Raising Maize (Zea mays L.) Productivity Through Different Moisture Conservation Practices at Moisture Stress Area of Borana Zone for Small Scale Agro-Pastoralists

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Abstract: Maize (Zea mays L.) is one of the most important cereals broadly adapted worldwide. The experiment was objected to improve production and productivity of maize by different moisture conservation practices and to determine and recommend best moisture conservation practice for small scale agro-pastoralists of Borana. The field experiment was conducted at Yabello Pastoral and Dryland Agricultural Research Center on site for three consecutive years from 2015 to 2017 main cropping seasons. The trial was laid in randomized complete block design (RCBD) of three replications. The combined analysis of variance showed that there was significant difference among treatments in ear height, plant height, cob diameter, hundred seed weight and grain yield in all cropping seasons. The highest grain yield was obtained for mulch application treatment (4.64 ton/ha) followed by open ridge treatment (4.25 ton/ha) (table 3). The lowest grain yield was recorded for check (Farmers practice) treatment (1.92 ton/ha). Moisture conservation treatments had 2.72 ton/ha (58.62%), 2.33 ton/ha (54.48%), 1.73 ton/ha (47.40%), 1.37 ton/ha (41.64%), 1.01 ton/ha (34.47%) and 0.91 ton/ha (32.16%) yield advantage over farmers practice for mulching, open ridge, tie ridge, half-moon, minimum tillage and strip planting, respectively. Therefore, moisture conservation practice is recommended for optimum production of maize in moisture stress areas of Borana Zone

Key words: Agro-Pastoralist • Conservation • Moisture • Small-Scale • Stress • Zea mays L.

INTRODUCTION

Maize (Zea mays L.) is one of the most important cereals crop broadly adapted worldwide [1]. It has the highest production potential among the cultivated field crops and is known as “queen of cereals”. Average annual per capita human consumption of maize is 20 kg in developing countries, but in Latin America and the Caribbean, it approaches 80 kg and, in Sub-Saharan Africa, it is estimated 6 tones [2]. Maize is largely produced in Western, Central, Southern and Eastern parts of Ethiopia. Maize is the most widely-grown staple food crop in sub-Saharan Africa occupying more than 33 million hectare each year [3]. In 2014/2015, cropping season 2, 114, 876.10 hectares of land was covered with maize with estimated production 7, 234, 955.10 tones [4]. In Ethiopia, maize is locally known as ‘Badala’ and is produced mainly for food purpose and staple food for low-income groups. Maize is consumed as vegetables at green stage and its grain is consumed as ‘Injera’ Porridge, Bread and ”Nefro”. In addition to the above, it is used to prepare local drink ”Tella” and ‘Areekie’ The leaf and stalk are used for animal feed and dried stalk and cob are used for fuel. Recently, maize is also used as industrial raw material for oil and glucose production [5].

Maize 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 crop. It is grown from 58°N to 40°S, with latitudinal ranges from 0 to 3000 masl and in areas with 250 mm to more than 5000 mm of rainfall per year [6]. 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 lied between an altitude of 1000 to 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 lay between an altitude 500 to 1800 masl and an area which receives rainfall less than 800 mm [7].

Conservation agricultural practice is aims to conserve, improve and make more efficient use of natural resources particularly water through integrated management of available soil and biological resources combined with external inputs [8]. It also contributes to environmental conservation as well as to enhanced and sustained agricultural production. Conservation agriculture promotes the efficient and effective use of available water resources [9]. In fact, conservation agriculture is at the base of the resource conservation technologies that have been shown to improve yields while reducing water, nutrient and energy consumption and lowering the impact on environmental quality. The plantation of cover crops may influence soil aggregation and associated Carbon and Nitrogen pools, thereby affecting soil quality and productivity [10].

The planted land of maize and grain production has increased significantly in Ethiopia [11]. Since moisture is the important requirement for crop production, especially in arid and semi-arid regions where it is one of the most important limiting factors of crop production. In areas where moisture stress is prolonged using different moisture conservation practices is crucial [12]. In moisture stress areas farming systems aim at making the maximum use of incident rainfall by ensuring that wasteful surface runoff is avoided. Hence, in arid areas, where rainfall is erratic, the conservation, development and management of the moisture is a prime importance to reducing run off, prolonging the infiltration opportunity and minimizing evaporation from soil are important methods. [13]. Among different moisture conservation practices tied ridging, open ridges (Farrow), mulching, minimum tillage, strip cropping and half-moon constriction in crop farm are some important cultural practices for moisture conservation. The presence of surface cover (Mulching) helps to prevent erosion and compaction by minimizing the dispersion of the soil surface by rain or irrigation and it further serves to act as a sponge, retaining rain water long enough for it to infiltrate into the soil [14]. Positive yield responses were reported to various moisture conservation techniques [15]. Therefore, the following experiment was objected to increase production and productivity of maize in moisture stress areas through moisture conservation practices and to determine and recommend best moisture conservation practice for small scale agro-pastoralists of Borana.

MATERIALS AND METHODS

The experiment was conducted at Yabello Pastoral and Dryland Agricultural Research Center on station for three consecutive main cropping seasons. Yabello is found 565 km from Addis Ababa to south direction. Yabello is situated at 04° 52’ 49” and 038° 08’ 55” latitude and longitude, respectively, at an altitude of 1656 masl. The soil of the study area is characterized by well-drained sandy loam (46% sand, 36% silt and 18% clay), with a pH of 7.03. It has 0.026% total nitrogen, 15.36 ppm Phosphorus and 20.4 meq of/100 g soil CEC. The total annual rainfall in 2015 2016 and 2017 were 861.6mm, 990.3mm and 732.7mm respectively (Figure 2, 3, 4). The average temperature for 2015, 2016 and 2017 was 19.78°C, 22.97°C 21.5°C respectively (Figure 2, 3). The most commonly cultivated crops in its surrounding areas are maize (Zea mays L.), haricot bean (Phaseolus vulgaris L.), tef (Eragrostis tef L.) wheat (Triticum aestivum L.). Maize and haricot bean are the principal crops grown for food and feed purpose in Borana moisture stress areas.

Experimental Materials and Design: Adaptable maize variety Melkassa 1 was used as planting material. Randomized complete block design (RCBD) with three replications were used. Two seed per hill planting was applied manually by using recommended spacing (75×25 cm) for maize. Recommended cultural practices like meowing, weeding and field management were accompanied for all treatments without disturbing the conservation practices when necessary.

Six conservation practices were used as treatments including check (Farmers practice). All treatments were prepared by using human labor.

- **Mulching:** locally available material (Sudan grass) was applied between rows of maize at planting time in 5 cm thickness. Mulching material was treated with chemical to protect early decomposition.
- **Strip cropping:** Hawassa dume haricot bean variety (large canopy) was planted with maize in strip cropping system.
Fig. 1: Yield of maize under different moisture conservation practices in different at Yabello

Fig. 2: Maximum, minimum, average and total rainfall of 2015 cropping seasons

Fig. 3: Maximum, minimum, average and total rainfall of 2016 cropping seasons
Open ridge: open ridge was constricted by using shovel and hoe between two rows of maize accordingly and the ridges were remaining openly.

Tied ridge: ridge was constricted by using shovel and hoe between two rows of maize accordingly and the ridges were tied in one-meter distance.

Minimum tillage: hole was made by locally available farm materials in recommended spacing without disturbing the whole plot soil.

Half-moon: half-moon shape ridge was constructed between rows of maize by using shovel and hoe.

Control (farmers practice): no any moisture conservation practice was done for this treatment.

Data Collection: The data on yield attributes, biological yield, grain yield was collected from all treatments equally. Plot base collected data were Days to physiological maturity and Grain yield. Plant base collected data were Hundred kernels, weight, Plant height, Ear height, Ear length and Ear diameter. The description of each data collection methods was as follows:

Days to Physiological Maturity (DPM): 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.

Hundred Kernels Weight (TKW) (g): Hundred seeds randomly taken from each plot and weighed using sensitive balance and adjusted to the standard moisture content (12.5%).

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.

Ear Diameter (ED): The average diameter of five randomly selected ears measured on the centimeter at midsection along the length of the ear using caliper.

Grain Yield per Plot (Yld): Measuring the amount of grain yield obtained from a plot in kilogram Number of rows per ear (NRPE): Total row numbers were counted from five randomly taken ears and the average was recorded.

Number of Kernels per Row (NKPR): This was recorded by counting kernels in each row from five randomly taken ears and the average value was calculated and recorded.

Data Analysis: The collected phenological, yield and yield related data were subjected to SAS computer software as per the method described by Gomez Kwanchai and Arturo Gomez [14]. Least significant difference was used to compare means of treatments at P<0.05.
RESULTS

Combined analysis of variance showed that there was significant difference among treatments in ear height, plant height, cob diameter, hundred seed weight and grain yield in all cropping season at P<0.05 (Table 2). Significance difference was observed across years for ear height, plant height, cob diameter and grain yield (Table 2) The highest grain yield recorded was 5.31 tone/ha while the lowest grain yield was 1.45 tone/ha (Table 1).

Combined Analysis of Variance: Days to physiological maturity: Analysis of variance showed significant difference among different moisture conservation methods (Table 2). Farmer practice (Check) (81.2 days) was relatively mature earlier than all other methods while mulch applications (86.48 days) mature later than all other conservation methods (Table 3). The maximum and minimum days to maturity were 92.10 days and 75.69 days respectively (Table 1).

Ear Height: Analysis of variance for individual year showed significant difference in ear height among different moisture conservation treatments. The highest ear height was recorded for tied ridge (46 cm) followed by mulch application (43.67 cm) while the lowest ear high was recorded for strip planting (36.33 cm) (Table 1).

Cob Diameter: Analysis of variance showed significant difference among treatments (P<0.01). The highest cob diameter was recorded for half-moon structure (4.41 cm) followed by mulch application (0.38 cm) while the lowest cob diameter was recorded for farmers practice treatment (3.84 cm) (Table 3).

Plant Height: Analysis of variance showed significant difference among different conservation methods. Plot treated with mulch application was relatively showed longer plant height (141.08 cm) than other treatments. The lowest plant height was recorded for check (134.5 cm) (Table 1).

Number of Rows per Cob: Analysis of variance showed highly significant difference were observed among treatments (P<0.001) (Table 2). Open ridge treatment showed high number of rows per cob (12.11 rows) which is followed by half-moon structure (11.79 rows) while the lowest number of rows per cob was observed for farmers practice (Check) (9.56 rows).

Number of Seeds per Row: Analysis of variance showed highly significant difference among treatments (P<0.001). Mulching treatment was showed high number of seed per row (32.54 seeds) which is followed by open ridge structure (29.68 seeds) while relatively the lowest number of rows per cob was observed for minimum tillage (25.27 seeds) (Table 2).

Table 1: Mean, maximum and minimum of yield and yield traits for maize under different conservation methods (pooled data)

<table>
<thead>
<tr>
<th>Traits</th>
<th>Mean±StdDev</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>84.22±3.88</td>
<td>75.69</td>
<td>92.10</td>
</tr>
<tr>
<td>EH</td>
<td>44.54±8.24</td>
<td>30.20</td>
<td>61.60</td>
</tr>
<tr>
<td>PH</td>
<td>137.72±13.52</td>
<td>120.30</td>
<td>167.00</td>
</tr>
<tr>
<td>EL</td>
<td>13.22±1.65</td>
<td>10.40</td>
<td>17.70</td>
</tr>
<tr>
<td>NRPC</td>
<td>10.89±1.92</td>
<td>8.00</td>
<td>14.00</td>
</tr>
<tr>
<td>NSPR</td>
<td>28.39±3.17</td>
<td>22.00</td>
<td>37.30</td>
</tr>
<tr>
<td>CD</td>
<td>4.18±0.40</td>
<td>3.50</td>
<td>4.90</td>
</tr>
<tr>
<td>HSW</td>
<td>26.31±3.28</td>
<td>21.00</td>
<td>35.00</td>
</tr>
<tr>
<td>GY</td>
<td>3.36±0.97</td>
<td>1.45</td>
<td>5.31</td>
</tr>
</tbody>
</table>

StdDev=standard deviation, DM=days to maturity (days), EH=ear height (cm), PH=plant height (cm), EL=ear length (cm), NRPC=number of row per cob (no), NSPR=number of seed per row (no), CD=Cob diameter (cm), HSW=hundred seed weight (g), GY=grain yield (Tone ha⁻¹).

Table 2: Mean square of maize under different moisture conservation methods for yield and yield related traits (pooled data)

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>DM (day)</th>
<th>EH (cm)</th>
<th>PH (cm)</th>
<th>EL (cm)</th>
<th>NRPC (no)</th>
<th>NSPR (no)</th>
<th>CD (cm)</th>
<th>HSW (g)</th>
<th>GY (tone/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>74.56**</td>
<td>1586.19***</td>
<td>4896.27***</td>
<td>26.29***</td>
<td>38.90***</td>
<td>11.84ns</td>
<td>0.47***</td>
<td>61.48***</td>
<td>3.40***</td>
</tr>
<tr>
<td>Replication</td>
<td>3.92ns</td>
<td>10.67ns</td>
<td>6.84ns</td>
<td>7.13*</td>
<td>0.27ns</td>
<td>21.00*</td>
<td>0.17**</td>
<td>1.96ns</td>
<td>0.08ns</td>
</tr>
<tr>
<td>Treatment</td>
<td>29.93*</td>
<td>48.93***</td>
<td>56.67*</td>
<td>2.86ns</td>
<td>7.90***</td>
<td>49.70***</td>
<td>0.37***</td>
<td>38.01***</td>
<td>7.00***</td>
</tr>
<tr>
<td>Year * treatment</td>
<td>13.94ns</td>
<td>35.53***</td>
<td>39.08*</td>
<td>1.89ns</td>
<td>2.90ns</td>
<td>2.46ns</td>
<td>0.40***</td>
<td>15.05ns</td>
<td>0.60***</td>
</tr>
</tbody>
</table>

DM=days to maturity, EH=ear height, PH=plant height, EL=ear length, NRPC=number of row per cob, NSPR=number of seed per row, CD=Cob diameter, HSW=hundred seed weight, GY=grain yield, ns=non-significant, **=significant at 0.001, *=significant at 0.05.
Table 3: Mean performance of maize under different moisture conservation methods (Pooled mean)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>DM (day)</th>
<th>EH (cm)</th>
<th>PH (cm)</th>
<th>EL (cm)</th>
<th>NRPC (no)</th>
<th>NSPR (no)</th>
<th>CD (cm)</th>
<th>HSW (gm)</th>
<th>GY (tone/ha)</th>
<th>% yield increment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mulching</td>
<td>86.48a</td>
<td>44.56b</td>
<td>141.08a</td>
<td>13.98a</td>
<td>11.33ab</td>
<td>32.54a</td>
<td>4.38a</td>
<td>26.46ab</td>
<td>4.64a</td>
<td>58.62</td>
</tr>
<tr>
<td>Strip planting</td>
<td>82.34bc</td>
<td>44.74b</td>
<td>134.73cd</td>
<td>13.40a-c</td>
<td>10.67cd</td>
<td>29.12bc</td>
<td>4.15bc</td>
<td>24.90bc</td>
<td>2.93e</td>
<td>32.16</td>
</tr>
<tr>
<td>Minimum tillage</td>
<td>84.85a-c</td>
<td>44.94b</td>
<td>139.76ab</td>
<td>13.54a-c</td>
<td>9.89cd</td>
<td>25.27e</td>
<td>4.01cd</td>
<td>24.90bc</td>
<td>2.93e</td>
<td>34.47</td>
</tr>
<tr>
<td>Farmer practices</td>
<td>81.26e-c</td>
<td>43.84bc</td>
<td>134.50d</td>
<td>12.37e</td>
<td>9.89cd</td>
<td>28.07d</td>
<td>3.84d</td>
<td>23.33c</td>
<td>1.92f</td>
<td>0.00</td>
</tr>
<tr>
<td>Tied ridging</td>
<td>84.98ab</td>
<td>42.71bc</td>
<td>138.54a-c</td>
<td>12.68c</td>
<td>10.89a-c</td>
<td>27.22c-e</td>
<td>4.24ab</td>
<td>27.44ab</td>
<td>3.65d</td>
<td>47.40</td>
</tr>
<tr>
<td>Half moon</td>
<td>84.16a-c</td>
<td>41.84c</td>
<td>136.64a-c</td>
<td>12.99a-c</td>
<td>11.79ab</td>
<td>26.80de</td>
<td>4.41a</td>
<td>27.74a</td>
<td>3.29d</td>
<td>41.64</td>
</tr>
<tr>
<td>Open ridge</td>
<td>85.48a</td>
<td>49.16a</td>
<td>138.80ab</td>
<td>13.57ab</td>
<td>12.11a</td>
<td>29.68b</td>
<td>4.24ab</td>
<td>28.44a</td>
<td>4.25b</td>
<td>54.82</td>
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<tr>
<td>Mean</td>
<td>84.22</td>
<td>44.54</td>
<td>137.72</td>
<td>13.22</td>
<td>10.89</td>
<td>28.39</td>
<td>4.18</td>
<td>25.99</td>
<td>3.36</td>
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<td>CV</td>
<td>3.56</td>
<td>6.07</td>
<td>3.08</td>
<td>9.43</td>
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<td>8.41</td>
<td>4.69</td>
<td>10.82</td>
<td>7.25</td>
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<tr>
<td>LSD</td>
<td>3.13*</td>
<td>2.28***</td>
<td>4.04*</td>
<td>1.19ns</td>
<td>1.24***</td>
<td>2.27***</td>
<td>0.18***</td>
<td>2.68***</td>
<td>0.23***</td>
<td></td>
</tr>
</tbody>
</table>

DM=days to maturity, EH=ear height, PH=plant height, EL=ear length, NRPC=number of row per cob, NSPR=number of seed per row, CD=Cob diameter, HSW=hundred seed weight, GY=grain yield, CV=coefficient of variance, LSD=least significant difference, ns=non-significant, ***=significant at 0.001, **=significant at 0.01, *=significant at 0.05.

Hundred Seed Weight: Analysis of variance showed significance difference among different moisture conservation methods (P<0.001). Open ridge treatment showed highest hundred seed weight than all other treatments (28.44gm) while farmers practice treatment showed the lowest hundred seed weight (23.33gm).

Grain Yield: From the analysis of variance, significant differences were observed among treatments (P<0.01). The highly significant difference observed among treatments in grain yield showed, the importance of treatments. The highest grain yield was obtained for mulch application treatment (4.64ton/ha) followed by open ridge treatment (4.25ton/ha) (Table 3). The lowest grain yield was recorded for check (farmers practice) treatment (1.92ton/ha). Moisture conservation treatments had 2.72ton/ha (58.62%), 2.33ton/ha (54.48%), 1.73ton/ha (47.40%), 1.37ton/ha (41.64%), 1.01ton/ha (34.47%) and 0.91ton/ha (32.16%) yield advantage or increment for mulching, open ridge, tie ridge, half-moon, minimum tillage and strip planting respectively (Table 3).

DISCUSSION

Analysis of variance showed that there was significant difference among treatments in ear height, plant height, cob diameter, hundred seed weight and grain yield in all cropping season. From the results, different conservation methods used for this experiment was improve yield and yield related traits indicate, the importance of moisture conservation cultural practices for maize. Different authors reported [16-18] had reported significant yield-increasing effects compared with the flat farming practice in for different field crops. Li and Gong [19] also reported 21%~92% yield increment in study that under the rainwater collecting practice of mulching ridges with plastic film. Jiang et al. [20] reported yield advantage of conservation practices over flat farming practice in mung bean production. In the same way, the significant difference observed in plant height indicate, growing on flat land (Without any conservation method) depressed the growth of maize, this could be due to loss of moisture from the soil in the form of flood during rainy time and in the form of evaporation after rainy time which is disadvantageous for low moisture receiving areas. Biazin and Stroosnijder [21] and Wiyo et al. [22] reported the advantage of moisture conservation practices over flat growing in maize production for moisture stress areas.

CONCLUSION

This investigation demonstrated the beneficial effect of the different moisture conservation practices for arid and semi-arid areas. Based on the result, yield and yield related traits of maize were improved under low moisture condition. Planting in the farrow (Open ridge) was found to be more effective than all other conservation methods under study. Even though, using different moisture conservation practices were effective than farmers practice, early sowing was suggested for maize.

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