

Genetic variability, Heritability and Association of Traits in Released tef [*Eragrostis tef* (Zucc.)Trotter] Varieties Evaluated in Southwestern and Central Ethiopia

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¹Holetta Research Center, P. O. Box 31, Holetta, Ethiopia

²Addis Ababa University, P.O.Box 1176, Addis Ababa, Ethiopia

³Debre Zeit Research Center, P. O. Box 32, Debre Zeit, Ethiopia;

Abstract

Nineteen released tef varieties and two landraces were evaluated in Completely Randomized Block Design with three replications at Debre Zeit and Jimma Agricultural Research Centers during the 2007/08 cropping season. The objectives were to assess the extent of genetic variability; to estimate the variance and broad sense heritability for the various traits, and to examine the phenotypic and genotypic correlation for grain yield and yield related traits in released tef varieties. The mean squares due to genotype and genotype by environment interaction were highly significant ($P \leq 0.01$) for all traits while that due to locations were highly significant ($P \leq 0.01$) for thirteen of the fifteen traits. The phenotypic variance value was higher than genotypic variance for all the traits and genotypic and phenotypic coefficient of variation ranged from 5.06 to 20.47% and 5.91 to 21.66%, respectively. Similarly, broad sense heritability ranged from 47.9 to, 92.9%. Expected genetic advance and genetic advance as percent of the mean respectively varied from 0.04 to 56.84 and 7.21% 29.65%. Grain yield showed positive and significant ($P < 0.01$) phenotypic and genotypic correlation with shoot biomass yield and harvest index only. Lodging index, however, had shown significant phenotypic and genotypic association with most of the traits in the current study. In general, wider phenotypic variability in terms of plant morphology, phenology and yield attribute were observed in the current study that would help to utilize in the future breeding works.

J 9*Eragrostis tef*, Genotypes, Variability, Varieties

Introduction

Tef [*Eragrostis tef* (Zucc.) Trotter] is an allotetraploid plant with a base chromosome number of 10 ($2n = 4x = 40$) (Jones *et al.*, 1978; Tavassoli, 1986). It is a C4, self-pollinated chasmogamous annual cereal bearing both the stamens and pistils in the same floret (Seyfu, 1997). The center of origin and diversity of tef is in Ethiopia (Vavilov, 1951) where it is primarily grown as a staple cereal (Amanda and Doyle,

2003). It is the only cultivated cereal in the genus *Eragrostis* which consists of 350 species (Hailu and Seyfu, 2001; Hailu *et al.*, 2003). Tef crop exhibits high level of phenotypic plasticity in phenology and agronomic traits depending on the environment where it is grown. Tef days to heading and to maturity and grain yield per plant, for instance, ranges from 25 to 81 and 60 to 140 days and 0.78 to 5.96 gram per plant respectively (Kebebew *et al.*, 2001). The grain yield and quality also vary with the soil type, climate,

season and varieties. Therefore, better tef grain yield and quality is obtained when grown on black soils and at an altitude range of 1800-2400m a. s. l. and areas receiving annual rainfall of 750-850mm (Seyfu, 1993).

Tef is an excellent source of human food and livestock feed that provide better market prices for its grain and straw than all other cereals grown in Ethiopia. It is a gluten free cereal (Spaenij-Dekking *et al.*, 2005), tolerant to moisture stresses, suitable for double cropping and has long shelf life and low post harvest pest problem (Seyfu, 1993)

It is ranked first in area coverage and second to maize in total volume of grain production in Ethiopia (CSA, 2012). However, national average yield is very low (below 1.3 t/ha) when compared to other cereals, (CSA, 2012). Nevertheless, it was reported that the use of appropriate tef technologies can increase tef yield to over 4.5 t/ha (Hailu and Seyfu, 2001). According to MoA (2012), over 33 varieties had been developed and released for commercial use in Ethiopia.

Knowing the genetic variability existing among released tef varieties enable breeders to utilize the genetic potential for further breeding and avoid the suspected redundancy. A considerable genetic variation, heritability, genetic advance and correlation among different traits of

tef germplasm had been reported (Kebebew *et al.*, 2001) and released varieties (Yifru and Hailu, 2005; Habte *et al.*, 2011). However, previous studies conducted on released varieties by Yifru and Hailu (2005) and Habte *et al* (2011) did not include released varieties after 1995 and the high potential tef growing central region of Ethiopia. Hence, both reports have some limitations. The objectives of the current study, therefore, were: 1) to assess the extent of genetic variability among released tef varieties, 2) to estimate the genotypic and phenotypic variances and broad sense heritability and 3) to examine the phenotypic and genotypic correlation coefficients for grain yield and yield related traits in released tef varieties under two environments.

Materials and Methods

Description of experimental sites

Two field experiments were carried out at Jimma Agricultural Research Center (8° 44' N, 38° 58' E, and 1860 m. a. s. l.) and Debre Zeit Agricultural Research Center (8° 44' N, 38° 58' E, and 1753 m. a. s. l.) of the Ethiopian Institute of Agricultural Research (EIAR) during the 2007/2008 GC cropping season. The soil of the experimental site at Jimma and Debre Zeit research center is Eutric Nitosol with a pH of 5.2 and Inceptisol with pH of 6.9, respectively.

Experimental materials and design

Nineteen commercial tef varieties released before 2006 and two local landraces from around Jimma (Table 1) were evaluated in a randomized complete block design with three

replications in 2007/08 cropping season. The experimental plot size was 1m x 1m (1m²) and consisted of five rows. Three grams of seeds was drilled along the surface of the five rows in each plot using a seed rate of 30 kilogram per hectare.

* Both are local landraces from Jimma area

Phosphorus and nitrogen fertilizer was applied at the rate of 60 KgP₂O₅ and 40 KgN per hectare fertilizer. Diammonium phosphate (DAP) was the source of P₂O₅, while N was obtained from both DAP and Urea. DAP was applied at planting while Urea was top dressed at tillering stage.

The plants in each row were thinned four weeks after planting to have 20 plants per row at an intra-row spacing

of five centimeters. All other crop management practices were applied as per the recommendation and standard procedure for each location. Five randomly selected plants from the central rows of each plot were tagged on the main shoots at early tillering for assessment of all plant related data.

Data collection

Data was collected on fifteen phenological and morpho-agronomic traits. Days to heading and maturity, biomass and grain yield (g/m²), thousand seed weight (g), harvest index (%) and lodging index (%) were assessed on plot basis. On the other hand plant height (cm), length of culm and panicle (cm), number of fertile tillers per plant and spikelet per panicle, were assessed on a single plant basis.

Statistical analysis and partitioning of the variance components

All measured data were subjected to the analysis of variance (ANOVA) to assess the differences among the genotypes under investigation using the SAS program software (SAS, 2002). Significance of variability test was made at 5 and 1% probability level.

The total phenotypic variance of each trait was partitioned into contribution due to genetic and non-genetic factors using the variance component method based on the combined analyses of the two test locations as per the method suggested in Kebebew *et al.*, (1999):

$$Vg = [MSG - \frac{(MSG - MSE)}{r} - MSE] / rl ;$$

$$VP = Vg + \frac{Vgl}{r} + \frac{Ve}{rl}$$

Where: MSG, MSG_L and MSE are the mean squares of genotypes, genotype

X location interaction, and experimental error; *r* and *l* are the number of replications and locations; and *V_{gl}* and *V_e* are genotype × location interaction and error variance estimated by $(MSG - MSE) / r$ and *MSE*, respectively.

Phenotypic (PCV) and genotypic (GCV) coefficient of variation were also calculated following the method of Burton and de Vane (1953).

$$PCV = \left(\frac{\sqrt{\sigma^2 P}}{X} \right) \times 100 ;$$

$$GCV = \left(\frac{\sqrt{\sigma^2 g}}{X} \right) \times 100$$

Where: X= the grand mean for the trait considered.

Broad-sense heritability (*h*²) was calculated as the ratio of genotypic variance to phenotypic variance according to Allard (1960):

$$h^2 = \frac{Vg}{Vp} \times 100$$

Genetic advance in absolute unit (GA) and genetic advance as percentage of the mean (GAM), assuming selection of the superior 5% of the genotypes were estimated following the procedure elaborated by Singh and Chaudhary (1996):

$$GA = K(\sqrt{\sigma^2 P} \times h^2)$$

$$GAM = \left(\frac{GA}{X} \right) \times 100$$

Where: K is a constant with a value of 2.06 at selection intensity of 5%;

$\sqrt{\sigma^2 P}$ = Square root of phenotypic variance and h^2 = heritability in broad sense.

Traits association

Phenotypic and genotypic correlation coefficients between pairs of traits were computed from the components of variance and co variances as described by Singh and Chaudhury (1996).

$$rP_{xy} = \frac{Pcov_{xy}}{\sqrt{\sigma^2 p_x \times \sigma^2 p_y}};$$

$$rG_{xy} = \frac{Gcov_{xy}}{\sqrt{\sigma^2 g_x \times \sigma^2 g_y}}$$

Where: r_p and r_g is the phenotypic and genotypic correlation coefficient between variables x and y, $Pcov_{xy}$ and $Gcov_{xy}$ is the phenotypic and genotypic covariance between variables x and y; $\sigma^2 g_x$ and $\sigma^2 g_y$ is the genotypic variance for trait X and Y; $\sigma^2 p_x$ and $\sigma^2 p_y$ is the phenotypic variance for trait X and Y, respectively

Results and Discussion

The combined analyses of variance results of two locations for the investigated traits are presented in Table 2. The result showed that the mean squares due to location were highly significant ($P \leq 0.01$) for all traits except shoot biomass yield per plot and thousand seed weight ($P \leq 0.05$), indicating that there are differences

between the two environments to examine the genetic performance of tef genotypes. The mean square due to genotypes and that of genotype by environment interactions were also highly significant ($P \leq 0.01$) for all traits under investigation. The significant variation observed among genotypes implied the presence of substantial variation among genotypes, which give an opportunity for plant breeders to improve those traits through breeding. On the other hand, the significant genotype by location interaction for all the traits in this study indicated that some genotypes perform differently under different environment. Similar results had been reported for the combined analysis of variance across two locations, which collaborates the findings regarding most of the traits in the present study (Solomon *et al.*, 2009; Ayalneh *et al.*, 2012; Wendeweson *et al.*, 2012).

Descriptive statistics of quantitative traits

Means, range and standard deviation of each trait of the test genotypes were computed and are presented in Table 2. The mean grain yield of the genotypes ranged from 61.76 to 296 g/m² for genotype DZ-01-196 and DZ-01-354, respectively. Likewise, the shoot biomass yield also ranged from 290 g/m² for genotype DZ-01-196 to 475 g/m² for DZ-01-974. Furthermore, thousand seed weight ranged from 0.25g to 0.42 g for genotype DZ-01-196 and genotype DZ-01-1285,

respectively. From this result, one can understand that those varieties having loose type of panicle (DZ-01=974, DZ-01-1285 and DZ-01-354) are high yielders as compared to the semi compact varieties like DZ-01-196. This finding is in line with Hailu (1988). On the other hand, shorter days to grain filling and maturity were observed for Ho-Cr-136 while longer days to grain filling and maturity were recorded for genotype DZ-01-354. This is due to the inherent differences in the genetic makeup of the two varieties since the former variety was an escape type developed and released for moisture stress areas while DZ-01-354 was meant to serve the high potential areas with relaxed growing season. Thus, the result obtained in the present study is still in the range previously reported (Kebebew *et al.*,

2001). The minimum and maximum number of fertile tillers per plant was recorded for DZ-Cr-82 and DZ-cr-37, respectively. DZ-01-2053 was found to have the shortest plant height (43.4cm) and panicle length (18.9cm) while the longest plant height (96.6cm) and panicle length (41cm) was recorded for DZ-01-2675 and DZ-Cr-82 respectively (Table 3). This is a good indication that most white seeded varieties have usually longer plant height and panicle length as compared to the brown seeded varieties like DZ-01-2053 (Holetta red). In general, higher phenotypic variability in terms of plant morphology, phenology and yield attribute were observed which agrees with the works of Kebebew *et al.*, (2001) and Habte *et al.*, (2011).

Estimates of phenotypic and genotypic variation

The estimates of the genotypic and phenotypic variance, genotypic (GCV) and phenotypic (PCV) coefficient of variability, broad sense heritability (h^2), genetic advance (GA) & genetic advance as per cent of mean (GAM) are presented in Table 4. The estimated phenotypic variance ranged from 0.0007 for thousand seed weight to 2108.47 for number of spikelet per panicle. Similarly, the lowest and highest genotypic variance of 0.0005 and 1258.03 was also estimated for the above two traits respectively. On the other hand, GCV values of greater than 10% were observed for number of fertile tiller per plant (20.47%), grain yield per plot (15.26%), SBCD (13.65 %), NSP (11.88%), PBM (10.32%) and harvest index (10.27%) while the remaining traits had a value less than 10%. Similarly, number of fertile tiller per plant, grain yield per plot, SBCD, NSP, PBM, lodging index and harvest index had PCV values greater than 10% while values for the remaining traits were below 10%. Maximum PCV was observed for number of fertile tillers per plant (21.66%) followed by grain yield per plot (16.19%), number of spikelet per panicle (15.38%) and second basal culm diameter (15.11%). Unlike the present study, Kebebew *et al.* (2000) had reported a PCV and GCV values of less than five percent for SBCD. The higher PCV and GCV values observed

for some of the traits could be an evidence for the existence of wide range of variation to improve those traits. The lower GCV for phenological traits and culm length, however, suggests the difficulty of manipulating these traits. In general, PCV values in the current study were higher than GCV values for all traits indicating that the environmental effect was higher for the expression of the traits under investigation.

The estimates of heritability indicated that higher values were recorded for shoot biomass (92.85%), fertile tillers number (89.39%), grain yield/m² (88.89%), harvest index (86.95%), days to panicle emergence (82.75) and second basal culm diameter (81.16) (Table 4). Similarly, high heritability values were reported previously for days to panicle emergence (Kebebew *et al.*, 2001; Tilahun *et al.*, 2012). On the other hand, the minimum heritability value estimated in this study was 53.6 and 47.9% for days to grain filling and culm length respectively.

High heritability along with high genetic advance is an important factor to predict the resultant effect for selecting the best genotypes. High expected genetic advance estimates were obtained for shoot biomass yield per plot (56.84%), number of spikelet per panicle (56.44%) and grain yield per plot (30.16%). Unlike the present findings, estimates of genetic advance ranging from less than 1% to 21% had been reported by Kebebew *et al.*,

(2000), and from less than 2% to 23% (Kebebew *et al.*, 2001).

High estimates of both heritability and genetic advance values were recorded for shoot biomass yield and grain yield per plot suggesting the possibility of improving tef grain yield through direct selection for both traits. On the other hand, number of

fertile tiller per plant, harvest index and days to panicle emergence had average broad sense heritability value coupled with low expected genetic advance. Conversely, number of spikelet per panicle in the current study had moderately low broad sense heritability value accompanied with higher genetic advance value.

Table 4.

Higher genetic advance as the percent of mean values were obtained for number of fertile tillers per plant (39.9), grain yield per plot (29.7%) and second basal culm diameter (25.3%). The GA as percent of mean values in the current study (7.2% for culm length to 39.9% for number of fertile tillers per plant) is far higher than the

previous report that was just under 21% (Kebebew *et al.* 2000).

Association of grain yield and related traits

Estimation of the degree of genotypic and phenotypic correlation of grain yield and yield components is very important to utilize the available genetic variability through selection

(Singh *et al.*, 1998). The phenotypic and genotypic correlations for morpho-agronomic traits are presented in Table 5. Grain yield per plot showed positive and significant ($P<0.01$) phenotypic and genotypic correlation with shoot biomass yield per plot and harvest index, implying that improving these traits could result in high grain yield. On the other hand, grain yield per plot showed negative but non-significant correlation with days to grain filling, days to maturity, panicle length, second basal culm diameter and thousand seed weight. This finding is contrary to Habte *et al.*, (2011) that reported positive and highly significant genotypic and phenotypic correlation for grain yield with both days to panicle emergence and maturity. Moreover, the insignificant association observed between grain yield and that of days to maturity and days to panicle emergence is in line with the previous findings of Yifru and Hailu (2005). Shoot biomass yield had shown non-significant association with all traits except grain yield per plot and harvest index. Meanwhile

lodging index showed significant phenotypic and genotypic association with nine and seven of the fifteen traits under the current study, respectively. Days to panicle emergence also showed significant positive correlation with most of the traits ; days to grain filling, days to maturity, plant height, culm and panicle length, spikelet per panicle and panicle branch per main stem at both phenotypic and genotypic level. This finding agrees with the result of Temesgen *et al.* (2005).

Maximum genotypic and phenotypic correlation values were observed between grain yield per plot and harvest index ($r_g=91$, $r_p=90$) followed by days to maturity and days to panicle emergence ($r_g=0.90$, $r_p=73$), culm length and plant height ($r_g=87$, $r_p=0.90$) and plant height and panicle length ($r_g=0.88$, $r_p=70$). This indicates a great possibility of making

Table 5.

Conclusion

These study findings showed the presence of considerable variations among 19 released tef varieties for all traits tested which gives an opportunity to plant breeders for the improvement of these traits. High estimates of broad sense heritability accompanied by high genetic advance values were recorded for shoot biomass yield and grain yield per plot suggesting the possibility of improving tef grain yield through direct selection for the two traits. Besides, the positive genotypic and phenotypic correlation of shoot biomass yield per plot and harvest index traits with that of grain yield per plot suggests a common genetic/physiological basis among these traits and the possibility of simultaneous improvement of the traits. Biomass and harvest index can, therefore, be considered as a suitable selection criteria for the development of high yielding tef varieties.

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References

- Allard R.W. 1960. *Principles of Plant Breeding*. John Wiley & Son, New York.
- Amanda L. I. and Doyle J. J. 2003. The origin and evolution of tef (Poaceae) and related polyploids: Evidence from waxy and plastid rps16. *Am. J. Bot.* **8** (1):9116-122.
- Ayalneh T., Habtamu Z. and Amsalu A. 2012. Heritability and genetic advance in tef [*Eragrostis Tef*] Zucc. Trotter] lines at Sinana and Adaba. *International Journal of Plant Breeding and Genetics* **5** (1): 40-46.
- Burton G.W. and Devane E.H. 1953. Estimation of heritability in tall *Festuca* (*Festuca arundinacea*) from replicated clonal material. *Agron. J.* **34**:478-481.
- Central Statistical Agency (CSA). 2012. Agricultural Sample Survey 2011/2012 (2004 E.C.) (September - December 2011). *Report on Area and Production of Major Crops, (Private Peasant Holdings, Meher Season)*. Statistical Bulletin, Volume I Addis Ababa, Ethiopia
- Habte J., Endashaw B and Kebebew A. 2011. Genetic variability in released tef [*Eragrostis tef* (Zucc.) Trotter] varieties of Ethiopia. *Crop Science Society of Ethiopia* (CSSE). Sebil Vol. 13. Proceedings of the Thirteenth Biennial Conferences, 31st Dec. 2008 to 2nd Jan. 2009. Addis Ababa, Ethiopia.
- Hailu T. and Seyfu K. 2001. Production and importance of tef in Ethiopian Agriculture. In: *Narrowing the Rift: Tef Research and Development: Proceedings of the International Workshop on Tef Genetics and Improvement*, 16-19 October 2000, Addis Ababa, Ethiopia,

- (Hailu Tefera, Getachew Belay and Sorrells, M. eds) Ethiopian Agricultural Research Organization, Addis Ababa, pp 3-7.
- Hailu T., Kebebew A., Fufa H., Tiruneh K. and Tesfaye T. 2003. Heritability and genetic advance in recombinant inbred lines of tef *Eragrostis tef*). *Euphytica* **020**: 91-96.
- Jones B.M.G, Ponti J., Tavassoli A. and Dixon P.A. 1978. Relationships of Ethiopian Cereal
- Tef [*Eragrostis tef* (Zucc) Trotter]: Evidence from morphology and chromosome number. *Ann. Bot.* **319**:369-1373.
- Kebebew A., Seyfu K. and Hailu T. 1999. Diversity among germplasm lines of the Ethiopian cereal tef [*Eragrostis tef* (Zucc.) Trotter]. *Euphytica*. **0** **59**:87-97.
- Kebebew A., Seyfu K. and Hailu T. 2000. Trait diversity, heritability and genetic advance in selected germplasms lines of tef [*Eragrostis tef* (Zucc.) Trotter]. *Hereditas*. **0229**:29-37.
- Kebebew A., Seyfu K., Hailu T., Fufa H. and Tiruneh K. 2001. Genetic diversity for agronomic traits in tef. pp 33-47. In: Hailu Tefera, Getachew Belay and M. Sorrells (eds.). *Narrowing the Rift: Tef Research and Development*. Proceedings of the International Workshop on Tef Genetics and Improvement, 16-19 October 2000, Addis Ababa, Ethiopia., pp 33-48.
- Kebebew A., Hailu T. and A. Merker. 2002. Variation and inter-relationships of quantitative traits in tef (*Eragrostis tef* (Zucc.) Trotter) germplasms from western and southern Ethiopia. *Hereditas* **025**: 116-125.
- Ministry of Agriculture (MoA). 2012. Animal and Plant Health Regulatory Directorate. *Crop Variety Registry Issue No. 15*. Addis Ababa, Ethiopia.
- SAS Institute. 2002. Proprietary Software version 9.00, Cary, NC, USA
- Seyfu K.1993. *Tef (Eragrostis tef): Breeding, Genetic Resources, Agronomy, Utilization and Role in Ethiopian Agriculture*. Institute of Agricultural Research, Addis Ababa, Ethiopia.
- Singh R.K. and Chaudhury B.D. 1996. *Biometrical Method in Quantitative Genetic Analysis*. Kalyani publisher, Ludhiana, India. Pp. 388.
- Singh AK, Singh SB, Yasave SH.1998. Correlation and path analysis in early generation. *Indian J. Genet.*, **4** (3): 260-264.
- Spaenij-Dekking, Liesbeth, Yvonne Kooy-Winkelaar and Frits Koning. 2005. The Ethiopian Cereal teff in celiac disease, *The New England Jour. of Medicine* 353: 1748-1749.
- Tavassoli A. 1986. The cytology of *Eragrostis tef* with special reference to *E. tef* and its relatives. PhD Thesis, University of London, London, UK.
- Temesgen A. 2002. Genetic Divergence and Association of Characters among quantitative traits in tef [*Eragrostis tef* (Zucc.) Trotter] germplasm. M.Sc. Thesis, Alemaya University.
- Wondewosen S., Alemayehu B and Husien M. 2012. Genetic Variation for Grain Yield and Yield Related Traits in Tef [*Eragrostis tef* (Zucc.)Trotter] under Moisture Stress and Non-Stress Environments. *American Jour. of Plant Sciences* **2**:1041-1046
- Yifru T. and Hailu T. 2005. Genetic improvement in grain yield potential and associated agronomic traits of tef (*Eragrostis tef*). *Euphytica* **030**: 247-254.
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