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Determination of optimum plant density of broadcasting, row planting and transplanting on yield and yield components of Tef [*Eragrostis tef* (Zucc.) Trotter] in Central Zone of Tigray, Ethiopia

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The low national tef productivity is mainly attributed by lack of improved agronomic practices. The row planting and transplanting is one of the promising planting techniques proved to boost the yield of tef. The objective was to determine the optimum seed rate, row, broadcasting and plant population in intra and inter row spacing of transplanted tef. A field experiment was carried out at Laelay maychew and Naeder adet for two years. The experiment was laid out in RCBD with three replications having 3×3 (9 m^2) and seven treatments. The analysis of variance showed that there were a significance difference at (P≤0.001) for days to maturity, plant height and panicle length, whereas grain yield was significantly difference at (P≤0.01). The treatment with transplanting 20 cm intra row spacing distance resulted in the highest grain yield of 2586 $kgha^{-1}$ followed by broadcasting at 5 $kgha^{-1}$ (2547.2 $kgha^{-1}$). Even though there was a significant difference among the treatments, combined mean performance of grain yield showed that there was no statically significant difference mainly among treatments of transplanting with 20×20 and 20×15 cm inters and intra row spacing and broadcasting at 5 kg ha-1 which was recorded as the higher grain yield. The present study recommended that the use of the broadcasting with seed rate of 5 $kgha^{-1}$ and even though the transplanting is a labor consumer, it might be important for early drought faced tef growing areas with intra row spacing of 20×15 cm depending on the rain fail condition. Further tef planter machine development for lower seed rate is needed.

Key words: Tef transplanting, seeding rate, row spacing.

INTRODUCTION

Tef [Eragrostis tef (Zucc.) Trotter], which has genetic origin and center diversity in Ethiopia (Vavilov, 1951). Tef is an important staple cereal crop in Ethiopia occupying more than three million hectare of land. It is first in area coverage but second and last in production and productivity, respectively, from cereals under production in Ethiopia. It is grown by over 6.6 million households and constitutes the major staple food grain for over 50 million Ethiopians (CSA, 2015).

Nutritionally, tef has been receiving global attention as health food because of its gluten-free nature that renders it suitable for people suffering from gluten allergy known

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as celiac disease and slow release carbohydrates that make it suitable for diabetic people. Antibody-based assay have shown that tef does not contain the offending epitopes (Spaenij-Dekking et al., 2005). Prossesion of the genomic sequence allow for confirmation of these assay (Cannarozzi et al., 2014). Tef has high iron content that makes it suitable for pregnancy-related and hookworm infestation related anemia (Alaunyte et al., 2012). The iron content seems to play a particularly important role in Ethiopia, as absence of anemia has been found to correlate with areas of tef consumption (BoSTID, 1996).

The current low yield levels can be attributed to different production constraints such as susceptibility to lodging, moisture stress, and poor pre- and post-harvest agronomic management practices (Abrha, 2016). It has been argued that more efficient agronomic management could double the yield of crop plants (Mueller et al., 2012). Currently, the majority of the farmers practise broadcast sowing, which is associated with a high incidence of lodging, reduced plant growth and yield (Asargew et al., 2014).

The low national or regional tef productivity is mainly attributed by lack of improved agronomic practices. Broadcast method of sowing has been predominantly used in the past years; however, new agronomic practices could increase the productivity of the crop. Row planting and transplanting method of a month age tef seedlings are one of the promising planting techniques to boost the yield of tef (Seyfu, 1997; Kebebew et al., 2011). Transplanting is assumed to have the benefits of escaping dry spells occurring in any particular season and enhancing productivity under dry land areas. Transplanting in a row considerably increased the seed yield compared to the broadcasting method. In addition to this, it reduces the seed rate compared with the broadcasting method that a farmer uses 25 to 50 kg/ha tef as compared to transplanting required only 2 to 2.5kg/ha (Tareke et al., 2013).

The main effect of transplanting is increasing tiller number, producing strong and fertile tiller culms, increasing the number of productive tillers, which increased number of seeds/panicle. Best results came from wider spacing, giving individual plants wider space to show their potential, and the use of complete fertilizers (Zewdie, 2010). Transplanting is commonly practiced as a method of weed control for wet soil. Since the seedlings are vigor than the weed will help for control. While, requiring less seed transplanting require much more labor as compared to direct seeding (unpublished). Therefore, the present study was conducted to determine the optimum seed rate and plant population in intra and inter row spacing of transplanted tef.

MATERIALS AND METHODS

The field experiment was carried out at Axum Agricultural Research Center (AxARC) in Laelay Maychew (vertisoil) and Naeder-adet (light soil) districts of the Central Zone of Tigray, Northern Ethiopia, during the main production season of (July-November) 2012 and 2013. The sites are located at 250 km and 284 North West of Mekelle and 1024 and 1069 km North of Addis Ababa at a latitude of 14°07' 235" and 13°06'762"N, at a longitude of 038°43'987'' and 038°48'38'' E, at an altitude of 2118 and 2121 m above sea level, respectively. The experiment was lay down by the design RCBD with three replications and plot size of 3 m length and 3 m width (9 m^2) and spaces between plot and replication was 1 and 1.5 m, respectively.

Variety Quncho was used as an experimental material with the different seed rates. The treatments were (1) broadcasting at 5 $kgha^{-1}$, (2) broadcasting at 25 $kgha^{-1}$, (3) 15 cm, and (4) 20 cm of inter row spacing at 5 kg ha^{-1} seed rate for row planting and (5)10, (6)15, and (7) 20 cm intra row spacing and 20 cm inter row spacing for transplanting methods. Both the broadcasting and row planting were planted by hand drilling left on the surface little bet compacted by labors. The inter row spacing for row planting method were adjusted as 15 and 20 cm whereas for transplanting 20 cm inter row and 10, 15 and 20 cm intra row spacing were used. The treatment combinations are structured in Table 1.

According to the recommendation, tef fertilizer application for black soil 60 kg ha^{-1} P_2O_5 and N at Laelay maychew (Hatsebo) was applied and 60 kg ha^{-1} P_2O_5 and 40 kg ha^{-1} N also for light soil at Naeder–adet was applied (Seyfu, 1997). DAP was applied at planting and urea was applied in two splits, half at the time of planting and the remaining half at tillering stage. Seedling for transplanting was grown in a bed and transplanted to experimental plot at one month age (about three to four leaf atage), with three seedlings per hill at the spacing per the treatment.

The time of transplanting was in the morning for better survival of the seedling. The experimental materials were sown on the second week of July 2012 and 2013 main production seasons. All other pre and post-planting management practices were done in accordance with the research recommendations for tef production in the area. Days to maturity were determined from 50% seedling emergence to 90% physiological maturity. Plant height in centimeters was measured from the base of the plant to the tip of the panicle on the primary tiller of five randomly selected plants per plot. Panicle length of the central tillers in centimeters was measured as the average length of the panicle from the node where the first panicle branch starts to the tip of the central tiller of five randomly selected plants per plot. Whereas, the grain yield (kg ha^{-1}) weighed the grain harvested from entire plot and the average was used to statistical analysis. Data were collected on plant and plot based and analyzed by SAS software version 9.1.3 (SAS Institute Inc. 2004) to evaluate the variance and mean separation using LSD at alpha level $\alpha \leq 0.05$.

RESULTS AND DISCUSSION

The analysis of variance (ANOVA) shows there was a statistically significant difference at ($P \leq 0.001$) for days to maturity, plant height and panicle length, whereas grain yield was significantly different at ($P \leq 0.01$). The highest grain yield was recorded for transplanting in 20×20 cm row spacing (2586.5 kg ha^{-1}) followed by broadcasting at 5 kg ha^{-1} (2547.2 kg ha^{-1}), transplanting (20×15 cm) at 2456.2 kg ha^{-1} and the row planting at 5 $kgha^{-1}$ (20 cm, 2279.00 $kgha^{-1}$) (Table 1). Transplanting was greater than both direct planting methods. The present result was similar to Tareke et al. (2013) who reported that transplanting had the highest grain yield than broadcasting and row planting. Fekremariam et al. (2014) reported that transplanting tef gave a yield advantage ranging from 29.2 to 39.3% over broadcasting

Table 1. The combined mean performance of tef yield and yield components evaluated by the different planting methods, seed rate, inter and intra broadcasting, row planting and transplanting at Laelay Maychew and Naeder Adet in 2012 and 2013 cropping season.

Treatment	DM (days)	pH (cm)	Pan (cm)	Gy (kg ha^{-1})
Broadcasting at 5 kg/ha	113.92^{a}	122.18^{ab}	49.63^{ab}	2547.20^{a}
Broadcasting at 25 kg/ha	95.92^{b}	104.91^{c}	43.63^{c}	1719.70^{b}
Row planting (20 cm) at 5 kg/ha	115.08^{a}	122.97^{ab}	49.88^{ab}	2279.00^{a}
Row planting (15 cm) at 5 kg/ha	97.17^{b}	108.51^{c}	43.23^{c}	1723.90^{b}
Transplanting (20×10 cm)	97.33^{b}	113.23^{bc}	46.63^{bc}	2134.20^{ab}
Transplanting (20×15 cm)	97.00^{b}	123.54^{ab}	51.45^{a}	2456.20^{a}
Transplanting (20×20 cm)	113.58^{a}	131.40^{a}	53.98^{a}	2586.50^{a}
Grand mean	104.28	118.10	48.35	2206.65
Coefficient of variance	9.93	12.60	11.35	33.11
Least significance difference	8.44	12.14	2.39	595.92
R-square	0.64	0.56	0.61	0.42
Treatments × locations(α≤0.05)	0.3103	0.0768	0.0080**	0.5597^{ns}
Treatments(α≤0.05)	<0.0001**	0.0004**	<.0001**	0.0118*
Location(α≤0.05)	<.0001**	<.0001**	0.0035**	0.0002**

DM: Days to maturity, pH: plant height, Pan: panicle length, Gy: grain yield, * and ** significance , p<0.05 and p<0.01, respectively.

method. Even though there was a significant difference among the treatments the combined mean performance of grain yield showed that there was no statistically significant difference between treatments mainly between broadcasting at 5 kg ha^{-1}, row planting at 5 kg ha^{-1} with 20 cm and transplanting with 20×20 cm and 20×15 cm inter and intra row spacing, which was recorded the highest grain yield. The highest grain yield was recorded with wider inter and intra row spacing aligned with previous report (Zewdie, 2010).

For optimum and well distribution of rainfall, both broadcasting and row planting with seeding rate of 5 kgha^{-1} might enhance yield. Whereas, the transplanting method economically important when the environment is faced with early drought. Since, it is time consuming and labor intensive, Abraha et al. (2016) reported that transplanting maximized the yield of tef, but a cost-benefit analysis showed that row sowing was more profitable. Practically, the lower seed rate on small scale farming had a draw back in establishing of seedling with erratic rain fail in Tigray region; unless, there is development of tef planter. The results depend on the condition that low seed rate and transplanting increase the productivity of tef.

Days to maturity had a significant difference among the treatments. Broadcasting and row planting at 5 kg ha^{-1} of seed rate at 115 and 113 days, respectively and for the transplanting at 113 days scored longer days to maturity. Whereas, the shorter days to maturity were observed at the higher seed rate of broadcasting at 25 kgha^{-1} for 96 days and narrow inter and intra row spacing and transplanting at 5 kg ha^{-1}. This could be because of competition due to high population for nutrient and moisture was limited. The reason for the longest days to maturity might be the lower seed rate or population had slow growth due to the less competition among the individual plants. Therefore, this competition leads to late maturity. In addition to this, the short plant height was recorded from the higher seed rate of broadcasting at 25 kg ha^{-1} and 15 cm inter row spacing at 5 kg ha^{-1} of seed rate. The longest plant height was obtained from the transplanting 20×20 cm. Meantime, the longest panicle length was measured from the transplanting 20×20 cm, the best determined population density for production and productivity of tef.

CONCLUSION AND RECOMMENDATION

From the examined treatments from the two locations and two seasons, with broadcasting, row planting and transplanting type of planting methods, the highest grain yield was obtained from transplanting 20 × 20 cm (2586.5 kgha^{-1}) followed by broadcasting at 5 kgha^{-1} (2547.2 kgha^{-1}) and transplanting 20 × 15 cm (2456.2 kgha^{-1}) followed by row planting at 5 kgha^{-1} (2279.00 kgha^{-1}). The present study recommended that use of row planting at 5 kgha^{-1} and broadcasting with seed rate of at 5 kgha^{-1}, and even though transplanting is labor intensive it might be important for early drought growing areas of tef with intra row spacing of 20 × 20 cm. However, the low seed rate had a problem of tef seedling establishment at large farm field. Unless there is an appropriate tef planter and field leveling machine. The reason for the low seedling stand establishment is due to unevenly distribution of seeds during sowing. Thus, use of low seed rate is if a manually or motor-driven broadcaster or drill in available for both large and small scale farmers in the study areas and similar agro-ecology.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

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