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Adaptability Evaluation of Released Tef [*Eragrostis tef* (Zucc.) Trotter] Varieties at Southern Tigray, Northern Ethiopia

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Tef is endemic to Ethiopia and has been widely cultivated in the country for centuries and it adapts to a wide range of ecological conditions. A field experiment was conducted during 2017 and 2018 main cropping seasons using a randomized complete block design with three replications to evaluate adaptability of eight tef varieties under rain-fed conditions at Endamehoni districts, Southern Tigray, northern part of Ethiopia. Data was collected on various characters and subjected to analysis of variance. The result of combined analysis of variance over years showed that varieties were significantly different for days to heading, days to maturity, plant height, panicle length, stand percent, shoot biomass and grain yield. However, the difference for year by variety interaction was non-significant on panicle length and shoot biomass. From the tested varieties, Flagot showed early maturing and better performance for most of the studied characters including grain yield. The highest grain yield (2.175 t/ha) was recorded for Flagot followed by Tesfa (1.561 t/ha). Therefore, it could be concluded that variety Flagot could be recommended for the study areas and similar agro ecologies.

Keywords: Eragrostis tef, Grain yield, Tef, Varieties

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INTRODUCTION

Tef, *Eragrostis tef* (Zucc.) Trotter is a member of the grass family Poaceae and genus *Eragrostis.* It is endemic to Ethiopia and has been widely cultivated in the country for centuries (Teklu and Tefera, 2005). Tef is believed to have originated and diversified in Ethiopia (Vavilov, 1951). In recent years, tef is receiving global attention for its nutritional and health-related benefits (Provost and Jobson, 2014) especially due to the absence of gluten, a cause for celiac disease, in its grain (Spaenij-Dekking *et al.*, 2005). It represents a unique biodiversity component in the agriculture and food security systems of millions of poor farmers in Ethiopia. The area under tef cultivation is over one million hectares of land each year. In 2016/17, it was estimated that tef made up to 24% of all the cultivated area in Ethiopia, covering about 3.02 million hectares and grown by 6.99 million farmers (CSA, 2016). Tef is grown in almost all regions of the country; it is grown mainly in Amhara and Oromiya, which together accounted for 84 and 86% of the total cultivated area and production in 2011. East and West Gojjam of Amhara and East and West Shoa of Oromiya are particularly known tef producing areas in the country (Demeke and Marcantonio, 2013).

Tef is resistant to extreme water conditions; it is a highly versatile crop with respect to adaptation to different agro-ecologies, with reasonable resilience to both drought and water logging (Assefa *et al.,* 2010). It is adaptable to a wide range of ecological conditions in altitudes ranging from near sea level to 3000 m.a.s.l and even it can be grown in an environment unfavorable for most cereal, while the best performance occurs between 1100 and 2950 m.a.s.l in Ethiopia (Hailu and Seyfu, 2000), and mean temperature range from 10^{o}C to 27^{o}C under various rainfall and soil conditions (Seyfu, 1997). Compared to other cereal crops, tef is a lower risk crop to drought as it can withstand adverse weather condition which makes it a preferred crop by the rain fed subsistence agriculture for Ethiopian farmers. Minten *et al*. (2013) evaluated national Tef production for 2012 and estimated that tef is the most important food crop in the country.

Tef is produced for different purposes including food and feed, cash and foreign currency earnings. The primary use of tef grain is ground to flour, which is mainly used for making popular pancake like local bread called "*injera*" and sometimes for making porridge and the grain is also used to make local alcoholic drinks, called "*tella*" (Assefa *et al*., 2011). Tef straw, besides being the most appreciated feed for cattle, it is also used to supplement a building material by acting as a reinforcing agent in mud bricks (Woyessa and Assefa, 2011) and local grain storage facilities called "*gotera*" (Seyfu, 1997). Nutritionally, tef contains 11% protein, 80% complex carbohydrate and 3% fat. It is an excellent source of essential amino acids, especially lysine, the amino acid that is most often deficient in grain foods (Piccinin, 2002).

In Ethiopia the last 50 year's many researchers were done to improve tef with primary focus on yield but this could not include the whole country; it was only covered a few main tef producing area of the country (Abebe and Wondwosen, 2017). Even though tef is the most important growing cereal in Ethiopia and is adapted to a wide range of ecological conditions, the access of this technology is highly limited in the smallholder farmers living in Southern Tigray Zone at Endamehoni district, which may be due to lack of improved varieties, non-adoption of improved technologies, disease, pests and farmers use local variety than improved variety in the area and this could lead to less production and productivity of tef in the areas. Therefore, the present study was conducted to address the above problem through evaluating and selecting adaptable, high yielding and early maturing improved tef varieties in Southern Tigray, Endamehoni districts.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted in northern Ethiopia, southern zone of Tigray regional state, Endamehoni district in the year of 2017 and 2018 cropping seasons. Endamehoni district is located about 665 km from the capital city of Addis Ababa and about 120 km south of Mekelle, the capital city of Tigray regional state, northern Ethiopia. Geographically, Endamehoni district is extends between 39^{0} 18' 10'' E to 39^{0} 39' 50'' E and 12^{0} 33' 20'' N to 12^{0} 55' 0'' N with an average altitude of 2250 meters above sea level. The area is characterized by bimodal rainfall pattern and receives a mean annual rainfall of 68.87 mm. The average minimum and maximum temperatures were 10.4 ^{0}C and 22.5 ^{0}C, respectively (Gidena, 2015).

Experimental Materials

A total of eight tef varieties, seven released and a local check from the area were used in the experiment. The seven improved Tef varieties namely, DZ-Cr-438 (RIL 133B) (Kora), DZ-Cr-438 (RIL 91A) (Dagiem), DZ-Cr-429 (Neguse), DZ-Cr-457 (Tesfa), DZ-Cr-442 (Flagot), DZ-Cr-419 (DZ-Cr-974 XPI222988) and DZ-Cr-438 (RIL 7) (Abola) were brought from Debre Zeit Agricultural Research Center, which is the national tef research coordinating center.

Experimental Design and Procedures

The experiment was arranged in Randomized Complete Block Design (RCBD) with three replications. Each experimental plot had 10 rows at a spacing of 20cm, having plot length of 2 m and width of 2 m. Spacing between plots were 1m and the distances between blocks were 1.5 m. The experimental field was selected and all unwanted materials like straw, weed and other were removed. The land was prepared very well by ploughing four times using draft animals and human labor. Rows were made by hand pulled row-marker. Fertilizer was applied at the rate of 60 kg DAP/ha and 60 kg urea/ha. Sowing was done by hand drilling at the seed rate of 15 kg/ha. All other recommended agronomic practices were kept normal and uniform to ensure normal plant growth and development at the experimental field.

Data Collection

Data on days to heading, days to maturity, stand (%), shoot biomass (t/ha) and grain yield (t/ha) were assessed on plot basis. On the other hand, plant height (cm) and panicle length (cm) were recorded from randomly selected and tagged five samples of plants from the central parts of each plot. Eight central rows were used for data collection on plot basis, whereas mean values of the five random samples of plants per plot were then used for the analyses of data collected on individual plant basis. Seed yield of each plot was recorded and then converted into ton per hectare.

Data Analysis

All the collected agronomic and growth components data were subjected to analysis of variance (ANOVA) as suggested by Gomez and Gomez (1984) using SAS statistical software (9.2) version. Combined analysis of variance over years was carried out and Least significant difference (LSD) test was used to compare the means at $P<0.05$.

RESULTS AND DISCUSSION

Phenological Characters

Days to Heading

The combined analysis of variance showed that there was very highly significant difference ($P<0.001$) was observed among the tested varieties in days to heading (Table 1). The highest days to heading (65.00 days) was recorded for DZ-Cr-419 variety followed by Dagiem (64.33 days) and Tesfa (64.00) (Table 2). However, the local variety showed early heading (57.67 days) followed by Flagot (58.67 days) (Table 2), while selecting varieties for early maturity, considering early heading varieties could be essential. Fentie *et al*. (2012) reported significant difference among the tested varieties for days to heading. Chondie and Bekele (2017) also reported similar results.

Days to Maturity

Analysis of variance showed a very highly significant difference among tef varieties at ($P<0.001$) and also varieties by year interaction indicated that there was highly significant ($P<0.01$) difference for days to maturity from the combined analysis (Table 1). The variation for days to maturity ranged from 85 to 97.83 days. Variety Flagot (85 days) followed by local variety (85.17 days) had short period for maturity while Dagiem (97.83 days) had long period for maturity (Table 2). This implies that the higher chance of selecting early maturing varieties. Early maturing varieties complete their life cycle in relatively shorter period. Thus, early maturing varieties have advantage over the late maturity ones in environments where rain begins late and ends early. Fentie *et al.* (2012) and Chondie and Bekele (2017) also reported considerable variation in the days to maturity of different tef varieties when planted over years. These results also supported by Bakala *et al*. (2018) who observed significant different among the tested varieties in days to maturity.

Plant height (cm)

Statistical analysis showed that plant height had very highly significantly ($P< 0.001$) affected by variety while the interaction is significant (Table 1). The maximum plant height was recorded from DZ-Cr-419 and Kora varieties with a height of 100.43 cm and 100.37 cm respectively. Whereas, the shortest plant height was recorded for the local variety with 70.60 cm height (Table 2). Even though those varieties scored high in plant height but they recorded low grain yield. This might be the longest variety is susceptible to lodging while the shortest variety is resistant to lodging. These results are further supported by Chondie and Bekele (2017) and Bakala *et al.* (2018) reported significant plant height among different tef varieties. But, this study result is in contrast to the finding of Fentie *et al.* (2012) who reported non-significant difference among tef varieties over years in plant height.

Panicle length (cm)

The analysis of variance for panicle length revealed very highly significant difference ($P<0.001$) among the tested varieties for panicle length but it was non-significant difference for the interaction over year (Table 1). The average panicle length was 33.15 cm, with a range of 27.40 cm (Local variety) to 38.48cm (DZ-Cr-419). Chondie and Bekele (2017) and Aliyi *et al.* (2016) reported significant panicle length among different tef varieties. Also these results are in line with the earlier findings of Fentie *et al.* (2012) who noted that the effect of different varieties used over years didn't show significant difference for panicle length. Similar result was also reported by Abel (2005) who reported that panicle length varied from 17 cm to 42 cm.

Stand percent (%)

Stand percent had significantly affected ($P<0.001$) by variety and the interaction between year by variety (Table 1), which was ranged from 60.33% to 85.00%. Maximum stand percent was exerted by variety Neguse (85.00%) followed by Kora (79.50%) and Flagot (78.67%), while the minimum stand percent was revealed by local variety (60.33%) (Table 2). Stand percent is related to biomass quality which is the highest stand percent have a good quality of straw and it is important to animal feed.

Yield and Yield Components

Shoot Biomass

As indicated in Table 1, there were significant variations ($P<0.05$) among the tested varieties, but there was non-significant difference at the interaction year by variety. The highest shoot biomass in ton per hectare was recorded for variety Abola (9.881 t ha^{-1}), DZ-Cr-419 (9.026 t ha^{-1}) and Neguse (8.839 t ha^{-1}) while the lowest

Table 1. Mean square from the first year (2017) and second year (2018) combined analysis of variance for tef varieties

SOV	DF	DH	DM	PH (cm)	PL (cm)	Stand (%)	SB (t/ha)	GY (t/ha)
Rep	2	7.75	10.02	52.99	2.32	202.27	11.5578	0.0008
Year	1	50.02***	3434.1***	10.36^{ns}	0.48^{ns}	368.52*	11.2271*	0.0502^{ns}
Variety	7	52.76***	148.4***	675.3***	76.11***	301.83***	6.7289*	0.674***
YxVar	7	26.02***	62.08**	57.58*	13.20^{ns}	665.99***	3.2212^{ns}	0.122***
Error	30	2.79	13.02	23.55	5.98	43.47	1.5809	0.0149
CV (%)	-	2.69	3.95	5.52	7.38	8.77	15.35	8.40

*ns= non-significant, *=significant, **= highly significant, ***= very highly significant at P<0.05, SOV= Source of variance, DF=Degree of freedom, CV=Coefficient of variance, Rep= replication, YxVar= year x variety, DH= days to heading, DM= days to maturity, PH (cm)= plant height in centimeter, PL (cm)= panicle length in centimeter, Stand (%)= stand percent, SB (t/ha)= shoot biomass in ton per hectare, GY (t/ha)= grain yield in ton per hectare.*

Table 2. Mean of adaptability evaluation of released tef varieties (combined analysis of year 1 and year 2)

Varieties	DH	DM	PH (cm)	PL (cm)	Stand (%)	SB (t/ha)	GY (t/ha)
Kora	63.83^{a}	95.83^{ab}	100.37^{a}	36.42^{a}	79.50^{ab}	8.371^{bc}	1.141^{cd}
Dagiem	64.33^{a}	97.83^{a}	91.17^{b}	33.34^{bc}	73.33^{b}	7.819^{bcd}	1.105^{d}
Neguse	59.33^{b}	90.00^{c}	82.90^{c}	31.70^{c}	85.00^{a}	8.839^{abc}	1.459^{b}
Tesfa	64.00^{a}	93.00^{bc}	81.73^{c}	31.13^{c}	75.17^{b}	7.529^{cd}	1.561^{b}
Flagot	58.67^{b}	85.00^{d}	81.18^{c}	31.09^{c}	78.67^{ab}	7.582^{bcd}	2.175^{a}
DZ-Cr-419	65.00^{a}	88.83^{cd}	100.43^{a}	38.48^{a}	74.17^{b}	9.026^{ab}	1.273^{c}
Abola	63.67^{a}	96.00^{ab}	95.47^{ab}	35.63^{ab}	75.00^{b}	9.881^{a}	1.431^{b}
Local	57.67^{b}	85.17^{d}	70.60^{d}	27.40^{d}	60.33^{c}	6.488^{d}	1.505^{b}
Means	62.06	91.46	87.98	33.15	75.15	8.192	1.456
CV (%)	2.69	3.95	5.52	7.38	8.77	15.35	8.40
LSD (5%)	1.97	4.25	5.72	2.88	7.77	1.483	0.144

Column of Means with the same letter (s) are not significantly different at P< 0.05; where DH= days to heading, DM= days to maturity, PH (cm) = plant height in centimeter, PL (cm) = panicle length in centimeter, Stand (%) = stand percent, SB (t/ha) = shoot biomass in ton per hectare, GY (t/ha) = grain yield in ton per hectare, CV= coefficient of variance and LSD= least significant difference.

shoot biomass was recorded for local variety (6.488 t ha^{-1}) (Table 2). In agreement with the present study, Addisu (2018) conducted evaluation of adaptability and improvement of tef varieties in western part of Ethiopia and reported significant variation in above ground biomass among different tef varieties.

Grain Yield

The statistical analysis showed that very highly significant (*P<0.001*) difference was observed on grain yield of released tef varieties, which was ranged from 1.105 t/ha to 2.175 t/ha with the mean value of 1.456 t/ha and coefficient of variation 8.40%. The highest grain yield was procured from Flagot variety (2.175 t ha^{-1}) followed by Tesfa (1.561 t ha^{-1}), while the lowest grain yield was recorded for variety Dagiem (1.105 t ha^{-1}) followed by Kora variety with average grain yield of 1.141 t ha^{-1} (Table 2). Fentie *et al.* (2012); Aliyi *et al.* (2016) and Chondie and Bekele (2017) reported significant variation in grain yield among different tef varieties. Bakala *et al*. (2018) also conducted performance evaluation and adaptation trial of tef genotypes for moisture stress areas of Borena, Southern Oromia and reported considerable variation in grain yield of different tef varieties when planted over years.

CONCLUSION AND RECOMMENDATION

The combined analysis of variance over years showed that varieties were significantly different for all characters including grain yield. Grain yield is an important character to be considered for variety selection to address the objective of the conducted activity. From the tested varieties, Flagot showed early maturing and better performance for most of the studied characters including grain yield. The highest grain yield (2.175 t/ha) was recorded for Flagot followed by Tesfa (1.561 t/ha). Therefore, it could be concluded that variety Flagot could be recommended for the study areas and similar agro ecologies.

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