VARIATION AND ASSOCIATION OF YIELD AND YIELD RELATED TRAITS IN RELEASED TEF (*eragrostis tef* (zucc.) trotter) VARIETIES EVALUATED DURING OFF-SEASON IN ETHIOPIA

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ABSTRACT

Tef is an indigenous and major staple cereal crop in Ethiopia. It adapts to a wide range of environmental conditions and fits to different production systems. Nineteen released tef varieties were evaluated in a randomized complete block design with three replications during the 2007/08 off-season at Debre Zeit Agricultural Research Center (DZARC). The objectives were to estimate the genetic variation in grain yield and yield related traits, and to see the association among traits of released tef varieties under off-season condition. The analysis of variance showed significant ($P \leq 0.01$) variation among the varieties for all traits evaluated except total shoot biomass yield. The correlation analysis showed positive and significant association of grain yield with number of fertile tillers (rg = 0.49, rp=0.32), shoot biomass yield (rg= 0.77, rp=0.71), harvest index (rg = 0.87, rp=0.73) and lodging index (rg = 0.23, rp=0.10). Days to panicle emergence and to maturity, on the other hand, have shown negative association with number of fertile tillers, shoot biomass yield, grain yield, harvest index and lodging index. The highest means of harvest index and grain yield per hectare were obtained for the early maturing varieties as compared to the late ones. Therefore, it is better to use the early maturing varieties (DZ-Cr-37 and Ho-Cr-136) for off- season planting, and double cropping in the central highlands of Ethiopia.

Key words: association, variation, varieties, off-season, tef, yield

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INTRODUCTION

Tef [*Eragrostis tef* (Zucc.)Trotter] is an indigenous staple cereal crop of Ethiopia. It exhibits high level of phenotypic plasticity in phenology and agronomic traits depending on the growing environment. Tef can grow under both low moisture and waterlogging conditions, and is suitable for double and relay cropping (Seyfu, 1993). Its grain and straw are nutritious and well suited for human food and livestock feed, respectively. It is a gluten-free cereal (Spaenij-Dekking *et al.*, 2005), and as such it can be used as an alternative for people allergic to gluten such as wheat products. Due to its gluten free nature and other merits, the current acceptance of tef in Europe, USA and other regions of the world is increasing. All available information, therefore, confirm that tef is a healthy, reliable and low risk crop.

Tef is the leading cereal crop in area coverage (over 2.7 million hectares) and second in total production among all cereals grown in Ethiopia (CSA, 2011). However, its national average yield of 1.27 tons per hectare is very low as compared to other cereals grown in Ethiopia (CSA, 2011). But, it is possible to increase its grain yield up to 4 tons/ha by using improved varieties and management practices under non-lodging condition (Hailu and Seyfu, 2001). The quality and productivity of tef grain are found to vary with the climate and soil types under which it is grown (Seyfu, 1993), the variety and crop management practices used, and season of the year.

The number of released tef varieties in Ethiopia is increasing by more than half in the last six years. It was only about 20 varieties in 2005 (MoARD, 2006) and increased to about 33 varieties in 2010 (MoA, 2011). Most of these varieties were released for high potential areas of the country with the

exception of very few early maturing varieties that were specifically released for the low moisture stress areas. Some of the varieties released for high potential areas are, however, found to grow over a wide range of environment (personal observation). But, critical examination of the potential of all released varieties under different environmental condition is still very essential to generate additional information that can augment our future research.

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, basal culm diameter, shoot biomass and 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).

Studies of correlations among different traits enable determination of the level and magnitude of the components that affect a character. Previous research reports have indicated the presence of significant associations between different traits of tef. Yifru and Hailu (2005) reported significant and positive association between grain yield and number of spikelets per panicle. Similarly, Hailu *et al.* (2003) and Habtamu *et al.* (2011) have reported strong positive association of grain yield with shoot biomass, lodging index, panicle length and plant height. Yifru and Hailu (2005), on the other hand, have found no significant association between grain yield

and all phenologic traits (days to panicle emergence and to maturity, and grain filling period).

No information is so far available on the off-season performance of reeleased tef varieties in Ethiopia. The objectives of the current study, therefore, were: 1) to assess the genetic variability for yield and yield related traits of tef evaluated under off-season conditions; and 2) to see the association among important traits of the released tef varieties under off-season condition at Debre Zeit Agricultural Research Center (DZARC) in the central highlands of Ethiopia.

MATERIALS AND METHODS

The plant materials used in the present study consisted of 19 improved tef varieties released by Debre Zeit and Holetta Agricultural Research centers between 1970 and 2006. The name, year of release, seed color and ecological adaptation of each of the varieties used in the study are given on Table 1.

Table 1. Description of released tef varieties used in the study

Name of Varieties	Year of release	Seed color	Adaptation zone (mase)
DZ-01-354 (Enatite)	1970	Pale white	1600-2400
DZ-01-99	1970	Brown	1600-2400
DZ-01-196 (Magna)	1970	Very white	1800-2400
DZ-01-787	1978	Pale White	1600-2400
DZ-Cr-44	1982	White	1800-2500
DZ-Cr-82	1982	Pale white	1700-2000
DZ-Cr-37 (Tsedey)	1984	White	1600-2400
DZ-Cr-255 (Gibe)	1993	White	1700-2000
DZ-Cr-358 (Ziquala)	1995	White	1400-2400
DZ-01-974 (Dukem)	1995	White	1400-2400
DZ-01-2053 (Holetta Key)	1999	Brown	1900-2700
DZ-01-1278(Ambo-Toke)	2000	White	2200-2400
DZ-01-1281(Gerado)	2002	White	1850
DZ-01-1285 (Koye)	2002	White	1900-2200
DZ-01-1681(Key Tena)	2002	Brown	1600-1900
DZ-01-2675 (Dega Tef)	2005	White	1800-2500
DZ-01-899 (Gimbichu)	2005	White	2000-2500
Ho -Cr-136 (Amarach)	2006	White	Low moisture areas of rift valley
DZ-Cr-387 (Quncho)	2006	Very white	1800-2400

The field experiment was carried out at Debre Zeit Agricultural Research Center (8^0 44' N, 38^0 58 E, and ca. 1860 m. a. s. l.) of the Ethiopian Institute of Agricultural Research (EIAR) during the 2007/08 off-season. The experimental design was randomized complete block design with three replications. Each experimental unit had a plot size of one meter by one meter divided into six rows of one meter length. The spacing between rows, plots and replications was 20 cm, 50 cm and 2 m, respectively. Three grams of seeds was broadcasted along the surface of the six rows in each plot based on the recommended seeding rate of 30 kg per hectare. Planting was done on the 20^{th} of December 2007 by drilling along the rows in each plot.

Forty kg N and 26 kg P (or 60 kg P_2O_5) per hectare fertilizers were used in the form of Urea and diammonkium phosphate (DAP), respectively. DAP was applied at planting while the remaining N as Urea was top dressed at tillering stage. Irrigation water was provided uniformly to each plot every three to five days depending on the availability of moisturc in the soil. All other cultural management operations were done as per the recommended practices for the test locality (Fufa *et al.*, 2001). Plot stands were thinned to 5 cm intra-row spacing at the early tillering stage.

Data were collected on plant and plot basis for 13 phenologic and morpho-agronomic traits. Days to panicle emergence and to maturity, biomass and grain yield, thousand seed weight, harvest and lodging index were assessed on plot basis. On the other hand, data on plant height, length of culm and panicle, and number of fertile tillers per plant and spikelet per panicle were assessed on single plant basis of five previously selected and tagged random samples of plants from each plot and the mean data of the five plants were used for analysis.

For all the traits assessed simple statiscs were first computed to get the ranges, means and standard deviations. Likewise, all data of the measured variables were subjected to analysis of variance to assess the variations among the released varieties under investigation, and simple correlation analyses were performed using the means of the genotypes. All statistical analyses were done using the SAS statistical package version 9 (SAS, 2002).

RESULTS AND DISCUSSION

Estimates of the ranges, means and standard deviations of the various traits evaluated have been presented on Table 2. The varietal mean values for days to panicle emergence and maturity ranged from 46 to 59 and from 90 to 121, respectively. The values observed for days to panicle emergence and maturity in the present study were similar to the results in previous studies reported by Kebebew *et al.* (2001, 2002) and Habte *et al.* (2011). The lowest mean days to panicle emergence and to maturity were in that order observed for Ho-Cr-136, DZ-Cr-37 and DZ-01-99 with values of 47 and 91 days, 48 and 91 days, and 47 and 98 days, respectively. The present findings in these phenologic traits were in line with the main season study results reported for the same genotypes by Habte *et al.* (2011).

Plant height and panicle length in the present study also ranged from 61.2 to 96.6 cm and 24.8 to 40.2 cm, respectively (Table 2). This result is a bit higher for plant height (51-77 cm) and similar for panicle length (24-37cm) with that of the previous main season study reported by Habte *et al.* (2011). On the other hand, the range values observed for plant height (35.4 cm) and panicle length (15.4 cm) in the current study are relatively higher than what had been previously reported by Kebebew *et al.* (2002) and Habte *et al.* (2011).

Likewise, the mean values for shoot biomass and grain yield ranged from 5.0 to 9.0 t/ha and 0.94 to 3.01 t/ha, respectively (Table 2). The highest mean grain yield, shoot biomass yield, number of fertile tillers/plant and harvest index were recorded for those early maturing ones as compared to the late maturing varieties. Thus, DZ-Cr-37 (2.64 t/ha), Ho-Cr-136 (2.248

t/ha) and DZ-01-2053 (2.244 t/ha) were the three top yielders in the current study. DZ-01-99 (1.29 t/ha), DZ-01-196 (1.37 t/ha) and DZ-01-899 (1.445 t/ha), on the other hand, were found to give the lowest mean grain yield. This is contrary to the previous findings reported from evaluations in the main season where the highest yield was obtained from the late maturing varieties (Habte *et al.*, 2011).

The number of fertile tillers per plant ranged from 4.4 to 15.8 with an average of 8.92. The highest mean number of fertile tillers/plant (14.67) was recorded for DZ-Cr-37 (Table 2), and this has correspondence with the previous main season results (Habte *et al.*, 2011). Thus, DZ- Cr-37 and Ho-Cr-136 which gave the highest shoot biomass yield, grain yield and harvest index in the present study, are the most suitable varieties for off-season production.

Table 2. Ranges, means and standard deviations for 13 traits of 19 tef varieties evaluated at DZARC during the 2007/2008 off-season

Traits	Range of values for genotypes				Mean	Standard deviation (±)
	Minimum		Maximum			
	Value	Genotype	Value	Genotype		
Days to panicle emergence	46.00	Ho -Cr-136	59.00	DZ-01-787	53.79	3.63
Days to maturity	90.00	DZ-Cr-37	121.00	DZ-01-354	109.23	9.36
Plant height (cm)	61.20	Ho -Cr-136	96.60	DZ-01-2675	79.69	8.11
Panicle length (cm)	24.80	Ho -Cr-136	40.20	DZ-01-2675	31.47	3.58
Culm length (cm)	39.40	Ho -Cr-136	60.00	DZ-Cr-387	48.21	4.56
No. of fertile tillers/plant	4.40	DZ-Cr-82	15.80	DZ-Cr-37	8.92	2.28
No. of spikelet/main panicle	241.20	DZ-Cr-37	513.80	DZ-Cr-387	401.34	64.42
No. of main panicle branches	10.80	DZ-Cr-37	26.60	DZ-Cr-387	18.53	3.71
Shoot biomass yield (t/ha)	5.00	DZ-01-899	9.00	DZ-Cr-37	7.053	0.999
Grain yield (t/ha)	0.94	DZ-01-99	3.010	DZ-Cr-37	1.879	0.400
Harvest index	0.18	DZ-01-99	0.36	DZ-Cr-37	0.27	0.04
1000- seed weight (mg)	0.25	DZ-Cr-37	0.42	DZ-01-1285	0.34	0.04
Lodging index (%)	56.00	DZ-01-196	79.00	DZ-01-2675	65.70	4.78

The analysis of variance showed that there were significant off-season performance differences for grain yield and yield related traits among the 19 released tef varieties evaluated. Highly significant ($P<0.01$) genotype differences were noted for all of the traits evaluated, except shoot biomass yield which did not exhibit significant ($P=0.05$) genotype effects (Table 3). This finding is in line with the previous reports of Hailu (1988), Habte *et al.* (2011) and Ayalneh *et al.* (2012).

Table 3. Mean squares and simple coefficient of variability for 13 traits of 19 tef varieties evaluated at DZARC during the 2007/2008 off-season

Variable	Replications (df=2)	Varieties (df=18)	Error (df = 36)	CV (%)
Days to panicle emergence	1.95NS	36.38***	2.19	2.75
Days to maturity	16.33***	267.15***	1.80	1.23
Plant height (cm)	27.22NS	132.91***	34.44	7.36
Panicle length (cm)	1.47NS	27.22***	6.22	7.93
Culm length (cm)	11.09NS	45.90***	8.72	6.13
No. fertile tillers/plant	5.88**	13.16***	1.17	12.14
No. spikelet per main panicle	8.08NS	11996.59***	457.25	5.33
No, main panicle branches	2.44NS	33.22***	4.67	11.66
Shoot biomass yield (t/ha)	13.43NS	13.80NS	7.87	12.58
Grain yield (t/ha)	0.73NS	3.63***	0.63	13.39
Harvest index	0.00002NS	0.0034**	0.0010	12.07
Thousand seed weight (mg)	0.00181*	0.0032***	0.0005	6.59
Lodging Index (%)	7.65NS	50.81***	9.72	4.75

df= degrees of freedom; NS = Non significant; *, **, *** significant at P≤0.05, P≤0.01 and P≤0.001, respectively

Genotypic (rg) and phenotypic (rp) correlation analysess were also performed for the 13 traits of tef evaluated in the present study, and highly significant (P≤0.01) correlations were detected among most of the traits of tef evaluated under off-season condition (Table 4). The highest positive correlation was between plant height and panicle length (rg=0.93, rp=0.80), plant height and culm length (rg=0.95, rp=0.81), grain yield and harvest index (rg=0.87, rp=0.73) and between thousand seed weight and lodging index (rg=0.88, rp=0.81). Positive and significant correlations were estimated for grain yield with number of fertile tillers per plant (rg= 0.49, rp=0.32), shoot biomass (rg= 0.77, rp=0.71), harvest index (rg = 0.87, rp=0.73) and lodging index (rg = 0.23, rp=0.10). In the present experiment, the associations between most of the traits showed that the genotypic correlations are higher than the phenotypic correlation coefficients. The positive and significant correlation observed between grain yield and most

of the important traits in this study is in agreement with the previous reports (Hailu, 1988; Kebebew *et al.,* 2003; Habte *et al.,* 2011). Days to both panicle emergence and to maturity, on the other hand, were negatively correlated with number of fertile tillers per plant, shoot biomass yield, grain yield and harvest index. Likewise, at both genotypic and phenotypic level, number of fertile tillers per plant was significantly and negatively correlated with all traits except shoot biomass yield, grain yield, harvest index and lodging index. This is usually a predictable result since most plants with more number of tillers per plant have more grain and biomass yield, harvest index and are easily vulnerable to lodging. The results in the current study are in par with the previous findings of Habtamu *et al.* (2011).

On the other hand, there was negative and non-significant correlation of panicle length with grain yield and harvest index. This indicates that the early maturing varieties with relatively shorter panicle length are most suitable to grow under off-season condition. The current result is in line with the previous findings of Wondewosen *et al.* (2012).

Table 4. Estimates of genotypic (upper diagonal) and phenotypic (lower diagonal) correlation coefficients among 13 traits of 19 released tef varieties evaluated at Debre Zeit during the 2007/08 off season

Para-meters †	DH	DM	PH	PL	CL	FT	SPK	PBMS	SBM	GYP	HI	TSW	LI
DH	1.00	0.85**	0.46*	0.38ns	0.51*	-0.43ns	0.56**	0.58**	-0.16ns	-0.22ns	-0.15ns	0.50*	0.32ns
DM	0.79**	1.00	0.53*	0.46*	0.52*	-0.48*	0.52*	0.51*	-0.15ns	-0.40ns	-0.42ns	0.47*	0.25ns
PH	0.35**	0.43**	1.00	0.93**	0.95**	-0.25ns	0.58**	0.69**	0.14ns	-0.17ns	-0.34ns	0.54*	0.55**
PL	0.31*	0.38**	0.80**	1.00	0.78**	-0.11ns	0.63**	0.63**	0.19ns	-0.09ns	-0.25ns	0.52*	0.57**
CL	0.39**	0.40**	0.81**	0.59**	1.00	-0.32ns	0.52*	0.70**	0.12ns	-0.20ns	-0.37ns	0.50*	0.47*
FT	-0.37**	-0.43**	-0.11**	-0.02**	-0.14ns	1.00	-0.53*	-0.44*	0.28ns	0.49*	0.45*	-0.11ns	0.06ns
SPK	0.52**	0.49**	0.50**	0.54**	0.43**	-0.48**	1.00	0.70**	0.03ns	-0.16ns	-0.19ns	0.46*	0.39ns
PBMS	0.53**	0.45**	0.58**	0.50**	0.57**	-0.31*	0.60**	1.00	0.16ns	-0.08ns	-0.18ns	0.72**	0.66**
SBM	-0.08ns	-0.07ns	0.17ns	0.11ns	0.13ns	0.15ns	0.01ns	0.26*	1.00	0.79**	0.38ns	0.10ns	0.29ns
GYP	-0.17ns	-0.32*	-0.09ns	-0.06ns	-0.17ns	0.32ns	-0.16ns	0.02ns	0.71**	1.00	0.87**	-0.07ns	0.23ns
HI	-0.13ns	-0.33**	-0.22ns	-0.13ns	-0.33**	0.24ns	-0.17ns	-0.17ns	0.04ns	0.73**	1.00	-0.16ns	0.13ns
TSW	0.44**	0.37**	0.42**	0.41**	0.37**	-0.04ns	0.45**	0.58**	0.08ns	-0.13ns	-0.25ns	1.00	0.88**
LI	0.26*	0.20ns	0.48**	0.51**	0.37**	0.10ns	0.39**	0.47**	0.11ns	0.10ns	0.05ns	.81**	1.00

ns = Non significant; *, **, *** significant at P≤0.05, P≤0.01 and P≤0.001, respectively

† DH = Days to heading; DM = Days to maturity; PH= Plant height; CL = Culm length; FT = No. fertile tillers/plant; SPK = No. spikelets/panicle; PBMS = No, main panicle branches; SBM = Shoot biomass yield/plot; GY = Grain yield/plot; HI = Harvest index; TSW = Thousand seed weight; LI = Lodging index.

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Conclusions

The current study revealed the presence of high level of genetic variation among yield and yield related traits of released tef varieties evaluated under off-season condition at Debre Zeit Agricultural Research Center. The analysis of variance also showed highly significant differences for all traits of tef except total shoot biomass yield. The highest number of tillers/plant, grain and biomass yield as well as harvest index and the shortest mean days to panicle emergence and maturity were observed for Ho-Cr-136 and DZ-Cr-37. This shows that both varieties are suitable for off-season production. A positive and significant correlation was detected for grain yield with number of fertile tillers per plant, shoot biomass, harvest index and lodging index. On the other hand, both days to panicle emergence and maturity showed negative correlation with the four most important traits of tef, namely: grain yield; number of fertile tillers per plant; shoot biomass; and harvest index. Therefore, the varieties Ho-Cr-136 and DZ-Cr-37 would be recommended for double cropping and off-season production.

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