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Performance of Tef (Eragrostis tef (Zucc.)Trotter) Varieties at Chora District, Buno Bedele Zone

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Abstract: Tef is the most important staple cereal crop in Ethiopia. However, its productivity is low due to several biotic and abiotic constraints. The diverse and dynamic environmental condition of Ethiopia needs detailed and sustainable study of under different environment for developed Tef varieties. The objective of this study was to evaluate and select better performed Tef varieties for the study area and similar agro ecologies. Ten (10) improved Tef varieties were tested at Chora district during the 2019-2020 main cropping seasons using Randomized Complete Block Design (RCBD) with three replications. An important data like Days to heading, Plant height, Panicle length, Total productive tillers per plant, Biomass yield and Grain yield were recorded and mean performances of these traits were evaluated using Genstat 18th edition software. The results showed significant differences among Tef varieties for grain yield and yield related traits. Combined mean grain yield of the Tef varieties varied from 1733kg ha^{-1} for variety Dega-Tef, to 2217kg ha^{-1} for variety Dursi. The maximum yield was obtained from Dursi variety (2217kg ha^{-1}) followed by Dukem variety (2171kg ha^{-1}). The results from this study gave valuable information and input for researchers who were interested to examine the effect of environment on the performance of Tef varieties for future breeding program in the Southwest Ethiopian condition (Buno-Bedele Zone). Therefore, these two varieties were recommended to be demonstrated under farmers' field for further scaling up.

Keywords: Adaptability: Eragrostis Tef: Varieties: Yield Related: Oromia: Bedele: Ethiopia.

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1.0 Introduction of the Study

Eragrostis Tef (Zucc.) Trotter is a member of the grass family Poaceae and genus Eragrostis. The genus Eragrostis constitutes about 350 species of which only Tef is cultivated for human consumption (Watson & Dallwitz, 1992). Fifty-four Eragrostis species are found in Ethiopia, out of which fourteen are known to be endemic. Worldwide, Africa contributes 43% of the genus, while South America contributes 18%. Likewise, 12%, 10%, 9%, 6% and 2% of the genus Eragrostisis from Asia, Australia, Central America, North America, and Europe, respectively (Costanza *et al*., 1979). Tef is an allotetraploid species with a base chromosome number of 10 (2n=4x=40) with genome size of 730 Mbp (Mulu *et al*., 1996). It is self-pollinated with chasmogamous and hermaphroditic flowers. It has very low degree of out-crossing, that ranges from 0.2% -1.0% (Seyfu, 1997).

Tef is a crop for which Ethiopia is the center of origin and diversity (Vavilov, 1951). Tef is endemic to Ethiopia and its major diversity is found only in that country. As with several other crops, the exact date and location for the domestication of tef is unknown. However, there is no doubt that it is a very ancient crop in Ethiopia, where domestication took place before the birth of Christ (Seyfu, 1997). It was probably cultivated in Ethiopia even before the ancient introduction of wheat and barley (Shaw, 1976).

According to Ethiopian flora, Tef grows up to 2500 m.a.s.l. However, the Ethiopian biodiversity institute expedition and collection database indicates that Tef is collected from the altitudinal range of 800 to 3200 m.a.s.l. (Alganesh, 2013). Maximum production occurs at altitudes between 1800 and 2100 m, annual rainfall of 750 to 850 mm with growing season rainfall of 450 to 550 mm and a temperature range of 10 to 27°C. A very good result can also be obtained at an altitude range of 1700 to 2200 m and growing season rainfall of 300 mm (Seyfu, 1993). The temperature range of 10 to 27°C is most suitable to avoid frost (Seyfu, 1997), and soil temperature range of 18 to 27°C and above was recommended in US (Miller, 2008).

Tef is the most preferred crop as source of food and feed in Ethiopia. Besides, it is tolerant to drought, water logging and pests particularly against storage pests. Now a day, Tef has become a globally popular crop for its gluten free property that makes it conducive for people suffering from celiac disease and diabetic because of its slow release of carbohydrates. Hence, it is regarded as a promising alternative food replacing gluten containing cereals like wheat, barley and rye in products such as pasta, bread, beer, cookies and pancakes (Spaenij *et al.,* 2005). Recently, Gina *et al*. (2014) supported this fact with results from the genome sequence initiative. Tef has high iron content that makes it appropriate for pregnancy related anemia (Alaunyte *et al.*, 2012). The iron content mainly seems to play an essential role in Ethiopia, as there is absence of anemia in areas of Tef consumption (BoSTID, 1996).

It is the major cereal crop in Ethiopia where it is staple food for about 50 million people (Kebebew *et al.,* 2015). Its resilience to extreme environmental conditions and high in nutrition makes Tef the preferred crop among both farmers and consumers (Plaza *et al*., 2015). Among the food crops grown in Ethiopia, Tef is cultivated on about 3 million hectare producing 5.02 million tons (CSA, 2017). In spite of the low productivity, Tef is widely cultivated by over six million small-scale farmers' households in Ethiopia. It is considered to be an orphan crop because it has benefited little from international agricultural research system (Kebebew *et al*., 2015).

The low national Tef productivity is mainly attributed to susceptibility to lodging, low yield potential of landraces under widespread cultivation, poor agronomic management practices, biotic and abiotic stresses (Kebebew *et al*., 2011). Nevertheless, it is possible to increase the yield up to 4.5ton per hectare by using improved varieties and proper management practices (Likyelesh, 2013). Determining the magnitude and nature of the production environment is also the most important strategy to maximize grain yield and ensure stable performance of Tef varieties across varying environments (Tiruneh, 2000).

Even if Tef is the most important staple food and enrich with different mineral elements and vitamins, the production and productivity of the crop is below average because of different production constraints (lack of farmer's awareness, lack of improved variety(s) that adapted to their environment, inadequate supply of seed and other agricultural input). For that reason, this study was initiated to improve the production and productivity of Tef by evaluating and selecting high yield Tef variety (s) for Tef growing district of Buno - Bedele Zone. Therefore, the study was initiated with the objective to evaluate and select best adapted Tef varieties for high yielder and diseases and insect tolerant for the study areas of Chora district and other similar agro ecologies.

2.0 Materials and Methods

2.1 Description of the Study Area

The experiment was conducted at Chora district on different farmers' field during 2019-2020 main cropping seasons. Chora is one of the districts in Buno - Bedele Zone, Oromia Regional State Southwest part of Ethiopia. The district is bordered on the south by Setema, on the west by Yayo and Dorani, on the north by Dega, and on the east by Bedele. The administrative center of this district is Kumbabe. The district is located 519 km away from the capital city of the country and 36 km away from Bedele Town of Buno - Bedele Zone. The district is located at an average elevation 2000 masl and located at $08^{0}13'33.7"$ to $08^{0}33'55.0"$ N latitude and $035^{0}59'59.7"$ to $036^{0}15'15.8"$ E longitude. It is generally characterized by warm climate with a mean annual maximum temperature of 25.5°C and a mean annual minimum temperature of 12.5°C. The driest season lasts between December and January, while the coldest month being December. The annual rainfall ranges from 1440 mm. The soil of the area is characterized as an old soil called Nitosols. The economy of the area is based on mixed cropping system and livestock raring agricultural production system among which dominant crops are maize, Tef, sorghum and wheat and also horticultural crops.

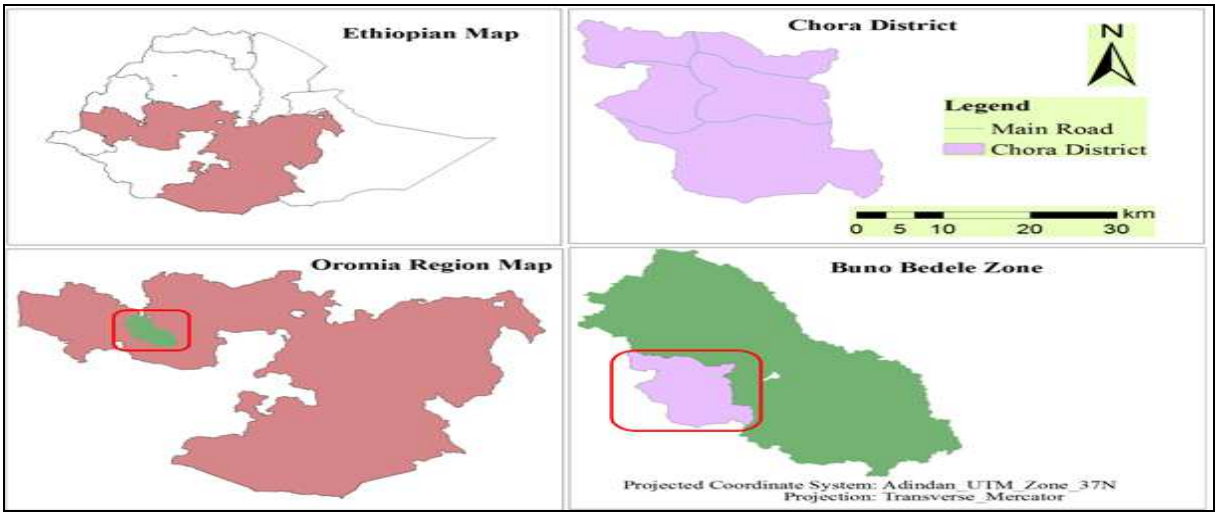

Figure 1. Map of the study area (Chora) district

2.2 Experimental Materials and Design

Ten (10) improved Tef varieties were brought from Debrezeit and Bako Agricultural Research Centers and evaluated as experimental materials. These materials were randomly assigned to the experimental block and the experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The spacing between blocks and plots was 1m and 0.5m, respectively. The gross size of each plot was $4m^2$ (2m x 2m) having ten rows with a row-to-row spacing of 20cm.The total area of the experimental field was $196m^2$ (24.5m x 8m).Planting was done by drilling seeds in rows with a seed rate of 25kg ha^{-1}. NPS fertilizer was applied at the rate of 100kg ha^{-1} (30g per plot) at the time of planting; and Urea was also applied at vegetative stage at the rate of 100 kg ha^{-1}.

Table 1: Description of the Tef varieties used in the experiment

No	Variety Names	Altitude ranges (m.a.s.l)	Year of Release	Maintainer
1	Dagem	NA	2016	DZARC
2	Dega-teff	1400-2400	2005	DZARC
3	Gimbichu	1400-2400	2005	DZARC
4	Dukem	1400-2400	1995	DZARC
5	Dursi	1850-2500	2018	BARC
6	Flagot	NA	2017	DZARC
7	Kena	1850-2400	2008	BARC
8	Kora	NA	2014	DZARC
9	Quncho	1500-2500	2006	DZARC
10	Guduru	1850-2500	2006	BARC

NA=Non-available

2.3 Data Collected

Data were recorded on plot and single plant basis and taken from the central eight rows of the plot. Individual plant based data were taken from five plants in each plot taken randomly from the central eight rows of each plot.

2.3.1 Data Collected on Plot Basis

Days to heading (DH): The number of days from 50% of the plots showing emergence of seedlings up to the emergence of the tips of the panicles from the flag leaf sheath in 50% of the plot stands

Total biomass yield (g/plot): The weight of all the central row plants including tillers harvested at the level of the ground

Grain yield (g/plot): The weight of grain for all the central row plants including tillers harvested at the level of the ground

Harvest index (%): The value computed as the ratio of grain yield to the total (grain plus straw) biomass multiplied by 100

2.3.2 Data collected on plant basis

Plant Height (cm): Measured as the distance from the base of the stem of the main tiller to the tip of the panicle at maturity

Panicle Length (cm): The length from the node where the first panicle branch starts up to the tip of the main panicle at maturity.

3.0 Data Analyses

Genstat 18th Edition was used to analyze all the collected data from individual farmers and the combined data over locations. Mean separations was carried out using least significant difference (LSD) at 5% probability level.

4.0 Results and Discussions

The overall combined analysis of variance across the two years for grain yield revealed highly significant (P<0.01) difference among varieties due to the main effect of varieties and years (Table 2). This suggests the existence of genetic variation among the tasted tef varieties with differential response's across years.

Table 2: Combined mean ANOVA of 10 tef varieties for grain yield in kg ha^{-1} in 2019-2020 cropping season

	Degree of freedom	Sum of squares	Mean of squares	F value	Pr (>F)
Year	1	101757815	101757815	518.62	<0.001 ***
Treatments	9	5175805	575089	2.93	0.003 **
Replications	2	384786	192393	0.98	0.04*
Years*Treatments	9	1725180	191687	0.98	0.460
Residuals	36	42773599	196209		

Table 3: Combined mean grain yield (kg ha^{-1}), BMY (kg ha^{-1}), and HI of tef varieties tested at Chora district for two years

Sr. No	Varieties	Year 1 combined	Year 2 combined	Over all Combined	BMY	HI (%)
1	Dagem	2729^{ab}	1308^{abc}	2019^{ab}	12417^{a}	16.26^{e}
2	Dega-tef	2438^{c}	1029^{c}	1733^{b}	7833^{de}	22.12^{bcd}
3	Gimbichu	2646^{abc}	1171^{bc}	1908^{ab}	7083^{e}	26.94^{ab}
4	Dukem	2688^{abc}	1654^{a}	2171^{ab}	8958^{b-e}	24.24^{abc}
5	Dursi	2750^{a}	1683^{a}	2217^{a}	11083^{ab}	20.00^{cde}
6	Flagot	2479^{bc}	1029^{c}	1754b	8750^{cde}	20.05^{cde}
7	Kena	2729^{ab}	1258^{abc}	1994^{ab}	10167^{bc}	19.61^{cde}

8	Kora	2688^{abc}	1373^{abc}	2030^{ab}	8917^{b-e}	22.77^{a-d}
9	Quncho	2625^{abc}	1317^{abc}	1971^{ab}	9917^{bcd}	19.87^{cde}
10	Guduru	2604^{abc}	1529^{ab}	2067^{ab}	11000^{ab}	18.79^{de}
GM		264	1335	199	9612	21.07
LSD(0.05)		269	431	455	2234	4.76
CV%		12.6	36.9	35.3	13.5	22.5
P-value		*	*	*	**	**

BMY= Biomass yield, HI= Harvest Index, GM= grand mean, LSD=least significant difference, CV= coefficient of variation.

The combined analysis of variance across the two years revealed highly significant (P<0.01) difference among varieties for almost all traits (Table 3). Dursi variety gave the highest grain yield (2217kg ha^{-1}) followed by Dukem variety (2171kg ha^{-1}) which is within the yield potential (20-24 qt ha^{-1}) during its release in crop variety registration (crop variety registration, 2018). In agreement with this finding; previous studies of Genotype x environment interaction on 22 Tef genotypes at four locations in Southern regions of Ethiopia have indicated significant variations in grain yield for the tested genotypes (Ashamo & Belay, 2012). Similar study on phenotypic diversity in Tef germ plasm in a pot experiment using 124 single panicle sample collection showed substantial variability for traits such as plant height, panicle length, maturity, seed color, seed yield, lodging and panicle type (Malak *et al*., 1965).

Table 4: Combined mean of yield related traits of tef varieties over two years

Sr. No	varieties	DH (days)	PH (cm)	PL (cm)	NTP	BMY (kg ha^{-1})
1	Dagem	52.46^{a}	88.63^{a}	38.51^{ab}	3.67^{a}	12417^{a}
2	Dega-tef	49.29^{bc}	86.07^{ab}	36.01^{bc}	3.33^{abc}	7833de
3	Gimbichu	48.88^{c}	86.56^{ab}	35.47^{bc}	3.33^{abc}	7083^{e}
4	Dukem	51.04^{abc}	91.36^{a}	37.32^{b}	3.67^{a}	8958^{b-e}
5	Dursi	52.75^{a}	93.92^{a}	42.36^{a}	3.50^{ab}	11083^{ab}
6	Flagot	43.62^{d}	76.98^{b}	32.29^{c}	3.00^{c}	8750^{cde}
7	Kena	51.62^{abc}	86.65^{ab}	35.65^{bc}	3.17^{bc}	10167^{bc}
8	Kora	52.04^{ab}	92.52^{a}	38.08^{b}	3.33^{abc}	8917^{b-e}
9	Quncho	51.29^{abc}	90.92^{a}	36.88^{b}	3.25^{bc}	9917^{bcd}
10	Guduru	51.96^{abc}	95.68^{a}	42.26^{a}	3.50^{ab}	11000^{ab}
GM		50.50	88.9	37.48	3.38	9612
LSD (0.05)		3.16	11.42	3.97	0.39	2234.1
CV%		11.0	22.6	18.6	14.2	13.5
P-value		**	*	**	*	**

DH= days to heading, PH= plant height, PL= panicle length, NTP= total number of tillers per plant BMY= Biomass yield, GM= grand mean, LSD=least significant difference, CV= coefficient of variation

Analysis of variance (ANOVA) revealed highly significant difference (P< 0.001) among the ten (10) Tef varieties in phenological traits such as days to heading, panicle length and Biomass yields and significantly difference (P<0.05) for plant height and total productive tillers per plant. The combined analysis of variance for biomass depicted significant (P<0.05) difference among the tested varieties. Dagem variety gave the highest shoot biomass (12417 kg ha^{-1}) followed by Dursi (11083 kg ha^{-1}) (Table 4).

Many studies have indicated the presence of substantial variation among tef genotypes for different traits of Tef. Habte *et al*., (2011) reported highly significant genotype variation for days to panicle emergence and maturity, plant height, culm and panicle length, shoot biomass, grain yield, harvest index, lodging index and thousand seed weight. Similarly, highly significant (P<0.01) genotype differences for days to panicle emergence, lodging percentage, thousands kernel weight, grain yield per plant and grain yield per hectare were also reported by Ayalneh *et al*. (2012).

Guduru followed by Dursi exhibited longest plant height with the respective values of 95.68cm, 93.92cm respectively. The mean plant height was ranged from 76.98cm to 95.68cm. Flagot showed the shortest plant height (76.98cm) (Table 4).

From the combined data analysis, Panicle length ranged from 42.26cm to 42.36cm. Variety Dursi had longest panicle (42.36cm) followed by Guduru (42.26cm), while the shortest panicle length was recorded from Flagot (32.29cm). Number of tillers per plant (NTP) refers to the number of shoots that emerge at the base of the main stem excluding the main shoot. Number of fertile tillers per plant ranged from 3 to 3.67 (Table 4).

5.0 Pearson Correlation Coefficient

Correlation coefficient analysis helps to determine the nature and degree of relationship between any two measurable characters. It resolves the complex relations between the events into simple form of association. But measure of correlation does not consider dependence of one variable over the other (Falconer and Mackay, 1996). To know the nature and magnitude of relationship existing between yield and its component characters as well as the association among the components character themselves, the phenotypic correlations among the eight characters were computed and presented in table 5.

Grain yield showed positive and highly significant phenotypic association with panicle length (0.38**), plant height (0.74**), days to heading (0.45**), biomass yield (0.31*) and harvest index (0.58**). Therefore, any improvement of these characters would result a substantial increment on grain yield. Similar finding has been reported by Solomon *et al*. (2009) and Ayalneh *et al*. (2012) that day to heading and plant height were significantly correlated and biomass yield and harvest index is highly and positively correlated with grain yield but; inconsistent with this finding, days to maturity indicated that highly and negatively correlated with grain yield. According to Habtamu *et al.* (2011), biomass yield but harvest index had positive and highly significant association with grain yield and also positively and significantly correlated with day to heading. On the other hand, previous research reports showed that association between traits varied with location and years (Abebe, 1985). In addition, Kebebew *et al*. (2002) reported that yield and yield component associations showed differences in different locations, which is signified by the variation of association observed between grain yield and component traits.

Table 5: Correlation coefficients among morpho-physiological traits evaluated between grain yield and yield related traits of 10 Tef varieties tested for two consecutive years.

Traits	DH	PH	PL	DM	NTPP	BMY	GY	HI (%)
DH	1							
PH	0.36*	1						
PL	0.07^{ns}	-0.27*	1					
DM	0.43**	0.19^{ns}	0.26*	1				
NTPP	0.17^{ns}	0.14^{ns}	0.14*	0.24*	1			
BMY	0.28*	0.27*	0.09^{ns}	0.32*	0.25*	1		
GY	0.45**	0.74**	0.38*	0.19*	0.14*	0.31*	1	
HI (%)	0.23*	0.37*	-0.26*	0.05^{ns}	0.06^{ns}	-0.31*	0.58**	1

DH= days to heading, PH= plant height, PL= panicle length, DM= days to maturity, NTPP= Number of tiller per plant, BMY= Biomass yield (kg ha^{-1}), GY= Grain yield (kg ha^{-1}), HI= harvest index.

6.0 Conclusions and Recommendations

Studying varietal response to different environment is crucial for plant breeding programmes where there is a diverse natural, environmental, climatic and soil variability is existing. In line with this, a total of 10 Tef varieties were studied at Chora district on different farmers during 2019-2020 main cropping seasons with the objective to select the best adaptive Tef varieties with high yield and good agronomic trait to the area. The result of the experiment showed that tef varieties were showed a significant difference both at individual farmers' level and

combined mean effects. Varieties were highly affected due to the main effect of years and varieties which show year dynamics with soil and environment. Varieties were affected due to the main effect varieties and years. All the collected agronomic data were positively and significantly correlated with grain yield. Generally, Dursi and Dukem were the best varieties that showed the stability of these varieties as well as higher yielder than other improved varieties tested across two years. Therefore; these two varieties are recommended as improved varieties and demonstrated on farmers' field for further scaling up.

7.0 References of the Study

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