Assessments of Genetic Diversity for Agro Morphological Traits of *Teff* [*Eragrostis tef (Zucc)* Trotter] Germplasm Collections of Ethiopia

Walelign Azene, Ethiopian Biodiversity Institute

Abstract

One hundred fifty-two teff genotypes and two checks (Filagot and Tesfa) were used for the field experiment. The objective of this study was to characterize and assess the genetic diversity for traits of teff genotypes during the cropping season of 2019/2020 at Debre Zeit Agricultural Research Center. The augmented design was used with eleven blocks. Results obtained from the analysis of variance for quantitative traits showed a highly significant difference for culm diameter and panicle length of the main panicle; significant difference for traits such as days to 50% maturity, and plant height. These findings revealed that there was a significant difference among most of the traits. There was a wide range of variations for days to 50% flowering and 50% maturity, plant height, panicle length, spikelet per panicle, and grain yield. Higher Genotypic coefficient of variation, phenotypic coefficient of variation, genetic advance (as % mean), and heritability in the broader sense were observed for grain yield per plot, spikelet per panicle, grain yield per plot, and culm diameter, respectively. Cluster analysis of teff genotypes in the formation of 4 clusters ranging with high inter and intracluster distances between them. The first four principal components explained about 79.37% of the entire diversity among teff population. Days to 50% flowering, days to 50% maturity, plant height, panicle length, culm diameter, and spikelet per panicle showed greater loadings in the first principal component. The observed genetic diversity suggested the importance of further evaluation of these genotypes across locations and seasons to develop varieties.

Keywords: Teff, Variation, Cluster, Principal Component, Genotypes, and Quantitative traits

1. Introduction

Teff belongs to the grass family Gramineae, tribe Eragrostideae, and genus Eragrostis. As one of the biggest genera in the grass family, the genus Eragrostis includes about 350 species. The most suitable for excellent Teff performance is at an altitude of 1800-2100m, annual rainfall of 750 – 850mm, and a temperature range of

10^0C - 27^0C. The composition of Teff shows that it has good mineral content and a generally higher amount of the essential amino acids (Assefa *et al.,* 2011). Despite its various uses, the national productivity of teff (1.66 t/ha) is still very low compared to the common cereals grown in Ethiopia (CSA, 2017).

Characterization of germplasm is the process of detecting genetic diversity existing within or among germplasm accessions using descriptor lists of morphological characters (de Vicente et al., 2005). Morphological markers are the earliest markers utilized in the assessment of genetic diversity within and between populations. They are inexpensive, simple, and rapid to score. Various studies reported the existence of a wide range of variation in teff varieties (Habte *et al.,* 2017), and germplasm accessions (Kebebew *et al.,* 2001a).

However, efficient utilization of the *teff* genetic resources still requires comprehensive, systematic, and intensive characterization and evaluation of the genetic diversity of both old and new collections to provide essential information for germplasm utilization in the breeding programs, the establishment of core collections, as well as detection of duplications in collections for utilization. The present study was, therefore, designed to characterize and assess the genetic diversity for agro morphological traits of *teff* collections of the Ethiopian Biodiversity Institute.

2. Methods and Materials

152 *teff* genotypes were selected from collections in the Ethiopian Biodiversity Institute. Two Improved varieties (Filagot and Tesfa) were used as a check. The field experiment was conducted at Debre Zeit Agricultural Research Center during the main cropping season of 2019/20. The experimental field was laid in augmented design in eleven blocks with spaces 1m between plots and 1m between blocks, and each genotype was grown on four rows of 2m length with 0.2 m inter-row space. 25kg/ha (4 grams) of seeds were hand-broadcasted. The experimental fields were fertilized with 150kg/ha (24g) DAP, and 100kg/ha (16g) urea which was applied at the time of sowing (8gm) and vegetative stage (8gm). All recommended agronomic and cultural practices were applied.

Data were collected for days to 50% flowering and maturity, plant height, panicle length, culm diameter, number of florets per spikelet at upper, middle, and bottom of panicles, spikelet per panicles, and grain yield per plot. All data were collected on a plot basis, except for plant height, panicle length, culm diameter, and number of spikelets per panicles, number of florets per spikelet at the upper, middle, and bottom of the panicles that were recorded using the average of twenty plants randomly tagged in each plot.

The collected data were subjected to analysis of variance, principal components (PC), and cluster analyses. All statistical analyses were performed using the R software version 4.0.3. The variability of each trait was estimated by using simple statistical measures such as mean, range, variances and coefficient of variation. Variances and coefficient of variations and Broad sense heritability were calculated using the formula suggested by Falconer and Markay (1996). An expected genetic advance of 5% selection intensity (K=2.056) was computed using the methodology described by Johnson *et al*., (1955).

3. Results and Discussion

Analysis of Variance

Result obtained from the analysis of variance for 154 teff population showed highly significant ($P \leq 0.01$) difference for culm diameter & panicle length of the main panicle; significant difference ($P \leq 0.05$) for traits such as days to 50% maturity, and plant height (Table 1). The result is almost similar with the study conducted by Nigus, *et al.*, (2016); and Adenew (2002) who reported the presence of significant genotypic variations for most of these traits.

Table 1. Block Adjusted ANOVA, Mean & CV for 10 Traits of 154 *Teff* Genotypes

Source	Df	CLM	DF	DM	FSL	FSU	FSM	PHT	PNL	SPL	YLD
Treatment (ignoring Blocks)	153	0.14 **	11.75 *	17.76 *	0.38 *	0.44 **	0.55 *	77.64 *	15.21 **	18012.62 ns	2974.66 ns
Treatment: Check	1	1.43 **	20.05 ns	0.18 ns	2.16 **	6.33 **	5.01 **	251.61 **	30.96 *	145966.55 *	23276.52 **

Treatment: Test vs. Check	1	7.5e-05 ns	90.44 **	217.05 **	0.39 ns	0.02 ns	0.34 ns	1.76 ns	0.02 ns	41102.96 ns	10858.23 *
Treatment: Test	151	0.13 **	11.17 ns	16.56 *	0.36 *	0.41 *	0.52 *	76.99 *	15.2 **	17012.33 ns	2788.01 ns
Block (eliminating Treatments)	10	0.03 ns	4.11 ns	16.08 ns	0.22 ns	0.42 *	0.21 ns	18.55 ns	4.02 ns	18753.04 ns	3014.65 ns
Residuals	10	0.01	4.55	5.88	0.1	0.1	0.17	22.38	3.24	20802.75	1220.16
CV		5.35	3.97	2.93	8.59	5.48	7.83	4.7	5.1	41.11	22.98
Mean		2	54.03	83.22	3.67	5.87	5.23	100.8	35.33	347.8	148.8

Abbreviations: CLM: culm diameter; DF: days to 50% flowering; DM: days to 50% maturity; PHT: plant height; PNL: panicle length; FSU: floret per spikelet at upper half of the panicle; FSM: floret per spikelet at the middle of the panicle; FSL: floret per spikelet at the lower part of the panicle; SPL: number of spikelet per panicle; YLD: yield. *, ** significantly different at 5% and 1%, respectively.

Patterns of Quantitative Traits Variation

A wider range of variations was observed for all traits of the 154 teff genotypes (Table 2). The days to 50% flowering and 50% maturity ranged from 40.86 to 70.86 and 54.41 to 95.41 days, respectively. This is in agreement with the study conducted by Habte *et al*., (2018), and Kebebew *et al.* (2001a). The results showed that these local variations are very essential to develop potential varieties that can adapt fitting to various agro-ecologies and cropping systems. Plant height and panicle length were also found to range between 57.25cm to 125.5cm and 21.65cm to 44.9cm, respectively (Table 2). This is in line with the previous studies conducted by Habte *et al*., (2018), and Nigus, *et al*., (2016). In this study, spikelet per panicle and grain yield ranged from 35.27 to 741.77 and 19.31 to 271.81gm/plot, respectively. The range was wider than the results of previous studies reported by Tsion F., (2016), and Kebebew *et al*., (2001a). The wide variation observed for plant height, culm diameter and panicle length indicated the possibilities to obtain lodging resistant varieties. Similarly, the variation in the number of spikelet per panicle, and grain yield implies that it is possible to develop varieties with better grain yield.

Table 2: Range, Mean and Standard Error (SE) of Mean for 10 Different Traits of *Teff* Genotypes

Traits	Range				Mean±SE
	Min		Max		
	Value	Genotype	Value	Genotype	
Days to 50% flowering	40.86	Acc. 236090	70.86	Acc. 234720	54.03±0.26
Days to 50% maturity	54.41	Acc. 236090	95.41	Acc. 242171	83.22±0.32
Plant height	57.25	Acc. 236090	125.5	Acc. 202959	100.8±0.73
Panicle length	21.65	Acc. 234718	44.9	Acc. 236351, acc. 244880	35.33±0.33
Culm diameter	1.4	Acc. 219884, Acc. 27595	2.95	Acc. 237703	2±0.03
Floret per spikelet at the upper half of the panicle	4.24	Acc.244793	7.59	Acc.234718	5.87±0.06
Floret per spikelet at the middle of the panicle	3.45	Acc. 237245	7.1	Acc.229101	5.23±0.05
Floret per spikelet at the lower part of the panicle	2.12	Acc. 203005	5.67	Acc. 234718	3.67±0.05
Number of spikelet per panicle	35.27	Acc. 234471	741.7	Acc. 242570	347.8±11.21
Yield	19.31	Acc. 235321	271.8	Acc. 242162	148.8±3.82

Phenotypic, Genotypic Coefficient of Variation, Broad Sense Heritability and Genetic Advance

Genotypic coefficient of variation (GCV), genotypic variation (GV), phenotypic coefficient of variation (PCV), phenotypic variation (PV), environmental variation (EV), heritability in the broader sense (HBS), genetic advance (as % mean) and genetic advance (GA) values are summarized in Table 3. High PCV were observed for yield (35.48%), and spikelet per panicle (37.5%). This result is similar to the report of Dagnachew L., (2008), and T. Ayalneh *et al.*, (2012), whereas it is far below the previous findings reported by Habte J. *et al.*, (2018), and Habtamu A. *et* *al*., (2011). Higher GCV values were noted only for grain yield (26.61%). This is in agreement with the study reported by T. Ayalneh *et al*., (2012), and Dagnachew L., (2008). An estimate of heritability varied from 56.24% (for grain yield) to 91.34% (for culm diameter) (Table 3). Hence, the highest heritability estimate was observed for culm diameter (91.34%), panicle length (78.7%), plant height (70.93%), and days to 50% maturity (64.47%). This is in line with the previous studies conducted by Habte *et al*., (2018), Tsion F., (2016), and Asefa *et al*. (2011). Culm diameter (34.28%), and grain yield (41.17%) were the traits with maximum genetic advance as percent mean. Thus, the estimate of GA as a percent of mean was lower in this investigation as compared to the former two reports by Chanyalew (2007). However, this result is comparable to the study conducted by Habte J., (2018).

Table 3: Estimates of Variance Components, Heritability, Coefficient of variation, and Genetic Advance for 152 Teff Landraces and 2 Checks

Traits	**Mean**	**PV**	**GV**	**EV**	**GCV**	**PCV**	**ECV**	**hBS**	**GA**	**GAM**
Days to 50% flowering	54.03	11.17	6.63	4.55	4.76	6.19	3.95	59.31	4.09	7.57
Days to 50% maturity	83.22	16.56	10.67	5.88	3.93	4.89	2.91	64.47	5.41	6.5
Plant height	100.8	76.99	54.6	22.38	7.33	8.7	4.69	70.93	12.84	12.74
Panicle length	35.33	15.2	11.96	3.24	9.79	11.04	5.09	78.7	6.33	17.92
Culm diameter	2	0.13	0.12	0.01	17.39	18.19	5.35	91.34	0.69	34.28
Floret per spikelet at the upper half of the panicle	5.87	0.41	0.31	0.1	9.41	10.88	5.47	74.78	0.99	16.79
Floret per spikelet at the middle of the panicle	5.23	0.52	0.36	0.17	11.41	13.82	7.8	68.17	1.02	19.44
Floret per spikelet at the lower part of the panicle	3.67	0.36	0.27	0.1	14.07	16.46	8.54	73.1	0.91	24.83
Number of spikelet per panicle	347.8	17012.33		20802.75		37.5	41.47			

Yield	148.8	2788.01	1567.85	1220.16	26.61	35.48	23.47	56.24	61.26	41.17

Cluster Analysis

Cluster analysis of 154 *teff* genotypes resulted in the formation of four clusters consisting of 22 to 58 genotypes. These numbers of clusters are comparable to the studies conducted by Nigus, *et al*.,(2016), and Habte *et al*., (2018). Cluster I and II consisted of the highest number of genotypes (58 &50), whereas cluster III and IV consisted of 22 and 24 genotypes, respectively (Fig. 1).

Table 4: Intra and Inter-cluster Distances among Five Clusters of 154 Teff Genotypes

	C1	C2	C3	C4
C1	**38.75326**			
C2	120.1439	**34.49956**		
C3	231.9841	198.5005	**58.57993**	
C4	177.0340	161.0267	342.6693	**45.10991**

According to table 4, the largest inter-cluster distance that provides the best level of genetic recombination was found between Cluster 3 and 4. Findings of the present study are in agreement with the results reported by Tsion F., (2016), and Thomas *et al*., (2018). The highest intra cluster distances were observed for clusters 3 and 4 (Table 4). This indicated that genotypes in the same clusters had sufficient distances with each other for cultivar development.

Principal Component Analysis

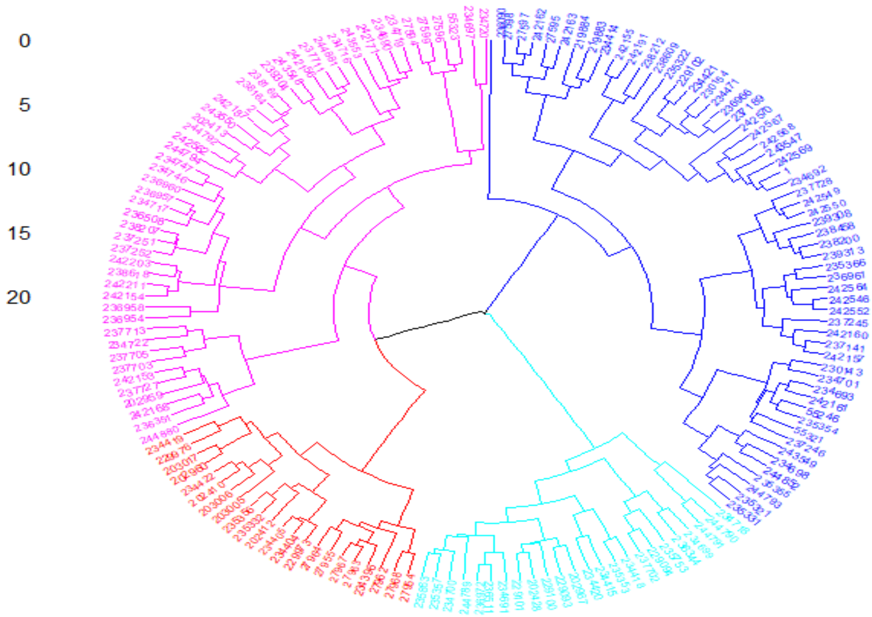

Figure 1: Dendrogram Based on ward.D2 Method Showing the Genetic Relationship among 152 Teff populations and Checks for Quantitative Traits

79% of variation was described by the first four PCs, in which their Eigen values were greater than one (Table 5). The present investigation goes along with the results reported by Habte *et al*., (2017), and Thomas *et al*., (2018). However, it is lower than the result reported by Kebebew *et al*., (2003). Days to 50% flowering, days to 50% maturity, plant height, panicle length, culm diameter, and spikelet per panicle showed greater loadings in the first PC (Table 5). This finding is similar to the studies conducted by Kebebew *et al*., (2003), Habte *et al*., (2017), and Nigus *et al.* (2016). Finally, traits that showed a greater loading in the fourth PC were days to 50% maturity, days to 50% flowering, culm diameter, and grain yield.

Table 5: Principal Component Analysis for 10 Quantitative Traits of 154 Teff Genotypes

Variale	**PC1**	**PC2**	**PC3**	**PC4**
Days to 50% flowering	0.669	0.144	-0.470	0.423

Days to 50% maturity	0.683	-0.031	-0.031	0.653
Plant height	0.903	0.043	0.054	-0.116
Panicle length	0.721	0.245	0.398	-0.175
Culm diameter	0.687	-0.206	-0.113	-0.411
Floret per spikelet at the upper half of the panicle	0.215	-0.817	0.367	-0.001
Floret per spikelet at the middle of the panicle	0.140	-0.936	0.073	0.054
Floret per spikelet at the lower part of the panicle	-0.118	-0.847	-0.284	0.007
Number of spikelet per panicle	0.436	0.140	0.437	-0.192
Yield	-0.313	0.012	0.754	0.440
Eigenvalue	3.094	2.410	1.379	1.053
Variance%	30.94	24.10	13.79	10.53
Cumulative%	30.94	55.04	68.84	79.37

4. Conclusions

Genetic characterization and evaluation of indigenous germplasm resources are very essential for the development of new *teff* varieties with traits of interest. In this study, assessments of genetic diversity for agro morphological traits of teff germplasm collections of Ethiopian Biodiversity Institute revealed that the existence of a wide range of trait variation, especially, genotypes with the highest grain yield, shorter maturity date, plant height, panicle length, and the number of spikelets per panicle were identified. Such variations suggested the importance of further evaluation of these genotypes to develop varieties and for selection of the genotypes with desirable traits.

References

Adenew, T. 2002. Genetic Divergence and Association of Characters among Quantitative Traits in tef [Eragrostis tef (Zucc.) Trotter] Germplasm. M.Sc. Thesis, Alemaya University.

Assefa, K., Yu, J.K, Zeid M, Belay, G., Tefera, H. and Sorells, ME (2011). Breeding tef [Eragrostis tef (Zucc.) trotter]: Conventional and Molecular Approaches. Plant Breeding 130: 1-9.)

Chekole Nigus, Wassu Mohammed, Tebkew Damte (2016). Genetic Diversity of Tef [Eragrostis Tef) Zucc. Trotter] Genotypes Based on Cluster and Principal Component Analyses for Breeding Strategies. American Journal of Research Communication,, 4(12): 46-73} www.usa-journals.com, ISSN: 2325-4076.

CSA .2017. Agricultural Sample Survey 2016/17 (2009 E.C.). Report on Area and Production of Major Crops, (Private Peasant Housholdings, Meher Season). Statistical Bulletin 584. Addis Ababa, Ethiopia.

Dagnachew L. 2008. Genetic Diversity Of Tef [Eragrosties Tef (Zucc.) Trotter] Landraces From Various Regions Of Ethiopia. M.Sc. Thesis, Addis Ababa University.

de Vicente MC, Guzma´n FA, Engels J, Ramanatha Rao V 2006. Genetic Characterization and Its Use in Decision Making for the Conservation of Crop Germplasm. In: Ruane J, Sonnino A (eds) The role of Biotechnology in Exploring and Protecting Agricultural Genetic Resources, Chap. 12.FAO, Rome, pp 129–138. ISBN 978-92-5-105480-2

Engdawork, T., 2009. Understanding Teff: A Review of Supply and Marketing Issues .Ethiopia Commodity Exchange Authority.

Falconer, D.S. and T.F.C. Markay, 1996. Introduction to Quantitative Genetics. 4th. ed. Prentice Hall, Harlow, pp. 107-124.

Habtamu Ayalew, Tsige G., Tadesse D., and Landuber W. 2011. Multivariate Diversity, Heritability and Genetic Advance in *Tef* Landraces in Ethiopia. *Afric. Crop Sci. J.*,Vol. 19, No. 3, pp. 201 – 212.

Habte Jifar, Kassahun T Kebebew A, Solomon C, and Zerihun T. 2017. Semi Dwarf Tef (Eragrostis tef) Lines for High Seed Yield and Lodging Tolerance in Central Ethiopia. Afric. Crop Sci. J., 25 (4): 419 - 439.

Johanson, H.W., Robinson, H.F. and Comstok, R.E. 1955. Estimation of Genetic and Environmental Variability in Soybeans. Agronomy Journal 47: 314 - 318.

Kebebew Assefa, A Merker and Hailu T. 2001a. Qualitative Trait Variation in Tef [Eragrostis tef (Zucc.) Trotter]Germplasm fromWestern and Southern Ethiopia. Euphytica 127: 399-410.

Kebbew Assefa, A Merker and Hailu T. 2003. Multivariate Analysis of Diversity of Tef (Eragrostis tef (Zucc.) Trotter) Germplasm from Western and Southern Ethiopia. Hereditas 138: 228-236

Thomas Tsige, Andagrachew Gedebo and Kebebe 2018. Multivariate Analysis of Phenotypic Variability in Tef [Eragrostis tef (Zucc.) Trotter] Genotypes from Ethiopia. Afric. J. of Agri. Research 13(34), pp. 1787-1795.

Tsion F. 2016. Genetic Diversity of Ethiopian Tef (Eragrostis tef (Zucc.) Trotter) Varieties as Revealed by Morphological and Microsatellite Markers. M.Sc. Thesis, Addis Ababa University.