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Research Article

Performance Evaluation of Tef [*Eragrostis tef* (Zucc.) Trotter] Varieties for Moisture Stress Areas of Simada, Northwestern Ethiopia

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Abstract

Tef is the major staple cereal crop in Ethiopia, mainly grown under rainfed condition. The major objective of this study was to evaluate and recommend the best performed tef varieties for the tef growers of moisture stress areas. Field experiment was conducted to select well adapted and high yielder tef varieties at Simada North western, Ethiopia during 2021/2022 and 2022/2023 main cropping season. The experiment was conducted by using 12 tef varieties through a randomized complete block design with three replications. The combined analysis of variance over years revealed a highly significant difference ($p<0.01$) among studied tef varieties for days to maturity, biomass yield, grain yield and harvest index and significant difference ($p<0.05$) for plant height. Infarct, the cultivation of improved tef varieties in moisture deficit areas is absolutely crucial for food security and income generation to the communities by enhanced tef production and productivity through using recommended varieties as compared to the farmers local varieties. So, the Two tef varieties, Mechere and Zoble provided as higher grain yield 1830kg/ha, 1824 kg/ha respectively at moisture stress area. Therefore, based on grain yield and other important traits, Mechere and Zoble varieties could be recommended for Simada district and similar moisture stressed agro ecologies.

Keywords

Evaluation, Grain Yield, Moisture Stress, Tef Varieties

1. Introduction

Tef (*Eragrostis tef* (Zucc.) Trotter) ($2n=4x=40$) classified under *poaceae* family and *Eragrostis* genus. Tef is an annual cereal crop most widely grown over broad environmental conditions. It owes its center of origin and diversity in Ethiopia and is widely cultivated throughout the country as a staple food crop [17].

Tef is the most important and wider adaptable cereal crop in Ethiopia. Tef is grown by more than 6.8 million households [3] with growing season rainfall of 450-550 mm [9]. It grows in various agro climatic condition from sea level to 3000 meter above sea level and different types of soil related factors thus from light sandy to heavy clay soil in variable fertility [8].

Tef is mainly serve as staple food, majority of people are preferring grain of tef for consumptions by making *Injera* and *local beverage* [15]. In a country of over 90 million people, tef ac-

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counts for about 15% of all calories consumed [10]. It is highly nutritious, excellent in amino acid composition, its lysine content is higher than that of all cereals except rice and oats [7], it has good mineral content and considerable amount of iron content when compared with other cereal crops [12]. Tef is free of protein known as gluten which found in wheat, barley and rice, and can cause celiac disease by aberrant T-cell [16].

Tef productivity in moisture stress areas of Simada is lower than the average grain yield, which mainly due to lack of moisture stress resistance improved varieties in the area. Currently different varieties of tef have been released from the regional and federal research center [8]. Even though some varieties of tef have been released in Ethiopia, most of them were not evaluated around moisture stress areas of South Gonder zone at Simada district. Therefore, the major objective of this study was to evaluate and recommend the best performed tef varieties for the tef growers of moisture stress areas of Simada district in South Gonder zone Ethiopia.

2. Material and Methods

2.1. Description of the Study Area

The experiment was conducted at Simada district in the South Gondar Zone of Amhara Region of Ethiopia during the 2022 and 2023 main cropping season. Simada is located at 11° 29’59.99’’ N latitude and 38° 14’60’’ with elevations ranging from 1196 to 3525 m above sea level and the district divided into three climatic zones: middle altitude (40 %), highland (10 %), and lowland (50 % [13]. Annual rainfall for Simada ranges from 1000 to 1500 mm. The main soil types in Simada are red, brown, black, and gray, which account for about 30%, 30%, 25%, and 15% of the total area, respectively, with red and brown soils being the most common [11].

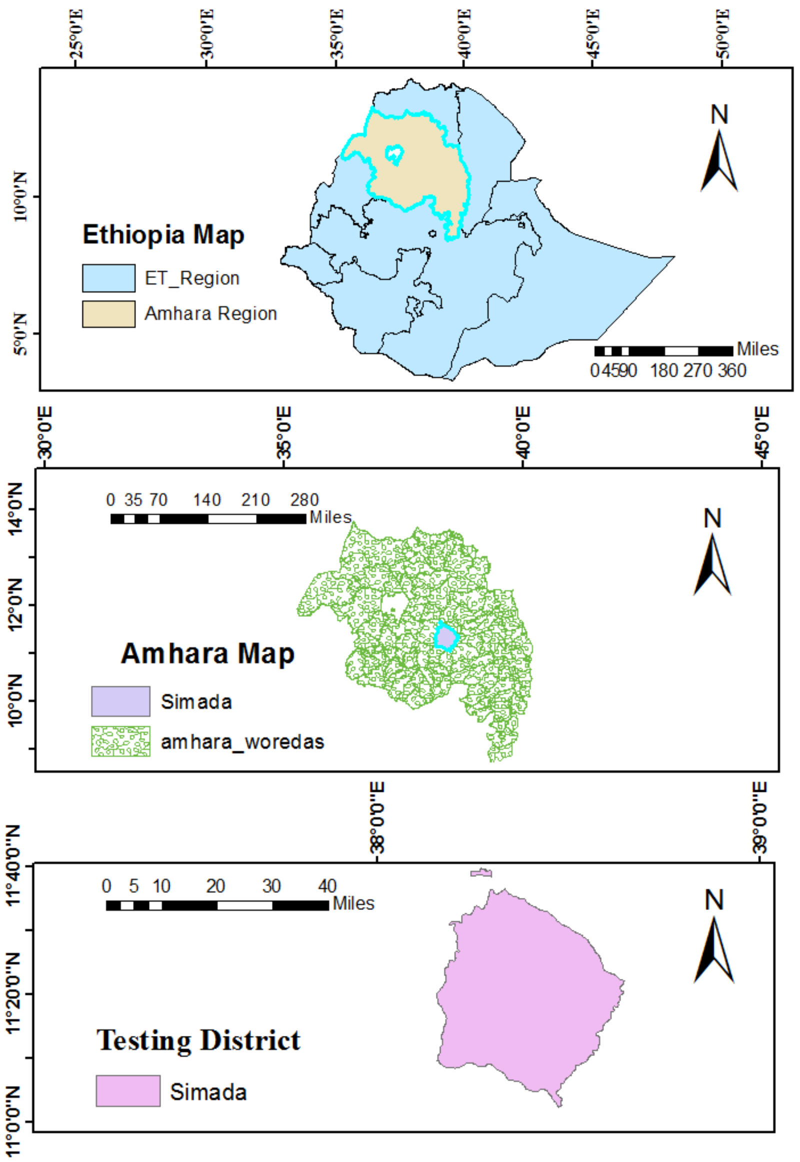

Figure 1. Map of the study area.

2.2. Plant Materials Used and Design

The experiment was conducted during the 2022 and 2023 main cropping season at Simada research site of Fogera, Northwestern Ethiopia. Twelve nationally released tef varieties were used for this study (Table 1). These varieties were obtained from Debre Zeit national tef research program. The experiment was arranged in Randomized complete block design with three replications. Each variety was planted in the plot size of 2 m length and 2 m width and sown in 20cm distance between rows.

Table 1. 12 released tef varieties used for this study.

No	Pedigree	Year	Released Center	Altitude	Rainfall
1	Tseday (DZ-CR-37)	1984	DZARC	500-700	300-700
2	Amarachi (Ho-Cr-136)	2006	DZARC	1600-1700	500-850
3	Gemechis (DZ-Cr-387-RIL#127	2007	Melkassa	1450-1695	690-965
4	Simada (Dz-Cr-385 RIL295)	2009	DZARC	1500-1900	300-700
5	Genete (Dz-01-146)	2005	Sirinka	1450-1850	660-1025
6	Zobel (Dz-01-1821)	2005	Sirinka	1450-1850	660-1025
7	Mechere (Acc.205953)	2007	Sirinka	1450-1851	660-1026
8	Lakech (SR-RIL-273)	2009	Sirinka	1450-1852	660-1027
9	Boset (Dz-Cr-409/RIL50D)	2012	DZARC	1500-1750	500-850
10	Bora (DZ-Cr-453)	NA	NA	NA	NA
11	Worekiyu (Acc.214746A)	2014	Sirinka	1450-1850	505-1025
12	Mena (Dz-Cr-428)	NA	NA	NA	NA

NA=Not Available

2.3. Data Collection

Data were recorded on plot and plant basis. Individual plant-based data were taken from randomly pre-tagged five plants in each harvestable plot.

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

Days to maturity (DM): The number of days from 50% of the plots showing seedling emergence up to 90% of the plants in the plot reaching phenological maturity stage (as evidenced by eye-ball judgment of the plant stands when the color is changed from green to yellow color of straw).

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

Grain yield (g/plot): The weight of grain from the central row in each plot and finally converted to hectare based.

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

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.

2.4. Statistical Analysis

All measured quantitative parameters were subjected to Analysis of Variance (ANOVA) by using R.4.0.3 software to assess the significance of the difference between the varieties. Mean separation was carried out using the Least Significance Difference test (LSD) at a 5% probability level.

3. Result and Discussion

3.1. Analysis of Variance

The combined analysis of variance over years among tef varieties revealed that there was highly significant difference ($p<0.01$) for days to maturity, biomass yield, grain yield and harvest index and significant difference ($p<0.05$) for plant height. Varieties by year interaction indicated that there was highly significant ($p<0.01$) difference for days to maturity, biomass yield, grain yield and significant (p<0.05) difference for harvest index. Such considerable variations would provide a good opportunity for yield selection and improvement. [2] also conducted yield and agronomic performance of released tef varieties under irrigation condition at Dembia, North western, Ethiopia. They reported considerable variation in the days to maturity, biomass yield and grain yield of different tef varieties when planted over years. Moreover, similar result reported by [5], genotypes by year interaction showed highly significant (P < 0.01) difference for days to maturity, biomass yield and grain yield. While the interaction exhibited also non-significant for plant height and panicle length at Raya valley, Northern Ethiopia under irrigation condition. They also reported that highly significant differences (P < 0.01) were observed among genotypes for grain yield and significant (P < 0.05) difference were observed for days to maturity and biomass yield. However, non-significant difference was observed in plant height and panicle length. Similar result was found by [14].

Table 2. *Mean squares from combined analysis of variance for yield and other traits of Tef varieties evaluated over two (2022 and 2023) cropping season.*

SOV	DM	PH	PL	BY	GY	HI
Var	78.58**	143.63*	26.04^{ns}	2060538**	254068**	63.69**
Yr	39.41**	1418.73^{ns}	11.88^{ns}	375816^{ns}	1754795**	567.43**
Var *Yr	13.04**	118.38^{ns}	12.82^{ns}	1560386**	147574**	23.76*
Error	2.17	60.5	8.56	459260	44256	8.88
CV	1.25	10.58	9.58	14.10	13.49	9.10

SOV=Source of variation, CV=Coefficient of variation, **, *, ^{ns}= highly Significant at P < 0.01, significant at P < 0.05 and non-significant respectively, Var=Variety, Var: Yr= Variety combined by Year, DM=Days to maturity, PH=plant height, PL=Panicle length, BY=Biomass Yield, GY=Grain yield, HI=Harvest index

3.2. Days to Maturity

Identification of tef varieties considering days to maturity is absolutely important for adjusting sowing date to avoid adverse climatic conditions such as severe frost or extreme heat in summer, particularly during flowering and grain filling period. Moreover, planting tef varieties with the appropriate growing period allows effective use of seasonal rainfall [6]. Combined analysis of variance revealed that varieties years and varieties by year interaction were highly significant (p<0.01) difference on days to maturity of twelve tef varieties indicating that differences due to the presence of genetic variability among tef varieties and the change cropping season (Table 2). In combined mean varieties Amarach (122.33 days) and Mena (121.17 days) had the longest period for maturity while Simada variety (110.5 days) exceeded by Bora (112.33 days) relatively had the shortest period of maturity (Table 3). In 2022-year Amarach (122 days), Genete (121 days), Mena (121.74 days) and Zobel (121 days) tef varieties had the longest period for physiological maturity. Whereas the shortest days to maturity was obtained from the varieties of Boset (115 days) followed by Simada (114 days) and Bora (113 (Table 4). In 2023-year Amarach (122.67 days), Lakech (120.6 days), Mena (120.67 days) varieties had the longest period for maturity. While the shortest days to maturity was obtained from the varieties of Bora (111.67 days) and Simada (107 days) (Table 5). Similar results obtained by [4] the shortest days to maturity on Simada varieties. Moreover, in lined with [1], the shortest days to maturity was obtained from the variety named ‘Simada’.

3.3. Plant Height

Combined analysis of variance revealed that varieties was significant (p<0.05) difference on plant height of twelve tef varieties which indicates the presence of genetic variability among tef varieties. In combined mean varieties Workiyu (81.1cm), Mena (77.73cm) and Zobel (77.37cm) had the longest plant height while Simada variety (64.57) followed by Boset (67.07cm) had the shortest plant height (Table 3). In 2023-year Genete (76.00cm), and Lakech (75cm), varieties had the longest plant height. This results in line with [4] reported that the highest plant height recorded from the Genete varieties. While the shortest plant height was obtained from the varieties of Simada (54.47cm) (Table 5). These results agreed with [4] findings that the lowest plant height recorded from Genete tef varieties.

3.4. Biomass Yield

The analysis of variance revealed that varieties, years and varieties by year interaction were highly significant (p<0.01) difference on biomass yield of twelve tef varieties indicating that differences due to the presence of genetic variability among the tested tef varieties on biomass (Table 2). In combined mean the variety Mechare gave the highest biomass yield (5561kg/ha), followed by Amarach (5347kg/ha), Boset (5390kg/ha) and Tseday (5229 kg/ha). While the lowest biomass yield was obtained in the variety of Mena (3988kg/ha) in both years and performed consistently over years (Table 3). In 2022-year Boset (5966kg/ha), Gemechis (7997kg/ha), Tseday (6237kg/ha), varieties had the highest biomass yield. While the lowest biomass yield was recorded from the varieties of Workiyu (3333kg/ha) and Mena (3533kg/ha) (Table 4).

3.5. Grain Yield

Combined analysis of variance revealed that varieties, years and varieties by year interaction were shown highly significant ($p<0.01$) difference on grain yield of twelve tef varieties which indicates the presence of genetic variability among the tested tef varieties (Table 2). In combined mean the variety Mechere gave the highest grain yield (1830kg/ha) followed by Zobel (1824 kg/ha) while the lowest grain yield was obtained in the variety of Mena (1312kg/ha) in both years and performed consistently over years (Table 3). In 2022-year Boset (2075kg/ha), Gemechis (2858kg/ha), Mechere (2049kg/ha), Tseday (2153kg/ha), varieties had the highest grain yield. While the lowest grain yield was recorded from the varieties of Workiyu (1293kg/ha) and Mena (1327kg/ha) (Table 4). In 2023-year Genete (1576kg/ha), Mechere (1611kg/ha), Zobel (1677kg/ha), varieties had the highest grain yield. While the lowest grain yield was recorded from the varieties of Bora (1154kg/ha) (Table 5). In 2022 cropping year relatively higher yield was obtained as compared to in 2023 cropping season that may due to the suitable climatic condition such as moisture and proper crop management in the critical cropping period. Generally, Mechere and Zoble are the two important varieties which have given the highest grain yield as compared to other varieties.

Table 3. *Mean separation from combined analysis of variance for yield and other traits of Tef Varieties evaluated over two (2022 and 2023) cropping season.*

Varieties	DM	PH	PL	BY	GY	HI
Amarach	122.33	74.1	30.7	5347.22	1694.32	31.69
Bora	112.33	71.43	30.5	4806.02	1334.74	27.76
Boset	116.83	67.07	27.43	5390.41	1707.4	31.4
Genete	119.5	74.07	29.8	5192.59	1496.34	28.87
Lakech	119.67	74.53	31.2	4610.5	1395.2	30.27
Mechere	119.33	76.83	33.67	5561.57	1830.18	33.21
Mena	121.17	77.73	31.4	3988.89	1312.62	33.62
Simada	110.5	64.57	27.07	4004.63	1438.5	36.47
Tseday	115.5	70.27	29.13	5229.94	1761.22	33.57
Workiyu	118.17	81.1	32.77	4074.07	1354.15	34.47
Zobel	118.83	77.37	32.33	4679.76	1824.42	38.98
GM	117.65	73.55	30.55	4807.78	1559.01	32.75
LSD	0.73	3.87	ns	337.19	104.67	1.48

LSD= Least significant difference, GM=Grand mean, DM=Days to maturity, PH=plant height, PL=Panicle length, BY=Biomass Yield, GY=Grain yield, HI=Harvest index

Table 4. *Mean separation from separate analysis for yield and yield related traits of tef varieties evaluated at Simada in 2022 cropping season.*

Varieties	DM	PH	PL	BY	GY	HI
Amarach	122.0	84.2	32.4	5416.67	1981.88	36.46
Bora	113.0	73.4	30.4	5075.00	1514.58	29.96

Varieties	DM	PH	PL	BY	GY	HI
Boset	115.0	67.4	26.47	5966.00	2075.44	34.77
Gemechis	117.0	92.67	35.07	7997.33	2858.35	35.81
Genete	121.0	72.13	27.8	4866.67	1415.83	29.10
Lakech	118.7	73.53	30.33	5054.33	1580.58	31.53
Mechere	120.3	83.33	34.53	5475.00	2049.06	37.47
Mena	121.74	85.2	32.07	3533.33	1327.56	37.61
Simada	114.0	74.67	29.13	3750.00	1580.52	42.24
Tseday	116.3	73.53	28.93	6237.67	2153.00	34.58
Workiyu	119.7	85.8	33.27	3333.33	1293.02	39.46
Zobel	121.0	86.87	35.33	5007.67	1971.25	39.36
Mean	118.31	79.39	31.31	5142.75	1816.76	35.70
CV	1.38	12.29	11.24	12.00	13.00	8.30
LSD	2.76	ns	ns	1045.03	399.97	5.01

LSD= Least significant difference, GM=Grand mean, DM=Days to maturity, PH=plant height, PL=Panicle length, BY=Biomass Yield, GY=Grain yield, HI=Harvest index

Table 5. *Mean separation from separate analysis for yield and yield related traits of tef varieties evaluated at Simada in 2023 cropping Season.*

Varieties	DM	PH	PL	BY	GY	HI
Amarach	122.67	64.00	29.00	5277.78	1406.76	26.91
Bora	111.67	69.47	30.60	4537.04	1154.91	25.56
Boset	118.67	66.73	28.40	4814.81	1339.35	28.03
Genete	118.00	76.00	31.80	5518.52	1576.85	28.64
Lakech	120.67	75.53	32.07	4166.67	1209.81	29.01
Mechere	118.33	70.33	32.80	5648.15	1611.30	28.95
Mena	120.67	70.27	30.73	4444.44	1297.68	29.63
Simada	107.00	54.47	25.00	4259.26	1296.48	30.69
Tseday	114.67	67.00	29.33	4222.22	1369.45	32.56
Workiyu	116.67	76.40	32.27	4814.81	1415.28	29.47
Zobel	116.67	67.87	29.33	4351.85	1677.59	38.59
Mean	116.88	68.92	30.12	4732.32	1395.95	29.82
CV	1.43	7.98	7.9	15.17	12.63	9.86
LSD	2.84	9.37	4.05	ns	300.39	5.01

LSD= Least significant difference, GM=Grand mean, DM=Days to maturity, PH=plant height, PL=Panicle length, BY=Biomass Yield, GY=Grain yield, HI=Harvest index

3.6. Association of Grain Yield and Yield Related Traits

In 2022 cropping season biomass yield was positively correlated with grain yield. Days to maturity showed positively and significant ($p<0.05$) correlated with days to heading (0.87*), plant height showed positively and significant ($p<0.05$) correlated with days to maturity (0.48*), panicle length showed positively and significant ($p<0.05$) correlated with days to maturity (0.47*), panicle length showed positively and highly significant ($p<0.01$) correlated with plant height (0.89**), gain yield showed positively and highly significant ($p<0.01$) correlated with biomass yield (0.89**) and strong and non-significant correlation coefficient between grain yield with days to maturity (0.75^{ns}).

Table 6. *Correlation Coefficient of traits.*

	2022						
	DH	**DM**	**PH**	**PL**	**BY**	**GY**	**HI**
DH	1						
DM	0.87*	1					
PH	-0.11	0.48*	1				
PL	-0.14	0.47*	0.89**	1			
BY	-0.17	-0.17^{ns}	0.12^{ns}	0.12^{ns}	1		
GY	-0.21	0.75^{ns}	0.29^{ns}	0.29^{ns}	0.89**	1	
HI	-0.09	0.19^{ns}	0.35^{ns}	0.35*	-0.32^{ns}	0.12^{ns}	1
	2023						
	DM	PH	PL	BY	GY	HI	
DM	1						
PH	0.46**	1					
PL	0.42**	0.827**	1				
BY	0.05^{ns}	0.029^{ns}	0.097^{ns}	1			
GY	0.14^{ns}	0.31*	0.23^{ns}	0.7**	1		
HI	0.12^{ns}	0.41**	0.21^{ns}	-0.32	0.43**	1	

**= highly Significant difference at $P < 0.01$, * =Significant difference at $P < 0.05$, ns=non-significant difference, DH=Days to heading, DM=Days to maturity, PH=plant height, PL=Panicle length, BY=Biomass Yield, GY=Grain yield, HI=Harvest index

In 2023 cropping season, biomass yield, plant height and harvest index were positively correlated with grain yield. Plant height showed positively and highly significant ($p<0.01$) correlated with days to maturity (0.46**), panicle length showed positively and highly significant ($p<0.01$) correlated with days to maturity (0.42**), panicle length showed positively and significant ($p<0.01$) correlated with plant height (0.83**), grain yield showed positively and significant ($p<0.05$) correlated with plant height (0.31*), gain yield showed positively and highly significant ($p<0.01$) correlated with biomass yield (0.7**), harvest index showed positively and highly significant ($p<0.01$) correlated with plant height (0.7**) and moderately and highly significant correlation coefficient between harvest index with grain yield (0.43**).

4. Conclusion and Recommendation

This study evaluated twelve nationally released tef varieties at a known moisture stress area in South Gondar zone. The combined analysis of variance showed that the tested varieties have different performance to different traits like, days to heading, days to maturity, panicle length, plant height, biomass yield and grain yield. Grain yield is primarily important trait for genotype selection to meet the objective of the conducted activity. Despite the difference in performance of varieties for different traits across years and varieties, namely Mechere and Zoble had the highest yield and consistent performance for grain yield. Generally, the cultivation of improved tef varieties in moisture deficit areas is absolutely crucial for food security and income generation to the communities by enhanced tef production and productivity through using recommended varieties as compared to farmer local varieties. Therefore, these two varieties could be recommended for Simada district and similar areas under rain fed condition.

Abbreviations

CSA: Central Statistics Agency
DZARC: Debrezeyiet Agricultural Research Center

Author Contributions

Alamir Ayenew Worku: Data curation, Formal Analysis, Methodology, Writing - original draft, Writing - review & editing

Dejen Bekis Fentie: Data analysis and writing-reviewing and editing

Conflicts of Interest

The authors declare no conflicts of interest.

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