Genetic Variation, Correlation and Path Coefficient Analysis In Tef [*Eragrostis Tef* (Zucc.) Trotter] Genotypes For Yield,Yield Related Traits At Maysiye, Northern Ethiopia

Chekole Nigus[1], Wassu Mohammed[2] and Tebkew Damte[3]

[1]Tigray Agricultural Research Institute, Axum Center, P. O. Box.230, Axum, Ethiopia.
[2]Haramaya University Plant Breeding and Genetics, Dire dawa Ethiopia
[3]Ethiopian institute of Agricultural Research, Debre Zeit Center. P. O. Box 32, Debre Zeit, Ethiopia

ABSTRACT

Knowledge on nature and magnitude of variation in tef [Eragrostis Tef (Zucc.) Trotter] genotypes is of great importance to develop varieties for high yield and other desirable traits. The aim of this study was to assess the genetic variation, to determine the association of traits, estimate the direct and indirect effect of yield, and yield related traits. Field experiment was conducted in 2015 cropping season at Maysiye, northern Ethiopia. The genotypes were planted in triple lattice design and evaluated for yield and yield related traits. Genotypes exhibited significant differences for 12 traits and further genetic analyses were carried out. Genotypic (GCV) and phenotypic (PCV) coefficient of variations ranged from 3.35 to 29.58% and 4.4 to 38.44%, respectively. Both the lowest and highest values were for days to maturity and for productive tillers, respectively. Heritability in broad sense (H^2) ranged from 21.74 (culm length) to 74.83% (days to heading) and genetic advance as percent of mean (GAM) ranged from 4.19 (culm length) to 46.89% (productive tillers). Both heritability and genetic advance had medium to high values for lodging index, productive tillers,days to heading and above ground biomass yield. Above ground biomass yield (BIOM), harvest index (HI) and productive tillers both at genotypic and phenotypic levels, while culm length at phenotypic level had positive and significant correlations with yield. Grain yield had significant and negative correlation with days to maturity. Moreover, biomass and harvest index exerted high and positive direct effect on yield and also had positive indirect effects through other traits both at genotypic and phenotypic levels. Therefore, selection of genotypes for biomass, harvest index, early maturity, and higher productive tillers can be used to improve tef grain yield in areas where terminal drought is the major constraints of production. Continuing the study of variability in tef genotypes at different location to identify which traits can be used for direct and causal selection of genotypes for grain yield.

Keywords: Direct Effect, Heritability, Genotypic and Phenotypic (PCV) Coefficient of VariationsandTef Genotypes.

{**Citation:** Chekole Nigus, Wassu Mohammed, Tebkew Damte. Genetic variation, correlation and path coefficient analysis in Tef [*Eragrostis Tef* (Zucc.) Trotter] genotypes for yield, yield related traits at Maysiye, Northern Ethiopia. American Journal of Research Communication, 2016, 4(11): 73-102} www.usa-journals.com, ISSN: 2325-4076.

INTRODUCTION

Ethiopia is center of origin and diversity for Tef, [*Eragrostis tef*(Zucc.) Trotter] (Vavilov, as cited in Seyfu, 1997).Tef is grown by over 6.6 million households, occupying more than three million hectare of land, and constitutes the major staple food grain for over 50 million Ethiopians (CSA, 2015).The crop has desirable traits to cope with the changing climate that generate household income, and fulfilling nutritional needs of farmers (Assefa *et al*., 2015).Tef is also considered to be a healthy food since its grain is free of gluten (SpaenijDekking*et al*., 2005).

In Tigray regional state, tef area coverage, total production and productivity were 184,848.49 hectares, 2,636,017.90 quintal and 1426 kg ha^{-1}, respectively. In this Regional State, tef ranks first in area coverage and production, but low in productivity. Even though, tef has numerous merits and considerable economic significance in Ethiopia, the national average grain yield of tef is relatively low (1575 kg ha^{-1}) (CSA, 2015). However, Tareke *et al*. (2013) reported that the tef yields of 4000 and 2500 kg ha^{-1} on research fields and on farmers' fields, respectively. The major yield limiting factors are the low yield potential of landrace tef, lack of cultivars tolerant to lodging, drought and pests (Assefa *et al.*, 2011). The presence of diverse genotypes in tef has been reported and it is a good opportunity for breeders to select genotypes for traits of interest. The characters with huge variability include days to maturity (60 to 120 days), plant height (31 to 155 cm), number of tillers/plant (5 to 35) (Seyfu, 1993; Kebebew *et al*., 2001). However, it is necessary to investigate further about the magnitude of variation for desirable traits in many genotypes at different locations as much as possible to have good knowledge that can be used to select tef genotypes in breeding programs (Khan *et al.,* 2010; Kotal *et al.,* 2010).

The variability of a crop under study is better assessed from genotypic (GCV) and phenotypic (PCV) coefficients of variations of which high GCV is breeders usually focus for the traits of interest (Solomon *et al*., 2013). Existence of high GCV among the lines indicates the possibility of selecting for some most important traits such as grain yield, panicle length, and harvest index (Kebebew et al. 2001). Heritability also the other genetic parameter to be considered since it indicates how much of the phenotypic variability has a genetic origin thatgives objective information for the genetic selection process (Nechifor *et al.,* 2011). Heritability estimates need to be considered together with genetic advance, which is more important than heritability alone to predict the resulting effect of selecting the best individuals. It had been generally believed that the higher the heritability estimates of given traits, the simpler the selection procedure and the better would be the response to selection (Baloch, 2004). Determination of the interrelationships between various agronomic characters and their direct and indirect effect on grain yield also provide good information necessary for breeders in improving the productivity of crops. Therefore, this research has been conducted; i) to assess the genetic variability in tef genotypes, ii) to determine the heritability and association of traits, and ii) to estimate the direct and indirect effects of traits on grain yield of tef.

MATERIALS AND METHODS

The field experiment was carried out at Axum Agricultural Research Center (AxARC) during 2015 main cropping season at the substation Maysiye (14^{0} 6'43'' North and 38^{0} 36 '41 '' East, altitude of 2200 m.a.s.l.) in TahitaeyMaichew district, in central zone of Tigray, Ethiopia. The agro-ecology is sub humid where most of the middle altitude crops such as tef, wheat, faba bean are commonly grown. The annual rainfall received at the experimental site during the main cropping season was 613.92 mm. Moreover, the mean average annual minimum and maximum temperatures are 12.16 ^{o}C and 26.78^{o}C, respectively. The area is characterized by monomodal rainfall pattern that the main rainy season, locally called *kiremty*, extends from July to end of August.

The experimental material consisted of 49 tef genotypes including released tef varieties and farmers' cultivars aslocal check obtained from Deber Zeit Agricultural Research Center (DZARC), Axum Agriculture Research Centers and farmers. The experiment was laid out in 7x7 triple lattice designs. Each genotype was sown in three rows spaced at 0.2m on 2m x 0.6m plot, while plots, blocks and replications were spaced at 1m, 0.5m and 1.5m, respectively. The recommended tef seed rate of 10 kg/ha (AxARC, 2013/14), 1.2 g of seeds per plot was hand-drilled in rows. Fertilizer rates of 60 kg N and 40 kg P_2O_5 ha^{-1}was used (Seyfu, 1997). The source of nitrogen was Urea and di-ammonium phosphate (DAP) was sources of phosphorus. Di-ammonium phosphate (DAP) applied once at the time of sowing, while urea also applied in split after germination. The first urea application was two weeks after seed germination and the second split was two weeks later after the first application.

Data Collection and Analysis

Data were collected for 14 traits. Days to heading was number of days from 50% of the emergence plants in the plots to 50% plants in the plots showed panicle emergence.Days to 90% maturity number of days from emergence of 50% plant on the plot to the day of 90% plants in the plot reached physiological maturity.Grain filling period was the period from heading to maturity.

Whereas, the following data was collected based on ten randomly selected individual plants.Plant height (cm)ten randomly selected plants from the whole plot was measured from ground level to the tip of the main shoot panicle at maturity and the average were compute for statistical analysis. Plant height was divided into culm and panicle length. Panicle length (cm) Panicle length from the base of the panicle to the tip of panicle and with ten randomly selected panicles averaging for statistical analysis.Culm length (cm) Plant height minus the panicle length of the plant. Lodging index (%) was estimated using the method of Caldicott and Nutall (1979) which gives an index based on both the degree (angle of leaning) on a 0-5 scale and severity percent for each degree of lodging. Where zero indicates plants in upright position and five for plants lying flat on the ground for each plot

$$\text{Lodging index} = \frac{\text{Sum(Lodging scores or degree X the respective percentage area lodged)}}{5}$$

Above ground biomass (kg ha^{-1}) the total above ground biomass for the entire plot and after ten days of sun drying.Grain yield (kg ha^{-1}) the weight of the grain harvested from entire plot. 1000-seed weight the weight of 1000 kernels sampled from the each plot.Harvest index (%) the ratio of grain yield to above ground biomass of the entire plot.

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Above Ground Biomass}} * 100$$

Analysis of variance (ANOVA), using triple lattice design, was computed for all traits by SAS software of version 9.1.3 (SAS Institute Inc., 2004). The variability of each quantitative trait were estimated by simple measures such as mean, range, standard deviation in addition to phenotypic and genotypic variances and coefficients of variation. The phenotypic and genotypic coefficient of variation was computed using the formula suggested by Burton and de Vane (1953) as follows.

$$\text{Genotypic variance } (\sigma^2_g) = \frac{MSt - MSe}{r}$$

Where, σ^2_g = genotypic variance

MSt = mean square of treatment

MSe = mean square of error

r = number of replications

Phenotypic variance (σ^2_p) = $\sigma^2_g + \sigma^2_e$

Where, σ^2_g = Genotypic variance

σ^2_e = Environmental variance

σ^2_p = Phenotypic variance

$$PCV = \left(\frac{\sqrt{\sigma_p^2}}{\bar{x}} \right) \times 100 \quad \text{and} \quad GCV = \left(\frac{\sqrt{\sigma_g^2}}{\bar{x}} \right) \times 100$$

Where: PCV= Phenotypic coefficient of variation

GCV= Genotypic coefficient of variation

$\bar{x}$ = Population mean of the character being evaluated

PCV and GCV values were categorized as low (0-10%), moderate (10-20%) and high (>20) values as indicated by Sivasubranian and Menon (1973).

Broad sense heritability values were estimated using the formula adopted by Falconer and Mackay (1996) as follows.

$$H^2 = \frac{\sigma^2 g}{\sigma^2 p} x100$$

Where, H^2 = heritability in broad sense

σ^2_p = phenotypic variance

σ^2_g = Genotypic variance

Heritability was classified as suggested by Robinson *et al.* (1949) into low (0-30%), moderate (30.1-60%) and high (>60%).

Genetic advance in absolute unit (GA) and percent of the mean (GAM), assuming selection of superior 5% of the genotypes were estimated in accordance with the methods illustrated by Johnson *et al*. (1955) as:

$$GA = K * SDp * H^2$$

Where, GA = Genetic advance

SDp = Phenotypic standard deviation on mean basis;

H^2 = Heritability in the broad sense.

k = the standardized selection differential at 5% selection intensity (K = 2.063).

Genetic advance as percent of mean was estimated as follows:

$$GAM = = \frac{GA}{\bar{X}} x100$$

Where, GAM = Genetic advance as percent of mean

GA = Genetic advance

The GA as percent of mean categorized as suggested by Johnson *et al*.(1955) as follows.0 - 10% = Low, 10 – 20 = Moderate and > 20 = High

Phenotypic and Genotypic Correlation Coefficient Analysis

Phenotypic (rp) and genotypic (rg) correlations between two traits was estimated using the formula suggested by Johnson *et al*. (1955).

$$r_g = \frac{G\,cov_{xy}}{\sqrt{(V_g x.V_g y)}} \qquad r_p = \frac{P\,cov_{xy}}{\sqrt{(V_p x.V_p y)}}$$

Where, r_p = Phenotypic correlation coefficient

r_g = Genotypic correlation coefficient

P_{covxy} = Phenotypic covariance between variables x and y

G_{covxy} = Genotypic covariance between variables x and y

V_{px} = Phenotypic variance of variable x

V_{gx} = Genotypic variance of variable x

V_{py}= Phenotypic variance of variable y

V^{gy} = Genotypic variance of variable y

Path Coefficient Analysis

Path coefficient analysis was carried out using the phenotypic correlation coefficients as well as genotypic correlation coefficients to determine the direct and indirect effects of the yield components and other morphological characters on grain yield. This analysis was computed as suggested by Dewey and Lu (1959) with the following formula**.**

$r_{ij} = P_{ij} + \Sigma r_i k p k_j$

Where,

r_{ij} = mutual association between the independent character (i) and dependent character, grain yield (j) as measured by the correlation coefficients,

P_{ij}= components of direct effects of the independent character (i) on the dependent character(j)as measured by the path coefficients and $\sum rik\,pkj$ = summation of components of indirect effects of a given independent character (i) on a given dependent character (j) via all other independent characters (k). The contribution of the remaining unknown factor was measured as the residual factor (PR), which is calculated as

$$PR= \sqrt{(1-\sum rij\ pij)}$$

RESULTS AND DISCUSSION

The analysis of variance results for the 12traits of 49 tef genotypes are presented in Table 1. The results showed the presence of highly significant (P≤0.01) differences among tef genotypes; for days to heading, plant height, panicle length, culm length, grain filling period, productive tiller, days to maturity, grain yield, above ground biomass, lodging index, thousand seed weight and harvest index. Generally, the analysis of variance results showed the presence of considerable variations among the 49-tef genotypes for all the traits suggesting the higher chance of selecting genotype(s) for trait of interest. The results of analysis of variance allows to carry out further genetic analyses for all traits.

Several authors reported considerable genetic variability for grain yield and its components in tef (Seyfu, 1993; Kebebew *et al*., 2000, 2001, 2002;Habtamu *et al*., 2011a; Plaza-Wüthrich*et al*.2013;Motuma*et al*.,2015). However, the results of the present study is in contrast to the findings of Habtamu *et al*. (2011a) that reported non-significant differences among tef genotypes tested in east Gojam for yield, biomass yield and harvest index. This disparity may be due to the differences of genotypes used in the studies and environments used to test the genotypes. In general, the presence of variations among genotypes for the traits indicate the higher chance of improving the crop through selection.

Table 1. Mean squares from analysis of variances for 12 traits of 49 tef genotypes tested at Maysiye in 2015

Source of variation	Mean square							RE to RCBD (%)	CV(%)
	Replication (2)	Treatments(48)		Block with in reps (adj)(18)	Error		R^2(%)		
		Un-adj	Adj		Intra block(78)	RCBD(96)			
Grain filling period	44.45**	56.53	53.45**	7.2945	7.27	7.27	81	100.00	6.76
Days to heading	44.78**	90.26	90.29**	9.3095	8.97	9.04	85	100.02	6.81
Days to maturity	18.12*	32.31	31.54**	4.7542	5.12	5.06	79	98.6406	2.63
Plant height(cm)	180.6**	63.65	62.82**	18.6983	18.49	18.53	68	100.00	4.91
Panicle length(cm)	42.57*	38.57	36.03**	7.4763	9.88	9.43	70	95.4287	7.43
Culm length(cm)	70.62**	27.23	26.36**	21.1397	13.490	14.92	54	103.60	8.28
Lodging index(%)	202.64ns	264.71	247.68**	72.6784	100.84	95.56	62	94.7632	34.35
Grain yield(kg ha^{-1})	393954*	259848	245521.22**	166522	110676	121147	57	102.99	17.75
Thousand seed weight(g)	0.01ns	0.0186	0.01**	0.007940	0.008	0.01	50	99.0858	25.73
Above ground biomass(kg/ha)	1538699ns	4719736	4659012.7**	1140450	1346059	1307508	67	97.1360	12.75
Harvest index(%)	49.91**	22.783	21.43**	11.0395	9.40	9.7154	59	100.47	14.180

*, and **, significant at P≤0.05 and P≤0.01, respectively.Number in parenthesis representdegree of freedom. Un.adj and adj = unadjusted and adjusted mean squares, respectively RCBD= Randomized completed block design, RE to RCBD =Relative efficiency to randomized completed block design CV= Coefficient of variation, R^2 (%)= R-square by percent

Phenotypic and Genotypic Coefficient of Variation

The GCV ranged from 3.5% for days to maturity to 29.58 % for productive tillers. Traits grouped at lower GCV were grain filling period, days to maturity, plant height, panicle length, culm length, thousand seed weight and harvest index. According to Solomon *et al*. (2009, 2010) plant height, days to maturity and harvest index had low GCV values. In addition, Habtamu*et al*.(2011a) and Habte*et al*. (2015) reported that days to maturity and days to grain filling had low GCV values, respectively.The GCV value found in the present study for harvest index was less than the GCV value reported by Habtamu *et al. (2011a*), which might be attributed due to the influence of the environment on the genotypes. Whereas, days to heading, grain yield, above ground biomass had intermediate GCV value. Only productive tillers and lodging index showed highest GCV value in this study. High values of GCV suggest better scope of improvement for these traits by selection. Therefore, selecting the tef genotypes having higher productive tillers and lower lodging index could help enhancing the productivity of tef.Magnitude of genetic variation has better assessed from genotypic coefficients of variation (GCV) (Solomon *et al*., 2013).

Phenotypic coefficient of variation value ranges from 4.4% for days to maturity to 38.44% for productive tillers. The productive tillers, lodging index, grain yield and grain filling period were categorized into high (>20%) PCV. However, days to heading, panicle length, above ground biomass, thousand seed weight and harvest index were grouped into intermediate (10-20%) PCV value. The third group of PCV had a low (0-10%) value, which was computed for days to maturity, plant height, panicle length and culm length. The different categories (low, intermediate and high) were adopted from Sivasubranian and Menon (1973). Phenotypic coefficient of variation is usually the reflection of the effects of genotypes and environment, if the PCV is greater than GCV it means the environment contributes more than the genes effect for phenotypic expression of the trait (Habte *et al.*, 2015). Previous findings by different researchers (Kebebew *et al*., 2001; Solomon, 2010; Habtamu *et al.* (2011); Habte *et al*., 2015) are similar to the present study results.

Table 2. Therange ,mean, standard deviation, estimates of variance components, broad sense heritability, and genetic advance for 12 traits of 49 tef genotypes at Maysiye in 2015

Traits	Range	Mean ±SD	σ^2g	σ^2ph	H^2	GCV (%)	PCV (%)	GA	GAM (5%)
DH	31.33-56.00	44.32±5.49	27.06	36.17	74.83	11.74	13.57	9.27	20.92
DM	74.67-89.67	84.49±3.28	8.87	13.8	64.28	3.53	4.4	4.92	5.82
PH	77.50-99.10	87.49±4.61	14.78	33.26	44.45	4.39	6.59	5.28	6.03
PAN	32.87-47.33	41.71±3.59	8.81	18.42	47.82	7.11	10.29	4.23	10.13
CL	39.50-51.77	45.76±3.04	3.99	18.37	21.74	4.37	9.36	1.92	4.19
LD	12.00-55.33	28.12±9.39	51.46	144.76	35.55	25.51	42.79	8.81	31.33
PRT	2.13-7.00	3.36±1.12	0.98	1.65	59.22	29.58	38.44	1.57	46.89
GF	29.33-45.33	40.16±4.34	15.36	22.74	68	9.76	11.87	6.64	17
GY	1011.10-2377.20	1937.83±294.30	42391.1	160739	26.37	10.62	20.69	217.81	11.24
BIOM	4369.20-11444.40	8930.43±1254.29	1120513	2417987	46.34	11.85	17.41	1484.42	16.62
TSW	0.23-.53	0.35±0.07	3.96	13.52	29.27	9.12	16.86	2.22	10.17
HI	14.13-27.79	21.80±2.76	3.96	13.52	29.27	9.12	16.86	2.22	10.16

DH= days to heading, GF=grain filling period, DM=days to maturity, PH=plant height, PAN=panicle length, CL=culm length, PRT= productive tiller, LD=lodging index,Gy=grain yield, BIOM=above ground biomass, TSW=thousand seed weight and HI=harvest index σ^2g =genotypic variance, σ^2p= phenotypic variance, H^2=Heritability, GCV (%)= genotypic coefficient of variation, PCV(%)= phenotypic coefficient of variation, GA=genetic advance, GAM=genetic advance percent of mean.

Heritability and Expected Genetic Advance

The number of days to heading, and days to maturity had the highest estimated heritability value (>60%). Thus, this showed that selection of short days to heading and days to maturity is effective for the objective of improvement towards selection of early maturing genotypes. Highest heritability indicates the lesser influence of environment as compared to the genetic factors in controlling the traits and it suggested the progenies had a higher chance to perform the same as the parent. Selection of tef genotypes that had short days to heading and days to maturity is one of the objectives of breeding program in the study area and other areas where erratic rainfall and terminal moisture stress are the major constraints of obtaining high yield. This suggestion is supported with the findings and suggestions of several authors who conducted studies on tef (Kebebew *et al.*,2000,2001; Solomon *et al.*, 2009; Solomon, 2010; Habtamu *et al.*, 2011; Abel *et al*., 2012;Habte *et al*., 2015).

Plant height, panicle length, above ground biomass and productive tillers had moderate heritability values (30-60%). Solomon (2010) reported the above ground biomass was categorized under moderate heritability. Abel *et al*. (2012) also found similar results with the present study results indicating mainly on plant height and panicle length processing intermediate heritability. Whereas, grain yield, grain filling period, harvest index, thousand seeds weight and culm length were categorized into low heritability values (<30%). The low heritability indicates the non- predictable of the phenotype range of environments. Therefore, selection of harvest index, thousand seeds weight, lodging index and culm length will not be predicated over the range of the environments. This showed that these traits are highly influenced by environment. Solomon *et al*. (2009) reported a low heritability and genetic advance estimates for lodging index, which suggested that breeding for lodging resistance in tef would be a demanding task.

Johnson *et al.* (1955) in soybean suggested that heritability estimate with genetic gain are more useful for effective improvement. In addition to high heritability along with high genetic advance as percentage of mean implies the role of additive genes for the expression of the characters and thus it could be very effective in improvement upon selection.

The estimated genetic advance(GA)(as percentage of mean) ranged from 4.19% for culm length to 20.92% for days to heading. The high heritability estimates along with low genetic advance indicates that non-additive type of gene action and genotype x environment interaction plays a significant role in the expression of the trait (Fatema*et al.*, 2011). A similar finding with the present study was reported by Abel *et al*.(2012) and Habte *et al.*(2015). However, Kebebew *et al*. (2001) who found high GA for fertile tiller per plant. The GA values for plant height, culm length, productive tillers and days to maturity were less than 10%. Abel *et al.* (2012) reported low GA for plant height and Kebebew *et al*. (2001) for days to maturity. The estimated genetic advance for grain filling period, grain yield, above ground biomass, thousand seed weight, percent of tef shoot fly damage, panicle length and harvest index was between 10 and 20%. Abel *et al* (2012) reported a moderate GA for panicle length. In general, high GCV, heritability and genetic advance for traits could be an excellent tool for improving through selection of high performing genotypes (Akbar *et al.*, 2003).

Correlation Coefficient of Grain Yield with Others Traits

The phenotypic and genotypic correlations of the different traits are presented in Table 3. There was positive and significant correlation ($P \leq 0.01$) at genotypic level between grain yield and the developmental characters, namely; productive tiller (rg=0.35), above ground biomass (rg=0.62) and harvest index (rg=0.42). While, at phenotypic level grain yield was positively and significantly correlated with above ground biomass (rp=0.57), culm length (rp= 0.22), productive tillers (rp= 0.25) and harvest index (rp=0.51). Correlation between traits used to determine whether selection for one trait will have an effect on another. Positive and significant correlation between traits can be the result of strong coupling linkage between their genes or the characters may be the result of pleiotropic genes that control these characters in the same direction (Kearsey and Pooni, 1996).This positive association of grain yield with productive tillers, biomass and harvest index showed that the selection of these traits enhance the tef production. The positive correlations of tef yield with above ground biomass and harvest index was reported by many authors (Solomon, 2010; Abel *et al.*, 2013; Dagnachew and Girma, 2014; Habte *et.al*, 2015).

At genotypic level grain yield was negatively correlated with days to maturity (rg=-0.28). The negative correlation of grain yield with days to maturity indicated that varieties that require longer days to maturity are not suitable for the study area, as the area is mostly prone to early and late season drought. In contrast to the present study Wondewosen*et al.,* (2012) reported that the negative correlation (*rg*= –0.75, *rp*= –0.49) between grain yield and grain filling period under stress environment suggests the possibility of using rapid maturity to escape the effects of drought.

Even though, it is known that lodging causes yield loss and tef grain quality deterioration, lodging index did not show significant association ($P \geq 0.05$) with grain yield at genotypic level. Negative correlation is due to the effect of different genes or pleiotrophic genes that have dominance on the characters and control the characters in different directions (Kearsey and Pooni, 1996). Significant and negatively correlated trait indicated that as the independent trait increased the dependent trait grain yield decreased. On both signs of association the significance level tells, weather the association is by chance or not.

Correlation Coefficient of Above Ground Biomass with other Traits

Above ground biomass had positive and negative significant correlation with other traits. At genotypic level, above ground biomass yield showed highly significant and positive correlation ($P \leq 0.01$) with plant height (rg=0.4), culm length (rg=0.45) and thousand seed weight(rg=0.33) . Whereas, at phenotypic level, above ground biomass had positively correlated ($P \leq 0.05$) with days to heading (rp= 0.21), days to maturity (rp=0.18), plant height (rp= 0.40), panicle length(rp= 0.21) and culm length (rp= 0.33). But, the harvest index (rg=-0.41, rp=-0.33) at genotypic and phenotypic level, respectively, had negative and significant ($P \leq 0.01$) correlation with above ground biomass. Positive association of days to heading with above ground plant biomass revealed that long duration plants were more vigorous (Solomon *et al*., 2009).

The direct selection of positively correlated traits like plant height and thousand seed weight with above ground biomass could improve total biomass, while, selection of negatively correlated traits reduce the biomass.

Correlation Coefficient among others Traits

Days to heading was positively and significantly ($P \leq 0.01$) correlated with days to maturity (rg= 0.61), plant height (rg= 0.68), panicle length (rg= 0.55) and culm length (rg= 0.40) at genotypic level. In addition to this, plant height (rp=0.47) and panicle length (rp= 0.41), culm length (rp=0.23) had positive association with days to heading at phenotypic level. In contrary, days to heading had negative and highly significant ($P \leq 0.01$) correlation with lodging index (rg=-0.51) and grain filling period (rg=-0.80) at genotypic level. At phenotypic level, days to heading was negatively associated with productive tillers (rp=-0.48), lodging index (rp=-0.33) and grain filling period (rp=-0.78) and harvest index (rg=-0.32). When a plant had high number of productive tillers, it needs more nutrient and moisture for its growth. However, if moisture is limiting as it was in the study site, these tillers would compete for moisture and were forced to early heading. Good performance of plant growth required long time; thus plant height, panicle length, culm length and biomass showed positive correlation with days to heading. Kebebw*et al*., (2002) findings the positive association of Days to heading and days to maturity.

Days to maturity had positive and significant association with plant height (rg= 0.51,rp= 0.35), panicle length (rg= 0.51,rp= 0.41) at genotypic and phenotypic level, respectively. However, there was negative and significant correlation between days to maturity and productive tillers (rg= -0.75, rp= -0.53) and harvest index (rg=-0.42,rp= -0.21) at genotypic and phenotypic level, respectively. Tef genotypes with long days to maturity have tall plant height and longer panicle, as a consequence, more photosynthetic products is not used for the seed setting. The harvest index was negatively correlated with days to maturity, because of the long time to maturity causes low grain yield production in areas having moisture stress. As Wondewosen*et al*.(2012) reported this is due to results in poor assimilation, reduced translocation of photosynthates to the grain and higher respiratory losses. In addition to this wondewosen found negative correlation between days to maturity and harvest index at genotypic and phenotypic level. Hence, grain yield is positively correlated with harvest index in such condition.

At genotypic level, lodging index had positive and significant ($P<0.01$) correlation with grain filling period (rg=0.5), productive tillers (rg= 0.32) and also at phenotypic level, with productive tillers (rp=0.25), grain filling period (rp=0.37) and harvest index (rp=0.18). The positive association between lodging index and grain filling period indicated that the shorter the time to grain filling, might help to reduce lodging of tef as well as the longer grain filling period giving higher grain and causes higher lodging. However, lodging index does not have correlation with grain yield. Similarly, high harvest index means high grain yield and high grain yield in turn is correlated negatively with lodging index. Varieties, which have large number of tillers, also had large number of plant population per unit area and weak stem because of competition. Consequently, the tef plants lodge easily. Therefore, selection of genotypes with short days to grain filling and maximum number of productive tillers reduce the lodging index and increase lodging index, respectively. This study was in agreement with Habte *et al*. (2015) finding that showed lodging index had negative correlation with days to head , days to maturity , plant height and culm length.

Number of productive tillers had positive and significant ($P \leq 0.01$) correlation with harvest index (rg=0.38,rp=0.24) at genotypic and phenotypic level, respectively. The more the number of productive tiller, relatively the more will be the grain yield, which ultimately increases the harvest index. The lack of variation for lodging resistance and other lodging-resistance related traits may be a result of un favorable associations/correlations of lodging tolerance with productivity promoting traits such as plant height, panicle length, grain and shoot biomass yield (Kebebew *et al*., 2011).

Table 3.Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients for 12 grain yield and yield related traits in 49 tef genotypes

Traits	GF	DH	DM	PH	PAN	CL	LD	PRT	GY	TSW	BIOM	HI
GF		-0.8**	-0.02	-0.48**	-0.31*	-0.37**	0.5**	0.28*	0.1	0.09	-0.15	0.24
DH	-0.78**		0.61**	0.68**	0.55**	0.39**	-0.51**	-0.67**	-0.25	-0.01	0.22	-0.44**
DM	0.05	0.58**		0.51**	0.51**	0.18	-0.18	-0.75**	-0.28*	0.09	0.16	-0.42**
PH	-0.31**	0.47**	0.35**		0.76**	0.63**	-0.37**	-0.58**	-0.02	0.2	0.39**	-0.41**
PAN	-0.18*	0.41**	0.41**	0.68**		-0.02*	-0.39	-0.71	-0.15	0.21	0.14	-0.26
CL	-0.24**	0.23**	0.05	0.67**	-0.09		-0.09	-0.04*	0.16	0.06	0.45**	-0.32*
LD	0.37**	-0.33**	-0.04	-0.2*	-0.22**	-0.05		0.32*	0.002	-0.06	-0.22	0.23
PRT	0.18*	-0.48**	-0.53**	-0.37**	-0.49**	0.01	0.25**		0.35*	-0.13	-0.028	0.38**
GY	0.09	-0.11	-0.06	0.17*	0.01	0.22**	0.09	0.25**		0.23	0.61**	0.42**
TSW	0.1	-0.01	0.11	0.15	0.18*	0.02	-0.08	-0.08	0.08		0.33*	-0.08
BIOM	-0.12	0.21*	0.18*	0.39**	0.21*	0.33**	-0.1	0.03	0.57**	0.16*		-0.41**
HI	0.23**	-0.32**	-0.21**	-0.19*	-0.16	-0.11	0.18*	0.24**	0.51**	-0.05	-0.33**	

GF=grain filling period, DH=days to heading, DM=days to maturity, PH=plant height, PANL=panicle length, CL=culm length LD=lodging index, PRT= productive tiller, GY=grain yield, BIOM= above ground biomass, HI=harvest index and TSW=thousand seed weight. At * and ** p≤0.05 and p≤0.01 level, respectively

Path Coefficient Analysis

The path coefficient analysis using grain yield as dependent variable and the other characters as independent variable was carried out. Direct and indirect effect at genotypic and phenotypic level is presented in Table 4 and 5, respectively.Path coefficient analysis measures the direct influence of one variable upon the other, and permits separation of correlation coefficients into components of direct and indirect effects. Portioning of total correlation into direct and indirect effects provide actual information on contribution of characters and thus form the basis for selection to improve the yield (Mudasir*et al*., 2010). The residual factor for tef at genotypic level was 0.2428 implied that characters included in the path analysis explained 75.72 % of the total variation in grain yield per hectare while, the remaining 24.28 % was contributed by other factors not included in the path analysis. Moreover, the residual factor for phenotypic level was 0.344 by explaining 65.6% total variation in the grain yield per hectare whereas; the remaining 34.4% was out of the path. The maximum value of residual factor in phenotypic path analysis indicates the higher environmental factors influenced grain yield than at genotypic level.

Genotypic Path Coefficient Analysis

Above ground biomass and harvest index exerted positive and direct effect of 0.928 and 0.739, respectively, on grain yield. These traits also had significant and positive genotypic correlations with grain yield. Productive tillers had negative direct effect (-0.08) on grain yield. Selection of traits that had positive and direct effect on yield enhances the tef yield in subsequent generation. The strong and positive correlation along with positive direct effect was indicating the truerelationship between above ground biomass and grain yield. Moreover, traits that had both positive direct effects and positive and significantly correlated with grain yield are the most preferred traits for selection. Above ground biomass had also positive indirect effect through days to heading, panicle length and culm length. However, it had negative indirect effect via plant height, grain filling, days to maturity and harvest index. Therefore, above ground biomass as well as days to heading, panicle length and culm length can be considered asgood contributor tograin yield and suggesting important traitsfor selection in a breeding program for higher grain yield of tef. However, traits with negative indirect effect through above ground biomass yield need to be managed during selection because the selection of traits might have reducing effect on yield.

Dagnachew and Girma (2014) found positive and direct effect of days to heading, panicle length and harvest index on grain yield. Days to 90% maturity had negative direct effect on tef grain yield. Mengesha *et al*. (1965) reported that panicle length has strong and positive direct effect on grain yield. In contrast to present study Ayalneh*et al*.(2012) reported the highest direct effect of thousand seed weight on grain yield (0.393). Habtamu *et al*. (2011b) reported that Biomass had the highest direct effect on grain yield. While, harvest index had negative direct effect on grain yield. Grain filling period had high indirect effect through biomass on grain yield.

The path coefficient analysis showed that days to heading followed by grain filling period exhibited the highest direct effect at genotypic level suggested the high contribution of this trait to grain yield of tef. Days to heading had also positive and high indirect effect through panicle length, culm length,above ground biomass yield, in the ranged between 0.2 to 1.45. But it had negative and highest indirect effect via grain filling period, plant height, days to maturity and harvest index ranged from -0.34 to -2.31 with cumulative contribution of -0.25. Whereas, grain-filling period had positive and high indirect effect plant height and harvest index but it had also negative and highest indirect effect through days to heading, panicle length and above ground biomass ranged from -0.14 to -2.60 with positive cumulative contribution of 0.1. The experimental site is experienced short rainy season suggesting the short days to heading and short grain filling period might contributing to the high yield of early maturing genotypes. This implies that days to heading has significant influence on grain yield of tef that the short days to heading and grain filling the higher would be the grain yield. Thus, tef genotypes that exhibited short days to heading and grain filling period need to be considered as potential genetic materials for improving tef production through selection.

Table 4.Estimates of direct (bold and underlined diagonal) and indirect effect (off diagonal) of 11 traits on grain yield at genotypic level in 49 tef genotypes at Maysiye in 2015

	GF	DH	DM	PH	PAN	CL	LD	PRT	TSW	BIOM	HI	rg
GF	**2.645**	-2.562	0.032	1.594	-0.787	-0.813	-0.015	-0.022	-0.002	-0.143	0.177	0.102
DH	-2.121	**3.196**	-1.272	-2.283	1.404	0.879	0.016	0.054	0.000	0.203	-0.325	-0.248
DM	-0.040	1.949	**-2.085**	-1.705	1.304	0.393	0.006	0.060	-0.003	0.150	-0.309	-0.280*
PH	-1.259	2.178	-1.061	**-3.350**	1.955	1.395	0.011	0.046	-0.006	0.371	-0.302	-0.020
PAN	-0.812	1.749	-1.060	-2.553	**2.565**	-0.049	0.012	0.057	-0.006	0.137	-0.193	-0.152
CL	-0.972	1.270	-0.370	-2.112	-0.056	**2.212**	0.003	0.003	-0.002	0.418	-0.234	0.160
LD	1.324	-1.621	0.385	1.245	-1.023	-0.215	**-0.031**	-0.026	0.002	-0.206	0.169	0.002
PRT	0.738	-2.140	1.563	1.930	-1.814	-0.096	-0.010	**-0.080**	0.003	-0.026	0.281	0.350*
TSW	0.242	-0.044	-0.205	-0.677	0.543	0.134	0.002	0.010	**-0.027**	0.310	-0.057	0.230
BIOM	-0.408	0.700	-0.337	-1.340	0.378	0.996	0.007	0.002	-0.009	**0.928**	-0.301	0.616
HI	0.634	-1.406	0.871	1.367	-0.669	-0.702	-0.007	-0.031	0.002	-0.378	**0.739**	0.421

GF=grain filling period, DH=days to heading, DM=days to maturity, PH=plant height, PANL=panicle length, CL=culm length LD=lodging index, PRT= productive tiller, GY=grain yield, BIOM= above ground biomass, HI=harvest index and TSW=thousand seed weight. At * and ** p≤0.05 and p≤0.01 level, respectively, r=0.2428.

Phenotypic Path Coefficient Analysis

Above ground biomass (0.817) and harvest index (0.77) had high and positive direct effect on grain yield. Days to maturity exerted positive direct effect on grain yield at phenotypic level. All except days to maturity had positive correlations with grain yield, however, above ground biomass yield and harvest index had significant and positive correlations. This showed that the strong correlationsof above ground biomass yield and harvest index with grain yield were largely due to the direct effect of the traits. Therefore, direct selection of the high performing genotypes for these traits will improve the mean grain yield of the selected genotypes. Dagnachew and Girma (2014) and Abel *et al*. (2013) in agreement to the present result the highest direct effect obtained on harvest index(0.617) and biomass weight per plant (0.079). Habtamu et al.(2011b) findings showed that biomass had the higher direct effect on grain yield.

Days to heading (-0.42), grain filling period (-0.33) and plant height (-1.27) had negative direct effect on grain yield. All except days to heading had positive correlation with yield. This showed that the negative correlation of days to heading with yieldwas largely due to the direct effect of the trait. Therefore, direct selectionlong days to heading will led to grain yield reduction. The higher phenotypic direct effect indicated that environment constituted a major portion of the total phenotypic variation of the trait. Generally, direct selection of traits with higher phenotypic and negative direct effect for the improvement of the tef production might be misleading. The negative direct effect by plant height was also reported by Dagnachew and Girma (2014). Negative direct effect by days to heading on grain yield was also reported by Habtamu et al., 2011b).

In general, direct selection of panicle length, above ground biomass, culm length and harvest index at phenotypic level enhance the improvement of tef grain yield. However, direct selection of days to heading, grain filling and plant height hinders the improvement of tef grain yield. Tef grain yield can improve through indirect selection of grain filling period and panicle length via days to heading. In addition, panicle length and culm length also enhance the yield by indirect selection via plant height. As Ayalneh*et al*. (2012) reported number of productive tillers had positive correlation with grain yield but, negative direct phenotypic effect.

Days to maturity had positive direct effect (0.304) on grain yield and positive indirect effect through panicle length (0.316), but it had also negative indirect effect via days to heading (-0.309) and plant height (-0.357). Above ground biomass (0.817) and harvest index (0.77) had positive direct effect on grain yield. But both had negative indirect effect one through the other viz. above ground biomass through harvest index (-0.25) and harvest index through above ground biomass (-0.26). In addition, harvest index via plant height (0.199) had positive indirect effect on grain yield. Habtamu et al. (2011b) reported that days to heading and plant height had negative indirect effect on grain yield through grain filling period. Whereas, days to maturity has positive direct effect on grain yield and negative direct of plant height on grain yield.

There was a zero direct effect thousand seed weight on grain yield. The result of zero indirect effect of these traits might be due to the correlation might be weak. Habtamu et al (2011b) reported that panicle length exerted negligible direct effect due to counterbalancing of indirect effects through other traits. As Mamma (2014) reported, the number of leaves per plant had zero percent of contribution on grain yield on cowpea.

Table 5.Estimates of direct (bold and underlined diagonal) and indirect effect (off diagonal) of 11 traits on grain yield at phenotypic level in 49 tef genotypes at Maysiye in 2015

TRAITS	GF	DH	DM	PH	PAN	CL	LD	PRT	TSW	BIOM	HI	rp
GF	**-0.432**	0.413	0.016	0.318	-0.137	-0.191	0.015	0.004	0.000	-0.098	0.180	0.088
DH	0.338	**-0.530**	0.177	-0.483	0.309	0.182	-0.013	-0.011	0.000	0.170	-0.249	-0.109
DM	-0.023	-0.309	**0.304**	-0.357	0.316	0.042	-0.002	-0.012	0.000	0.144	-0.163	-0.060
PH	0.135	-0.250	0.106	**-1.022**	0.517	0.525	-0.008	-0.008	0.000	0.324	-0.150	0.168
PAN	0.078	-0.215	0.126	-0.694	**0.761**	-0.071	-0.009	-0.011	0.000	0.170	-0.120	0.014
CL	0.105	-0.123	0.016	-0.683	-0.069	**0.785**	-0.002	0.000	0.000	0.271	-0.083	0.217
LD	-0.160	0.172	-0.012	0.205	-0.165	-0.043	**0.040**	0.006	0.000	-0.083	0.139	0.100
PRT	-0.077	0.254	-0.162	0.373	-0.377	0.008	0.010	**0.023**	0.000	0.021	0.182	0.254
TSW	-0.044	0.008	0.033	-0.158	0.140	0.017	-0.003	-0.002	**-0.003**	0.132	-0.037	0.085
BIOM	0.052	-0.110	0.053	-0.405	0.159	0.260	-0.004	0.001	0.000	**0.817**	-0.254	0.568
HI	-0.101	0.171	-0.064	0.199	-0.119	-0.085	0.007	0.005	0.000	-0.269	**0.770**	0.515

GF=grain filling period, DH=days to heading, DM=days to maturity, PH=plant height, PANL=panicle length, CL=culm length LD=lodging index, PRT= productive tiller, GY=grain yield, BIOM= above ground biomass, HI=harvest index and TSW=thousand seed weight. At * and ** $p \leq 0.05$ and $p \leq 0.01$ level, respectively, **r=0.344**.

Conclusion

The presence of considerable variations among tef genotypes has been observed indicating the potential of improving the crop through selection of genotypes that combine the traits of interest. It also suggested the country has rich genetic resources for the crop as center of origin and diversity. Days to maturity, biomass and productive tillers had medium to high values of heritability whereas, except days to maturity failed at low genetic advance as percent of mean biomass, productive tillers and harvest index had medium to high values of genetic advance indicating that these traits were less influenced by environmental factors. Considering all genetic variability components biomass yield and harvest index can be used for, directselection while, early maturity, and productive tillers indirect selection of genotypes to improve tef grain yield in areas where terminal drought is the major constraints of production. Tef genotypes that exhibited short days to heading and grain filling period need to be considered as potential genetic materials for improving tef production through selection. It can be concluded that the importance of continuing the study of variability in tef genotypes at different location to identify which traits can be used for causal selection of genotypes for grain yield.

ACKNOWLEDGEMENTS

I thank you for Axum Agricultural Research Center for supporting the financial support and DebreZeit Agricultural Research Center providing a material of tef seed

REFERENCES

Abel Debebe, Harijat Singh and HailuTefera. 2012. Genetic Variability and Heritability Studies in F_4 Progenies of Tef (*Eragrostistef*).*Asian Journal of Agricultural Sciences* 4(3): 225-228.

Assefa K, Cannarozzi G, Girma D, Kamies R, Chanyalew S, Plaza-Wüthrich S, Blösch R, Rindisbacher A, Rafudeen S and Tadele Z. 2015. Genetic diversity in tef [*Eragrostistef*(Zucc.)Trotter].*Frontiers in Plant Science,* 6:177.

Assefa, K.,Yu,J.K., Zeid, M., Belay, G.,Tefera, H., and Sorrells, M.E. 2011. Breeding tef [*Eragrosttef*(Zucc.) trotter]:conventional and molecular approaches. *Plant Breed.*130,1-9 .doi:10.1111/j.1439- 523.2010.01782.x.

Axum Agriculture Research Center(AxARC). 2014. Axum Agriculture Research Center annual research report for the period of 2013/14. Axum Tigray, Ethiopia.

Ayalneh T., A. Amsalu and Z. Habtamu. 2012. Genetic Divergence, Trait Association and Path Analysis of TEF (*Eragrostistef*(Zucc.) Trotter) Lines.*World Journal of Agricultural Sciences*, 8 (6): 642-646.

Baloch M J. 2004.Genetic variability and heritability estimates of some polygenic traits in upland cotton.*Pakistan Journal of Science,* 47(6): 451-454.

Burton GWand de vane EH. 1953. Estimating heritability in Tall Fescue (*FestucaArundinacea*) from replicated clonal material. *Agronomy Journal*. 45: 481-487.

Caldicott JJB and Nuttall AM. 1979.A method for the assessment of lodging in crops. *Netherland Journal of Agricultural Bot*any, 15:88-91.

CSA(Central Statistical Agency). 2015. Agricultural Sample Survey *for2013/14*.Statistical Bulletin 578 .Addis ababa, Ethiopia: Central Statistical Agency. 26

DagnachewLule and GirmaMengistu. 2014. Correlation and Path Coefficient Analysis of Quantitative Traits in Tef [*Eragrostistef (Zucc*.) Trotter] Germplasm Accessions from Different Regions of Ethiopia.*American Journal of Research Communication*.Vol 2(2) 194-204.

Dewey, D.R.and K.H. Lu. 1959. A Correlation and path-coefficient analysis of components of crested wheatgrass seed production. *Agronomy Journal*., 51: 515-518.

Falconer, D.S. and T.F.C. Mackay. 1996. *Introduction to Quantitative Genetics*. 4th edit., Benjamin Cummings, England, Pages: 464.

GutaMotumaBedane, AlosioMomoSaukuru, Doug Lloyd George, MadanLal Gupta. 2015. Evaluation of teff (*Eragrostistef*[Zucc.] Trotter) lines for agronomic traits in Australia.*Australian Journal of Crop Science,* 9(3):242-247.

HabtamuAyalew, Tsige Genet and LanduberWondale .2011b.Correlation and Path Coefficient Analysis among Yield Component Traits in Tef [*Eragrostistef*) Zucc.Trotter] Landraces.*Libyan Agriculture Research Center Journal International* 2 (4): 180-185.

HabtamuAyalew, Tsige Genet, TadesseDessalegn and LanduberWondale. 2011a. Multivariate Diversity, Heritability And Genetic Advance In *Tef*Landraces In Ethiopia.*African Crop Science Journal*, 19(3): 201 – 212.

HabteJifar , KebebewAssefa and ZerihunTadele. 2015. Grain yield variation and association of major traits in brown-seeded genotypes of tef [*Eragrostistef* (Zucc.)Trotter].*Agriculture and Food Security* 4:7.

Johnson HW, Robinson HF, Comstock RE. 1955. Estimates of genetic and environmental variability in soybeans. *Agronomy of Jouranl.* 47: 314-318.

Kanizfatema, M. G. rasul, M. A. K. mian and M. M. Rahman .2011. Genetic variability for grain quality traits in aromatic rice (*oryza sativa* l).*Bangladesh Journal of plant breeding and Genetic*, 24(2): 19-24.

Kearsey, M.J. and Pooni, H.S. 1996. *The genetical analysis of quantitative traits.*Chapman and Hall, London, Weinhein, New York, pp. 381.

KebebewAssefa, HailuTefera andArnulfMerker. 2002. Variation and inter-relationships of quantitative traits in tef (*Eragrostistef*(Zucc.) Trotter) germplasm from western and southern Ethiopia.*Hereditas,* 136: 116–125.

KebebewAssefa, HailuTefera, Merker A, TirunehKefyalew and FufaHundera. 2001. Quantitative trait diversity in tef [Eragrostistef (Zucc.) Trotter] germplasm from central and northern Ethiopia.*Genetic Resource and Crop Evolution,* 48:53-61.

KebebewAssefa, SeyfuKetema, HailuTefera, TirunehKefyalewAndFufaHundera .2000. Trait diversity, heritability and genetic advance in selected germplasm lines of tef*[*Eragrostis*tef*(Zucc.) Trotter].*Hereditas* 133: 29-37.

KebebewAssefa, Yu J.K., M. Zeid, G. Gelay, H. Tefera and M. E. Sorrells 2011. Breeding tef [Eragrostistef (Zucc.) trotter]: conventional and molecular approaches. *Plant Breeding* 130, 1-9.

Khan A.J., Azam F., Ali A. 2010.Relationship of morphological traits and grain yield in recombinant inbred wheat lines grown under drought conditions.*Pakistan Journal of Botany*.42(1): 259-267.

Kotal B.D., Das A., and Choudhury B.K. 2010.Genetic variability and association of characters in wheat (*Triticumaestivum*L.).*Asian journal of Crop science*,2(3):155-160.

Mengesha M, Pickett R, and Davis R .1965.Genetic variability and inter-relationships of characters in tef [*Eragrostistef*(Zucc.)Trotter].*Crop Science*, 5:155-157.

Mudasir Hafiz Khan And Abdul NayeemDar . 2010. Correlation And Path Coefficient Analysis Of Some Quantitative Traits In Wheat.*African Crop Science Journal*, Vol. 18, No. 1, Pp. 9 – 14.

Nechifor B., RalucaFilimon, and LizicaSzilagyi. 2011. Genetic Variability, Heritability And Expected Genetic Advance As Indices For Yield And Yield Components Selection In Common Bean (*Phaseolus Vulgaris* L.). *Scientific Papers, University*

SAS Institute Inc. 2004. SAS 9.1.3 Users Guide Cary, NC: SAS institute Inc. USA. S. Memon, M. J.

SeyfuKetema. 1993. Tef, (*Eragrostistef*): Breeding, genetic resources, agronomy, utilization and role in Ethiopian agriculture. Institute of Agricultural Research, Addis Ababa, Ethiopia.

SeyfuKetema. 1997. TefEragrostis*tef*(Zucc.)Trotter.Promoting the conservation and use of underutilized and neglected crops. 12. *Institute of Plant Genetics and Crop Plant Research*, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy.

SivasubranianS, and Menon M. 1973.Heterosis and inbreeding depression in rice.*Madras Agricultural Journal*, 60, 1139-1144. 29.

Solomon Chanyalew, HailuTefera and Harjit-Singh. 2009.Genetic Variability, Heritability and Trait Relationships in Recombinant Inbred Lines of Tef [*EragrostisTef*(Zucc.) Trotter].*Research Journal of Agriculture and Biological Sciences*, 5(4): 474-479.

Solomon Chanyalew, KebebewAssefa and GizawMetaferia. 2013.Phenotypic and Molecular Diversity in Tefpp 22-23. In: ZerihunTadele (eds.) *Achievements and Prospects of tef Improvement; Proceedings of the Second International Workshop*, November 7-9, 2011,DebreZeit, Ethiopia. Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia; Institute of Plant Sciences, University of Bern, Switzerland.Printed at Stampfli AG, 3001 Bern, Switzerland. ISBN: 978-3-033-03818-9.

Solomon Chanyalew.2010.Genetic Analyses of Agronomic Traits of Tef (*Eragrostistef*) Genotypes.*Research Journal of Agriculture and Biological Sciences*, 6(6): 912-916.

Sonia Plaza-Wüthrich, Gina Cannarozzi and ZerihunTadele. 2013. Genetic and phenotypic diversity in selected genotypes of tef [*Eragrostistef*(Zucc.) Trotter.*African journal of agricultural research*,8(12):1041-1049.

Spaenij-Dekking, L, Kooy-Winkelaar, Y and Frits, K. 2005.The Ethiopian Cereal tef in celiac disease.*The New England Journal of Medicine*, 353: 1748-1749.

TarekeBerhe, ZewdieGebretsadik, Sue Edwards and Hailu Araya. 2013. Boosting tef productivity Using Improved Agronomic Practices and Appropriate Fertilizer .pp -143.In: ZerihunTadele (eds.) *Achievements and Prospects of tef Improvement; Proceedings of the Second International Workshop*, November 7-9, 2011, DebreZeit, Ethiopia. Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia; Institute of Plant Sciences, University of Bern, Switzerland.Printed at Stampfli AG, 3001 Bern, Switzerland. ISBN: 978-3-033-03818-9.

WondewosenShiferaw, AlemayehuBalcha, and Hussen Mohammed. 2012.Genetic Variation for Grain Yield and Yield Related Traits in Tef [*Eragrostistef*(Zucc.)Trotter] under Moisture Stress and Non-tress Environments.*American Journal of Plant Sciences,2(3) 1041-1046.*

Yohanna Mamma Kwaga .2014.Direct and Indirect Contribution of Yield Attributes to the Grain Yield of Cowpea [*Vignaunguiculata*(L.)Walp], grown in Northern Guinea Savanna, Nigeria. Research Journal of Pharmaceutical, iological and Chemical Sciences

Table S1. Means of the traits from the 49 tef genotypes tested at Maysiye in 2015

S. No	Tef genotypes	DH	DM	PH	PAN	CL	GF	LD	PRT	GY	BIOM	HI	TSW
1	DZ-01-99(Asgori)	43.67^{e-i}	81.67^{b-i}	88.40^{a-d}	45.73^{ab}	42.67^{a}	38.00^{a-j}	12.67^{d}	3.30^{cde}	2335.60^{a}	9444.40^{a-d}	24.51^{a-d}	0.36^{a}
2	DZ-01-354 (Enatit)	36.33^{ij}	80.33^{e-i}	84.97^{a-d}	38.07^{a-d}	46.90^{a}	44.00^{a-d}	30.00^{a-d}	3.60^{a-d}	2298.10^{a}	9444.40^{a-d}	21.49^{a-d}	0.50^{a}
3	DZ-01-196 (Magna)	47.33^{a-h}	87.00^{a-e}	88.23^{a-d}	43.47^{a-d}	44.77^{a}	39.67^{a-g}	25.67^{a-d}	2.70^{de}	2064.70^{ab}	8888.90^{a-d}	23.28^{a-d}	0.27^{a}
4	DZ-01-787 (Wellenkomi)	45.00^{b-i}	88.33^{abc}	87.30^{a-e}	42.53^{a-e}	44.77^{a}	43.33^{a-d}	28.33^{a-d}	3.07^{de}	1832.50^{ab}	8333.30^{a-d}	21.99^{a-d}	0.40^{a}
5	DZ-Cr-44 (Menagesha	42.67^{d-i}	83.67^{a-h}	93.83^{abc}	47.30^{a}	46.53^{a}	41.00^{a-e}	25.33^{ab}	3.37^{cde}	2255.80^{a}	9444.40^{a-d}	24.08^{a-d}	0.43^{a}
6	DZ-Cr-82 (Melko)	41.00^{e-j}	86.33^{a-f}	88.10^{a-d}	45.87^{ab}	42.23^{a}	45.33^{a}	27.33^{a-d}	2.13^{e}	1385.80^{ab}	6666.70^{cde}	21.79^{a-d}	0.40^{a}
7	DZ-Cr-37(Tsedey	36.67^{ij}	79.33^{f-i}	85.63^{a-d}	37.57^{a-e}	48.07^{a}	42.67^{a-e}	49.67^{ab}	5.17^{a-d}	2085.60^{ab}	9444.40^{a-d}	22.21^{a-d}	0.37^{a}
8	DZ-Cr-255 (Gibe	42.00^{d-i}	85.00^{ab}	88.40^{a-d}	43.53^{a-d}	44.87^{a}	43.00^{a-d}	29.00^{a-d}	3.00^{de}	2286.70^{a}	10000.0^{a-d}	22.87^{a-d}	0.40^{a}
9	DZ-Cr-358 (Ziquala)	39.67^{f-j}	84.00^{a-h}	84.30^{bcd}	42.67^{a-e}	41.63^{a}	44.33^{a-d}	37.67^{a-d}	3.20^{cde}	1854.20^{ab}	7222.20^{b-e}	27.79^{a}	0.40^{a}
10	DZ-01-974 (Dukem)	42.33^{d-i}	85.67^{a-f}	86.97^{a-d}	39.97^{a-e}	47.00^{a}	43.33^{a-d}	37.68^{a-d}	2.67^{de}	1475.80^{ab}	7333.30^{b-e}	19.72^{a-d}	0.37^{a}
11	DZ-01-1281(Gerado	42.33^{d-i}	87.00^{a-f}	83.00^{cd}	39.00^{a-e}	44.00^{a}	44.67^{abc}	26.60^{a-d}	2.530^{de}	1761.20^{ab}	7777.80^{a-e}	22.89^{a-d}	0.37^{a}
12	DZ-01-1285 (Koye)	40.33^{e-j}	83.00^{a-h}	81.20^{cd}	41.70^{a-e}	39.50^{a}	42.67^{a-e}	46.53^{ab}	3.53^{cde}	1667.20^{ab}	7777.80^{a-e}	21.48^{a-d}	0.23^{a}
13	DZ-01-1681 (KeyTena)	40.67^{e-j}	80.33^{e-i}	84.27^{bcd}	42.87^{a-e}	41.40^{a}	39.67^{a-g}	12.00^{d}	3.53^{cde}	2160.80^{ab}	10000.0^{a-d}	21.81^{a-d}	0.27^{a}
14	DZ-01-899 (Gimbichu)	44.33^{b-i}	85.00^{a-h}	89.70^{a-d}	42.43^{a-e}	47.27^{a}	40.67^{a-f}	25.00^{a-d}	3.00^{de}	1882.30^{ab}	9444.40^{a-d}	20.06^{a-d}	0.30^{a}
15	DZ-01-2675 (DegaTef)	41.67^{e-i}	86.33^{a-f}	83.73^{bcd}	39.03^{a-e}	44.70^{a}	44.67^{abc}	44.33^{abc}	2.67^{de}	1908.50^{ab}	9666.70^{a-d}	19.61^{a-d}	0.33^{a}
16	DZ-Cr-387 RIL355 (Quncho)	52.00^{abc}	87.67^{a-e}	99.10^{a}	47.33^{a}	51.77^{a}	35.67^{c-j}	19.67^{bcd}	3.30^{cde}	2130.80^{ab}	11444.40^{a}	20.63^{a-d}	0.53^{a}
17	Ho-Cr-136 (Amarach)	38.67^{f-j}	78.33^{ghi}	85.53^{a-d}	33.80^{de}	51.73^{a}	39.67^{a-g}	55.33^{a}	5.87^{abc}	2177.20^{a}	8888.90^{a-d}	24.47^{a-d}	0.27^{a}
18	DZ-Cr-285 RIL295 (Simada)	31.33^{j}	74.67^{i}	80.37^{cd}	34.87^{cde}	45.50^{a}	43.33^{a-d}	43.33^{a-d}	6.37^{ab}	2139.20^{ab}	8333.30^{a-d}	24.14^{a-d}	0.37^{a}
19	DZ-01-2053 (Holetta Key	37.54^{hij}	82.02^{b-i}	81.72^{cd}	40.00^{a-e}	40.00^{a}	44.48^{a-d}	34.94^{a-d}	4.18^{b-e}	1011.10^{b}	4369.20^{e}	23.40^{a-d}	0.30^{a}
20	DZ-01-1278(Ambo Toke	43.00^{c-i}	85.00^{a-h}	83.50^{bcd}	43.00^{a-e}	40.50^{a}	42.00^{a-e}	40.33^{a-d}	2.80^{de}	1874.40^{ab}	8333.30^{a-d}	22.49^{a-d}	0.33^{a}
21	9441	44.33^{b-i}	85.00^{a-h}	86.53^{a-d}	39.13^{a-e}	47.40^{a}	40.67^{a-f}	35.33^{a-d}	2.83^{de}	2109.70^{ab}	7777.80^{a-d}	27.27^{ab}	0.30^{a}
22	DZ-01-2054 (Gola)	45.33^{b-i}	88.33^{abc}	87.30^{a-d}	43.10^{a-e}	44.57^{a}	43.00^{a-d}	33.33^{a-d}	3.33^{cde}	2091.70^{ab}	8333.30^{a-d}	25.43^{abc}	0.23^{a}
23	DZ-01-146 (Genete)	44.00^{c-i}	88.67^{ab}	88.57^{a-d}	43.23^{a-e}	45.33^{a}	44.67^{abc}	41.00^{a-d}	3.13^{cde}	1917.90^{ab}	9444.40^{a-d}	20.27^{a-d}	0.50^{a}
24	DZ-01-1821 (Zobel)	44.33^{b-i}	88.33^{abc}	90.67^{a-d}	43.30^{a-e}	47.37^{a}	44.00^{a-d}	27.33^{a-d}	3.53^{cde}	2081.10^{ab}	10000.0^{a-d}	20.81^{a-d}	0.37^{a}
25	Acc. 205953 (Mechare)	44.33^{b-i}	86.33^{a-f}	89.33^{a-d}	42.93^{a-e}	46.40^{a}	42.00^{a-d}	21.33^{bcd}	3.00^{de}	2177.20^{a}	10000.0^{a-d}	21.71^{a-d}	0.40^{a}
26	RIL273(Laketch)	45.00^{b-i}	87.67^{a-f}	91.83^{a-d}	40.90^{a-e}	50.93^{a}	42.67^{a-e}	27.33^{a-d}	2.83^{de}	2306.90^{a}	10555.6^{ab}	21.84^{a-d}	0.37^{a}
27	DZ-01-1868 (Yilmana	44.33^{b-i}	88.67^{ab}	91.63^{a-d}	42.87^{a-e}	48.77^{a}	44.33^{a-d}	20.33^{bcd}	2.53^{de}	1555.80^{ab}	9444.40^{a-d}	14.13^{d}	0.30^{a}
28	DZ-01-2423(Dima)	43.00^{c-i}	83.33^{a-h}	83.07^{cd}	38.93^{a-e}	44.00^{a}	40.33^{a-f}	34.20^{a-d}	3.87^{b-e}	2337.90^{a}	10555.6^{ab}	22.08^{a-d}	0.40^{a}
29	DZ-01-3186 (Etsub)	46.00^{a-i}	86.67^{a-f}	91.43^{a-d}	45.13^{abc}	46.30^{a}	40.67^{a-f}	30.33^{a-d}	3.10^{cde}	2129.70^{ab}	10000.0^{a-d}	21.30^{a-d}	0.47^{a}
30	DZ-01-1880 (Guduru	46.33^{a-i}	89.67^{a}	91.20^{a-d}	43.57^{a-d}	47.63^{a}	43.33^{a-d}	30.33^{a-d}	2.23^{e}	1569.20^{ab}	10000.0^{a-d}	16.14^{cd}	0.37^{a}
31	acc. 17 WJ	36.67^{ij}	78.00^{hi}	79.30^{cd}	32.87^{e}	46.63^{a}	41.33^{a-e}	24.00^{a-d}	7.00^{a}	2377.20^{a}	9444.40^{a-d}	25.27^{abc}	0.37^{a}
32	PGRC/E 205396 Ajora)	38.33^{hij}	83.33^{a-h}	89.50^{a-d}	47.20^{a}	42.30^{a}	45.00^{ab}	29.00^{a-d}	3.27^{de}	2278.90^{a}	8888.90^{a-d}	24.33^{a-d}	0.40^{a}
33	DZ-Cr-409/RIL50d (Boset)	43.33^{c-i}	82.00^{b-i}	85.33^{a-d}	41.40^{a-e}	43.93^{a}	38.67^{a-i}	24.33^{a-d}	3.20^{cde}	1633.30^{ab}	6222.20^{de}	25.92^{abc}	0.40^{a}
34	Kora	53.00^{abc}	82.33^{a-h}	93.76^{abc}	47.17^{a}	46.60^{a}	29.33^{i}	17.33^{bcd}	2.47^{de}	1797.90^{ab}	8333.30^{a-d}	22.25^{a-d}	0.33^{a}
35	Zagre (local 1)	38.33^{ghij}	80.33^{e-i}	80.37^{cd}	38.70^{a-e}	41.67^{a}	42.00^{a-e}	22.00^{bcd}	4.87^{a-e}	2017.50^{ab}	10000.0^{a-d}	20.17^{a-d}	0.40^{a}
36	Zezew(local-2)	40.33^{e-j}	81.00^{c-i}	82.07^{cd}	35.87^{b-e}	46.20^{a}	40.67^{a-f}	21.33^{bcd}	5.87^{abc}	2093.10^{ab}	8888.90^{a-d}	23.30^{a-d}	0.27^{a}
37	acc. 13 –AI	37.67^{hij}	80.67^{d-i}	77.50^{d}	34.20^{de}	43.30^{a}	43.00^{a-d}	25.67^{a-d}	4.83^{a-e}	2094.70^{ab}	8888.90^{a-d}	23.49^{a-d}	0.33^{a}

38	*RIL -65*	48.00^{a-g}	87.33^{a-e}	89.77^{a-d}	40.80^{a-e}	48.97^{a}	39.33^{a-h}	23.58^{a-d}	3.07^{de}	1999.40^{ab}	8888.90^{a-d}	22.56^{a-d}	0.27^{a}
39	*RIL-86*	50.33^{a-e}	86.33^{a-f}	86.20^{a-d}	40.13^{a-e}	46.07^{a}	36.00^{b-j}	19.33^{bcd}	2.17^{e}	2046.70^{ab}	9444.40^{a-d}	21.88^{a-d}	0.50^{a}
40	*RIL-190*	55.67^{a}	85.33^{a-h}	93.80^{abc}	43.27^{a-e}	50.53^{a}	29.67^{ij}	20.00^{bcd}	2.17^{e}	1816.90^{ab}	9444.40^{a-d}	19.13^{a-d}	0.33^{a}
41	*RIL-96*	48.67^{a-f}	87.33^{a-e}	86.23^{a-d}	42.80^{a-e}	43.43^{a}	38.67a-i	22.67^{bcd}	2.80^{de}	1629.70^{ab}	9444.40^{a-d}	17.31^{bcd}	0.37^{a}
42	*RIL-109A*	53.00^{abc}	84.67^{a-h}	90.37^{a-d}	45.33^{ab}	45.03^{a}	31.67f-j	25.67^{a-d}	2.33^{e}	2151.10^{ab}	10222.2^{a-d}	21.07^{a-d}	0.40^{a}
43	*RIL-15A*	54.33^{ab}	88.00^{a-d}	85.50^{a-d}	40.60^{a-e}	44.90^{a}	33.67^{e-j}	25.00^{a-d}	3.30^{cde}	1573.60^{ab}	7777.80^{abc}	20.20^{a-d}	0.30^{a}
44	*RIL-52*	47.00^{a-h}	82.67^{a-h}	92.93^{abc}	47.10^{a}	45.83^{a}	35.33^{d-j}	19.00^{bcd}	3.00^{de}	1665.80^{ab}	8333.30^{a-e}	20.33^{a-d}	0.33^{a}
45	*RIL-129A*	48.00^{a-g}	84.67^{a-h}	89.00^{a-d}	40.97^{a-e}	48.03^{a}	36.67^{a-j}	19.00^{bcd}	2.50^{de}	1541.10^{ab}	8888.90^{a-d}	18.20^{a-d}	0.37^{a}
46	*RIL-91Ap*	54.33^{ab}	84.67^{a-h}	89.90^{a-d}	42.50^{a-e}	47.40^{a}	30.33^{hij}	16.00^{cd}	2.17^{e}	1659.60^{ab}	7777.80^{a-e}	21.57^{a-d}	0.27^{a}
47	*RIL-101C*	56.00^{a}	86.67^{a-f}	97.90^{ab}	46.23^{ab}	51.67^{a}	30.67^{ghij}	22.33^{bcd}	2.17^{e}	1746.10^{ab}	10555.6^{ab}	14.47^{d}	0.37^{a}
48	*RIL-107*	47.67^{a-h}	87.00^{a-e}	85.57^{a-d}	40.70^{a-e}	44.87^{a}	39.33^{a-h}	25.00^{a-d}	3.23^{cde}	1841.70^{ab}	8333.30^{a-d}	22.41^{a-d}	0.33^{a}
49	RIL157	45.33^{b-i}	84.33^{a-h}	92.43^{abc}	41.97^{a-e}	50.47^{a}	39.00^{a-h}	24.33^{a-d}	3.67^{b-e}	2125.00^{ab}	9444.40^{a-d}	22.74^{a}	0.27^{a}
	MSD	10.17	7.48	14.49	10.45	12.7	9.158	32.56	2.77	1159.9	3840.4	10.42	0.3

DH=days to heading ,DM=days to maturity, PH=plant height, PAN=panicle length, CL=culm length, GF=grain filling period, LD=lodging index, PRT= productive tillers, GY=grain yield, BIOM=biomass, HI=harvest index, TSW=thousand seed weight,MSD=minimum significance difference