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# Determination of the Optimum Population Density of Seedlings during Transplanting for the Productivity Improvement of Tef [Eragrostis tef (Zucc.)] Trotter] in Central zone of Tigray, Etiopia

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**Abstract**
A study was conducted in 2012/13 cropping seasons across two locations (Adet in N/adet district and Axum in L/Maychew district) to determine the appropriate population density for transplanting Tef. Field experiment was conducted during the 2012 and 2013-cropping season from (June to December) to address the question whether or not the ***population for transplanting determines the yielding components of for Tef. The trial consisted of seven treatments and arranged in*** Randomized Complete Block Design (RCBD) with three replications. All agronomic data were collected and the difference was analyzed by Gene stat (16$^{th}$ edition). At Adet and Axum, the transplanted treatments had shorter maturity days, highest plant height, highest panicle length, more number of tillers per tuber and less lodging index percentages. In addition to this, the transplanted treatments T5 (20cm*10cm spacing) and T6 (20cm*15cm spacing) scored the highest grain yield (3086 Kg/ha and 3076 Kg/ha respectively). These treatments also scored the highest biomass yield (9593 Kg/ha and 9685 Kg/ha respectively). Hence based on these results, for transplanting Tef seedlings a row spacing of 20cm and plant spacing of 10cm-15cm is recommended for better Tef grain and biomass yield and for improved grain quality of the crop.
**Keywords:** Tef, transplanting, broadcasting, row planting, grain yield, biomass yield

## 1. Introduction

Tef [*Eragrostis tef* (Zucc.)] Trotter] is a cereal crop that belongs to the grass family Poaceae. It is a $C_4$, self pollinated chasmogamous annual cereal (Seyfu, 1993). Tef may have been domesticated in the highlands of Ethiopia by the pre-Semetic peoples, but it is not certain for how long it was under their cultivation (Hailu and Seyfu, 2001).

Tef grows at elevations ranging from 300-2800m above sea level, but the best yield are obtained between 1700 and 2200m altitude. The mean temperature range during the growing season is $10^0$C to $27^0$C, the lower temperature being necessary during pollination. The mean minimum temperature should not drop below $4^0$C. The optimum rainfall for Tef is 450-550mm. The length of the growing period (LGP) or number of days to maturity of Tef taking into account rainfall and an evapotranspiration of 2-6mm per day, ranges from 60-180 days (depending on variety and altitude) with an optimum of 90-130 days (Decker et al., 2001).

Tef is proven to be a $C_4$ crop species. A study made on its photosynthetic response to light showed increased photosynthesis with increased light intensity up to full sunlight coupled with increased stomatal conductance. Photosynthesis was not light-saturated at full sunlight (Abuhay *et al*., 2001).

In Ethiopia Tef is mainly grown for its grain. The flour is most widely used for making popular pancake-like local bread called *enjera* and sometimes for making porridge. Local alcoholic drinks, called *tella* and *katikalla*, are also made of Tef (Seyfu, 1993). Its straw is used as livestock feed and plastering component for construction purposes. Since Tef grain fetches a high market price, it also serves as an important cash crop. Tef has recently begun to be exported, thus contributing to foreign exchange generation for the country (Kenea *et al*., 2001).

The grain has a high concentration of different nutrients, very high calcium content, and high levels of phosphorus, iron, copper, barium and thiamin. A big advantage, the iron from Tef is easily absorbed by the body. Tef is high in protein. Tef is high in carbohydrates and fiber. It contains no gluten so it is appropriate for those with celiac diseases (Getachew *et al*., 2006).

Tef seed is very small, ranging from 1–1.7mm long and 0.6–1mm diameter with l000 seed weight averaging 0.3–0.4 grams. The small size of Tef seed poses problems during sowing, and indirectly during weeding and threshing. At sowing the very small seed size makes it difficult to control population density and its distribution. This remains true whether one broadcasts the seed by hand, uses a broadcaster or seed driller (Seyfu, 1997). Hand broadcasting is the usual method of sowing Tef. In most cases, the seeds are left uncovered; however tree branches may be pulled on the surface when there is dry spell after sowing. Uncovered seeds are prone to erosion (water and wind) and bird attack (Fufa *et al*., 2001).

In dry land areas, farmers traditionally use high seed rates to ensure adequate stands, because of the unreliability of the rainfall and its erratic nature. According to Seyfu (1997), farmers' traditional practice is to broadcast Tef at the rate of 40-50 kg/ha. Because of severe competition at the seedling stage, this practice usually results in poor seedling growth and development and leads to low yields. Therefore, plant densities should be adjusted to the available soil moisture to improve efficiency of crop water use.

The small size of Tef seed poses problems during sowing, and indirectly during weeding and threshing. At sowing the very small seed size makes it difficult to control population density and its distribution. This remains true whether one broadcasts the seed by hand, uses a broadcaster or seed driller (Seyfu, 1997). Hand broadcasting is the usual method of sowing Tef. In most cases, the seeds are left uncovered; however tree branches may be pulled on the surface when there is dry spell after sowing. Uncovered seeds are prone to erosion (water and wind) and bird attack (Fufa *et al*., 2001). New emerging ideology in the system of cereal intensification is transplanting of cereal crops. Such practice is assumed to have the benefits of escaping dry spells occurring in any particular season and enhancing productivity under dry land areas. Such practice is directly adopted from Asian countries which produce rice through transplanting. In Axum agricultural research centre have been conducted Tef transplanting trials in collaboration with Debrezeit agricultural research centre since 2011. Accordingly, this practice has been believed to have a good advantage in enhancing the productivity of Tef. However, it lacks such parameters as age and inter and intra row spacing of seedlings. This research was intended to determine the optimum inters and intra row spacing of seedlings on the productivity of transplanted Tef.

## 2. Methodology

The experiment was conducted in two locations at Axum and Adet, Northern Ethiopia. These locations are one of the main Tef growing areas of the country. Adet is 60 Km from Axum which has a cambisol type of soil where as Axum location has a vertisol. In these locations, Tef is the major crop and is a staple food of the society. The socio-economic activity of the both local population is mixed farming which involves both cultivation of crops and rearing of livestock.

Treatments were laid down in RCBD design with three replications. One month seedlings of Tef were used for transplanting and a plot size of 3m*3m (9m$^2$) was used. Seven treatments was used which combines broadcasting, row planting and transplanted treatments. The experiment was composed of 21 experimental units with 7- treatments replicated three times. The detailed treatment combination is shown in Table 2 below. For the trial, improved Tef variety "Quncho" was used for the trial. A fertilizer rate of 60 Kg/ha $P_2O_5$ and 60 Kg/ha and N was applied. All agronomic management was applied during the whole growing season. All necessary data such as days to maturity, plant height, panicle length, number of effective tillers, lodging index, biomass yield and grain yield was collected. Data was checked for meeting all the ANOVA assumptions and then was subjected to Gen-stat (Version 16$^{th}$) analysis software. When the analysis of variance (ANOVA) showed significant differences (at *P<0.05*), a mean separation was made using least significant difference (LSD).

**Table: 1. Treatment details**

| S.N. | Treatment code | Treatments |
|---|---|---|
| 1 | T1 | Broad casting at 5 kg/ha seed rate |
| 2 | T2 | Broad casting at 25 kg/ha seed rate |
| 3 | T3 | 20cm Row planting at 5 kg/ha seed rate |
| 4 | T4 | 15cm Row planting 5 kg/ha seed rate |
| 5 | T5 | Transplanting (20cm intra row and 10cm inter row spacing) |
| 6 | T6 | Transplanting (20cm intra row and 15cm inter row spacing) |
| **7** | T7 | Transplanting (20cm intra row and 20cm inter row spacing) |

## 3. Results and Discussion

### *3.1. Days to maturity*

The result in Table 2 showed that there was significant difference (at P<0.05) for the interaction effect of location and treatments for days to maturity. The shortest days to maturity were scored from treatments T7 (89.0 days) at Adet followed by T5 and T6 at the same location (89.67 and 90.00 days respectively). However, the treatments T1 at Axum reached its maturity stage late (105.67 days) followed by T3 (105.67 days) at Axum (Table 2). This result clearly showed that all the transplanted treatments reached their maturity state earlier than the other treatments. This is because the transplanted treatments had an advantage of four weeks before planting. The difference in maturity could have a big role on in their yields in dry land areas since dry lands have short period of growing season.

### *3.2. Plant height and panicle length*

There was no significant difference for the interaction effect of location and the treatments for their plant height (Table 2). However there was a significant difference (at P<0.5) for the main effect of the treatments (Table 4). The highest plant height was scored from the transplanted treatments i.e. T5, T6 and T7 (134.50 cm, 130.80 cm and 132.20 cm respectively). These treatments also scored the highest panicle length (55.33cm, 54.83cm and 54.50cm respectively). Having a long panicle is a great advantage since the length of the panicle is directly proportional with the yield of the crop in Tef. Because the average grain yield of the crop is the sum of the whole panicles.

### *3.3. Number of productive tillers per plant*

The result in Table 2 depicted that there was significant difference (at P<0.05) for the interaction effect of planting method and seed rate/spacing for the number of productive tillers per plant (Table 2). The highest number of tillers was recorded from treatment 7 at Adet (22.67) followed by treatment 6 at the same location (18.67). In contrast the lowest number of tillers was recorded from both treatments T2 at Adet and Axum (3.00). Regardless of their growing location, there was a clear difference in tillering capacity of the treatments (Table 4). Those transplanted treatments recorded the highest number of productive tillers than the other treatments. Abreham *et al.* (2012) also found similar result while studying row planted and broadcasted treatments i.e. the row planted treatments produced more number of productive tillers per plant than the broadcasted treatments.

**Table 2: Interaction effect of location and treatments on days to maturity, plant height, panicle length and number of tillers/plant**

| Location | Treatments | Codes | Maturity (days) | Plant height (cm) | Panicle length (cm) | No of tillers Per plant |
|---|---|---|---|---|---|---|
| Adet | Broadcasting (5kg/ha) | T1 | 95.00c | 121.30 | 44.33ef | 6.00bcd |
| | Broadcasting (25kg/ha) | T2 | 92.67b | 113.70 | 41.33f | 3.00d |
| | Row planting (20cm) | T3 | 94.67bc | 122.00 | 43.67ef | 4.33cd |
| | Row planting (15cm) | T4 | 94.67bc | 117.70 | 44.67ef | 4.00cd |
| | Transplanting (20cm*10cm) | T5 | 89.67a | 139.30 | 56.33ab | 17.67a |
| | Transplanting (20cm*15cm) | T6 | 90.00a | 142.30 | 58.33a | 18.67a |
| | Transplanting (20cm*20cm) | T7 | 89.00a | 139.30 | 56.33ab | 22.67a |
| Axum | Broadcasting (5kg/ha) | T1 | 101.00d | 113.00 | 50.00cd | 4.33cd |
| | Broadcasting (25kg/ha) | T2 | 99.67d | 112.70 | 50.33cd | 3.00d |
| | Row planting (20cm) | T3 | 105.67e | 111.30 | 51.00cd | 6.67bcd |
| | Row planting (15cm) | T4 | 105.67e | 108.70 | 48.00de | 7.00bcd |
| | Transplanting (20cm*10cm) | T5 | 96.33c | 129.70 | 53.33bc | 9.67bc |
| | Transplanting (20cm*15cm) | T6 | 96.33c | 122.00 | 52.33bcd | 10.67b |
| | Transplanting (20cm*20cm) | T7 | 96.00c | 122.30 | 52.67bcd | 10.67b |
| | CV | | 1.30 | 5.1 0 | 5.3 0 | 32.90 |
| | LSD | | 3.10 | NS | 4.4 0 | 5.10 |

*Means with same letter(s) within a column are not significantly different at p<0.05 based on Duncan's test; CV= Coefficient of Variation; LSD = Least Significant Difference*

### *3.4. Lodging index*

There was not a significant difference for the interaction effect of growing location and the treatments for their lodging index (Table 3). However there was a significant difference (at P<0.5) among the treatments for the main effect (Table 5). The least lodging index percentage was recorded from treatment T7 (47.83%) followed by treatments T6 and T5 (52.17% and 56.50% respectively). However the broadcasted treatments T1 and T2 scored the highest lodging index percentage (67.5% and 65.50% respectively). Those treatments with high seed rate exhibited to excessive loading where as the transplanted treatments scored the least lodging index percentage. This could be due to the low competition effect which makes the stock of the transplanted treatments strong. Lodging has a negative impact on quantity and quality of Tef grains.

### *3.5. Grain yield*

There was not a significant difference for the interaction effect of the treatments for their grain yield (Table 3). However there was a significant difference (at P<0.5) among the treatments for the main effect of grain yield (Table 5). As it is depicted in Table 5, the highest grain yield was recorded from treatment T5 (3086.00 Kg/ha) followed by treatment T6 (3076.00 Kg/ha). Whereas, the lowest grain yield was found from T2 (1824 Kg/ha) followed by T1 (1938.00 Kg/ha). These result also clearly showed that the transplanted treatments scored the highest grain yield result and in contrast the broadcasted treatments scored the lowest result. This could be due to the high competition effect of the broadcasted treatments. The other reason also could be due to the less percentage of lodging index and shorter maturity period of the transplanted treatments. had more spacing and they also had an advantage for having a longer growing season.

It was attempted to make correlation among the agronomic parameters. As it is shown in Table 6, Grain yield was positively correlated with panicle length ($r=0.53^{**}$), plant height ($r=0.74^{**}$) and number of tillers per plant ($r=0.51^{**}$). This result clearly shows that as the three parameters increase, the grain yield also increased. However, Grain yield negatively correlated with days to maturity ($r=-0.51^{**}$) and with lodging index ($r=-0.38^{*}$) implying that those treatments with short maturity period and with less lodging index value recorded higher grain yield.

### *3.5. Biomass yield*

The result in Table 3 depicted that there was significant difference (at P<0.05) for the interaction effect of growing location and treatments for the biomass yield. The highest biomass yield was recorded from treatment T6 at Adet (12630 Kg/ha) where as the lowest was from treatment T4 at Axum (4481Kg/ha).

### *3.6. Harvest Index*

There was significant difference (at P<0.05) for the interaction effect of planting method and seed rate/spacing for the harvest index (Table 3). Treatment T4 at Axum recorded the highest harvest index value (0.54) followed by treatments T6 and T7 at the same location. However the lowest value of harvest index was recorded from treatment T2 (0.17) followed by treatment T1 (0.19) both at Adet.

**Table 3: Interaction effect of location and treatments on lodging index, grain yield, biomass yield and harvest index**

| Location | Treatments | Codes | Lodging index (%) | Grain yield (Kg/ha) | Biomass yield (Kg/ha) | Harvest Index |
|---|---|---|---|---|---|---|
| Adet | Broadcasting (5kg/ha) | T1 | 53.33 | 2140.00 | 11370.00ab | 0.19 |
| | Broadcasting (25kg/ha) | T2 | 47.67 | 1955.00 | 11274.00ab | 0.17 |
| | Row planting (20cm) | T3 | 53.33 | 2282.00 | 11333.00ab | 0.20 |
| | Row planting (15cm) | T4 | 50.00 | 2146.00 | 10963.00ab | 0.20 |
| | Transplanting (20cm*10cm) | T5 | 40.67 | 3152.00 | 10222.00ab | 0.34 |
| | Transplanting (20cm*15cm) | T6 | 36.67 | 3396.00 | 12630.00a | 0.27 |
| | Transplanting (20cm*20cm) | T7 | 32.33 | 2400.00 | 10852.00ab | 0.22 |
| Axum | Broadcasting (5kg/ha) | T1 | 81.67 | 1736.00 | 5222.00d | 0.34 |
| | Broadcasting (25kg/ha) | T2 | 83.33 | 1694.00 | 4904.00d | 0.34 |
| | Row planting (20cm) | T3 | 75.67 | 1726.00 | 4963.00d | 0.35 |
| | Row planting (15cm) | T4 | 71.33 | 2207.00 | 4481.00d | 0.54 |
| | Transplanting (20cm*10cm) | T5 | 72.33 | 3021.00 | 8963.00bc | 0.34 |
| | Transplanting (20cm*15cm) | T6 | 67.67 | 2757.00 | 6741.00cd | 0.41 |
| | Transplanting (20cm*20cm) | T7 | 63.33 | 2337.00 | 6074.00d | 0.38 |
| | CV | | 10.20 | 16.80 | 16.40 | 25.40 |
| | LSD | | NS | NS | 2363.20 | NS |

*Means with same letter(s) within a column are not significantly different at p<0.05 based on Duncan's test; CV= Coefficient of Variation; LSD = Least Significant Difference*

**Table 4: Main effect of the treatments on days to maturity, plant height, panicle length and number of tillers/plant**

| Treatments | Codes | Maturity (days) | Plant height (cm) | Panicle length (cm) | No of tillers Per plant |
|---|---|---|---|---|---|
| Broadcasting (5kg/ha) | T1 | 98.00c | 117.2b | 47.17b | 5.17b |
| Broadcasting (25kg/ha) | T2 | 96.17b | 113.2b | 45.83b | 3.00b |
| Row planting (20cm) | T3 | 100.17d | 116.7b | 47.33b | 5.50b |
| Row planting (15cm) | T4 | 100.17d | 113.2b | 46.33b | 5.50b |
| Transplanting (20cm*10cm) | T5 | 93.00a | 134.5a | 54.83a | 13.67a |
| Transplanting (20cm*15cm) | T6 | 93.17a | 132.2a | 55.33a | 14.67a |
| Transplanting (20cm*20cm) | T7 | 92.50a | 130.8a | 54.50a | 16.67a |
| CV | | 1.3 | 5.1 | 5.3 | 32.9 |
| LSD | | 1.5 | 7.3 | 3.1 | 3.6 |

*Means with same letter(s) within a column are not significantly different at p<0.05 based on Duncan's test; CV= Coefficient of Variation; LSD = Least Significant Difference*

 

**Table 5: Main effect of the treatments on lodging index, grain yield, biomass yield and harvest index**

| Treatments | Codes | Lodging index (%) | Grain yield (Kg/ha) | Biomass yield (Kg/ha) | Harvest Index |
|---|---|---|---|---|---|
| Broadcasting (5kg/ha) | T1 | 67.50c | 1938bc | 8296ab | 0.26 |
| Broadcasting (25kg/ha) | T2 | 65.50c | 1824c | 8089ab | 0.26 |
| Row planting (20cm) | T3 | 64.50c | 2004bc | 8148ab | 0.28 |
| Row planting (15cm) | T4 | 60.67bc | 2177bc | 7722b | 0.37 |
| Transplanting (20cm*10cm) | T5 | 56.50abc | 3086a | 9593ab | 0.34 |
| Transplanting (20cm*15cm) | T6 | 52.17ab | 3076a | 9685a | 0.34 |
| Transplanting (20cm*20cm) | T7 | 47.83a | 2369b | 8463ab | 0.30 |
| CV | | 10.2 | 16.8 | 16.4 | 25.4 |
| LSD | | 7.10 | 468.01 | 1671.02 | NS |

*Means with same letter(s) within a column are not significantly different at p<0.05 based on Duncan's test; CV= Coefficient of Variation; LSD = Least Significant Difference*

**Table 6: Correlation of different parameters**

| Parameters | Codes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Maturity days | 1 | - | | | | | | | |
| Lodging Index | 2 | 0.76 | - | | | | | | |
| Panicle length | 3 | -0.20 | -0.12 | - | | | | | |
| Plant height | 4 | -0.70 | -0.57 | 0.73 | - | | | | |
| No of tillers/plant | 5 | -0.52 | -0.57 | 0.59 | 0.67 | - | | | |
| Grain yield | 6 | -0.51 | -0.38 | 0.53 | 0.74 | 0.51 | - | | |
| Biomass yield | 7 | -0.78 | -0.71 | -0.07 | 0.55 | 0.30 | 0.44 | - | |
| Harvest Index | 8 | 0.52 | 0.41 | 0.35 | -0.13 | -0.01 | 0.14 | -0.75 | - |
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |

## 5. Conclusions and recommendation

Days to maturity, panicle length, number of tillers per tuber, and biomass yield showed a significant difference (at P<0.5) for the interaction effect of location and planting method/seed rate. There was also a significant difference (at P<0.5) for the main effect of the treatments for all the agronomic parameters except harvest index. At both locations, the transplanted treatments had shorter maturity days, highest plant height, highest panicle length, more number of tillers per tuber and less lodging index percentages. In addition to this, the transplanted treatments T6 (20cm*15cm spacing) and T5 (20cm*10cm spacing) scored the highest grain yield and biomass yield at Adet and Axum locations. Grain yield increased with the increase of plant height, panicle length and number of tillers per plant. In contrast grain yield decreased with the increase of days to maturity and lodging index. Hence based on these results it could be recommended that, for better Tef grain and biomass yield and for improved grain quality of the crop, Tef should be planted by transplanting in a row spacing of 20cm and plant spacing of 15cm-10cm. Further research including the cost benefit analysis and the social perception on the new method of Tef planting method is suggested.

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