especially on farmers land. Participatory evaluation of technology under farmers' condition is an important approach in technology dissemination process. Above all, it is a systematic dialogue between farmers and scientists to solve problems related to agriculture and ultimately increase the impact of agricultural research. Since, participation of farmers in varietal choice has considerable value in technology evaluation, dissemination and production improvement for a given crop. Therefore, this study was designed to demonstrate and select adaptable maize variety/ies with better agronomic performance integrating farmer's criteria and to familiarize farmers with improved agronomic practices for moisture stress areas of the study area.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Dugda Dawa district, Mokonisa Magada PA for two consecutive years. Dugda Dawa district is found in Western Guji zone at 498 km from Addis Ababa to southern direction. Dugda Dawa had midaltitude (30%) and lowland (70%) environmental conditions. The district is found in lowland area which receives an average annual rainfall of 750 mm that is erratic and not evenly distributed. The altitude of the study area ranged from 300 to 1750 masl. The length of the growing season is between 60 and 100 days (March to June) "*Gana*" season and late August to late October "*Hagaya*" season. The types of soil found with the study area are mainly sandy loam to sandy clay with low moisture holding capacity. The temperature in the region ranges from 25 to 33°C. The dominant crops grown in this area are maize (*Z. mays* L), inset (*Ensete ventricosum* (Welw)), teff (*Eragrostis tef*) and haricot bean (*Phaseolus vulgaris* L).

Experimental setup and management

Selection of participants (agro-pastoralists) 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. Accordingly, a total of twenty-five farmers were selected from the following PA for this experiment for both years. After the farmers undergoing training, they were grouped into five participatory research (PRG) groups according to their proximity to the experimental sites. After the sites were selected for all groups, land was cleared, ploughed and harrowed by using an oxen-drawn plough at the end of the second rain season. Three improved maize varieties (MH-140, MHQ-138, and MH-130) released from Melkassa Agricultural Research Center were demonstrated on agro-pastoralist land. Each group planted all maize varieties on 10 × 10 m plot size for each variety with a gross area of 100 m^2 after the land was prepared in good manner with the help of expert. Recommended spacing of 75 and 25 cm between rows and plants, respectively was used. Planting was done immediately following the first rain shower. Two seeds per hill were sown, which were thinned to one plant per hill after three weeks. Sowing was done by hand drilling at a seeding rate of 25 kg ha^{-1}. The maize crops were sown at 2 seeds per hole (justify). Fertilizer was applied in the form of Urea and DAP in the rate of 200 and 150 kg ha^{-1}, respectively. DAP was used all once during planting, while half of the urea was applied during planting, one fourth at knee stage and one fourth at silking stage. All agronomic practices including weeding were done for all varieties equally as required.

Collected data

Days to physiological maturity (DM)

It is the number of days from date of emergence to the date when 90% of the plants in each plot are physiologically matured determined by the formation of black layer at the base of each kernel.

Plant height (PH)

A height of five randomly taken plants from each plot was measured from the ground level to the base of tassels and the average was recorded in centimeter.

Ear height (EH)

The height of five randomly taken plants from each plot was measured from the ground level of the node bearing upper ear and the average was recorded in centimeter.

Ear length (EL)

Length of five randomly taken ears from each plot was measured from the base to the tip of the ears and the average was recorded in centimeter.

Grain yield per plot (Yld)

Measuring the amount of grain yield obtained from a plot in kilogram.

Biomass (BM)

Total above ground yield (Grain yield and other morphological part) harvested from each plot was weighted after being dried under sun and converted to hectare base.

Harvest index

This was calculated for all varieties by using the following formula:

$$HI = \frac{\text{grain yield}}{\text{total yield}}$$

Finally, pastoral perception was collected to enhance the farmer's demands in technology recommendation across various criteria of socio-economics criteria.

Data analysis

The collected agronomic and phenological data were subjected to SAS computer software (SAS Institute, 2002). Means separation was done using least significant difference (LSD) at $p<0.05$. Farmer's perceptions were analyzed by descriptive statistics. Collected farmers preferences were analyzed by using formula described by De Boef and Thijssen (2007). The formula of ranking method used was:

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

where N is the value given by group of farmers for each variety based on the selection criteria and n is the number of selection criteria used by farmers.

RESULTS AND DISCUSSION

Agronomic performances

Analysis of variance showed significant difference among varieties in days to physiological maturity, plant height, biomass, grain yield, and harvest index. The significant difference observed among varieties showed the genetic difference of the varieties.

Days to maturity

In days to maturity, analysis of variance showed significant repetition difference among varieties ($p<0.05$). The highest days to maturity was recorded for MH140 (149 days) while the lowest days to maturity was recorded for MH130 which took 127.33 days to mature.

Plant height

Analysis of variance showed significant difference among varieties ($p<0.05$). The highest plant height was registered for MH140 (196.67 cm) followed by MHQ138 (187.23 cm), while the lowest plant height was registered for MH130 (166.67 cm) (Table 1). Different researchers reported significant difference in plant height for maize genotypes (Tadesse et al., 2014; Taye et al., 2016; Bakala et al., 2017).

Biomass

Analysis of variance showed significant difference among varieties in biomass yield ($p<0.01$). The highest biomass yield was recorded for MH140 (8.51 ton/ha) while the lowest was recorded for MH130 (7.87 ton/ha) (Table 1). In line with the aforementioned finding, Tadesse et al. (2014), reported significant difference in total biomass yield for different maize genotypes.

Grain yield

Analysis of the data revealed significant variations among the tested varieties ($p<0.01$). The variety MH130 (6.55 ton/ha) had higher grain yield than all other varieties

Figure 1. Pictorial presentation of MH130 maize variety 2017 main cropping season at grain filling stage (Natol, September, 2017).

Table 1. Mean performance of different maize variety at moisture stress areas of Western Guji Zone, Dugda-dawa district in 2017 main cropping season (pooled mean).

Variety	DM (days)	PH (cm)	EH (cm)	BM (tone/ha)	GY (tone/ha)	HI
MH130	127.33[b]	166.67[b]	86.27[a]	7.87[c]	6.55[a]	0.45[a]
MHQ138	147.33[a]	187.23[ab]	82.47[a]	8.29[b]	5.80[b]	0.41[b]
MH140	149.00[a]	196.67[a]	96.67[a]	8.51[a]	5.02[c]	0.37[c]
Mean	141.22	183.53	88.46	8.22	5.79	0.41
CV	5.14	9.59	7.36	5.64	6.98	5.62
LSD	16.47*	21.76*	14.76ns	0.15**	0.54**	0.03**

Means with the same letter are not significantly different. DM: Days to maturity, PH: Plant height, EH: Ear length, BM: Biomass, GY: Grain yield, HI: Harvest index, ns: Non-significant, **Significant at ($p<0.01$), *Significant at ($p<0.05$), LSD: Least significant difference, CV: Coefficient of variation.

under study while the variety MH140 (5.02 ton/ha) yielded the lowest grain than other varieties (Table 1). In the same way, Bassa and Goa (2016) reported significant difference among maize genotypes in grain yield in their study of maize performance evaluation at Southern Ethiopia Hadiya zone. Similar, Taye et al. (2016) reported significant difference in grain yield for high land maize genotypes evaluated at Bule Hora in Ethiopia. In contrast to the current finding, Tadesse et al. (2014), reported non-significant difference for different maize genotypes evaluated on farm at Chilga district of North Western Ethiopia.

Harvest index

Analysis of the data revealed significant variations among the tested varieties ($p<0.01$). The variety MH130 (45%) (Figure 1) had the highest harvest index while the variety MH140 (0.37) had the lowest harvest index (Table 1). This is in agreement with Worku and Zelleke (2007), who reported that mean harvest index varied from 31.1 to 45.0%. Tadesse et al. (2014) also reported harvest index ranging from 43.5 to 32.70% for different maize genotypes on farm evaluation.

Preference comparison

The producers were asked to list the main criteria to be considered in the selection of improved seed in their local condition. Responses given included variables such as: yield, early maturity, drought tolerant, disease, tolerance, seed size, seed color, plant height, less susceptibility for

Table 2. Variety ranking against various criteria.

Maize variety	Yield	Early maturity	Drought tolerant	Disease tolerance	Seed size	Seed color	Plant height	Less wildlife attack	Score (100%)
	23.5	**17.6**	**23.5**	**11.8**	**5.9**	**5.9**	**5.9**	**5.9**	**100**
MH130	94	70.4	94	47.2	23.6	23.6	23.6	5.9	38.2
MH140	47	35.2	23.5	23.6	17.7	11.8	17.7	17.7	19.4
MHQ138	70.5	52.8	70.5	35.4	11.8	5.9	5.9	11.8	22.0

wildlife attack, market demand and consumption. From these criteria, crop yield, drought tolerant, early maturity and disease tolerance were given a due attention by pastoral households. Although the aspect of the market demand and taste were not evaluated, at the current condition the producers preferred MH130, MHQ138 and MH140 (Table 2) as the most suitable maize varieties for the moisture stress regions of Dugda Dawa.

However, the preference was highly susceptible to rainfall condition. In good rainy season, MH140 can relatively provide higher yield than the other two varieties (MH130 and MHQ138), while MH130 and MHQ138 are highly preferable, respectively due to both drought resistant and early maturity. As compared to the local breed, however, MH130 and MHQ138 can highly withstands the moisture stress season that provides reasonable yield to ensure the food security of the households. Finally, MH130 and MHQ138 were selected as the first and second selected crop on average across various criteria (Table 2). Though the market demands were not yet evaluated the higher yield and resistant to moisture stress could be an indication to improve the income of the community as compared to the local seed.

CONCLUSION AND RECOMMENDATIONS

Maize (*Z. mays* L.) is one of the most important cereal grains grown worldwide in a wider range of environments because of its greater adaptability. Analysis of variance showed significant difference among varieties in days to physiological maturity, plant height, biomass, grain yield and harvest index. The significant difference observed among varieties showed the genetic difference of the varieties. In addition to its yield advantage over other varieties, MH130 variety was selected by PRG members and field day participants including district and zonal level experts as first and productive variety. MHQ138 was ranked second in grain yield and preference criteria's. Since maize is one of the most important food crop of the society, it needs further attention to increase the production and productivity than the currently obtained one. Based on the stated findings, the following recommendations were suggested for end users and researchers.

(1) Variety MHQ138 has very valuable quality protein very important for human consumption, so it is recommended to be produced for food purpose.
(2) Participatory varietal selection has significant role in rapid technology adaptation and dissemination than conventional approach.
(3) Highbred varieties need seed from its source (first line). Yet, the supply of these seeds to the demand of these producers need further attentions due to economy of scale for individual producers to collect the seed from its sources. Thus, it needs strong linkage of producers, agriculture and natural resource office of both district and zonal level office, seed supplier and seed enterprises.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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