Crops Production Management Technologies

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Comparative Evaluation of Transplanting and Sowing on Growth and Yield of Tef

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Introduction

Broadcasting is the major tef (Eragrostis tef) planting method in Ethiopia. However, transplanting is the major means of planting cereals like rice used in other parts of the world (Uphoof, 2003). Patel and Charugamba (1981) stated that transplanted seedlings e.g. in rice it is capable of yielding 30% more than broadcasted rice. The other advantage of transplanting is effective utilization of rainy season and faster maturity of crops particularly in rain-fed ecosystems since the crop partly passes some of its growth stage in nursery (Abeysiriwardena et al., 2005). As compared to broadcasted, transplanted crops competes better with weeds (Uphoof, 2003).

Labor intensiveness at the time of planting is the only drawback of transplanting compared to direct seeding (Uphoof, 2003). Ages of seedlings, spacing and number of seedlings per hill during transplanting are among the major factors that determine the extent of the system’s advantage (Morris, 1980; Uphoof, 2003).

To improve the yield and quality tef, seedlings need to be transplanted at their optimum age. Hence, this paper was initiated to compare the contribution of time of transplanting and direct planting of different seed rates planted either in row or broadcast in improving growth and yield of tef.

Materials and Methods

Experimental setup

A field experiment that compared transplanting time and direct seeding of tef at different seed rate was conducted in major tef growing woredas (Bedele and Tiro-Afeta) of southwestern part of the country. The experiment was laid out in RCBD with three replications. A plot of size 5 m x 5 m was used. The trial was carried out on two farmers’ field per woreda. Seeds were drilled in 20 cm rows apart. Tef variety Kuncho was used in the experiment. All other cultural practices were given based on available recommendations for tef in southwestern part of the country. Thus, the following nine treatments were tested:

- T1: Grown at nursery for 10 days ahead of planting, then transplanted to plots at sowing time
• T2: Grown at nursery for 20 days ahead of planting, then transplanted to plots at sowing time
• T3: Drill seeds in rows of 20 cm apart at the rate of 5 kg ha\(^{-1}\)
• T4: Drill seeds in rows of 20 cm apart at the rate of 10 kg ha\(^{-1}\)
• T5: Drill seeds in rows of 20 cm apart at the rate of 15 kg ha\(^{-1}\)
• T6: Drill seeds in rows of 20 cm apart at the rate of 20 kg ha\(^{-1}\)
• T7: Drill seeds in rows of 20 cm apart at the rate of 25 kg ha\(^{-1}\)
• T8: Broadcast seeds at the rate of 25 kg ha\(^{-1}\)
• T9: Broadcast seeds at the rate of 5 kg ha\(^{-1}\)

**Data collected**
The data collected were seeding and transplanting dates, tillers count per plant at maturity stage, disease and pest incidence, panicle length, plant height, % lodging, biomass, straw and grain yields. The harvest index of tef per treatment was calculated. Farmer assessment was done by inviting equal number of female and male farmers’ to evaluate the trial and share their opinions at mid grain filling stage of the crop. Finally, economic analysis was carried at completion period of the trial.

**Results and Discussion**

This trial was conducted for the three consecutive seasons on farmers field in Bedele and Tiro-Afeta woredas, where tef is considered to be one of the major crops in the farming system. In all seasons, due to sufficient amount of rainfall at sowing period better seedling emergence and stand establishment of tef was recorded. Based on varying seed rates, the expected stands of tef per square meter were optimized and found evenly distributed. Besides, lower seed rates gave more vigorous stands and transplanted seedlings had significantly higher number of productive tillers per plant that were able to produce three times of the tiller number over the direct sowing methods (Table 1). Higher tiller numbers deemed to compensate for optimum tef stands per unit area for both transplanting treatments.

Plant height and percent lodging showed significant differences due to transplanting and direct sowing methods. Both transplanting treatments had taller plant heights in the range of 132 to 134 cm and the lowest seed rate (5 kg ha\(^{-1}\)) had shown taller height in same range (Table 1). Significantly higher lodging percentage of 45% was also recorded from a treatment of seedling raised in nursery for 10 days ahead of planting then transplanted to plots at sowing time that might be due to its taller plant height. Whereas the lowest seed rate 5 kg ha\(^{-1}\) either planted in row or broadcast resulted in lower lodging percentage in range of 32 to 34%. Though mean values due to panicle length across all treatments were found in the range of 58.38 - 64.77 cm, there were no statistical difference among means of each treatment (Table 1).

Grain yield above ground biomass yield, straw yield showed significant (p<0.05) statistical differences across seasons and locations. The lowest seed rate of 5 kg ha\(^{-1}\) either planted in row or broadcast resulted in lower yields. Among all treatments, seedlings raised in nursery for 10 days ahead of planting then transplanted to plots at
sowing time gave significantly higher above ground biomass, straw and grain yield of 5.76 t ha\(^{-1}\), 4.30 t ha\(^{-1}\) and 1439.72 kg ha\(^{-1}\), respectively (Table 2). Similar result was recorded from two seeding method treatments that were drill seeds in rows of 20 cm apart at the rate of 15 kg ha\(^{-1}\) and broadcast seed at rate of 25 kg ha\(^{-1}\).

**Table 1. Evaluation of transplanting time and sowing method on growth parameters of tef**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of tillers/plant</th>
<th>Plant height (cm)</th>
<th>Panicle length (cm)</th>
<th>Lodging (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedlings raised in nursery for 10 days ahead of planting then transplanted to plots at sowing time</td>
<td>7.77a</td>
<td>134.00a</td>
<td>64.77</td>
<td>45.00a</td>
</tr>
<tr>
<td>Seedlings raised in nursery for 20 days ahead of planting then transplanted to plots at sowing time</td>
<td>7.55a</td>
<td>132.06ab</td>
<td>59.44</td>
<td>38.88ab</td>
</tr>
<tr>
<td>Drill seeds in rows at the rate of 5 kg ha(^{-1})</td>
<td>2.55bc</td>
<td>132.03ab</td>
<td>59.55</td>
<td>34.50b</td>
</tr>
<tr>
<td>Drill seeds in rows at the rate of 10 kg ha(^{-1})</td>
<td>1.99c</td>
<td>127.97abc</td>
<td>60.94</td>
<td>39.16ab</td>
</tr>
<tr>
<td>Drill seeds in rows at the rate of 15 kg ha(^{-1})</td>
<td>2.61bc</td>
<td>129.02ab</td>
<td>61.38</td>
<td>40.00ab</td>
</tr>
<tr>
<td>Drill seeds in rows at the rate of 20 kg ha(^{-1})</td>
<td>2.55bc</td>
<td>120.35c</td>
<td>58.38</td>
<td>44.44a</td>
</tr>
<tr>
<td>Drill seeds in rows at the rate of 25 kg ha(^{-1})</td>
<td>2.61bc</td>
<td>125.92bc</td>
<td>59.61</td>
<td>42.50a</td>
</tr>
<tr>
<td>Broadcast seeds at the rate of 25 kg ha(^{-1})</td>
<td>2.38bc</td>
<td>125.13bc</td>
<td>58.61</td>
<td>41.38ab</td>
</tr>
<tr>
<td>Broadcast seeds at the rate of 5 kg ha(^{-1})</td>
<td>2.77b</td>
<td>131.98ab</td>
<td>62.83</td>
<td>32.22c</td>
</tr>
<tr>
<td>LSD &lt; 0.05</td>
<td>**</td>
<td>*</td>
<td>ns</td>
<td>**</td>
</tr>
<tr>
<td>CV</td>
<td>19.53</td>
<td>9.40</td>
<td>11.63</td>
<td>17.77</td>
</tr>
</tbody>
</table>

**Table 2. Evaluation of transplanting time and sowing method on yield and yield components of tef**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (kg ha(^{-1}))</th>
<th>Straw (t ha(^{-1}))</th>
<th>Above ground biomass (t ha(^{-1}))</th>
<th>Harvest index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedlings raised in nursery for 10 days ahead of planting then transplanted to plots at sowing time</td>
<td>1439.72a</td>
<td>4.30a</td>
<td>5.76a</td>
<td>0.25</td>
</tr>
<tr>
<td>Seedlings raised in nursery for 20 days ahead of planting then transplanted to plots at sowing time</td>
<td>1302.17b</td>
<td>3.97c</td>
<td>5.09cd</td>
<td>0.26</td>
</tr>
<tr>
<td>Drill seeds in rows at the rate of 5 kg ha(^{-1})</td>
<td>1195.39bc</td>
<td>3.67cd</td>
<td>4.86d</td>
<td>0.25</td>
</tr>
<tr>
<td>Drill seeds in rows at the rate of 10 kg ha(^{-1})</td>
<td>1235.94bc</td>
<td>3.73c</td>
<td>4.97d</td>
<td>0.25</td>
</tr>
<tr>
<td>Drill seeds in rows at the rate of 15 kg ha(^{-1})</td>
<td>1318.83ab</td>
<td>4.24ab</td>
<td>5.56abc</td>
<td>0.24</td>
</tr>
<tr>
<td>Drill seeds in rows at the rate of 20 kg ha(^{-1})</td>
<td>1299.61b</td>
<td>3.92bc</td>
<td>5.22bcd</td>
<td>0.25</td>
</tr>
<tr>
<td>Drill seeds in rows at the rate of 25 kg ha(^{-1})</td>
<td>1306.50b</td>
<td>4.26ab</td>
<td>5.56abc</td>
<td>0.23</td>
</tr>
<tr>
<td>Broadcast seeds at the rate of 25 kg ha(^{-1})</td>
<td>1438.94a</td>
<td>4.21ab</td>
<td>5.65ab</td>
<td>0.25</td>
</tr>
<tr>
<td>Broadcast seeds at the rate of 5 kg ha(^{-1})</td>
<td>1167.67c</td>
<td>3.32d</td>
<td>4.44e</td>
<td>0.26</td>
</tr>
<tr>
<td>LSD &lt; 0.05</td>
<td>**</td>
<td>*</td>
<td>*</td>
<td>ns</td>
</tr>
<tr>
<td>CV</td>
<td>14.51</td>
<td>14.15</td>
<td>13.91</td>
<td>7.02</td>
</tr>
</tbody>
</table>

The Partial Budget analysis done by including all treatments showed better net benefit and higher marginal rate of return for these two treatments with values of 1680% and 3462%, respectively (Table 3). Similarly, seedlings raised in nursery for 10 days ahead of planting then transplanted to plots at sowing time also had higher marginal rate of return of 968%. The use of the above mentioned top performing tef planting methods could result in 9.68-34.62 Birr upon investing one Birr for tef production in humid
zones of Southwestern part of the country. Therefore, the result of current study in Bedele and Tiro-Afeta woredas suggests that three candidate treatments that is from time of transplanting; a seedlings raised in nursery for 10 days ahead of planting then transplanted to plots at sowing time and from seeding method; drill seeds in rows of 20 cm apart at the rate of 15 kg ha\(^{-1}\) and broadcast seed rate of 25 kg ha\(^{-1}\) should be validated for a season in the long run.

**Conclusion**

The treatments had a significant effect on growth and yield of teff. Seedlings raised in nursery for 10 days ahead of planting then transplanted to plots at sowing time, drill seeds in rows of 20 cm apart at the rate of 15 kg ha\(^{-1}\) and broadcast seed at rate of 25 kg ha\(^{-1}\) gave significantly higher yield than other treatments. Based on the Partial budget analysis the higher net benefit and higher marginal rate of return were obtained from treatments that drill seeds in rows of 20 cm apart at the rate of 15 kg/ha and broadcast seed at rate of 25 kg ha\(^{-1}\) with values of 1680% and 3462%, respectively. This is, therefore, drill seeds in rows of 20 cm apart at the rate of 15 kg ha\(^{-1}\) and broadcast seed at rate of 25 kg ha\(^{-1}\) can be used to high and economic yield of teff in the study area.
Table 3. Partial budget analysis for transplanting time and sowing method of tef

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (kg ha(^{-1}))</th>
<th>Straw yield (kg ha(^{-1}))</th>
<th>Gross return (Birr/ha)</th>
<th>Total variable cost (Birr/ha)</th>
<th>Net Benefit (Birr/ha)</th>
<th>Marginal rate of return (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedlings raised in nursery for 10 days ahead of planting then transplant to plots at sowing time</td>
<td>1439</td>
<td>4300</td>
<td>34319.1</td>
<td>5050</td>
<td>29269.1</td>
<td>967</td>
</tr>
<tr>
<td>Seedlings raised in nursery for 20 days ahead of planting then transplant to plots at sowing time</td>
<td>1302</td>
<td>3970</td>
<td>31117.0</td>
<td>4750</td>
<td>26367.1</td>
<td>-</td>
</tr>
<tr>
<td>Drill seeds in rows 20 cm at the rate of 5 kg ha(^{-1})</td>
<td>1195</td>
<td>3670</td>
<td>28589.6</td>
<td>365</td>
<td>28224.6</td>
<td>408</td>
</tr>
<tr>
<td>Drill seeds in rows 20 cm at the rate of 10 kg ha(^{-1})</td>
<td>1235</td>
<td>3730</td>
<td>29498.2</td>
<td>490</td>
<td>29008.2</td>
<td>626</td>
</tr>
<tr>
<td>Drill seeds in rows 20 cm at the rate of 15 kg ha(^{-1})</td>
<td>1319</td>
<td>4240</td>
<td>31723.4</td>
<td>615</td>
<td>31108.4</td>
<td>1680</td>
</tr>
<tr>
<td>Drill seeds in rows 20 cm at the rate of 20 kg ha(^{-1})</td>
<td>1299</td>
<td>3920</td>
<td>31015.8</td>
<td>740</td>
<td>30275.8</td>
<td>-</td>
</tr>
<tr>
<td>Drill seeds in rows 20 cm at the rate of 25 kg ha(^{-1})</td>
<td>1306</td>
<td>4260</td>
<td>31483.5</td>
<td>865</td>
<td>30618.5</td>
<td>-</td>
</tr>
<tr>
<td>Broadcast seeds at the rate of 25 kg ha(^{-1})</td>
<td>1439</td>
<td>4210</td>
<td>34217.2</td>
<td>685</td>
<td>33532.2</td>
<td>3462</td>
</tr>
<tr>
<td>Broadcast seeds at the rate of 5 kg ha(^{-1})</td>
<td>1168</td>
<td>3320</td>
<td>27675.1</td>
<td>185</td>
<td>27490.07</td>
<td>-</td>
</tr>
</tbody>
</table>
References


Influence of Seed Rate and Row Spacing on Growth and Yield of Tef

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Introduction

Many farmers in developing countries including Ethiopia prefer to use a higher seed rate than recommended, because they perceive it as a good strategy to control weeds and reduce the risks of crop production. Sowing of higher seed rates than the recommended rate is not encouraged because it reduces seed quality and yield. Instead of using higher rates, farmers must pay close attention to all recommended seed production practices. If low seed rate is used yield will be less due to lesser number of plants per unit area (Hameed et al., 2002).

Plant spacing determines the area available to each plant which in turn determines nutrient and moisture availability to the crop. Row spacing determines resource availability and utilization by individual plants in a given species. Planting decisions require that optimum row widths for the seed crop be determined. If the row is too wide, the crop is unable to rapidly shade the inter-row area to capture sunlight and weeds quickly become established. If the row is too narrow, inter-row crop competition results in poorer yields, difficulties in disease and insect control, and greater likelihood of lodging.

Hence, to alleviate the aforementioned persistent problems of crop production, there has been a growing interest to increase the productivity of tef through improved agronomic practices. Consequently, this experiment was initiated to with the objective of determining optimum seed rate and row spacing for major tef growing areas of southwestern part of Ethiopia.

Material and Methods

Experimental setup
The trial was conducted for the three consecutive seasons on farmers’ fields in Bedele woreda. The experiment was designed in a randomized complete block design with three levels of seed rates (5, 10 and 15 kg ha\(^{-1}\)) and three rows spacing (15, 20, 25cm) with three replications in a factorial arrangement. The plot size was 4m by 5m (20 m\(^2\)) and the spacing between plots and blocks were 0.5m and 1m,
respectively. The sources of nitrogen (N) and phosphorous (P) were urea and triple super phosphate (TSP), respectively. The P fertilizer was applied at planting. While the recommended N fertilizer was applied two doses; half at planting and half at tillering stage. Other agronomic practices were applied based on local research recommendations. The first weeding was done 30-35 days after planting and the second weeding was carried out a month after the first weeding.

Data collected
The data collected were: sowing dates, tiller count per plant at maturity stage, disease and pest incidence, panicle length, plant height, % lodging, biomass, straw yield, grain yield and harvest index. Farmer assessment was done by inviting equal number of female and male farmers’ to evaluate the trial and to share us their opinions at mid grain filling stage of the crop. Finally, economic analysis was carried out at completion period of trial.

Results and Discussion
The trial was conducted for the three consecutive seasons on farmers’ fields in Bedele woreda, where tef is considered to be one of the major crops in the farming system. In all seasons, due sufficient amount of rainfall at sowing period, better seedling emergence and stand establishment of tef were recorded. Based on varying seed rates, the expected stands of tef per square meter were optimized and found evenly distributed. Among the important growth parameters such as plant height and percent lodging only number of tillers per plant showed significant differences due to direct seeding of different seed rates that were 2-4 tillers/plant (Table 1). Though mean values due to plant height, panicle length and percent lodging across all treatments were found in the range of 132-137 cm, 53.77-56.44 cm, and 60.00-66.66%, respectively. There were no statistical differences among means of each treatment (Table 1). Though statistically significant harvest index values were recorded in the range of 0.17 - 0.24 due to seeding rate and row space combinations, these values were found similar to values for some other improved varieties of tef in production elsewhere (Table 2). From parameters used for yield measurement such as above ground biomass, straw and grain yield valid statistical differences were recorded across seasons and locations. Among all treatments, 15 kg ha⁻¹ seed rate x 25 cm row space gave significantly better above ground biomass (6.03 t ha⁻¹), and grain yield (1435.11 kg ha⁻¹) followed by 10 kg ha⁻¹ seed rate x row space 25 cm that had comparable yields (Table 2). While 15 kg ha⁻¹ seed rate x row space 15 cm had produced significantly higher above ground biomass and straw of 6.19 ton/ha and 5.01 ton/ha respectively (Tables 2 and 7). The Partial budget analysis done by including all treatments better net benefit and higher marginal rate of return with values of 4311% and 766% were recorded from 15 kg ha⁻¹ seed rate x 25 cm row space and 10 kg ha⁻¹ seed rate x row space 25 cm , respectively (Table 5). The use of these two top performing tef seed rates during planting could result in 43.11 and 7.66 Birr upon investing one Birr for tef production in humid zones of Southwestern part of the country.
In general, the main effect of spacing and seed rate and their mean results that were pooled over season clearly suggests that drilling 15 kg ha\(^{-1}\) seed of tef in rows 25 cm apart could be used for tef production in Bedele woreda (Table 3). This finding confirmed farmers perception assessed at full maturity period of tef that they tend to choose wider row spaces varying between 25 cm - 30 cm and seed rate not less than 15 kg ha\(^{-1}\). Many farmers commented that row seeding of tef will be more acceptable whenever appropriate planters demonstrated.

**Table 1.** Effect of seed rate and row spacing on few important growth parameters of tef at Bedele

<table>
<thead>
<tr>
<th>Row spacing (cm)</th>
<th>Number of tillers</th>
<th>Plant height (cm)</th>
<th>Panicle Length (cm)</th>
<th>Lodging (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 kg ha(^{-1}) x Row space 15</td>
<td>3.33ab</td>
<td>132.77</td>
<td>54.00</td>
<td>64.44</td>
</tr>
<tr>
<td>5 kg ha(^{-1}) x Row space 20</td>
<td>3.44a</td>
<td>137.11</td>
<td>56.44</td>
<td>65.00</td>
</tr>
<tr>
<td>5 kg ha(^{-1}) x Row space 25</td>
<td>3.00ab</td>
<td>131.66</td>
<td>55.22</td>
<td>64.44</td>
</tr>
<tr>
<td>10 kg ha(^{-1}) x Row space 15</td>
<td>1.99c</td>
<td>132.11</td>
<td>54.66</td>
<td>60.00</td>
</tr>
<tr>
<td>10 kg ha(^{-1}) x Row space 20</td>
<td>3.11ab</td>
<td>130.33</td>
<td>54.55</td>
<td>63.88</td>
</tr>
<tr>
<td>10 kg ha(^{-1}) x Row space 25</td>
<td>3.11ab</td>
<td>137.55</td>
<td>57.00</td>
<td>65.00</td>
</tr>
<tr>
<td>15 kg ha(^{-1}) x Row space 15</td>
<td>3.33ab</td>
<td>132.66</td>
<td>55.00</td>
<td>60.55</td>
</tr>
<tr>
<td>15 kg ha(^{-1}) x Row space 20</td>
<td>3.77a</td>
<td>133.55</td>
<td>53.77</td>
<td>66.11</td>
</tr>
<tr>
<td>15 kg ha(^{-1}) x Row space 25</td>
<td>2.88b</td>
<td>132.11</td>
<td>54.66</td>
<td>66.66</td>
</tr>
<tr>
<td>LSD &lt; 0.05</td>
<td>*</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>CV</td>
<td>18</td>
<td>5</td>
<td>7</td>
<td>15</td>
</tr>
</tbody>
</table>

Notes. Significant at *P<0.05, **P<0.01, *** P<0.001; ns, not significant

**Table 2.** Effect of seed rate and row spacing on some important yield parameters of tef at Bedele

<table>
<thead>
<tr>
<th>Row spacing (cm)</th>
<th>Grain yield (kg ha(^{-1}))</th>
<th>Straw (t ha(^{-1}))</th>
<th>AGB (t ha(^{-1}))</th>
<th>HI</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 kg ha(^{-1}) x Row space 15</td>
<td>1130.22e</td>
<td>4.64ab</td>
<td>5.71ab</td>
<td>0.20b</td>
</tr>
<tr>
<td>5 kg ha(^{-1}) x Row space 20</td>
<td>927.55ef</td>
<td>4.61ab</td>
<td>5.54b</td>
<td>0.17c</td>
</tr>
<tr>
<td>5 kg ha(^{-1}) x Row space 25</td>
<td>1300.11bcd</td>
<td>3.81c</td>
<td>5.11c</td>
<td>0.25a</td>
</tr>
<tr>
<td>10 kg ha(^{-1}) x Row space 15</td>
<td>1313.22abc</td>
<td>4.66ab</td>
<td>5.98ab</td>
<td>0.22b</td>
</tr>
<tr>
<td>10 kg ha(^{-1}) x Row space 20</td>
<td>1282.77bcd</td>
<td>3.91c</td>
<td>5.19c</td>
<td>0.25a</td>
</tr>
<tr>
<td>10 kg ha(^{-1}) x Row space 25</td>
<td>1393.77ab</td>
<td>4.76a</td>
<td>6.15a</td>
<td>0.23b</td>
</tr>
<tr>
<td>15 kg ha(^{-1}) x Row space 15</td>
<td>1179.33de</td>
<td>5.01a</td>
<td>6.19a</td>
<td>0.19bc</td>
</tr>
<tr>
<td>15 kg ha(^{-1}) x Row space 20</td>
<td>1182.55d</td>
<td>4.51b</td>
<td>5.70ab</td>
<td>0.21b</td>
</tr>
<tr>
<td>15 kg ha(^{-1}) x Row space 25</td>
<td>1435.11a</td>
<td>4.60b</td>
<td>6.03ab</td>
<td>0.24a</td>
</tr>
<tr>
<td>LSD&lt;0.05</td>
<td>*</td>
<td>**</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>CV</td>
<td>17</td>
<td>15</td>
<td>16</td>
<td>12</td>
</tr>
</tbody>
</table>

Notes. Significant at *P<0.05, **P<0.01, ***P<0.001; ns, not significant
### Table 3. Mean effects of seed rate and row spacing on grain yield and above ground biomass yield (AGB) and yield of tef at Bedele

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (kg ha⁻¹)</th>
<th>AGB (t ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 kg ha⁻¹</td>
<td>1119.30b</td>
<td>5.46b</td>
</tr>
<tr>
<td>10 kg ha⁻¹</td>
<td>1329.93a</td>
<td>5.77ab</td>
</tr>
<tr>
<td>15 kg ha⁻¹</td>
<td>1265.67a</td>
<td>5.97a</td>
</tr>
<tr>
<td>LSD</td>
<td>**</td>
<td>Ns</td>
</tr>
<tr>
<td>15 cm</td>
<td>1207.59b</td>
<td>5.96a</td>
</tr>
<tr>
<td>20 cm</td>
<td>1130.96b</td>
<td>5.48a</td>
</tr>
<tr>
<td>25 cm</td>
<td>1376.33a</td>
<td>5.77a</td>
</tr>
<tr>
<td>LSD</td>
<td>**</td>
<td>Ns</td>
</tr>
<tr>
<td>CV</td>
<td>17</td>
<td>16</td>
</tr>
</tbody>
</table>

Notes. Significant at *P<0.05, **P<0.01, ***P<0.001; ns, not significant

### Table 4. Interaction effect of seed rates and row spacing (cm) on tef straw yield at Bedele (t ha⁻¹)

<table>
<thead>
<tr>
<th>Seed rate (kg ha⁻¹)</th>
<th>Row spacing (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>4.64</td>
</tr>
<tr>
<td>10</td>
<td>4.66</td>
</tr>
<tr>
<td>15</td>
<td>5.01</td>
</tr>
<tr>
<td>CV</td>
<td></td>
</tr>
</tbody>
</table>

### Table 5. Partial budget analysis for seed rates and row spacing of tef

<table>
<thead>
<tr>
<th>Row spacing (cm)</th>
<th>Grain yield (kg ha⁻¹)</th>
<th>Straw yield (kg ha⁻¹)</th>
<th>Gross return (Birr/ha)</th>
<th>TCV* (Birr/ha)</th>
<th>Net benefit (Birr/ha)</th>
<th>MRR ** (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 kg ha⁻¹ x Row space 15</td>
<td>1130.22</td>
<td>4640</td>
<td>28142.62</td>
<td>125</td>
<td>28017.62</td>
<td>-</td>
</tr>
<tr>
<td>5 kg ha⁻¹ x Row space 20</td>
<td>927.55</td>
<td>4610</td>
<td>23858.05</td>
<td>125</td>
<td>23733.05</td>
<td>-</td>
</tr>
<tr>
<td>5 kg ha⁻¹ x Row space 25</td>
<td>1300.11</td>
<td>3810</td>
<td>30921.81</td>
<td>125</td>
<td>30796.81</td>
<td>-</td>
</tr>
<tr>
<td>10 kg ha⁻¹ x Row space 15</td>
<td>1313.22</td>
<td>4660</td>
<td>32004.62</td>
<td>250</td>
<td>31754.62</td>
<td>766</td>
</tr>
<tr>
<td>10 kg ha⁻¹ x Row space 20</td>
<td>1282.77</td>
<td>3910</td>
<td>30652.67</td>
<td>250</td>
<td>30402.67</td>
<td>-</td>
</tr>
<tr>
<td>10 kg ha⁻¹ x Row space 25</td>
<td>1393.77</td>
<td>4760</td>
<td>33791.17</td>
<td>250</td>
<td>33541.17</td>
<td>2510</td>
</tr>
<tr>
<td>15 kg ha⁻¹ x Row space 15</td>
<td>1179.33</td>
<td>5010</td>
<td>29525.43</td>
<td>375</td>
<td>29150.43</td>
<td>-</td>
</tr>
<tr>
<td>15 kg ha⁻¹ x Row space 20</td>
<td>1182.55</td>
<td>4510</td>
<td>29118.05</td>
<td>375</td>
<td>28743.05</td>
<td>-</td>
</tr>
<tr>
<td>15 kg ha⁻¹ x Row space 25</td>
<td>1435.11</td>
<td>4600</td>
<td>34507.31</td>
<td>375</td>
<td>34132.31</td>
<td>4311</td>
</tr>
</tbody>
</table>

TCV* (Total cost that vary), MRR** (Marginal rate of return) and - (Dominated treatments)
Conclusion

Treatments had a significant effect on yield of teff. Among the treatments, drilling 15 kg ha\(^{-1}\) seed of tef in rows 25 cm and 10 kg ha\(^{-1}\) seed rate x row space 25 cm gave significantly higher yield than other treatments. Partial budget analysis also revealed that drilling 15 kg ha\(^{-1}\) seed of tef in rows 25 cm and 10 kg ha\(^{-1}\) seed rate x row space 25 cm gave higher net benefit and MRR (%). However, based on farmer’s perception assessment, they choose seed rate not less than 15 kg ha\(^{-1}\) and wider row spaces varying between 25 cm - 30 cm when appropriate planters would be demonstrated. Therefore, drilling 15 kg ha-1 seed of tef in rows 25 cm apart can be used for high and economic teff production in the study woreda.

References


Determination of Appropriate Time of Nitrogen Application on Bread Wheat Productivity

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Kulumsa Agricultural Research Center
*Corresponding author: E-mail: wogayehuworku53@gmail.com

Introduction

The low yield and productivity of bread wheat in Ethiopia and elsewhere is associated with several biotic, abiotic and management factors. Nitrogen is the vital nutrient involved in crops growth and development. Inadequate supplies of nitrogen more often limit crop yields than by deficiencies of other essential nutrients. This is because losses of applied nitrogen can occur in different crop growth stage by several phenomena.

However, obtaining a high N-use efficiency generally requires splitting the nitrogen between planting and some growth stage of the crop as a top-dress application. Top dressing of nitrogen, 4 to 6 weeks after planting will supplement early season nitrogen losses by leaching and volatilization and provide available fertilizer nitrogen to the crop.

Nevertheless, timing of side/top-dress nitrogen applications is critical. Thus, it is important to determine accurately plant nitrogen requirements and to use effective management practices to minimize losses of applied nitrogen (Bundy and Andraski, 1998). The objective was to determine the appropriate application time of N fertilizer in wheat.

Material and Methods

The trial was conducted in 2015 and 2016 cropping seasons under on farm conditions in Bekoji area. The experiment was laid out in a randomized complete block design in split plot arrangement consisting of 4 nitrogen fertilizer rate as main plot (FR1 = 46 kg N ha\(^{-1}\), FR2 = 92 kg N ha\(^{-1}\), FR3 = 138 kg N ha\(^{-1}\) and FR4 = 184 kg N ha\(^{-1}\)) and 8 nitrogen fertilizer application time (T1 = 1/2 at planting + 1/2 at tillering, T2= 1/2 at emergence + 1/2 at tillering, T3= 1/3 at planting + 2/3 at tillering, T4= 1/3 at emergence + 2/3 at tillering, T5 = 1/2 at tillering + 1/2 at heading, T6= 2/3 at tillering + 1/3 at heading, T7= 1/3 at planting + 1/3 at tillering + 1/3 heading and T8= 1/3 at emergence + 1/3 at tillering + 1/3 at heading) as sub plot with three replications. The fertilizer was placed 6 cm away from the crop, side/top-dressing as per the recommended starter application. Diammonium Phosphate (DAP)
was applied at the rate 100 kg ha\(^{-1}\) during planting. A bread wheat variety, *Huluka* was drilled by hand at the rate of 125 kg ha\(^{-1}\) with 0.20m inters row spacing in plot sizes of 2.6 m by 4m. The spacing between plots and replications was 0.5 m and 1m, respectively. Other cultural and management practices were carried out as per the recommendations.

**Data collection and analysis**

The data comprised of yield and yield components such as grain yield, biomass, harvest index and thousand-kernel weight. Grain yield (kg ha\(^{-1}\)) was measured from net plot area and converted to kg per ha after harvesting and threshing the seed yield. The yield was adjusted to 12.5% moisture content. Biomass (kg ha\(^{-1}\)) was measured at harvest from the net plot area after sun drying and converted to kg per ha from ten randomly selected plants using sensitive balance. Thousand kernels weight (g) was determined based on the weight of 1000 kernels sampled from the grain yield of each treatment by using electronic seed counter and weighed with electronic balance. Harvest index was determined as the ratio of grain yield to the total dry biomass yield per plot multiply by 100. Data collected from the experiment were subjected to statistical analysis at each individual year and combined over years using Proc GLM procedure in SAS (SAS Institute Inc, 1994). Treatments with significant differences were compared with either LSD's or Tukey's test at \(P<0.05\) whenever necessary.

**Economic analysis**

A simple partial budget analysis was employed as per CIMMYT (CIMMT, 1988) for factors with significant effect. Gross yield benefit was obtained by multiplying the adjusted yield by the price of wheat grain at harvest in 2016 cropping season. Market price of bread wheat was estimated to be (8 Birr kg\(^{-1}\)) in Bekoji area in 2016. Then net benefit was calculated by subtracting variable cost from gross yield. The price of urea (1,100 Birr ha\(^{-1}\)) and DAP (1,200 Birr ha\(^{-1}\)) were used. DAP has 18% N and 46% P\(_2\)O\(_5\) (64% where N is estimated to be 28% cost of DAP, which was 336 Birr ha\(^{-1}\)). Estimated labor cost of 3641 Birr ha\(^{-1}\) was used for planting, fertilizer application and weeding at a time. Marginal rate of return (MRR) was calculated by dividing marginal net benefit to the marginal cost and expressed as percentage (CIMMT, 1988).

**Result and Discussion**

Effect of nitrogen fertilizer rate and its application time on yield and yield components of wheat around Bekoji area in 2015 and 2016 cropping seasons was shown in table 1. However, there was no interaction effect between fertilizer rate and fertilizer application time at both years. There was no significant difference for all parameters measured in 2015. This might be associated with El Nino effect in 2015. Except harvest index, grain yield, biomass and thousand kernel (TKW) weight were affected significantly \((P<0.05)\) by nitrogen fertilizer rate and its application time in 2016.
Table 1. Effects of N rate and its time of application on yield and yield components of bread wheat under on farm conditions at Bekoji in 2015 and 2016 cropping seasons

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (kg ha⁻¹)</th>
<th>Biomass (kg ha⁻¹)</th>
<th>Harvest index (%)</th>
<th>Thousand kernel weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen fertilizer rate (kg N ha⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>2451a</td>
<td>3073b</td>
<td>54.7a</td>
<td>6665b</td>
</tr>
<tr>
<td>92</td>
<td>2468a</td>
<td>3031b</td>
<td>54.16a</td>
<td>6546b</td>
</tr>
<tr>
<td>138</td>
<td>2425a</td>
<td>3164ab</td>
<td>45.94a</td>
<td>5040b</td>
</tr>
<tr>
<td>CV (%)</td>
<td>10.37</td>
<td>12.08</td>
<td>13.45</td>
<td>12.02</td>
</tr>
</tbody>
</table>
| Means in the same column followed by the same letters are not significantly different using Tukey's test at 5% level of significance. 

Grain yield and biomass were affected significantly (P<0.05) by 184 kg N/ha though there was no significant difference with 138 kg N/ha. TKW was significantly (P<0.05) different for 46 and 92 kg N/ha as compared to the last two doses. On the other hand, grain yield and biomass were affected significantly (P<0.05) by the second nitrogen fertilizer application time (T₂ = 1/2 at emergence + 1/2 at tillering). TKW was significantly (P<0.05) different for the third nitrogen fertilizer application time (T₃ = 1/3 at planting + 2/3 at tillering). T₂ might offer an advantage to avoid leaching of N at planting whenever there is excess rainfall or under dry conditions. Normally, the crop survives adverse conditions using its own reserve until emergence. Besides, application of N fertilizer in dry condition could have a negative effect for crop establishment. Therefore, T₂ has an advantage from these perspectives.

The combined analysis of variance over the two years indicated that there was no interaction effect between nitrogen fertilizer rate and its time of application on yield and yield components of bread wheat under on farm conditions in Bekoji area (Table 2). This could be related to occurrence of elnino in 2015 that affected the grain yield and associated components. That is why; the grain yield in 2016 was 25% greater than the grain yield obtained in 2015. Therefore, this data could be used to calculate economic analysis as given in Table 3.

Partial budget analysis

Effects of N-fertilizer rate and its application time on partial budget analysis of wheat under on farm conditions in Bekoji area in 2016 cropping season shown in Table 3. The 46 N kg ha⁻¹ was taken as a benchmark since Bekoji is a potential area...
for wheat production in the country. The minimum acceptable rate of return (MARR) at least ranges between 50 and 100% (CIMMYT, 1988). Neither N-fertilizer rate nor its application time exceeded the recommended rate of the area in calculating MARR. Accordingly, they excluded from calculation or it is considered as dominated treatment. Accordingly, the 46 N kg ha⁻¹ with the second nitrogen fertilizer application time \(T_2=1/2\) at emergence + 1/2 at tillering) has a net benefit of 19,507 and 23923 Birr/ha with MRR of 384 and MRR of 505%, respectively. Therefore, they seem to be beneficial as compared to the rest N rate and application time.

Table 2. Effects of N rate and its application time on yield and yield components of bread wheat under on farm conditions in Bekoji area combined over two years

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (kg ha⁻¹)</th>
<th>Biomass (kg ha⁻¹)</th>
<th>Harvest index (%)</th>
<th>Thousand kernel weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen fertilizer rate (kg N ha⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>2762a</td>
<td>6056a</td>
<td>45.66a</td>
<td>41.09a</td>
</tr>
<tr>
<td>92</td>
<td>2749a</td>
<td>6077a</td>
<td>45.31a</td>
<td>41.07a</td>
</tr>
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<td>138</td>
<td>2794a</td>
<td>6193a</td>
<td>45.49a</td>
<td>40.93a</td>
</tr>
<tr>
<td>184</td>
<td>2941a</td>
<td>6524a</td>
<td>45.31a</td>
<td>40.59a</td>
</tr>
<tr>
<td>Nitrogen fertilizer application time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T₁</td>
<td>2829a</td>
<td>6427a</td>
<td>44.13a</td>
<td>40.98a</td>
</tr>
<tr>
<td>T₂</td>
<td>2967a</td>
<td>6486a</td>
<td>45.88a</td>
<td>40.96a</td>
</tr>
<tr>
<td>T₃</td>
<td>2762a</td>
<td>6087a</td>
<td>45.67a</td>
<td>41.78a</td>
</tr>
<tr>
<td>T₄</td>
<td>2967a</td>
<td>6555a</td>
<td>45.41a</td>
<td>40.31a</td>
</tr>
<tr>
<td>T₅</td>
<td>2633a</td>
<td>5729a</td>
<td>46.10a</td>
<td>40.65a</td>
</tr>
<tr>
<td>T₆</td>
<td>2770a</td>
<td>6034a</td>
<td>46.12a</td>
<td>40.71a</td>
</tr>
<tr>
<td>T₇</td>
<td>2764a</td>
<td>6238a</td>
<td>44.66a</td>
<td>41.16a</td>
</tr>
<tr>
<td>T₈</td>
<td>2802a</td>
<td>6145a</td>
<td>45.56a</td>
<td>40.81a</td>
</tr>
<tr>
<td>Year</td>
<td>2015</td>
<td>2446b</td>
<td>45.37a</td>
<td>41.75a</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>3178a</td>
<td>45.51a</td>
<td>40.09b</td>
</tr>
<tr>
<td>CV (%)</td>
<td>14.74</td>
<td>15.82</td>
<td>5.74</td>
<td>4.58</td>
</tr>
</tbody>
</table>

Means in the same column followed by the same letters are not significantly different using Tukey's test at 5% level of significance.
### Table 3. Effects of N-fertilizer rate and its application time on partial budget analysis of wheat under on farm conditions in Bekoji area in 2016 cropping season

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Adjusted yield (kg ha(^{-1}))</th>
<th>Gross benefit (Birr/ha)</th>
<th>Total variable cost (Birr/ha)</th>
<th>Net benefit (Birr/ha)</th>
<th>MRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen fertilizer rate (kgNha(^{-1}))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>3073</td>
<td>24,584</td>
<td>5077</td>
<td>19,507</td>
<td>384</td>
</tr>
<tr>
<td>92</td>
<td>3031</td>
<td>24,248</td>
<td>6177</td>
<td>18,071</td>
<td>D</td>
</tr>
<tr>
<td>138</td>
<td>3164</td>
<td>25,352</td>
<td>7277</td>
<td>18,075</td>
<td>D</td>
</tr>
<tr>
<td>184</td>
<td>3443</td>
<td>27,544</td>
<td>8377</td>
<td>19,167</td>
<td>D</td>
</tr>
</tbody>
</table>

| Nitrogen fertilizer application time | | | | | |
| T\(_1\) | 3206                          | 25,648                  | 4741                          | 20907                | D       |
| T\(_2\) | 3583                          | 28,664                  | 4741                          | 23923                | 505     |
| T\(_3\) | 3071                          | 24,568                  | 4741                          | 19827                | D       |
| T\(_4\) | 3382                          | 27,056                  | 4741                          | 22315                | D       |
| T\(_5\) | 2822                          | 22,576                  | 4741                          | 17835                | D       |
| T\(_6\) | 3096                          | 24,768                  | 4741                          | 20027                | D       |
| T\(_7\) | 3046                          | 24,368                  | 14223                         | 10145                | D       |
| T\(_8\) | 3217                          | 25,736                  | 14223                         | 11513                | D       |

\(MRR = \text{Marginal Rate of Return}\) \(D = \text{treatments with } MRR<50\% \text{ considered as dominated}\)

### Conclusion

The result showed that treatments had not significant effect on yield, but the economic analysis showed that 46 kg ha\(^{-1}\) N fertilizer rate and equal split application of N at emergency and tillering gave higher net benefit and marginal rate of return. Therefore, N fertilizer rate of 46 kg ha\(^{-1}\) with equal split application at emergence and tillering stage can be recommended for giving higher grain and economic yield on the study area. However, further research is required to recommend for large scale wheat production.

### References


Effects of Seed Rates and Nitrogen Fertilizer Levels on Yield, Yield Components, and Grain Quality of Malt Barley

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*Corresponding author: E-mail: legesseadmas@yahoo.com

Introduction

Fertilizer use on food and malt barley is the lowest among all cereals, that is, only 48.3% of the total area of land covered by barley compared to tef, wheat, and maize receiving fertilizer on 59.7%, 69.1%, and 56.3% of their total land area, respectively (CSA 2010).

Nitrogen (N) is one of the most essential and vital elements in plants and is also a major limiting factor in crop production (Kraiser et al., 2011). Plants take up N from soil and utilize it for a variety of metabolic purposes, including synthesis of proteins, enzymes, phyto-hormones, nucleic acids ribonucleic acid and deoxyribonucleic acid (RNA and DNA), and other biological molecules. It particularly influences malting barley yield and grain protein content and consequently malting quality (Spaner et al., 2001). Excess soil N may raise the protein content of the kernel, which is undesirable for malting. It is also reported that excessive N rates reduce grain yields probably due to a lower efficiency in the remobilization of photo assimilates from the vegetative organs to the grains (Yang et al. 2001, Yang and Zhang 2006). Maximum yield is obtained by the application of nitrogen fertilizer at the higher end of current recommendations. So in malting barley production there is often a conflict between the aim of growing crops to meet the requirements of malting industries and of achieving the highest gross margin if the standard for grain nitrogen content is not met. Before anthesis, added nitrogen supply increases the number of tillers and apical primordia that survive and also the size of individual leaves (Hay and Walker, 1989). After anthesis, no more effective grain sites can be formed so the N is deposited in the grain. If for example, many grains are formed but the grain size is limited by the available carbohydrate after anthesis, the limited by the available carbohydrate after anthesis, the resulting high grain nitrogen concentration and low mean grain weight are undesirable for malting.

Controlling the supply and timing of nitrogen is crucial for optimum grain yield and quality. Barley grains with high protein content are more difficult to malt, yield low amounts of extracts and can cause difficulties in brewing (Mather et al. 1997; Schelling et al. 2003). In Ethiopia, where pH, organic carbon, and N content of most soil s are low, N fertilizer rates applied for malting barley production vary between 18 and 41 kg N ha⁻¹. In other part of the world the N fertilizer is usually applied to
malt barley varies between 25 and 60 kg N ha\(^{-1}\) (Lázzari et al., 2007). The N rate above 41 kg ha\(^{-1}\) in Ethiopia has been considered to produce higher grain N content.

To maximize yield and quality of malting barley, it has been shown that N management practices should be adjusted according to anticipated availability of water and N in the soil (McKenzie et al. 2005) and the needs of particular cultivars (Edney et al. 2012). Management strategies for malting barley must therefore maintain a balance between achieving economic yield responses and maintaining the grain protein concentration within a desirable range, which is possible under appropriate conditions of N application (Fathi, McDonald, and Lance 1997). Thus, management of N and seeding rate is a critical issue for yield and quality of malting barley. Although it is expected that N fertilizer rates and seeding rate are important, little is known about their effects and interactions in the Ethiopian context. Therefore, the objective of this study was to determine the effects of seeding rates and N fertilizer rates on the yield and quality of malting barley under rain-fed conditions in the Ethiopian highlands.

**Materials and Methods**

The trial was conducted on farmers’ fields from 2014-2016 during the main cropping seasons in West Shewa, Welmera Wereda in the central highlands of Ethiopia. The rainfall is bimodal with long-term average annual rainfall 1100mm, about 25% of which falls from June to September and the rest from January to May and average minimum and maximum air temperature of 6.2 and 22.1 °C, respectively. The environment is seasonally humid and major soil type of the trial sites is Eutric Nitisol (IUSS Working Group WRB, 2006). Treatments were a factorial combination of five levels of seed rates (75, 100, 125, 150 and 175 kg ha\(^{-1}\)) and four levels of N fertilizer (0, 23, 46, 69 kg N ha\(^{-1}\)). Treatments were laid out in randomized complete block design (RCBD) with three replications. The plot size was 3m by 3m (9 m\(^2\)) and the spacing between plots and blocks were 0.5m and 1m, respectively. The recommended phosphorus fertilizer amount (46 kg P ha\(^{-1}\)) was uniformly applied as triple super phosphate (TSP) to all plots at sowing. Urea was used as the source of N which was applied in two doses; half at sowing and half at mid tillering stage. Other agronomic practices were applied based on local research recommendations.

**Statistical analysis**

The data were subjected to analysis of variance using the procedure of the of SAS statistical package version 9.0 (SAS Institute, 2001). Means for the main effects were compared using the means statement with least significant difference (LSD) test at the 5% level.
Result and Discussion

Analysis of variance (ANOVA) showed that seeding rate did not significantly (p>0.05) affect grain yield, biomass yield, and yield components of barley like productive tiller and spike length (Table 1). Protein content was also not significantly (p>0.05) affected by seed rate though the highest protein content was obtained at 125 kg ha\(^{-1}\). N rate has significantly (p<0.001) affected grain and biomass yield of barley (Table 1). 46 kg ha\(^{-1}\) N rate gave significantly higher grain yield though it did not show significant difference with that of 69 kg N/ha. As N rate increased from 0 to 46 kg N/ha the grain yield also showed consistent increment but it showed slight decrease at a rate of 69 kg N ha\(^{-1}\). Significantly higher biomass yield was obtained with the N application rate of 46 kg ha\(^{-1}\) though it was statistically similar with N rate of 69 kg ha\(^{-1}\). Nil application of N significantly (p<0.001) brought about lower grain and biomass yield followed by 23 kg N ha\(^{-1}\). N rate has significantly (p<0.001) affected protein content of malt barley. Significantly higher protein content was recorded by the application of 46 kg ha\(^{-1}\) though it was not significantly different from 69 kg N ha\(^{-1}\). As N rate increased protein content also increased up to 46 kg N ha\(^{-1}\) then it started to decrease (Table 1).

Table 1: Table of means for main effects of seeding rate and N fertilizer application rate on malt barley crop parameters

<table>
<thead>
<tr>
<th>Seeding rate (kg ha(^{-1}))</th>
<th>Grain yield (kg ha(^{-1}))</th>
<th>Biomass yield (kg ha(^{-1}))</th>
<th>Protein content (%)</th>
<th>Productive tiller (m(^2))</th>
<th>Spike length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>2487</td>
<td>7892.9</td>
<td>10.59</td>
<td>280</td>
<td>6.6</td>
</tr>
<tr>
<td>100</td>
<td>2431</td>
<td>7706.4</td>
<td>10.52</td>
<td>284</td>
<td>6.4</td>
</tr>
<tr>
<td>125</td>
<td>2501</td>
<td>8177.1</td>
<td>10.74</td>
<td>290</td>
<td>6.4</td>
</tr>
<tr>
<td>150</td>
<td>2542</td>
<td>8207.1</td>
<td>10.35</td>
<td>293</td>
<td>6.4</td>
</tr>
<tr>
<td>175</td>
<td>2594</td>
<td>8243.9</td>
<td>10.54</td>
<td>309</td>
<td>6.2</td>
</tr>
<tr>
<td>Sig.</td>
<td>Ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nitrogen rate</th>
<th>Grain yield (kg ha(^{-1}))</th>
<th>Biomass yield (kg ha(^{-1}))</th>
<th>Protein content (%)</th>
<th>Productive tiller (m(^2))</th>
<th>Spike length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1611c</td>
<td>6528c</td>
<td>10.20c</td>
<td>233c</td>
<td>5.9c</td>
</tr>
<tr>
<td>23</td>
<td>2194b</td>
<td>8099b</td>
<td>10.35bc</td>
<td>272b</td>
<td>6.3b</td>
</tr>
<tr>
<td>46</td>
<td>3204a</td>
<td>8854a</td>
<td>10.95a</td>
<td>335a</td>
<td>6.6a</td>
</tr>
<tr>
<td>69</td>
<td>3035a</td>
<td>8701a</td>
<td>10.68ab</td>
<td>322a</td>
<td>6.8a</td>
</tr>
<tr>
<td>Sig.</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

Within each column, means with different letters are significantly different at p < 0.05; CV, coefficient of variation

The result also indicated that N rate has significantly (p<0.001) affected productive tillers of barley (Table 1). Significantly higher productive tillers were recorded by the application of 46 kg N ha\(^{-1}\) though it was statistically at par with 69 kg N ha\(^{-1}\). Significantly lowest tillers were recorded by the nil application of N followed by 23 kg N ha\(^{-1}\). Spike length of barley was also significantly (p<0.001) affected by N rate levels (Table 1). Significantly higher spike length was recorded by the application of
69 kg N ha\(^{-1}\) though it was not statistically different from that of 46 kg N/ha. Significantly higher spike length was recorded by 69 kg N per ha. Seeding rate by N rate interaction did bring significant differences in any of the dependent variables tested in this study. Similar result was also obtained by (O’Donovan et al., 2011) that indicated barley grain yield and tillers per plant increased with increasing N rate without pronounced effect on protein content.

Economic analysis revealed that optimum seeding rate has brought about economical advantages. The economic analysis revealed that optimum seeding rate was important due to the fact that it gave the highest net economic benefit (Table 2). Seeding rate of as low as 75 kg ha\(^{-1}\) have the highest monetary advantage in Birr over the recommended seeding rate (125 kg ha\(^{-1}\), 150 and 175 kg ha\(^{-1}\).

Economic analysis also indicated that N application was also observed to be economically advantageous. The economic analysis revealed that N fertilizer 46 kg ha\(^{-1}\) was the optimum N application rate due to the fact that it gave the highest net economic benefit (Table 2). Nitrogen application of 46 kg ha\(^{-1}\) gave a 21% monetary advantage in Birr 23 kg N per hectare.

**Conclusion**

Results of the study indicate that application of 46 kg N ha\(^{-1}\) gave better yield with acceptable protein content. A seeding rate of 75 kg ha\(^{-1}\) also gave higher grain yield with acceptable protein content. Use of 75 kg ha\(^{-1}\) seeding rate and 46 kg N/ha was more economically beneficial than other seeding and N rate. Farmers could use 75 kg ha\(^{-1}\) seed rate and 46 kg ha\(^{-1}\) for higher grain yield and best quality of malt barley on Nitisols of West Shoa under rainfed conditions.
References


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Determination of Appropriate Tied-Ridging with and without Fertilizer for Sorghum

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Introduction

Studies showed that moisture stress is the limiting factor for the productivity of rainfed agriculture in the semi-arid regions of northern Ethiopia (Haregeweyn et al., 2005). A similar report by McHugh et al. (2007) revealed grain production shortfalls in northern Ethiopia are commonly associated with occurrence of intra-seasonal dry spells or droughts and rapid land degradation which adversely impact crop yields. Therefore, for increased crop production and productivity, in the semi-arid areas should be accompanied with soil moisture conservation technologies. There are three major avenues to improve water productivity in rainfed agriculture in the semi-arid environments: 1), maximize plant water availability (maximize infiltration of rainfall, minimize unproductive water losses (evaporation); 2), increase soil water holding capacity and maximize root depth; 3) Maximize water-uptake capacity of plants (timelines of operation, crop management and soil fertility management) (Rockstrom et al., 2003b).

Experiences have shown that tied-ridge is a proven in-situ soil moisture conservation practice in the semi-arid areas and increases in grain yield of more than 50% have been reported at both Kobo and Melkassa by using tied-ridges (Reddy and Kidane, 1993; Kidane and Abuhay, 1997) as a soil moisture conservation practice. Response to fertilizer applications in the semi-arid areas was related to increasing rainfall and soil moisture availability (Reddy and Kidane, 1993). Experimental evidences indicate that the combined use of soil water conservation through tied ridges and fertilizer application is more effective and resulted in sustainable increase in crop production than the use of tied ridges or fertilizer use alone in semi-arid areas of Ethiopia (Kidane and Rezene, 1989).

Therefore, this study was aimed at determining the appropriate in-situ soil moisture conservation practices that enhance yield of sorghum in moisture stress areas under fertilized and non-fertilized conditions.
Materials and Methods

The experiment was carried out under rain fed conditions in 2015 and 2016 cropping seasons at Mehoni Agricultural Research Center at latitude of 12°41’50” N and longitudes of 39°42’08” E . The treatments were laid out under RCB design with three replications. Improved sorghum variety (Meko-I) adapted to the area was used. Two separate trials, where the first trial under tied-ridging with fertilizer and the second trial was under tied-ridging without fertilizer, were conducted for the same treatments. The treatments were (1) flat bed planting (control); (2) open end tied ridge, planting in furrow; (3) open end tied ridge, planting on ridges; (4) closed end tied ridge, planting in furrow; and (5) closed end tied ridge, planting on ridges. Meko-I sorghum was planted in a plot size of 3.75 x 4m (15 m²) with five rows at spacing of 75 cm between rows and 20 cm between plants within a row. Nitrogen in the form of urea at a rate of 41kg N ha⁻¹ and phosphorus in the form of Di Ammonium Phosphate (DAP) at a rate of 46 kg P₂O₅ ha⁻¹ were applied to each treatment of the first trial (Tied-ridging with fertilizer) where DAP was applied during planting while 50% of urea during planting and the remained 50% urea was applied at knee height. The ridges were made to be of 0.35m in height and the ties for closed end tied ridge treatments were at a height of 0.30m. All other appropriate agronomic practices such as weeding, thinning and hoeing were conducted uniformly in the experimental field.

Data on days to 90% maturity, plant height (cm), grain yield (kg ha⁻¹), and dry biomass yield (kg ha⁻¹) were collected. The collected agronomic data were deployed to the analysis of variance (ANOVA) using the SAS software computer package version 9.0 (SAS Institute, 2002). According to the standard procedure of Gomez and Gomez (1984), significant mean difference between the treatments was computed with least significant difference (LSD) at 5% probability level.

Results and Discussion

Days to 90% physiological maturity

Days to 90% physiological maturity was not significantly affected (P>0.05) by tied-ridging in 2015 cropping season while it was significantly influenced due to tied ridging in 2016 cropping season regardless of fertilizer (Table 1). Sorghum planted in furrow under closed end tied ridge took more time to mature while flat planting of sorghum contributed for earlier maturity of the crop under fertilized condition. In the case of unfertilized plots, sorghum planted in furrow under open and closed end tied ridging treatments matured late while the other treatments were significantly at par to mature sorghum earlier. This significant variation might be due to the effect of tied-ridge on retaining more water at the plant root zone. This result was contrasted with the findings of Tekle and Wedajo (2015) who noted that days to maturity was significantly affected by moisture conservation practices. According to these authors, tied ridge is the best practice of moisture conservation practices that increased crop productivity through enhanced soil moisture retention during the crop growing period.
Table 1. Days to 90% physiological maturity of sorghum as influenced by tied ridging under fertilized and non-fertilized conditions

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Days to maturity</th>
<th></th>
<th></th>
<th>With fertilizer</th>
<th></th>
<th></th>
<th>Without fertilizer</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Year_1</td>
<td>Year_2</td>
<td>Pooled mean</td>
<td>Year_1</td>
<td>Year_2</td>
<td>Pooled mean</td>
<td></td>
</tr>
<tr>
<td>Flat planting</td>
<td></td>
<td>111.33</td>
<td>109.67</td>
<td>110.50</td>
<td>109.33</td>
<td>101.67</td>
<td>105.50</td>
<td></td>
</tr>
<tr>
<td>OET, P in F</td>
<td></td>
<td>111.33</td>
<td>113.00</td>
<td>112.67</td>
<td>110.33</td>
<td>104.00</td>
<td>107.17</td>
<td></td>
</tr>
<tr>
<td>OET, P on R</td>
<td></td>
<td>111.67</td>
<td>110.33</td>
<td>111.00</td>
<td>110.00</td>
<td>101.33</td>
<td>105.67</td>
<td></td>
</tr>
<tr>
<td>CET, P in F</td>
<td></td>
<td>112.33</td>
<td>114.33</td>
<td>113.33</td>
<td>109.67</td>
<td>104.67</td>
<td>107.17</td>
<td></td>
</tr>
<tr>
<td>CET, P on R</td>
<td></td>
<td>112.00</td>
<td>111.33</td>
<td>111.67</td>
<td>110.33</td>
<td>101.00</td>
<td>105.67</td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td>1.03</td>
<td>1.51</td>
<td>1.14</td>
<td>1.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD (5%)</td>
<td></td>
<td>NS</td>
<td>3.19</td>
<td>NS</td>
<td>2.09</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NS= non significant; Means with the same letter(s) in the same column are not significantly different at P < 0.05; OET= Open end tied ridge; P in F= planting in furrow; P on R= planting on ridge; CET= closed end tied ridge; LSD= least significant difference; CV= coefficient of variance; Year_1= 2015; Year_2= 2016

Plant height
Tied ridging practices did not show significant effect on plant height of sorghum in both cropping seasons under fertilized and non-fertilized conditions. This could be because of the role of the treatments to supply optimum moisture needed for increment of plant height of sorghum. Plant height of sorghum ranged from 119.10 to 166.33 cm in the case of fertilized plots while under unfertilized plots, it ranged from 117.07 to 162.00 cm. Numerically, the highest plant height was obtained from closed end tied ridge and when sorghum was planted in furrow in both fertilized and non-fertilized conditions. In contrast, research works of Tekle and Wedajo (2015) on different soil moisture practices at Southern Ethiopia, showed a high significant plant height (180 cm) was recorded due to the effect of tied ridge as compared to circular pitting, open ridge, half moon and farmers' practice (flat bed) practices.

Grain yield
Tied ridging practices are crucial for sorghum yield improvement under moisture stress areas. Of which, closed end tied ridging integrated with planting in furrow gave significantly high grain yield in both cropping seasons under fertilized and non-fertilized plots (Table 2). Closed end tied ridging integrated with furrow planting of sorghum over yield farmers practice (flat planting) by 19.39 % to 39.11% and also by 27.06% to 30.56% under fertilized and non-fertilized conditions, respectively. This significant variation might be attributed to the effect of tied ridging on optimum moisture retention which required for development and production especially at the critical stages of growth such as flowering and seed formation. This also created favorable condition to absorb water by sorghum plants planted in furrow. Other research works indicated that main reasons for the increase in yields were better moisture availability, improved soil fertility and better root growth as a result of conservation tillage application (Temesgen et al., 2008).
Table 2. Mean grain yield of sorghum as influenced by tied ridging with and without fertilizer

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Grain yield (kg ha⁻¹)</th>
<th>With fertilizer</th>
<th>Without fertilizer</th>
<th>Year_1</th>
<th>Year_2</th>
<th>Pooled mean</th>
<th>Year_1</th>
<th>Year_2</th>
<th>Pooled mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Year_1</td>
<td>Year_2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat planting</td>
<td>3870.40bc</td>
<td>2319.50c</td>
<td>3094.95</td>
<td>3307.80c</td>
<td>2107.70b</td>
<td>2707.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OET, P in F</td>
<td>4292.90ab</td>
<td>3080.00ab</td>
<td>3686.45</td>
<td>3950.10ab</td>
<td>2629.10a</td>
<td>3289.60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OET, P on R</td>
<td>3706.50c</td>
<td>3074.60ab</td>
<td>3390.55</td>
<td>3570.00bc</td>
<td>2379.30ab</td>
<td>2974.65</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CET, P in F</td>
<td>4621.00a</td>
<td>3226.70a</td>
<td>3823.85</td>
<td>4318.80a</td>
<td>2678.00a</td>
<td>3498.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CET, P on R</td>
<td>4269.10ab</td>
<td>2515.10bc</td>
<td>3392.1</td>
<td>3771.30bc</td>
<td>2330.40ab</td>
<td>3050.85</td>
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<tr>
<td>CV (%)</td>
<td>5.47</td>
<td>12.11</td>
<td>7.45</td>
<td>7.97</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>427.36</td>
<td>648.37</td>
<td>530.62</td>
<td>363.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letter(s) in the same column are not significantly different at P < 0.05; OET= Open end tied ridge; P in F= planting in furrow; P on R= planting on ridge; CET= closed end tied ridge; LSD= least significant difference; CV= coefficient of variance; Year_1= 2015; Year_2=2016

Moreover, findings of Gebreyesus (2012) who conducted a research in the semi-arid areas of northern Ethiopia, sorghum yield showed increment by 7 to 48% due to the effect of conservation tillage integrated with fertilizers compared to the traditional tillage. The same author reported that tied-ridge and fertilizer, and its interaction were significantly influenced the yield of sorghum and resulted in up to 48% increment. According to Heluf and Yohannes (2002), tied ridge has resulted in yield increments of 15 to 50% on maize and 15 to 38% for sorghum on different soil types of eastern Ethiopia.

Dry biomass yield

The dry biomass yield data of sorghum (Meko-I) produced under rainfed conditions with and without NP fertilizers as influenced by tied ridges and planting methods are depicted in Table 3. Tied ridging practices significantly influenced biomass yield of sorghum. Closed end tied ridging integrated with planting in furrow gave significantly high grain yield in both cropping seasons under fertilized and non-fertilized plots. As compared to closed tied ridging practice, conventional practice (flat planting) reduced sorghum biomass yield by 14.07 % to 27.22% under fertilized condition and also showed 15.84% to 27.46% yield reduction under non-fertilized conditions. This might be attributed to less efficiency of flat planting to conserve and retain moisture as compared to the other moisture conservation practices.
Table 3. Mean biomass yield of sorghum as influenced by tied ridging with and without fertilizer

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Dry biomass yield (kg ha⁻¹)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With fertilizer</td>
<td>Without fertilizer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Year_1</td>
<td>Year_2</td>
<td>Pooled mean</td>
<td>Year_1</td>
<td>Year_2</td>
<td>Pooled mean</td>
</tr>
<tr>
<td>Flat planting</td>
<td>9856.50b</td>
<td>4981.20c</td>
<td>7418.85</td>
<td>8981.90bc</td>
<td>4112.40b</td>
<td>6547.15</td>
</tr>
<tr>
<td>OET, P in F</td>
<td>10962.50a</td>
<td>5741.70bc</td>
<td>8352.1</td>
<td>9170.10abc</td>
<td>5270.20a</td>
<td>7220.15</td>
</tr>
<tr>
<td>OET, P on R</td>
<td>9559.20b</td>
<td>5627.70bc</td>
<td>7593.45</td>
<td>8004.70c</td>
<td>4791.10ab</td>
<td>6397.90</td>
</tr>
<tr>
<td>CET, P in F</td>
<td>11471.00a</td>
<td>6844.40a</td>
<td>9157.7</td>
<td>10672.70a</td>
<td>5669.50a</td>
<td>8171.10</td>
</tr>
<tr>
<td>CET, P on R</td>
<td>11290.30a</td>
<td>6045.90ab</td>
<td>8668.1</td>
<td>9865.60ab</td>
<td>5110.50a</td>
<td>7488.05</td>
</tr>
<tr>
<td>CV (%)</td>
<td>5.22</td>
<td>8.36</td>
<td>8.61</td>
<td>9.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>1045.10</td>
<td>920.90</td>
<td>1513.80</td>
<td>912.84</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letter (s) in the same column are not significantly different at P<0.05; OET= Open end tied ridge; P in F= planting in furrow; P on R= planting on ridge; CET= closed end tied ridge; LSD= least significant difference; CV= coefficient of variance Year_1= 2015; Year_2=2016

This current result is in coherent with Tekle and Wodajo (2015) who reported that biomass yield of sorghum was significantly affected by moisture conservation practices where the highest total biomass weight (15.50 t ha⁻¹) and the lowest (9.53 t ha⁻¹) were recorded from tied ridge and farmers’ practice, respectively in southern Ethiopia. Another study in Ethiopia Somalia Region showed that biomass yield of sorghum was increased due to tied ridging at planting and after one month under fertilized and non-fertilized conditions as compared to farmers' practice (Aklilu and Mekiso, 2015). In general, the substantial biomass yield response of the crop to tied ridging on both the fertilized and unfertilized experiments indicated that in regions with poor rainfall distributions such as the Raya valley lowlands, soil and water conservation is a necessary agricultural operation.

Conclusion

In areas with low and erratic rainfall, use of effective moisture conservation practices is indispensable for increasing crop yield. According to this current finding, closed end tied ridge integrated with planting in furrow gave remarkably high grain and dry biomass yields as compared to the other tied ridging practices with planting methods in general and farmers’ practice in particular in both fertilized and non-fertilized conditions. It was observed that furrow planting, regardless of the type of the tied ridge, proved to be more effective in conserving water and increasing the yield of sorghum with relatively consistent effects in both seasons than planting on ridge and flat bed methods on both soil fertility levels. Generally, integrated soil and crop management practices should be addressed simultaneously to increase water infiltration and nutrient availability thereby increase crop productivity in moisture stress areas like Raya valley. Accordingly, efforts have to be made to disseminate the most outstanding findings of the present studies to the end users and, further research work is imperative to improve sorghum production in areas where moisture is the most limiting factor for sustainable crop production.
References


Response of Short Duration and Small Size Sorghum Variety to Inter and Intra-row Spacings

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Introduction

Even though sorghum adapts to wide ecological conditions, the yield still remains lower under the traditional farming practice. An optimum plant population with good management increases the yield of sorghum. Optimal plant densities for grain sorghum differ from region to region and grain yields generally increase as plant population increases (Staggenborg, 1999). Plant density is dependent on both row width and intra-row spacing and under dry land conditions row width plays an important role in determining plant density (Mashiqaa et al., 2011).

Optimizing plant population on the basis of the potential supply of water minimizes the opportunity for plant water stress that could be caused by high water demand (Yared et al., 2010). The impact of row spacing on cereal yield varies depending on the rainfall growing season, the time of sowing and the potential yield of the crop.

The nationally recommended spacing for sorghum in Ethiopia is 75 cm by 20 cm between rows and plants, respectively (MoARD, 2003). This row spacing is based on study of tall and late maturing sorghum varieties. But, farmers in the semi-arid area of Northern Ethiopia also practice this spacing for both late and early maturing sorghum varieties. This indicates that further study is needed to determine the response of short and early maturing sorghum varieties in terms of plant population densities.

Therefore, the objective of this study was to determine the optimum planting spacing for small size sorghum varieties productivity under irrigation conditions in the study area.

Material and Methods

The experiment was carried out at Meboni Agricultural Research Center (MeARC) testing station, Fachagama, under irrigation conditions in 2015 and 2016 cropping seasons. It was laid out in randomized complete block design (RCBD) with three replications. Improved, early matured sorghum variety (Meko-I) was used for the trial. A factorial combination of four intra-row spacing levels (10, 15, 20 and 25 cm) and three inter-row spacing levels (55, 65 and 75 cm) were applied as treatments. Each treatment was assigned a plot size of 4.5 m * 4.5 m having plot and block...
spacing of 1m and 1.5 m, respectively. All other appropriate agronomic practices such as recommended fertilizer application, weeding, thinning, watering and hoeing was conducted uniformly to the experimental field.

Data on days to 90% maturity, plant height (cm), panicle length (cm), thousand kernel weight (g), grain yield (kg ha\(^{-1}\)), dry biomass yield (kg ha\(^{-1}\)) were collected. The collected agronomic data were subjected to the analysis of variance (ANOVA) using the GenStat software computer package version 15.0 (VSN International, 2012) and significance difference among the treatment means was computed with least significant difference (LSD) at 5% probability level (Gomez and Gomez, 1984).

Economic analysis was also performed to investigate the economic feasibility of the treatments by using partial and marginal budget analysis. The marginal rate of return (MRR) was calculated as the change in net benefit (NB) divided by the change in total variable cost (TVC) of the successive net benefit and total variable cost levels (CIMMYT, 1988).

Results and Discussion

Days to maturity
Planting spacing significantly (P<0.01) affected the maturity of sorghum. Table 1 showed that the highest days to maturity (113) of Meko-I variety was recorded from 75 cm inter-row spacing. The highest days to maturity of Meko-I (115.3) was recorded at 25 cm intra row spacing. But, it is generally pointed out that sorghum was matured earlier in narrow planting spacing. On the other side, as inter-row spacing increased days to maturity was also increased which implied that wider inter-row spacing delayed sorghum maturity. Similar trend also observed in intra-row spacing. This attributed to free access for growth resources like water, nutrients and light which contributed for vegetative growth elongation. This current result was in agreement with the findings of Abdala (2015) who reported that maturity in maize delays as intra - row spacing increases. According to his finding, maturity of maize delayed at 40 cm spacing as compared to 25 cm, 30 cm and 35 cm intra-row spacing.
Table 1. Effect of intra and inter-row spacing on days to maturity and thousand kernel weight of sorghum

<table>
<thead>
<tr>
<th>Planting spacing (cm)</th>
<th>Days to 90% maturity</th>
<th>Plant height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>111.40b</td>
<td>147.80</td>
</tr>
<tr>
<td>65</td>
<td>112.80a</td>
<td>147.80</td>
</tr>
<tr>
<td>75</td>
<td>113.00a</td>
<td>144.60</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.85</td>
<td>NS</td>
</tr>
<tr>
<td>Intra</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>109.90c</td>
<td>153.70a</td>
</tr>
<tr>
<td>15</td>
<td>110.60c</td>
<td>146.60b</td>
</tr>
<tr>
<td>20</td>
<td>113.80b</td>
<td>143.50b</td>
</tr>
<tr>
<td>25</td>
<td>115.30a</td>
<td>143.20b</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.99</td>
<td>6.61</td>
</tr>
<tr>
<td>Year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y_1</td>
<td>110.45b</td>
<td>148.20</td>
</tr>
<tr>
<td>Y_2</td>
<td>114.33a</td>
<td>145.30</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.70</td>
<td>NS</td>
</tr>
<tr>
<td>CV (%)</td>
<td>1.30</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Means with the same letter(s) in the same column are not significantly different at $P<0.05$; LSD= least significant difference; CV= coefficient of variance; NS= non-significant; $Y_1=2015$; $Y_2=2016$

Plant height

Inter-row spacing and cropping year did not cause a significant effect on plant height of sorghum. However, plant height was significantly influenced due to intra-row spacing. Accordingly, the highest value (153.70 cm) of plant height for Meko-I was recorded from 10 cm while its lowest value was obtained from 25 cm though significantly at par with the 15 cm and 20 cm intra-row spacing (Table 1). According to Table 1, plant height of sorghum decreased as intra-row spacing increased. This ascribed to solar radiation that falls between crop rows and other soil nutrients remain unutilized. The current result was in conformity with the work of Babaji et al. (2012) who reported that taller plants from the highest density because of higher competition for light. Likewise, Ibeawuchi et al. (2008) reported that closely spaced plants compete for nutrient and other growth factors, which tend to grow taller than those with wider spacing.

Grain yield

Planting spacing caused a significant effect on grain yield of sorghum. According to Table 2, the interaction of inter and intra-row spacing significantly ($P<0.05$) affect grain yield of Meko-I. Consequently, the highest yield (4618.00 kg ha$^{-1}$) was obtained from the interaction of 65 cm by 15 cm while the lowest yields obtained at a wider inter-row and intra-row spacing interactions.
Table 2. Effect of year, intra-row spacing on grain yield of Meko-I sorghum variety

<table>
<thead>
<tr>
<th>Year</th>
<th>Grain yield (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y_1</td>
<td>3468.00</td>
</tr>
<tr>
<td>Y_2</td>
<td>3669.00</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>NS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inter-row spacing (cm)</th>
<th>Intra-row spacing (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>4233.00abc</td>
</tr>
<tr>
<td>65</td>
<td>3574.00d</td>
</tr>
<tr>
<td>75</td>
<td>3473.00d</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>550.80</td>
</tr>
<tr>
<td>CV (%)</td>
<td>13.40</td>
</tr>
</tbody>
</table>

Means with the same letter(s) in the same column are not significantly different at P<0.05; LSD= least significant difference; CV= coefficient of variance; NS= non-significant; Y_1= 2015; Y_2=2016

This might be due to the ability of closely spaced plants to trap most of the photo synthetically active radiation, more number of leaves per plant that provided more surfaces for photosynthesis and assimilates production. Generally, maximum yield was produced at closely spaced plants but not too narrow. This current report was in agreement with Babaji et al. (2012) who found that each increase in intra-row spacing has resulted in corresponding significant decrease in maize grain yield. Similarly, Miko and Manga (2008) confirmed this finding. According to Ali et al. (2017) and Lakew et al. (2016), grain yield of maize was highly significantly affected by the interaction of inter and intra-row spacing.

**Biomass yield**

Biomass yield of Meko-I was also highly significantly (P<0.01) influenced by inter-row spacing (Table 3). Thus, the highest yield (10481.00 kg ha\(^{-1}\)) was obtained from 65 cm while the other inter-row spacing treatments were statistically inferior.

This could be most probably due to the ability of the plant to use soil nutrients, water and light efficiently and effectively at 65 cm inter-row spacing. In addition, there is effective utilization of solar radiation, which is influenced by canopy structure, and directly leads to high dry matter production in crop plants.

Intra-row spacing and cropping year did not give a response on biomass. The biomass yields of sorghum decreased as intra and inter-row spacing increased. This current result was in line with the report of Gobeze et al. (2012) who found that subjecting plants to reduced row spacing increased the ability of plants for capturing resources which in turn reflected on high biomass production. It was also supported by the findings of Miko and Manga (2008) which revealed that the closest intra-row spacing (25cm) produced statistically higher dry matter per plant than 50 and 75cm spacing.
Table 3. Biomass yields of Meko-I sorghum variety as influenced by intra and inter-row spacings

<table>
<thead>
<tr>
<th>Planting spacing (cm)</th>
<th>Biomass yield (kg ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inter</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>10467.00b</td>
</tr>
<tr>
<td>65</td>
<td>10481.00a</td>
</tr>
<tr>
<td>75</td>
<td>8767.00b</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>1006.00</td>
</tr>
<tr>
<td>Intra</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10436.00</td>
</tr>
<tr>
<td>15</td>
<td>10357.00</td>
</tr>
<tr>
<td>20</td>
<td>9543.00</td>
</tr>
<tr>
<td>25</td>
<td>9283.00</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>NS</td>
</tr>
<tr>
<td>Year</td>
<td></td>
</tr>
<tr>
<td>Y_1</td>
<td>9961.00</td>
</tr>
<tr>
<td>Y_2</td>
<td>9849.00</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>NS</td>
</tr>
<tr>
<td>CV (%)</td>
<td>17.50</td>
</tr>
</tbody>
</table>

Means with the same letter (s) in the same column are not significantly different at $P<0.05$; LSD= least significant difference; CV= coefficient of variance; NS= non-significant; Y_1= 2015; Y_2=2016

Economic analysis
Farmers need economically feasible technologies. According to the economic analysis, the highest net profit (Birr. 40238.36) and MRR (3494.41%) were recorded from the planting spacing of 65*15cm (Table 4). Thus, sorghum farmers can plant short duration sorghum varieties at inter and intra row spacing of 65 by 15 m to obtain optimum yield under full irrigation conditions. From this analysis, it is generally observed that wider inter and intra row spacing gave minimum net benefit in relative to narrow planting spacing.

Conclusion

the highest grain and biomass yields were obtained at inter and intra-row spacings of 65 cm and 15 cm, respectively. The interaction of 65 cm by 15 cm gave a maximum grain yield. Optimum net profit and MRR were obtained at inter and intra-row spacing of 65 cm and 15 cm, respectively. Thus, the optimum planting spacing for sorghum under irrigated condition is at inter-row spacing of 65 cm and intra-row spacing of 15 cm. As a conclusion, sorghum farmers in the study area and other areas with similar agro-ecology are recommended to use 65 cm for inter-row and 15 cm intra-row spacing of sorghum to enhance the productivity of short duration and small size improved sorghum varieties in a sustainable mode.
Table 4. Marginal budget analysis of sorghum as affected by inter and intra-row spacing

<table>
<thead>
<tr>
<th>Treatment combination</th>
<th>75'25cm</th>
<th>75'20cm</th>
<th>65'25cm</th>
<th>65'20cm</th>
<th>75'15cm</th>
<th>55'25cm</th>
<th>65'15cm</th>
<th>75'10cm</th>
<th>55'20cm</th>
<th>65'10cm</th>
<th>55'15cm</th>
<th>55'10cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average grain yield (kg ha⁻¹)</td>
<td>2753.00</td>
<td>2678.00</td>
<td>3707.00</td>
<td>3750.00</td>
<td>3355.00</td>
<td>3396.00</td>
<td>4618.00</td>
<td>3473.00</td>
<td>3785.00</td>
<td>3574.00</td>
<td>4300.00</td>
<td>4233.00</td>
</tr>
<tr>
<td>Adjusted grain yield (kg ha⁻¹)</td>
<td>2477.70</td>
<td>2410.20</td>
<td>2616.30</td>
<td>3375.00</td>
<td>3019.50</td>
<td>3056.40</td>
<td>4156.20</td>
<td>3125.70</td>
<td>3406.50</td>
<td>3216.60</td>
<td>3870.00</td>
<td>3809.70</td>
</tr>
<tr>
<td>Benefit from grain yield (Birr ha⁻¹)</td>
<td>22299.30</td>
<td>21691.80</td>
<td>23546.70</td>
<td>30375.00</td>
<td>27175.50</td>
<td>27507.60</td>
<td>37405.80</td>
<td>28131.30</td>
<td>30658.50</td>
<td>28949.40</td>
<td>34830.00</td>
<td>34287.30</td>
</tr>
<tr>
<td>Adjusted biomass yield (kg ha⁻¹)</td>
<td>6663.60</td>
<td>7847.10</td>
<td>8626.50</td>
<td>8883.90</td>
<td>8359.20</td>
<td>9773.10</td>
<td>10436.40</td>
<td>8690.40</td>
<td>9036.00</td>
<td>9783.00</td>
<td>9169.20</td>
<td>9704.70</td>
</tr>
<tr>
<td>Benefit Biomass yield (Birr ha⁻¹)</td>
<td>2998.62</td>
<td>3531.20</td>
<td>3881.93</td>
<td>3997.76</td>
<td>3761.64</td>
<td>4397.89</td>
<td>4696.38</td>
<td>3910.68</td>
<td>4066.20</td>
<td>4402.35</td>
<td>4126.14</td>
<td>4367.16</td>
</tr>
<tr>
<td>Gross field benefits (Birr ha⁻¹)</td>
<td>25297.92</td>
<td>25223.00</td>
<td>25223.00</td>
<td>30937.14</td>
<td>31905.50</td>
<td>32041.98</td>
<td>34724.70</td>
<td>33351.75</td>
<td>38956.14</td>
<td>38654.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TVC (Birr ha⁻¹)</td>
<td>1285.63</td>
<td>1318.96</td>
<td>1435.17</td>
<td>1648.78</td>
<td>1661.74</td>
<td>1831.42</td>
<td>1863.82</td>
<td>2018.91</td>
<td>2245.15</td>
<td>2416.05</td>
<td>2474.70</td>
<td>2737.18</td>
</tr>
<tr>
<td>Net benefit (Birr)</td>
<td>24012.29</td>
<td>23904.04</td>
<td>25993.46</td>
<td>32723.98</td>
<td>29275.4</td>
<td>30074.08</td>
<td>40238.36</td>
<td>30023.07</td>
<td>32479.55</td>
<td>30935.7</td>
<td>36481.44</td>
<td>35917.24</td>
</tr>
<tr>
<td>MRR (%)</td>
<td>-</td>
<td>D</td>
<td>1324.84</td>
<td>3150.84</td>
<td>D</td>
<td>D</td>
<td>3494.41</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
</tbody>
</table>

TVC= total variable cost; MRR= marginal rate of return; D= Dominated treatment
References


**Striga Management on Sorghum**

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**Introduction**

Crop rotation and intercropping with trap crops (false hosts) are of practical importance in reducing the *Striga* seed reserves from the soil. Thus, conducting simultaneous experiments to determine effective intercrop or trap crop with the proper dose determination of N and compost rates seems to be a reasonable idea for better controlling measure, as fertility improvement is considered as a control (Chikoye et al., 2006; Mumera and Below, 1993; Kim et al., 1997). A work of Chikoye et al. (2006), conducted in Kenya, indicated that maize vigor and grain yield were lowest where no N was applied and increased with higher N rates. On the other hand, *Striga* incidence and crop damage are higher where no N was applied and decreased with higher N rates. From the point of economic analysis, the use of *Striga* tolerant maize and legume trap crops grown in rotation with maize can provide better returns than continuous maize.

In general, to alleviate yield loss due to *Striga* infestation and to have optimum crop productivity and to ensure food self sufficiency in the study area, agricultural research activities should focus on integrated agronomic *Striga* controlling as sustainable control of *Striga* through single control options is unlikely (Schulz et al., 2003). Therefore, this research study was initiated to evaluate each agronomic practices on *Striga* controlling management and to determine the most effective agronomic practices on sorghum crop yield.

**Materials and Methods**

The experiment was carried out under rain fed conditions in 2015 and 2016 cropping seasons in Alamata woreda which is situated at 12°15'N latitude and 39°35'E longitude. The area is found at an altitude of 1450 to 1750 meter above sea level (m.a.s.l) with average annual rainfall of 663 mm and mean annual temperature of 14.6°C to 29.7°C (Abay, 2013). The treatments were laid out under RCB design with three replications. Improved sorghum variety (Meko-I) adapted to the area was used. The treatments (T) were (T1) farmers’ practice (no fertilizer and intercropping) as a control; (T2) compost (at 10 ton ha\(^{-1}\)); (T3) intercropping with Mungbean variety (N-26) at seed rate of 20 kg ha\(^{-1}\); (T4) inorganic fertilizer (at 41kg N ha\(^{-1}\) and 46 kg P\(_2\)O\(_5\) ha\(^{-1}\)); (T5) 50% compost + 50% inorganic fertilizer; (T6) 50% compost + intercropping; (T7) 50% inorganic fertilizer + intercropping; (T8) 50% compost + intercropping + 50% inorganic fertilizer rate; (T9) *Striga* resistant sorghum (Gubiye variety). Meko-I sorghum variety was planted in a plot.
size of 3.75m * 4m (15 m²) with five rows at spacing of 75 cm between rows and 20 cm between plants within a row. Half dose of Nitrogen in the form of urea was applied during planting while the remained 50% urea was applied at knee height. Full dose of phosphorus was applied as band application method in the form of Di Ammonium Phosphate (DAP) at planting time. Compost was applied to the plots and mixed with the soil two weeks before planting. Intercropping of Mungbean was done simultaneously with sorghum at 1:1 planting pattern. Ridge on all plots to harvest water was made to be of 0.30 m in height and the ties were at a height of 0.25m. All other appropriate agronomic practices such as weeding excluding Striga weed and thinning were conducted uniformly to the experimental field.

Agronomic data on days to 90% maturity, plant height (cm), panicle length (cm), grain yield (kg ha⁻¹), dry biomass yield (kg ha⁻¹) and number of Striga m⁻² were collected. The collected agronomic data were subjected to the analysis of variance (ANOVA) using the SAS software computer package version 9.0 (SAS Institute, 2002) and least significant difference (LSD) at 5% probability level was employed to compute significance difference among the treatment means (Gomez and Gomez, 1984).

Economic analysis was also performed to investigate the economic feasibility of the treatments by using partial and marginal analyses. The marginal rate of return (MRR) was calculated as the change in net benefit (NB) divided by the change in total variable cost (TVC) of the successive net benefit and total variable cost levels (CIMMYT, 1988).

**Results and Discussion**

**Days to maturity**

As shown in Table 1, days to maturity was highly significantly (P<0.01) influenced in 2015 and also significantly (P<0.05) affected in 2016 cropping seasons. According to the current finding, Gubiye sorghum variety was late mature crop, which took 101.83 to 110 days, as compared to Meko-I. It matured in a range of 98.17 to 107.33 days. Early or late in the days to maturity might have been due to their inherited characters, early acclimatization to the growing area to enhance their growth and developments. Unlike to Gubiye and intercropping + 50% inorganic fertilizer, the other treatments were significantly at par with control in the year 2015. Similarly, without Gubiye, compost and 50% compost + 50% inorganic fertilizer treatments, the other agronomic practices were similarly affected days to maturity of Meko-I variety in 2016 cropping season. This present finding was in agreement with the work of Zerihun (2016) who reported that days to 90% physiological maturity was significantly different due to nitrogen and variety. He noted that high level of N delays maturity as it increases vegetative growth and difference in days to maturity of the varieties ascribed to their genetic characteristics.
Table 1. Effect of *Striga* controlling management practices on days to maturity of sorghum

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Days to maturity</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year_1</td>
<td>Year_2</td>
<td>Mean</td>
</tr>
<tr>
<td>Control /no fertilizer/</td>
<td>98.17c</td>
<td>105.00c</td>
<td>101.59</td>
</tr>
<tr>
<td>Compost</td>
<td>98.50bc</td>
<td>107.33b</td>
<td>102.92</td>
</tr>
<tr>
<td>Intercropping</td>
<td>99.00bc</td>
<td>106.67bc</td>
<td>102.84</td>
</tr>
<tr>
<td>Inorganic fertilizer</td>
<td>98.50bc</td>
<td>107.00bc</td>
<td>102.75</td>
</tr>
<tr>
<td>50% compost+50% inorganic fertilizer</td>
<td>99.00bc</td>
<td>107.33b</td>
<td>103.16</td>
</tr>
<tr>
<td>50% compost + intercropping</td>
<td>99.00bc</td>
<td>106.00bc</td>
<td>102.5</td>
</tr>
<tr>
<td>Intercropping + 50% inorganic fertilizer</td>
<td>99.33b</td>
<td>107.00bc</td>
<td>103.16</td>
</tr>
<tr>
<td>50% compost + intercropping + 50% inorganic fertilizer rate</td>
<td>98.83bc</td>
<td>106.67bc</td>
<td>102.75</td>
</tr>
<tr>
<td>Resistant sorghum crop (Gubiye)</td>
<td>101.83a</td>
<td>110.00a</td>
<td>105.92</td>
</tr>
<tr>
<td>CV (%)</td>
<td>0.61</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>1.05</td>
<td>2.32</td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letter (s) in the same column are not significantly different at P<0.05 and P<0.01; LSD = least significant difference; CV = coefficient of variance; Year_1 = 2015; Year_2 = 2016

**Plant height**

Agronomic practices showed highly significant difference (P<0.01) in affecting plant height in both cropping years. In 2015, the smallest plant height (106.00 cm) was recorded from Gubiye (Table 2). The other agronomic treatments were statistically at par, which they produced significantly higher plant height as compared to the control. Similar trend is also observed in 2016 where the minimum value (128.47 cm) was obtained from Gubiye while the maximum was due to the other treatments excluding intercropping. Generally, Meko-I was taller than Gubiye variety. It produced a plant height advantage of 25.32% to 48.11% over Gubiye. This was ascribed to the difference in genetic make-up of the varieties, and its efficient utilization of environmental growth resources so as to stimulate and enhance the photosynthetic and metabolic activities of the plant which reflected on the increase in the vegetative growth of Meko-I. This result was in conformity with the findings of Adekayode and Ogunkoya (2010) who reported significantly higher maize plant height (197.6 cm) in 300 kg NPK ha⁻¹ and lower value of 167.9 cm in plots without fertilizer (0 kg NPK ha⁻¹).

**Panicle length**

Panicle length was differed significantly (P<0.01) due to the effect of integrated agronomic practices in 2015 cropping season (Table 2). The maximum value (24.17 cm) was recorded from Gubiye while the minimum panicle length (19.17 cm) was from the control. As revealed in this table, similar trend was happened in 2016. Accordingly, Gubiye registered significantly (P<0.05) higher panicle length (26.60 cm) in contrast to the other treatments. It was generally noted that Gubiye gave high panicle length while Meko-I produced smaller value. Gubiye variety had 19.66% to 26.08% taller panicle length than Meko-I. This difference could be most probably due to their inherited traits and adaptability to the environmental condition of the study area. This current result was supported by the findings of
Zerihun (2016) who explained that the effect of variety on panicle length of sorghum was significant, where the longest panicle length (25.74 cm) was recorded from Gubiye among Hormat and Teshale varieties.

Table 2. Mean of plant height and panicle length of sorghum as influenced by Striga management

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height (cm)</th>
<th>Panicle length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year_1</td>
<td>Year_2</td>
</tr>
<tr>
<td>Control /no fertilizer/</td>
<td>135.67b</td>
<td>161.00ab</td>
</tr>
<tr>
<td>Compost rate</td>
<td>152.83a</td>
<td>166.27ab</td>
</tr>
<tr>
<td>Intercropping</td>
<td>151.17ab</td>
<td>146.93bc</td>
</tr>
<tr>
<td>Inorganic fertilizer</td>
<td>157.00a</td>
<td>171.33a</td>
</tr>
<tr>
<td>50%compost+50% inorganic fertilizer</td>
<td>156.67a</td>
<td>173.93a</td>
</tr>
<tr>
<td>50%compost+intercropping</td>
<td>152.83a</td>
<td>166.27ab</td>
</tr>
<tr>
<td>Intercropping+50% inorganic fertilizer</td>
<td>154.83a</td>
<td>168.40a</td>
</tr>
<tr>
<td>50%compost+intercropping+50% inorganic fertilizer rate</td>
<td>156.67a</td>
<td>168.93a</td>
</tr>
<tr>
<td>Resistant sorghum crop (Gubiye)</td>
<td>106.00c</td>
<td>128.47c</td>
</tr>
<tr>
<td>CV (%)</td>
<td>6.35</td>
<td>7.69</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>16.16</td>
<td>21.46</td>
</tr>
</tbody>
</table>

Means with the same letter (s) in the same column are not significantly different at P<0.05 and P<0.01; LSD= least significant difference; CV= coefficient of variance; Year_1= 2015; Year_2= 2016

Grain yield

The yield of sorghum was highly significantly (P<0.01) affected by integrated agronomic practices in 2015. According to Table 4, a prominent grain yield (4669.50 kg ha\(^{-1}\)) was produced due to application of inorganic fertilizer though statistically similar to the effect of compost, intercropping and 50%compost+50%inorganic fertilizer. Conversely, the smallest yield was recorded from Gubiye which gave 34.38 % to 45.36% lower yield than Meko-I. Similarly, the treatments showed significant difference (P<0.05) in influencing the grain yield of sorghum in 2016 cropping season (Table 4).

Like to in 2015, the smallest yield (2882.30 kg ha\(^{-1}\)) was achieved from resistant (Gubiye) sorghum variety while the maximum yield (4611.30 kg ha\(^{-1}\)) was obtained from application of inorganic fertilizer, which was significantly at par with the other treatments excluding use of 50%compost + intercropping and resistant sorghum crop. This yield increment could be attributed to the direct response of N on stimulation of plant growth, which in turn reflected on the grain yield production, and the role of compost in improving cation exchange capacity (CEC), aeration, root penetration, water storage capacity of the soil as well as being host of different microbes. This was supported by the report of Habtamu et al. (2015). In addition, other findings confirmed that the application of high N fertilizer (120 kg N ha\(^{-1}\)) enhanced grain yield, and 1000 grain weight of maize
(Miao et al., 2007). Moreover, the result of this experiment was coherent with previous research results of Dilshad et al. (2010); Nivong et al. (2007) noted that combined use of organic and inorganic fertilizers improved grain yield of maize.

Table 4. Effect of Striga controlling management practices on grain yield of sorghum

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Grain yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year-1</td>
</tr>
<tr>
<td>Control /no fertilizer/</td>
<td>3917.67bc</td>
</tr>
<tr>
<td>Compost rate</td>
<td>4042.83abc</td>
</tr>
<tr>
<td>Intercropping (Mungbean)</td>
<td>4029.50abc</td>
</tr>
<tr>
<td>Inorganic fertilizer</td>
<td>4669.50a</td>
</tr>
<tr>
<td>50%compost+50%inorganic fertilizer</td>
<td>4583.17ab</td>
</tr>
<tr>
<td>50%compost+intercropping(Mungbean)</td>
<td>3940.17bc</td>
</tr>
<tr>
<td>Intercropping (Mungbean)+50%inorganic fertilizer</td>
<td>3924.33bc</td>
</tr>
<tr>
<td>50%compost+intercropping+50%inorganic fertilizer rate</td>
<td>3887.83c</td>
</tr>
<tr>
<td>Resistant sorghum crop /Gubiye/</td>
<td>2551.17d</td>
</tr>
<tr>
<td>CV (%)</td>
<td>10.04</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>686.12</td>
</tr>
</tbody>
</table>

Means with the same letter (s) in the same column are not significantly different at P<0.05 and P<0.01; LSD= least significant difference; CV= coefficient of variance; Year_1= 2015; Year_2= 2016

Biomass yield

Table 5 revealed that biomass yield was significantly (P<0.05) affected by the treatments in the year of 2015. According to this mean result table (Table 5), the highest value (10722.10 kg ha⁻¹) was obtained due inorganic fertilizers which, however, significantly similar to the use of 50%compost+50%inorganic fertilizer. Equally important, biomass yield was highly significantly (P<0.01) influenced by the integrated agronomic practices in 2016. The highest mean numeric value (11037.00 kg ha⁻¹) was also produced from application of inorganic fertilizer. This might be ascribed to the vital role of N in exciting and enhancing the photosynthetic and metabolic activities of plants which reflected in the increase in the vegetative growth of sorghum. The highest N fertilizer application could improve the growth and above ground biomass production of sorghum crop. This complemented to the work of Wondimu et al. (2006) who reported that farmyard manure and inorganic fertilizers increased stover yield of sorghum by 8% to 21% and 14% to 21%, respectively. Furthermore, the present result was consistent with the findings of Kibunja et al. (2010) which showed total dry matter of maize was higher in treatment combinations of inorganic and organic fertilizers.

Number of Striga m²

Striga population was significantly (P<0.05) varied by agronomic Striga management practices in 2015 cropping season. According to Table 6, more number of Striga m² (1.78) existed in the farmers' practice (control) while the minimum Striga population was observed from plots treated with inorganic fertilizer, which produced 46.07% less number of Striga m² as compared to the
control. This was significantly similar with plots treated with 50% compost+50% inorganic fertilizer, and 50% compost+intercropping+50% inorganic fertilizer. Resistant sorghum variety (Gubiye), like inorganic fertilizer, was also producing significantly similar number of *Striga* m$^{-2}$.

Table 5. Biomass yield of sorghum as influenced by agronomic *Striga* management

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Biomass yield (kg ha$^{-1}$)</th>
<th>Year-1</th>
<th>Year-2</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (no fertilizer)</td>
<td></td>
<td>8291.90c</td>
<td>8444.40d</td>
<td>8368.20</td>
</tr>
<tr>
<td>Compost rate</td>
<td></td>
<td>8875.00bc</td>
<td>9543.00bcd</td>
<td>9209.00</td>
</tr>
<tr>
<td>Intercropping</td>
<td></td>
<td>8472.30c</td>
<td>8733.30cd</td>
<td>8602.80</td>
</tr>
<tr>
<td>Inorganic fertilizer</td>
<td></td>
<td>10722.10a</td>
<td>11037.00a</td>
<td>10879.60</td>
</tr>
<tr>
<td>50% compost+50% inorganic fertilizer</td>
<td></td>
<td>10333.40ab</td>
<td>10851.90ab</td>
<td>10592.60</td>
</tr>
<tr>
<td>50% compost+intercropping</td>
<td></td>
<td>8597.40c</td>
<td>9518.50bcd</td>
<td>9057.90</td>
</tr>
<tr>
<td>Intercropping +50% inorganic fertilizer</td>
<td></td>
<td>8523.80c</td>
<td>10629.60ab</td>
<td>9576.70</td>
</tr>
<tr>
<td>50% compost+intercropping+50% inorganic fertilizer rate</td>
<td></td>
<td>8555.50c</td>
<td>10111.10abc</td>
<td>9333.30</td>
</tr>
<tr>
<td>Resistant sorghum (Gubiye) crop</td>
<td></td>
<td>8616.80c</td>
<td>8629.60cd</td>
<td>8623.20</td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td>9.92</td>
<td>8.60</td>
<td></td>
</tr>
<tr>
<td>LSD(0.5)</td>
<td></td>
<td>1544.50</td>
<td>1446.40</td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letter (s) in the same column are not significantly different at P<0.05 and P<0.01; LSD = least significant difference; CV = coefficient of variance; Year_1 = 2015; Year_2 = 2016

Table 6 also showed that agronomic *Striga* management practices resulted highly significant (P<0.01) effect on the number of *Striga* m$^{-2}$ in 2016. Maximum number of *Striga* m$^{-2}$ (2.96) was recorded from the control while minimum mean *Striga* population (0.95) grew on plots treated with inorganic fertilizer. Similar to inorganic fertilizer, plots treated with 50% compost+50% inorganic fertilizer as well as resistant sorghum crop gave significantly similar *Striga* population. This significant variation might be ascribed to the effect of fertilizers in suppressing growth of *Striga* weed and low germination stimulant production by Gubiye which inhibit germination of *Striga* seed in the absence of chemical stimulant. This current result was in lined with the findings of Zerihun (2016) which indicated that number of *S.hermonthica* per plot was significantly influenced by N fertilizer, variety and their interaction. The author specified that low number of *Striga* registered from plots treated with high N level and *Striga* resistant sorghum variety (Gubiye). A report of Hassan *et al.* (2010) illustrated that Nitrogen inhibited to *Striga* growth, which reduced *Striga* infestation by 83%. In addition, Hassan *et al.* (2010) and Kudra *et al.* (2014) found that combination of chicken manure with nitrogen as urea is an effective weed management practice to control *Striga*. Generally, use of recommended cropping systems and plant populations, *Striga* resistant sorghum varieties, improved soil fertility and soil moisture conservation practices help to maximize crop vigor and minimize effects of *Striga* (Mgonja *et al.*, 2011).
Table 6. Mean number of Striga as influenced by Striga management

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of striga/m²</th>
<th>Year-1</th>
<th>Year-2</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control /no fertilizer/</td>
<td>1.78a</td>
<td>2.96a</td>
<td>2.37</td>
<td></td>
</tr>
<tr>
<td>Compost rate</td>
<td>1.41abc</td>
<td>2.76ab</td>
<td>2.08</td>
<td></td>
</tr>
<tr>
<td>Intercropping (Mungbean)</td>
<td>1.44abc</td>
<td>2.52ab</td>
<td>1.98</td>
<td></td>
</tr>
<tr>
<td>Inorganic fertilizer</td>
<td>0.96d</td>
<td>0.95d</td>
<td>0.95</td>
<td></td>
</tr>
<tr>
<td>50%compost+50%inorganic fertilizer</td>
<td>1.07cd</td>
<td>1.26cd</td>
<td>1.17</td>
<td></td>
</tr>
<tr>
<td>50%compost+intercropping (Mungbean)</td>
<td>1.44abc</td>
<td>2.48ab</td>
<td>1.96</td>
<td></td>
</tr>
<tr>
<td>Intercropping (Mungbean)+50%inorganic fertilizer</td>
<td>1.56ab</td>
<td>2.00bc</td>
<td>1.78</td>
<td></td>
</tr>
<tr>
<td>50%compost+intercropping+50%inorganic fertilizer</td>
<td>1.21bcd</td>
<td>2.17ab</td>
<td>1.69</td>
<td></td>
</tr>
<tr>
<td>Resistant sorghum crop (Gubiye)</td>
<td>1.23bcd</td>
<td>1.26cd</td>
<td>1.24</td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>19.26</td>
<td>23.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD(0.5)</td>
<td>0.45</td>
<td>0.84</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letter(s) in the same column are not significantly different at P<0.05 and P<0.01; LSD= least significant difference; CV= coefficient of variance; Year_1= 2015; Year_2= 2016

Economic analysis

Based on economic analysis, application of 50% compost + 50% inorganic fertilizers gave optimum MRR (165.66%) which was above the minimum rate of return (100%) (Table 6). The economic analysis was decided mainly on sustainability of soil health, and the increasing cost of inorganic fertilizers. Furthermore, poor farmers could not afford the cost for full rate of inorganic fertilizer. Thus, integrated use of organic (compost) and inorganic fertilizers is economically feasible to sustain the productivity of sorghum. According to this analysis, for farmers who use 50% compost + 50% inorganic fertilizer, investing in the higher fertilizer rate would give a marginal rate of return of 165.66%; for every 1.00 Birr invested in the higher fertilizer rate, they will recover the 1.00 Birr and an additional 1.6566 Birr.

Conclusion

The maximum grain yield and yield components of total biomass, head weight, and plant height were recorded prominently in plots treated with inorganic fertilizer. The combination of compost and inorganic fertilizer also gave remarkable grain and biomass yields. Moreover, Striga population reduced due application of inorganic fertilizers. A significant reduction was also observed when plots treated with the combination of compost and inorganic fertilizer. Similarly, low number of Striga m⁻² was recorded from resistant sorghum variety (Gubiye) which characterized by low germination stimulant (LGS) production, low production of the haustorial initiation factor and its incompatible response to parasitic invasion. Based on economic analysis, application of 50% compost + 50% inorganic fertilizers gave optimum MRR, which was above the minimum rate of return (100%). Thus, the use of integrated organic and inorganic fertilizers is economically feasible. Generally, this experiment showed that productivity of sorghum is considerably higher when farmers use integrated soil fertility.
management options. This is, therefore, the use of integrated compost and inorganic fertilizers should be recommended for farmers as they were affordable options for increasing sorghum yields with improving soil fertility in the small-scale farming systems of the study area. Furthermore, integrated agronomic control practices proved to be highly effective in terms of reducing *Striga* incidence both in terms of reduced seed density in the soil and decreased infection in sorghum.
Table 6. Marginal budget analysis of sorghum as affected by integrated agronomic practices

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Adjusted yield (kg ha(^{-1}))</th>
<th>Income (BIRR ha(^{-1}))</th>
<th>GFB (BIRR ha(^{-1}))</th>
<th>TVC (BIRR ha(^{-1}))</th>
<th>NI (BIRR ha(^{-1}))</th>
<th>MRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control /no fertilizer/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistant sorghum</td>
<td>2594</td>
<td>7766</td>
<td>23346</td>
<td>3494</td>
<td>26842</td>
<td>3740</td>
</tr>
<tr>
<td>Compost rate</td>
<td>3919</td>
<td>8588</td>
<td>35271</td>
<td>3864</td>
<td>39136</td>
<td>4727</td>
</tr>
<tr>
<td>50% compost + 50% inorganic fertilizer</td>
<td>4043</td>
<td>9766</td>
<td>36388</td>
<td>4395</td>
<td>40783</td>
<td>5280</td>
</tr>
<tr>
<td>Inorganic fertilizer</td>
<td>4150</td>
<td>9933</td>
<td>37351</td>
<td>4470</td>
<td>41821</td>
<td>5451</td>
</tr>
<tr>
<td>Inter cropping</td>
<td>3741</td>
<td>7859</td>
<td>39535</td>
<td>4217</td>
<td>43753</td>
<td>7260</td>
</tr>
<tr>
<td>50% compost + intercropping (Mungbean)</td>
<td>3366</td>
<td>8566</td>
<td>36213</td>
<td>4588</td>
<td>40801</td>
<td>8320</td>
</tr>
<tr>
<td>Intercropping + 50% inorganic fertilizer</td>
<td>3600</td>
<td>9566</td>
<td>39374</td>
<td>5077</td>
<td>44452</td>
<td>8533</td>
</tr>
<tr>
<td>50% compost + intercropping + 50% inorganic fertilizer</td>
<td>3920</td>
<td>9099</td>
<td>41321</td>
<td>4859</td>
<td>46181</td>
<td>9440</td>
</tr>
</tbody>
</table>

GY = grain yield, BY = biomass yield, GFB = net field benefit; NI = Net income; TVC = total variable cost; D = dominated treatment; Grain price of sorghum = BIRR 9 kg\(^{-1}\); Biomass yield of sorghum = BIRR 0.45 kg\(^{-1}\); Seed price of Mungbean = BIRR 18 kg\(^{-1}\); Biomass yield of Mungbean = BIRR 0.45 kg\(^{-1}\);
References


Plant Density and NP Fertilizer Requirements for Quality Protein Maize

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Introduction

Establishment of an optimum plant population is essential to get maximum yield. Plant density of crops should not be high to deplete most of the moisture before crop mature and low to leave the water and nutrient resources being unutilized. Inadequate plant density and NP fertilizer application to maize crop results in low maize yield. Studies on proper combination of NP and plant density for the recently released QPM maize that are adapting in the semi-arid agro-ecological maize growing zone of Central Rift Valley of Ethiopia is lacking. This research work was therefore conducted to investigate the effects of NP levels on yield of maize using different level of plant density. Plant density and NP have significant effects on the yield as a result of increase in the number of seeds ear\(^{-1}\) and number of ears plant\(^{-1}\) (Turgut, 2000). Inadequate plant density and NP application to maize crop results in low maize yield. The increase in the grain yield of maize in high density plots is due to the improvement in light interception during the critical period for grain set, while number of seeds plant\(^{-1}\) and plant growth rate is adversely affected by N deficiency and shading in the high density plots (Andrade et al., 2002). Therefore, the objective of the study was to identify optimum NP rates and population density where maximum yield potential for QPM variety attend.

Material and Method

Experiments were conducted at on farm fields at Adamitulu Jido-Kombolcha District, in the Central Rift Valley of Ethiopia during 2014 to 2016. The experiment was laid out in 4 × 4 two-way factorial arrangement of plant density (44,444, 53,555, 66,667, and 88,888 plants ha\(^{-1}\)) and NP fertilizer rates (48-35, 64-46, 80-58, and 96-69 of N-P kg ha\(^{-1}\), respectively) in randomized complete block design using three replications.

Flowering and maturity dates, stand and ear count, plant height, % lodging, above ground biomass and grain yields, kernel weight, number of kernels per ear, and harvest index.

Result and Discussion

The homogeneity test of the error variances for years indicated that the error variance was heterogeneous and hence combined analysis of variance was not conducted. In the
study, grain yield was only significantly affected by plant density in 2014; by the interaction effect of plant density by NP rate in 2015; and by the main effects of plant density and NP rate in 2016 (Figure 1). In 2014, the maximum grain yield was achieved by the maize crop at 66,667 plants ha\(^{-1}\) across the three lower NP rates. At maximum NP rate, grain yield was greater with 53,555 plants ha\(^{-1}\), and that was, however, statistically on a par with that of 66,667 plants ha\(^{-1}\). In 2015, Interaction between NP rates and plant density showed that increasing NP rate from baseline rate (48 kg–35P ha\(^{-1}\)) increased grain yield significantly at low plant density (44,444–53,555 plants ha\(^{-1}\)). The maximum grain yield was recorded in the crop grown at 53,555 plants ha\(^{-1}\) while fertilized with higher rates of NP fertilizer. Nevertheless, maximum grain yield was produced at 66,667 plants ha\(^{-1}\) to which the lowest rate of 48 kg N–35 kg P ha\(^{-1}\) was applied. In 2016, the highest average grain yield of 3970 kg ha\(^{-1}\) was obtained from plots to which NP was applied at a rate of 64N and 46 P kg ha\(^{-1}\). On the other hand, the maximum yield of 4479 kg ha\(^{-1}\) was achieved when maize was grown with 66,667 plants ha\(^{-1}\).

![Fig. 1: Effects of nitrogen (N) and phosphorus (P) level and plant density on grain yield of maize.](image)

**References**


Appropriate Nitrogen Application Time to Improve Growth and Productivity of Maize

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Introduction

In northwestern Ethiopia, farmers usually use blanket recommendation of chemical fertilizers such as 100 kg ha\(^{-1}\) DAP and 100 kg ha\(^{-1}\) Urea for P and N, respectively for maize production. DAP will be applied at planting and urea will be applied in the rate of half at planting and half at knee height of maize, without considering the N requirement time of the crop.

Even though farmers in the study areas know the need of fertilize to their maize crop to achieve high maize yield on sustainable basis, timing of the application of fertilizer to their maize crop has not been studied. Therefore, this field trial has been undertaken with the objective of determining the appropriate time of nitrogen application to maize to obtain an ideal yield.

Materials and Methods

The study was conducted at Pawe Agricultural Research Center, south western Ethiopia in 2015 and 2016 main cropping season. The soils of the area are broadly classified as Vertisols (40 – 45% of the area), Nitisols, (25 – 30%), and intermediate soils of a blackish brown color (25 – 30%) (Viezzoli, 1992).

The following treatments were included in the experiments. (T\(_1\): ½ at planting date and ½ at 21-30 Days After Emergence, T\(_2\): ½ at planting date and ½ at flower initiation, T\(_3\): ½ at 14-21 DAE and ½ at flower initiation, T\(_4\): full dose at 14-21 DAE, T\(_5\): full dose at flower initiation, T\(_6\):1/3 at Planting date and 2/3 at 21-30 DAE, T\(_7\): 1/3 at planting date, 1/3 at 21-30 DAE and 1/3 at flower initiation, T\(_8\): 1/3 at 14-21 DAE and 2/3 at flower initiation, T\(_9\): 2/3 at planting date and 1/3 at 21-30 DAE, T\(_10\): 2/3 at planting date and 1/3 at flower initiation T\(_11\): full dose at planting and T\(_12\): negative control).

The treatments were laid down in Randomized Complete Block Design (RCBD) with three replications. Seeds of maize were sown during early June at a seed rate of 30kg
Hybrid maize variety, BH-540 which is already recommended for the area was used for this study. Planting was done by sowing two seeds per hill and after two weeks of emergence, plants were thinned to one plant per hill. Each experimental plot was 3.75m x 5.1m consisting of five rows per plot (3 harvestable and 2 border rows). The plant spacing was 75cm and 30cm between rows and plants, respectively. Whole of the $\text{P}_2\text{O}_5$ was applied at sowing but nitrogen was applied at different growth stages. Hoeing was done manually to control weeds. All other agronomic and plant protection practices were kept normal for all the treatments.

Data on yield and yield components were recorded using standard procedures and subjected to analysis of variance (ANOVA) using the SAS program (SAS, 2000). Means were compared by using the LSD test at 5% level of probability.

**Result and Discussion**

**Plant height**
Application of nitrogen at different growth stages of the crop significantly affected (P<0.05) plant height of maize (Table 1). The combined analysis result showed that the highest plant heights of maize were recorded at $T_7$ (2.26m) followed by $T_6$ (2.25m). In 2015 there was no significant difference in plant height of maize due to different application time of nitrogen, whereas in 2016 there was a highly significant (P<0.05) differences in plant height of maize due to time of nitrogen application. The lowest plant height in 2016 cropping season was obtained from $T_{12}$ (1.5m). Similar results were reported by Raouf and Ali (2016) where plant height of maize was significantly influenced by rate and time of nitrogen application.

**Ear length**
In both years and the combined analysis result revealed that ear length of maize was significantly influenced by time of nitrogen application. The highest ear length (19.9cm) was obtained from $T_1$ which is the previous blanket nitrogen application time recommendation.

**No. of grains/cob**
The data showed that number of grains/cob were significantly affected by time of N application (Table 2). The treatment $T_9$ ($\frac{2}{3}$ @ planting and $\frac{1}{3}$ @ 21-30 DAE) recorded maximum number of grains/cob (488.4) in 2016 and (498.3) in the combined analysis result. This data was in line with (Hafiz Mohkum et al., 2011) where number of kernels per cob was significantly affected by time of N application. While no significant differences were observed between the treatments in 2015 cropping season. Time of nitrogen application was shown a significant negative effect and lowers the number of grains/cob of maize at $T_{12}$. As nitrogen level decreased for crops the number of grains per cob also decreased due to N stress. The result is supported by Melchiori and Caviglia, 2008.
Table 1. Effect of time of nitrogen application on plant height and ear length of maize grown at Pawe in 2015 and 2016 growing seasons.

<table>
<thead>
<tr>
<th>Time of N-app</th>
<th>Plant height (cm)</th>
<th>Ear Length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2015</td>
<td>2016</td>
</tr>
<tr>
<td>T1</td>
<td>2.26</td>
<td>2.11a</td>
</tr>
<tr>
<td>T2</td>
<td>2.38</td>
<td>2.0a</td>
</tr>
<tr>
<td>T3</td>
<td>2.25</td>
<td>1.85ab</td>
</tr>
<tr>
<td>T4</td>
<td>2.28</td>
<td>1.88ab</td>
</tr>
<tr>
<td>T5</td>
<td>2.40</td>
<td>1.58bc</td>
</tr>
<tr>
<td>T6</td>
<td>2.40</td>
<td>2.11a</td>
</tr>
<tr>
<td>T7</td>
<td>2.48</td>
<td>2.0a</td>
</tr>
<tr>
<td>T8</td>
<td>2.43</td>
<td>1.88ab</td>
</tr>
<tr>
<td>T9</td>
<td>2.23</td>
<td>2.15a</td>
</tr>
<tr>
<td>T10</td>
<td>2.28</td>
<td>1.98ab</td>
</tr>
<tr>
<td>T11</td>
<td>2.36</td>
<td>2.15a</td>
</tr>
<tr>
<td>T12</td>
<td>2.28</td>
<td>1.98ab</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>0.25</td>
<td>0.31</td>
</tr>
<tr>
<td>CV (%)</td>
<td>6.5</td>
<td>9.69</td>
</tr>
</tbody>
</table>

T1 (½@PD, ½@21-30DAE), T2 (½@PD, ½@FI), T3 (½@14-21, ½@FI), T4 (Full @14-21 DAE) T5 (Full @ FI) T6 (½@PD, ½@21-30DAE) T7 (½@PD, ½@21-30DAE, ½/3@FI) T8 (½@14-21DAE, ½@FI) T9 (½@PD, ½@21-30DAE) T10 (½@PD, ½@FI) T11 (Full at planting) T12 (Negative control).

**Hundred seed weight (g)**

Effect of nitrogen application timing had no significant effect on the seed weight of maize in both years. Whereas, a significantly differences were observed by the combined analysis result. The treatment means comparison showed that T1 gave the highest seed weight (40.8g). Except T1 all the other treatments were statistically at par with each other. This result is in line with the findings of Rizwan et al, (2003) who obtained significantly different 1000-grain weight due to time of N application at different growth stages of maize.

**Grain yield**

Grain yield was influenced by different times of N application. The maximum grain yield (8.5 t ha⁻¹) in the first year was obtained when T6 was applied. In 2016 the T11 recorded significantly highest (7.98 t ha⁻¹) grain yield of maize as compared with other treatments. The overall combined analysis result indicated that grain yield of maize was significantly (P<0.05) influenced by time of nitrogen application when N was applied at (T6) 1/3 N at PD, 2/3 N at 21-30DAE and the treatment T6 was statistically at par with treatment T7 and T11.
Table 2. Effect of time of nitrogen application on number of grains/cob and seed weight of maize grown at Pawe in 2015 and 2016 growing seasons.

<table>
<thead>
<tr>
<th>Time of N-app</th>
<th>Number of grains/cob</th>
<th>1000 grain weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2015</td>
<td>2016</td>
</tr>
<tr>
<td>T&lt;sub&gt;1&lt;/sub&gt;</td>
<td>500.4</td>
<td>462.8&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;2&lt;/sub&gt;</td>
<td>464.2</td>
<td>329.3&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;3&lt;/sub&gt;</td>
<td>492.6</td>
<td>262.8&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;4&lt;/sub&gt;</td>
<td>458.0</td>
<td>287.5&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;5&lt;/sub&gt;</td>
<td>504.2</td>
<td>263.8&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;6&lt;/sub&gt;</td>
<td>485.4</td>
<td>359.6&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;7&lt;/sub&gt;</td>
<td>442.8</td>
<td>363.0&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;8&lt;/sub&gt;</td>
<td>545.8</td>
<td>254.9&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;9&lt;/sub&gt;</td>
<td>508.1</td>
<td>488.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;10&lt;/sub&gt;</td>
<td>515.2</td>
<td>310.3&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;11&lt;/sub&gt;</td>
<td>446.1</td>
<td>358.2&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;12&lt;/sub&gt;</td>
<td>510.1</td>
<td>237.3&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD 5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>13.9</td>
<td>31.2</td>
</tr>
<tr>
<td>F value</td>
<td>0.53</td>
<td>1.65</td>
</tr>
</tbody>
</table>

Table 3. Effect of time of nitrogen application on grain and biomass yield of maize grown at Pawe in 2015 and 2016 growing seasons.

<table>
<thead>
<tr>
<th>Time of N app</th>
<th>Grain yield (t ha&lt;sup&gt;-1&lt;/sup&gt;)</th>
<th>Biomass yield (t ha&lt;sup&gt;-1&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2015</td>
<td>2016</td>
</tr>
<tr>
<td>T&lt;sub&gt;1&lt;/sub&gt;</td>
<td>7.7&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>7.03&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;2&lt;/sub&gt;</td>
<td>8.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.68&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;3&lt;/sub&gt;</td>
<td>7.25&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>5.73&lt;sup&gt;bcd&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;4&lt;/sub&gt;</td>
<td>7.14&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>4.60&lt;sup&gt;cde&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;5&lt;/sub&gt;</td>
<td>7.73&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>4.17&lt;sup&gt;de&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;6&lt;/sub&gt;</td>
<td>8.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.68&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;7&lt;/sub&gt;</td>
<td>8.06&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.77&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;8&lt;/sub&gt;</td>
<td>6.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.38&lt;sup&gt;bcd&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;9&lt;/sub&gt;</td>
<td>7.65&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.94&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;10&lt;/sub&gt;</td>
<td>7.82&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>6.07&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;11&lt;/sub&gt;</td>
<td>7.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.98&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;12&lt;/sub&gt;</td>
<td>7.47&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.47&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>1.47</td>
<td>1.64</td>
</tr>
<tr>
<td>CV (%)</td>
<td>11.4</td>
<td>16.33</td>
</tr>
<tr>
<td>F value</td>
<td>0.93</td>
<td>5.27</td>
</tr>
</tbody>
</table>

**Biomass yield**

Time of nitrogen application showed a significant effect on biomass yield of maize in each season. In 2015, the highest biomass yield (17.2 t ha<sup>-1</sup>) was obtained at T<sub>6</sub> followed by T<sub>2</sub> (16.7 t ha<sup>-1</sup>). However, nitrogen application time of T<sub>11</sub> showed the lowest biomass yield (13.9 t ha<sup>-1</sup>) as compared with the other treatments and even with previous recommendations. The overall means regardless of treatment variations revealed that significantly higher biomass yield was obtained in the 2015 than in 2016. This variation might be related to the effect of rain fall amount and distribution during the growing seasons. In contrast to the result observed in 2015, in 2016 the highest
biomass yield was obtained from nitrogen application time of $T_{11}$ which is 18.04 t ha$^{-1}$ and more than 11.58% and 3.23% yield advantage as compared to the control and the previously recommended time of N application, respectively. N application time of $T_9$, $T_7$, $T_6$ and $T_1$ statistically showed the succeeding highest biomass yield. The lowest biomass was recorded when N was applied at $T_5$ and the control treatment. In general the combined result revealed that N application time has a significant effect on the biomass yield of maize in all the treatments.

CONCLUSION

The result showed that time of N application influenced growth and yield of maize in both years. The application of N $\frac{1}{3}$@PD and $\frac{2}{3}$@21-30DAE in two splits produced the highest maize grain yield followed by N application time of full at planting and $\frac{1}{3}$@PD, $\frac{1}{3}$@21-30DAE and $\frac{1}{3}$@FI as compared to the negative control and the previous N application timing of $\frac{1}{2}$@PD and $\frac{1}{2}$@21-30DAE. Therefore, it would be better to apply nitrogen fertilizer in to splits of $\frac{1}{3}$ at planting and $\frac{2}{3}$ at 21-30DAE for giving higher yield of maize in the study area.

References


Appropriate Population Density and Pruning Methods for Hybrid Coffee

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Introduction

Using improved coffee cultivars alone cannot increase yield unless the appropriate cultural practices such as optimum plant population density and suitable pruning techniques applied.

However, research attempts have not focused on details of coffee plant population’s density and pruning practices for this growing area. Accordingly, information is also scant on optimum population density and pruning practices to widely adopt by coffee growers in major growing area of the country.

Therefore, this study was proposed to solve the above stated problems for low land area like Teppi and its surrounding with the objective of determining optimum spacing/population density and pruning methods that promote yield and quality of hybrid coffee variety.

Materials and Methods

The experiment was conducted at Teppi National Spices Research Center (TNSRC) during the main cropping season of 2012 - 2016. It is located at 70 10’ N latitude and 350 25’ E longitude. The treatments were consisted of three levels of planting space; Sp₁ (2.5 m * 2.5 m), Sp₂ (2.5 m * 2.0 m), Sp₃ (2.0 m * 2.0 m) and three types of pruning and training methods; V₁ (multiple stem capped), V₂ (multiple stem uncapped), V₃ (free growth). The experiment was conducted in RCBD with factorial arrangement of 9 treatment combinations (3 spacing x 3 pruning methods) in three replications. Hybrid coffee variety (74165*Dr1) was used for this experiment.

The data recorded in this study were subjected to statistical analysis. Analyses of variance were carried out using SAS version 9.2 computer statistical software (SAS Institute Inc., 2008). Significant differences between treatments were delineated by Least Significant Differences (LSD).
Results and Discussions

Number of bearing and non-bearing primary branches

The recorded data revealed that number of bearing primary branch was significantly (P<0.05) affected by the main effects of population density and by the interaction effects of population density and pruning methods (Table 1). However, bearing primary branch number was not significantly affected by the main effects of pruning methods. As indicated in the table 1, bearing primary branch number was linearly increased along with the population density. Thus, the maximum number of bearing primary branches (53.03 tree\(^{-1}\)) were recorded from coffee tree which was planted in 2.0 m * 2.0 m with free growth followed by the treatment which received a multiple stem capped with the same planting space (46.80 tree\(^{-1}\)). The increase in bearing primary branches per tree with increasing population density has been attributed to efficient utilization of environmental inputs, viz. light, moisture and nutrients, until the biological optimum is attained (Taye et al., 2001). Whereas, the minimum number of bearing primary branches (21.80 tree\(^{-1}\)) were recorded from coffee tree which was planted in 2.5 m * 2.5 m with multiple stem capped (Table 1).

Table 1. Number of bearing and non-bearing primary branches of hybrid coffee as influenced by the interaction of population density and pruning

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of bearing primary branches plant(^{-1})</th>
<th>Number of non-bearing primary branches plant(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sp1</td>
<td>Sp2</td>
</tr>
<tr>
<td>V1</td>
<td>21.80 e</td>
<td>39.73 bc</td>
</tr>
<tr>
<td>V2</td>
<td>28.00 de</td>
<td>42.87 bc</td>
</tr>
<tr>
<td>V3</td>
<td>26.33 de</td>
<td>35.03 cd</td>
</tr>
<tr>
<td>LSD((0.05))</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>CV%</td>
<td>23.80</td>
<td>26.19</td>
</tr>
</tbody>
</table>

Parameter means followed by the same letter within a column are not significantly different at 5% level of significance; *= significance at 5% probability, LSD= least significance difference; CV= coefficient of variance; Sp1= 2.5m*2.5m, Sp2= 2.5m*2.0m, Sp3= 2.0m*2.0m, V1= multiple stem capped, V2= multiple stem uncapped, V3= free growth.

Similarly, the number of non-bearing primary branch was significantly (P<0.05) affected by the main effects of population density and by the interaction effects of population density and pruning methods (Table 1). However, a main effect of pruning methods didn’t influence the non-bearing primary branch number per plant. In the same way, the non-bearing primary branch number was linearly increased along with the population density. Thus, the maximum number of non-bearing primary branches (19.47 tree\(^{-1}\)) was recorded from coffee tree which was planted at 2.0 m * 2.0 m with multiple stem capped. However, it was statistically non-significance difference with the treatments; multiple stem uncapped with 2.0 m * 2.0 m and free growth with 2.0 m * 2.0 m (Table 1).
The results could be associated with high coffee tree population density with enhanced branching leading to insufficient utilization and translocation of nutrients for some primary branches. Moreover, it might be due to less light absorption of some primary branches due to mutual over-shading effects of other branches and branches of other neighbor trees. Whereas, the minimum number of non-bearing primary branches (11.80 tree⁻¹) were recorded from coffee tree which was planted in a narrow space (2.0 m * 2.0 m) with multiple stem capped (Table 1).

**Internode length of primary branches**

The internode length of primary branch was significantly (P<0.05) affected by the main effects of population density and pruning methods, as well as by the interaction of the two factors (Table 2). Thus, the highest internode length (5.20 cm tree⁻¹) was recorded from coffee tree which was planted at 2.5 m * 2.5 m with free growth followed by the treatment which consists of similar planting space with multiple stem uncapped (4.78 cm tree⁻¹). This result could be associated with high amount of light absorption with less competing for nutrients and photosynthates accumulated in the main stem, thereby new primary branches might be grown and elongated. Whereas, the lowest internode length (4.11 cm tree⁻¹) was recorded from coffee tree which was planted at 2.5 m * 2.0 m with free growth habit (Table 2).

![Table 2: Internode length of primary branches of hybrid coffee as influenced by the interaction of population density and pruning](image)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Internode length of primary branches (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( S_p_1 )</td>
</tr>
<tr>
<td>( V_1 )</td>
<td>4.70 ( \text{bc} )</td>
</tr>
<tr>
<td>( V_2 )</td>
<td>4.78 ( \text{b} )</td>
</tr>
<tr>
<td>( V_3 )</td>
<td>5.20 ( \text{a} )</td>
</tr>
<tr>
<td>( \text{LSD (0.05)} )</td>
<td>*</td>
</tr>
<tr>
<td>( \text{CV%} )</td>
<td>5.90</td>
</tr>
</tbody>
</table>

Parameter means followed by the same letter within a column are not significantly different at 5% level of significance; * = significance at 5% probability, LSD= least significance difference; CV= coefficient of variance; \( S_p_1 = 2.5\text{m*2.5m}, S_p_2 = 2.5\text{m*2.0m}, S_p_3 = 2.0\text{m*2.0m}, V_1 = \text{multiple stem capped}, V_2 = \text{multiple stem uncapped}, V_3 = \text{free growth} \).

**Number of nodes of primary branch and main stem**

Analysis of variance of the data revealed that, number of nodes of primary branch was significantly (P<0.05) affected by the main effects of population density and pruning methods, as well as by the interaction of the two factors. Thus, the highest node number on primary branch (21.04 branch⁻¹) was recorded from treatment in which coffee planted in 2.5 m * 2.0 m with multiple stem capped, which had a non-significance difference with multiple stem uncapped and free growth with similar population density (2.5 m * 2.0 m). Whereas, the lowest node number on primary branch (17.31 branch⁻¹) was recorded from coffee tree which was planted in 2.5 m * 2.5 m with free growth habit (Table 3). As a result, multiple stem capped with optimum population density increase primary branches and node number, which is
associated with enhanced branching and increasing of light interception by individual coffee tree.

On the other hand, number of nodes of the main stem was significantly (P<0.05) affected by the main effects of population density, and interaction effects of population density and pruning methods. However, the main effect of pruning methods doesn’t influence the node number of the coffee main stem. The maximum node number on the main stem (50.33 tree\(^{-1}\)) was recorded from coffee tree which was planted at 2.5 m * 2.0 m with multiple stem uncapped which had a non-significant difference with other treatments such as, 2.5 m * 2.0 m with multiple stem capped, 2.0 m * 2.0 m with multiple stem capped, 2.5 m * 2.5 m with free growth habit and 2.5 m * 2.5 m with multiple stem uncapped. While, the minimum node number of coffee main stem (34.43 tree\(^{-1}\)) was recorded from coffee tree which was planted at 2.5 m * 2.5 m with multiple stem capped (Table 3). This could be associated with high amount of light absorption and photosynthates accumulated in the uncapped main stem, thereby new primary branches might be produced.

Table 3. Number of nodes of primary branch and main stem as influenced by the interaction of population density and pruning methods

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of nodes of primary branch</th>
<th>Number of nodes of the main stem</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(S_p^1)</td>
<td>(S_p^2)</td>
</tr>
<tr>
<td>(V_1)</td>
<td>19.53 bc</td>
<td>21.04 a</td>
</tr>
<tr>
<td>(V_2)</td>
<td>17.93 de</td>
<td>19.98 ab</td>
</tr>
<tr>
<td>(V_3)</td>
<td>17.31 e</td>
<td>20.57 ab</td>
</tr>
<tr>
<td>LSD(_{0.05})</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>CV%</td>
<td>6.30</td>
<td></td>
</tr>
</tbody>
</table>

Parameter means followed by the same letter within a column are not significantly different at 5% level of significance; *= significance at 5% probability, LSD= least significance difference; CV= coefficient of variance; \(S_p^1\)= 2.5m*2.5m, \(S_p^2\)= 2.5m*2.0m, \(S_p^3\)= 2.0m*2.0m, \(V_1\)= multiple stem capped, \(V_2\)= multiple stem uncapped, \(V_3\)= free growth.

Effects of population density and pruning on yield of clean coffee

As growth parameters, clean coffee yield was also significantly (P<0.05) influenced by the main effects of pruning methods, and interaction effects of population density and pruning methods. However, the coffee yield was not significantly affected by different types of population density. The clean coffee yield showed an increments as the population density of coffee tree increased. Thus, the highest clean coffee yield (1028.93 kg ha\(^{-1}\)) was obtained from treatment which is a planting space of 2.0 m * 2.0 m with free growth habit followed by the treatment which is a planting space of 2.5 m * 2.0 m with free growth habit (953.47 kg ha\(^{-1}\)) (Table 4). Whereas, the lowest clean coffee yield (509.33 kg ha\(^{-1}\)) was obtained from treatment which is a planting space of 2.5 m * 2.0 m with multiple stem capped (Table 4). The increase in coffee yield with increasing population density has been attributed to efficient utilization of environmental inputs, viz. light, moisture and nutrients, until the biological optimum is...
attained (Taye et al., 2001). Furthermore, free growth habit of coffee gave higher yield as compared to multiple stem uncapped and multiple stem capped growth habit.

Table 4. Clean coffee yield as influenced by the interaction of population density and pruning

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Clean coffee yield (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(S_p1)</td>
</tr>
<tr>
<td>(V_1)</td>
<td>727.50</td>
</tr>
<tr>
<td>(V_2)</td>
<td>581.00</td>
</tr>
<tr>
<td>(V_3)</td>
<td>863.87</td>
</tr>
<tr>
<td>LCD (0.05)</td>
<td>*</td>
</tr>
<tr>
<td>CV%</td>
<td></td>
</tr>
</tbody>
</table>

Parameter means followed by the same letter within a column are not significantly different at 5% level of significance; *= significance at 5% probability, LSD= least significance difference; CV= coefficient of variance; \(S_p1\)= 2.5m*2.5m, \(S_p2\)= 2.5m*2.0m, \(S_p3\)= 2.0m*2.0m, \(V_1\)= multiple stem capped, \(V_2\)= multiple stem uncapped, \(V_3\)= free growth.

**Conclusion**

Plant density and pruning method had a significant effect on growth and yield of coffee. The clean coffee yield increased as the population density of coffee tree increased. The highest coffee yield was observed in a planting space of 2.0 m * 2.0 m with free growth habit. Therefore, it could be concluded that using of optimum planting space of 2 m * 2 m with free growth habit enhanced the growth, yield and yield components of hybrid coffee.

**References**
