International Journal of Food Science and Agriculture, 2021, 5(1), 1-6
http://www.hillpublisher.com/journals/jsfa/
ISSN Online: 2578-3475
ISSN Print: 2578-3467

Studies on Character Association among Grain Yield and Related Agronomic Traits of Tef [Eragrostis tef (Zucc.) Trotter]

Nigus Belay

Tef Research Program, Ethiopian Institute of Agricultural Research, Holetta Research Center, Ethiopia.

How to cite this paper: Nigus Belay. (2021) Studies on Character Association among Grain Yield and Related Agronomic Traits of Tef [Eragrostis tef (Zucc.) Trotter]. *International Journal of the Science of Food and Agriculture*, 5(1), 1-6.
DOI: 10.26855/ijfsa.2021.03.001

Received: December 5, 2020
Accepted: December 28, 2020
Published: January 7, 2021

***Corresponding author:** Nigus Belay, Tef Research Program, Ethiopian Institute of Agricultural Research, Holetta Research Center, Ethiopia.
Email: nigusb2006@gmail.com

Abstract

Grain yield is a complex trait which is influenced by several component traits and direct selection for grain yield is often not effective. Thus, it is essential to study the association of yield components with yield. The objective of this study is to evaluate the genotypic association of yield components with yield and their direct and indirect effect on grain yield of tef. Eighteen tef genotypes were evaluated in a randomized complete block design with four replications at Holetta agricultural research center in central highland of Ethiopia. Analysis of variance revealed highly significant genotypic difference for most of evaluated traits. Grain yield had a positive and significant genotypic correlation with panicle length (rg = 0.98), plant height (rg = 0.64) and shoot biomass (rg = 0.53) indicating dependent genetic control between grain yield and these traits. Days to maturity, shoot biomass and harvest index exert favorable direct effects on grain yield. Panicle length, shoot biomass and plant height could be used as target traits to improve tef grain yield because of their significant genotypic correlations with grain yield and favorable direct and indirect effects via the other yield attributing traits.

Keywords

Tef, Genotypic Correlation, Genotypic Path Coefficient, Grain Yield

1. Introduction

Tef, Eragrostis tef (Zucc.) Trotter is the major staple cereal of Ethiopia. It is cultivated annually on more than three million hectares of land by over six million smallholder farmers, accounting one-third of the total cereal acreage [1]. The production of tef in Ethiopia has increased from 1.74 million metric tons to 5.28 million metric tons in between in 2000/01 to 2017/18 at an estimated rate of 7.97% per annum per annum whereas tef productivity has increased by 5.06% per annum during the same period to reach the current yield level of 1.73 tons/ha [2]. Ethiopia is both the origin and center of diversity for tef [3]. Eragrostis tef (Zucc.) Trotter, is an allotetraploid (2n = 4x = 40) and belongs to the Poaceae or grass family [1]. The genus Eragrostis constitutes about 350 species of which only tef is cultivated for human consumption [4].

Ethiopian farmers have cultivated tef because of various merits over other cereals. Tef cultivated under diverse range of agro-ecological conditions and performs better than other cereals under adverse and marginal conditions and fits in to various cropping and crop rotations system and useful as a catch crop and low-risk reliable crop [5]. Other benefits of tef are; tef seed can be stored for a long time as the grains not affected by storage pests, less susceptibility to disease and insect pests and tef straw is nutritious and serves as fodder for cattle feed [6]. Utilization of tef grain as food crop has been limited to Ethiopia for several centuries. However, currently tef has been gaining global popularity as health food because of tef is gluten-free, which is suitable for peoples suffering from gluten protein allergy known as celiac disease [7] and many other health-related benefits. Tef grain is primarily used for human consumption after baking the grain flour into popular cottage bread called "*injera*". The straw is an important source of feed for animals.

Despite its importance, the productivity of tef is about 1.76 tha^{-1}, which is low compared to 4.01 tha^{-1} for maize and 2.77 tha^{-1} for wheat [8]. This could be mainly due to susceptibility to lodging, low yield potential of local varieties used by farmers, drought and other biotic and abiotic stresses [5]. Therefore, this necessitates development of new high yielding tef varieties combining other important traits. Grain yield is a complex trait which is influenced by several component traits and direct selection for grain yield is often not effective. Thus, it is essential to study the association of yield components with yield. Genetic correlation estimates are useful in determining the components that influence a trait either positively or negatively. Genetic correlation (rg) is the association of breeding values (*i.e.*, additive genetic variance) of the two characters [9]. However, correlation estimate do not provide exact information of the relative importance of direct and indirect effects of component traits on complex traits such as yield. Path analysis provides more information among variables than do correlation coefficients. Path coefficient analysis is a standardized partial regression coefficient that permits partitioning of correlation coefficient into components of direct and indirect effects of various traits towards dependent variable [10]. Therefore, the objective of the present study was to evaluate the genotypic association of yield components with yield and their direct and indirect effect on grain yield of tef.

2. Methods

2.1 Experimental Sites and Materials

The study was conducted during the main cropping season of 2016 at Holetta, which is located in central highlands of Ethiopia at 09°03"N, 38°30"E, with an altitude of 2,400 m above sea level. It receives an average annual rainfall of 1102 mm and the soil type is Nitosol. Eighteen tef genotypes, including 16 tef lines, one standard check variety, and a local check obtained from Debrezeit agricultural research center were evaluated for grain yield and other agronomic traits. The 16 tef lines were generated from the hybridization different parental genotypes (Table 1).

Table 1. Lists of tef genotypes used in a study

No.	Genotypes	Source
1	Standard check	DZ-Cr-387 (Quncho)
2	RIL-50A	DZ-Cr-387 x DZ-01-192
3	RIL-52A	DZ-Cr-387 x DZ-01-192
4	RIL-113B	DZ-Cr-387x DZ-01-192
5	RIL-179A	DZ-Cr-387 x DZ-01-192)
6	RIL-66A	DZ-Cr-387 x Gealmie
7	RIL-115A	DZ-Cr-387 x Gealmie
8	RIL-55	Gomade x Gealmie
9	RIL-65	Gomade x Gealmie
10	RIL-123	DZ-Cr-387 x 3774-13
11	RIL-4	DZ-01-196 x 3774-13
12	RIL-30	DZ-01-196 x 3774-13
13	RIL-73	DZ-01-196 x 3774-13
14	RIL-126	DZ-01-196 x 3774-13
15	RIL-165	DZ-01-196 x 3774-13
16	RIL-244	DZ-01-196 x 3774-13
17	RIL-277	DZ-01-196 x 3774-13
18	Local check	Farmers' variety

2.2 Experimental Design and Data Collected

The experimental design was a randomized complete block with four replications. The plot size was 2 m x 2 m with 0.2 m between rows and 1 m between plots. Seeds were drilled along the 10 rows of each plot at the rate of 15 kg/ha.

Fertilizer was applied according to recommendation for each location (60 kg/ha P_2O_5 and 40 kg/ha N). All other cultural management practices were done as per recommended of the location.

Data were recorded for days to panicle emergency (days to heading), grain filling period, days to maturity, shoot biomass (t/ha), grain yield (t/ha), lodging index (%) and harvest index (%) on whole plot base. Lodging index was expressed following the method described by Caldicott and Nuttall [11], while harvest index was calculated as a ratio of the grain yield to shoot biomass. Grain filling period was determined as the difference between days to maturity and days to panicle emergency. On the other hand, data were measured from five randomly selected plants from each plot on plant height (cm) and panicle length (cm).

2.3 Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using agricolae package of R statistical software (version 3.6.1) [12] in RStudio (version 1.3.1093) [13]. The statistical model used for ANOVA is: $Y_{ik} = \mu + G_i + B_k + \varepsilon_{ik}$. Where, Y_{ik} = observed value of genotype i in block k, μ = grand mean, G_i = effect of genotype i, ,B_k = the effect of block k, ε_{ik} = error (residual) effect of genotype i in block k. Multivariate restricted maximum likelihood (REML) estimation method was used to estimate genotypic correlations (rg) among pair of traits and their corresponding standard errors using PROC MIXED procedure of SAS 9.3 software [14, 15]. Correlation estimates were considered significant when their 95% confidence intervals did not include zero [14]. The genetic correlation coefficients of all the traits were partitioned into direct and indirect effects by path coefficient analysis, using the Genes program [16] following the procedure Dewey and Lu [10].

3. Results and Discussion

3.1 Analysis of Variance and Mean Values

There were significant differences between the genotypes for all traits except grain filling period (Table 2). Significant differences observed among the genotypes for grain yield and yield related traits from analysis of variance suggests the presence of substantial variation in the inherent genetic potential of the genotypes studied, which allows the selection of high yielding tef genotypes. In line with the present study, significant genotypic differences were reported for these traits in tef genotypes [17-18]. Mean grain yields ranged from 1.89 t/ha for local check and RIL-165 to 2.54 t/ha for RIL-30. Nine genotypes had an above average grain yield, while six genotypes had an equal or higher grain yield than the standard check (Table 2). The top three high-yielding genotypes were RIL-30 (2.54 t/ha), RIL-115A (2.38 t/ha) and RIL 113B (2.35 t /ha). These genotypes were comparable with the standard check in terms of days to maturity, panicle length, shoot biomass and lodging index, but were slightly lower in days to panicle emergency and plant height. The range of values observed for grain yield and yield related traits in present study were within the range reported by other study [5].

3.2 Estimates of Genotypic Correlation

Estimates of genotypic correlations between pairs of traits are indicated in Table 3. Grain yield showed positive and significant genotypic associations with panicle length (rg = 0.98), plant height (rg = 0.64) and shoot biomass (rg = 0.53) indicating dependent genetic control between grain yield and these traits. The positive and significant genotypic correlation of grain yield with plant height, panicle length and shoot biomass indicate that these traits are essential yield components and the possibility of improving grain yield by improving and selecting either one or more of these traits. Similar relationships between these traits with grain yield have been reported in earlier studies on tef [19]. Similarly, Panicle length which is an important component of yield exhibited a strong positive genetic correlation with days to maturity, plant height and shoot biomass implying the possibility of simultaneous selection of panicle length and these traits. Study also showed that significant positive association of days to maturity, shoot biomass and plant height with panicle length [20]. Significant positive genetic association could be due to linkage disequilibrium or as a result of pleiotropic effects of genes that controlled these characters in the same direction [21].

Lodging index showed strong negative genotypic association with shoot biomass, plant height and days to maturity. Earlier study in tef also reported significant negative association these traits with lodging index at genotypic level in a study with recombinant tef inbred lines [22]. In contrary, previous study in tef reported significant positive association of lodging index with shoot biomass, plant height and days to maturity [20]. Lodging index exhibited negative association with grain yield, but the magnitude of association was low. Previous studies have mentioned non-significant and negative genetic correlation lodging index with and grain yield. Lodging is the major constraint in tef production and reduces the yield of tef by 11 to 22 % [2].

Table 2. Means for grain yield and agronomic traits of 18 tef genotypes

Genotype	DPE	DM	PH	PL	LI	SBM	GY	HI	GFP
Standard check	68.5	127.5	109.95	36.5	78.5	8.625	2.28	0.260	59
RIL-50A	63	133	104.65	30.6	79.5	7.938	2.05	0.255	70
RIL-52A	64.75	132.75	104.05	31.8	77	8.125	2.00	0.248	68
RIL-113B	63.5	135.25	102.3	33.85	79.5	8.188	2.35	0.288	71.75
RIL-179A	65.5	136	102.25	33.25	79.5	8.625	2.30	0.265	70.5
RIL-66A	68.25	137.5	102.1	33.6	64.5	9.313	2.23	0.238	69.25
RIL-115A	63.25	126.25	104.1	36.9	79.5	8.313	2.38	0.283	63
RIL-55	64.5	129.75	91.4	28.3	80	7.750	1.94	0.250	65.25
RIL-65	64.75	131.75	94.6	22.55	73	7.875	1.94	0.243	67
RIL-123	65.75	138	99.7	31.4	66	8.625	2.19	0.253	72.25
RIL-4	61	126.5	90.95	31.25	84.5	6.813	1.95	0.285	65.5
RIL-30	62.5	131.5	94.8	36.25	83.5	7.938	2.54	0.320	69
RIL-73	62.25	138.75	109.5	36.45	55	9.750	2.28	0.235	76.5
RIL-126	68	132	106.9	34.75	74	8.625	2.14	0.245	64
RIL-165	62.25	123	95.6	28.7	79.5	7.313	1.89	0.258	60.75
RIL-244	63.25	131.75	92.95	34.4	82	7.438	2.14	0.288	68.5
RIL-277	63.75	128	104.1	35.4	67.5	8.438	2.33	0.270	64.25
Local check	56.25	122	86.75	28.45	88	5.938	1.89	0.315	65.75
Genotype mean square	33.13***	97.38**	183.39***	56.48***	270.82***	3.080***	0.150***	0.003***	74.220ns
Error mean square	1.37	39.82	13.38	4.58	57.42	0.590	0.040	0.000	41.570
Mean	63.94	131.18	99.81	32.47	76.17	8.090	2.160	0.270	67.240
CV (%)	1.83	4.81	3.66	6.59	9.95	9.510	9.770	5.510	9.590
LSD 5%	1.66	8.96	5.19	3.04	10.76	1.090	0.299	0.020	9.150

Notes. Where, DPE = days to panicle emergency (days), DM = days to maturity (days), PH = plant height (cm), PL = panicle length (cm), LI = lodging index (%), SB = shoot biomass (t/ha), GY = grain yield (t/ha), HI = harvest index (%), GFP = grain filling period (days), ns = non-significant, ** and *** = significant at P <0.01 and p<0.001, Lsd 5% = Least significant difference at 5% probability level, CV% = Coefficient of variation.

Table 3. Estimates of genotypic correlation coefficients and their standard errors (in parentheses) of 9 traits in tef genotypes

Traits	DPE	DM	PH	PL	LI	SB	GY	HI	GFP
DPE	1	0.663† (0.232)	0.657† (0.155)	0.268 (0.241)	-0.502† (0.224)	0.806† (0.122)	0.348 (0.265)	-0.686† (0.148)	-0.106 (0.371)
DM		1	0.580† (0.251)	0.239 (0.315)	-0.901† (0.198)	0.999† (0.152)	0.544 (0.309)	-0.623† (0.246)	0.674† (0.229)
PH			1	0.590† (0.171)	-0.629† (0.183)	0.984† (0.079)	0.639† (0.209)	-0.586† (0.185)	0.122 (0.377)
PL				1	-0.240 (0.272)	0.584† (0.201)	0.980† (0.097)	0.185 (0.256)	0.053 (0.383)
LI					1	-1.000† (0.123)	-0.461 (0.303)	0.816† (0.132)	-0.700† (0.325)
SB						1	0.535† (0.222)	-0.704 10.092	0.532 (0.346)
GY							1	0.216 (0.288)	0.379 (0.412)
HI								1	-0.151 (0.379)
GFP									1

Note. [†]Correlation coefficient significantly different from zero, when |correlation|> 1.96 × SE.

3.3 Genotypic Path Coefficient Analysis

The genotypic direct and indirect effects of yield-related traits on grain yield are presented in Table 4. Path coefficient analysis was used to provide further information on the nature of the interrelations among the various characters and their effects on grain yield. The high value for determination coefficient of path analysis (0.97) and low effect of the residual variable (0.15) showed that there were strong cause and effect relationships between the analyzed variables. The highest positive direct effects on grain yield was recorded for days to maturity (1.404) followed by shoot biomass (0.879 and harvest index (0.679). In addition, panicle length, lodging index and plant height exhibited positive direct effects on grain yield. This indicates that more emphasis should be placed on genetic improvement of these traits to increase grain yield by indirect selection. In line with the present study, previous study in tef also reported a high direct effect of shoot biomass and harvest index on grain yield [23-24]. Similarly, Mizan et al. [25] also noted a positive genotypic direct effect of days to maturity. In contrast to present study Chekol et al. [26] reported a negative direct effect of days to maturity on grain yield. Days to panicle emergency and grain filling period in the present study showed negative direct on grain yield, but these traits showed positive correlation with grain yield. The negative direct effects observed in this study by days to panicle emergency and grain filling period indicate that these traits only contribute to grain yield mainly through their high and positive indirect effects on other characters. Shoot biomass followed by grain filling period and days to panicle emergency showed the highest positive indirect effect on grain yield through days to maturity. Similarly, days to maturity, plant height and panicle length had high positive indirect effect on grain yield via shoot biomass. This indicates that selection for these traits would be effective and it could increase grain yield by influencing shoot biomass indirectly.

Table 4. Genotypic path coefficient analysis showing direct and indirect effects of different characters on grain yield of tef

Effect	DPE	DM	PH	PL	LI	SB	HI	GFP
Direct effect on GY	-0.846	1.404	0.026	0.342	0.345	0.879	0.679	-0.803
Indirect effect via DPE	-	-0.561	-0.556	-0.227	0.425	-0.682	0.58	0.09
Indirect effect via DM	0.931	-	0.815	0.336	-1.265	1.404	-0.875	0.947
Indirect effect via PH	0.017	0.015	-	0.016	-0.017	0.026	-0.015	0.003
Indirect effect via PL	0.092	0.082	0.202	-	-0.082	0.2	0.063	0.018
Indirect effect via LI	-0.173	-0.311	-0.217	-0.083	-	-0.386	0.282	-0.242
Indirect effect via SB	0.709	0.879	0.864	0.513	-0.984	-	-0.618	0.468
Indirect effect via HI	-0.466	-0.424	-0.398	0.125	0.555	-0.478	-	-0.103
Indirect effect via GFP	0.085	-0.541	-0.098	-0.043	0.562	-0.427	0.121	-
Total	0.348	0.544	0.639	0.98	-0.461	0.535	0.216	0.379
Residual variable effect				0.15				
Coefficient of determination				0.97				

4. Conclusion

The present study revealed presence of genetic variability among tef genotypes for grain yield and yield related traits. Thus, there is an opportunity of exploiting the existing variability in tef improvement programs through selection and hybridization. Correlation study showed higher positive and significant genotypic association of panicle length, plant height and shoot biomass with grain yield indicating dependent genetic control between grain yield and these traits. These traits also exerted favorable direct and indirect effects via the other traits. Panicle length, shoot biomass and plant height had positive significant association with grain yield and positive direct and indirect effects on grain yield at genotypic level. Hence, these characters could be used as target traits for the improvement of grain yield in tef.

Acknowledgements

The author acknowledges the Ethiopian Institute of Agricultural Research for funding this study. The author is also thankful to the staff members of tef improvement program of Holetta agricultural research center for their technical support.

References

[1] Kebebew, A., Gina, C., Dejene, G., Rizqah, K., Solomon, C., Sonia, P., Regula, B., Abiel, R., Suhail, R., and Zerihun, T.

(2015). Genetic diversity in tef [Eragrostistef (Zucc.) Trotter]. Front. Plant Sci., 6: 177.

[2] Solomon, C., Setotaw, F., Tebkew, D., Tsion, F., Yazachew, G., Worku, K., Kidist, T., Zerihun, T., Kebebew, A. (2019). Significance and prospect of an orphan crop tef. Planta, 250: 753-767.

[3] Vavilov, N. I. (1951). The Origin, Variation, Immunity and Breeding of Cultivated Plants (Translated by S. K. Chester). Chronica Botonica, 13: 1-364.

[4] Watson, L., Dallwitz, M. J. (1992). The grass genus of the world. CAB International, Wallingford.

[5] Kebebew, A., Yu, J. K., Zeid, M., Getachew, B., Hailu, T., and Sorrells, M. E. (2011). Breeding tef [Eragrostis tef (Zucc.) Trotter]: Conventional and molecular approaches. Plant Breed., 130: 1-9.

[6] Seyfu, K. (1997). Tef (Eragrostis tef (Zucc.) Trotter) Promoting the Conservation and Use of Underutilized and Neglected Crops. Inst. of Plant Genetics and Crop Plant Research, Gatersleben/Int. Plant Genet. Resour. Inst., Rome, Italy.

[7] Spaenij-Dekking, L., Kooy-Winkelaar, Y., and Frits, K. (2005). The Ethiopian cereal tef in in celiac disease. The New England Journal of Medicine, 353: 1748-1749.

[8] CSA. (2019). Agricultural Sample Survey 2018/2019 (2011 E.C). Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Central Statistical Agency, Addis Ababa, Ethiopia, Statistical bulletin 589.

[9] Falconer, A. R. (1989). Introduction to Quantitative Genetics, 3rd ed.; Longman, New York, USA.

[10] Dewey, D. R. and Lu, K. H. (1959). A Correlation and Path-coefficient Analysis of Components of Crested Wheat Grass Seed Production. Agron. J., 51: 515-518.

[11] Caldicott, J. and Nuttall, A. (1979). A method for the assessment of lodging in cereal crops. Journal of the National Institute of Agricultural Botany, 15: 88-91.

[12] R Core Team. (2019). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

[13] RStudio Team. (2020). RStudio: Integrated Development Environment for R. RStudio, PBC, Boston, MA, USA.

[14] Holland, J. B. (2006). Estimating genotypic correlations and their standard errors using multivariate restricted maximum likelihood estimation with SAS Proc MIXED. Crop Science, 46: 642-654.

[15] SAS Institute. (2011). SAS® 9.3 for Windows. SAS Inst., Cary, NC.

[16] Cruz, C. D. (2016). Genes software-extended and integrated with the R, Matlab and Selegen. Acta Scientiarum. Agronomy, 38: 547-552.

[17] Solomon, C., Hailu, T., and Singh, H. (2009). Genetic variability, heritability, and trait relationships in recombinant inbred lines of tef [Eragrostis tef (Zucc.) Trotter]. Res. J. Agric. Biol. Sci., 5: 474-479.

[18] Hailu, T., Kebebew, A., Fufa, H., Tiruneh, K., and Tesfaye, T. (2003). Heritability and genetic advance in recombinant inbreed lines of tef (Eragrostis tef). Euphytica, 131: 91-6.

[19] Habte, J., Khashun, T., Kebebew, A., Solomon, C., and Zerihun, T. (2017). Semi-dwarf tef lines for high seed yield and lodging tolerance in central Ethiopia. Afri. Crop Sci. J., 4(25): 419-439.

[20] Nigus, B. (2018). Genetic Variability, Broad Sense Heritability and Trait Associations among Grain Yield and Yield Related Traits in Tef [Eragrostis tef (Zucc.) Trotter] Genotypes. Acad. Res. J. Agri. Sci. Res., 6(3): 163-171.

[21] Hallauer, A. R., Carena, M. J., and Miranda, Filho J. B. (2010). Quantitative Genetics in Maize Breeding, 3rd ed.; Springer, New York, USA.

[22] Solomon, C., Hailu, T., Habtamu, Z., and Singh, H. (2006). Correlation and path coefficient analysis of yield related traits in recombinant inbred lines of tef (Eragrostis tef). J. Genet. & Breed., 60: 209-216.

[23] Dagnachew, L. and Girma, M. (2014). Correlation and Path Coefficient Analysis of Quantitative Traits in Tef [Eragrostis tef (Zucc.) Trotter] Germplasm Accessions from Different Regions of Ethiopia. American Journal of Research Communication, 2(2): 194-204.

[24] Habte, J., Kebebew, A., Kassahun, T., and Zerihun, T. (2019). Genotype x environment interaction and stability analysis in grain yield of tef (Eragrostis tef) evaluated in Ethiopia. JEAI., 35(5): 1-13.

[25] Mizan, T. A., Shimelis, H., Mark, L., and Kebebew, A. (2017). Genetic variation and trait association of tef [Eragrostis tef (Zucc.) Trotter] evaluated under optimal and moisture stressed environments. Australian J. Crop Sci., 11(03): 241-247.

[26] Chekole, N., Wassu, M., and Tebkew, D. (2016). 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, 4(11): 73-102.