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Correlation and Path Coefficient Analysis among Yield Component Traits in Tef [*Eragrostis Tef*) Zucc. Trotter] Landraces

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Abstract: Understanding the nature of correlations among characters facilitates selection. The present study was undertaken to assess the nature of association of agronomic traits in 37 tef lines. The experiment was conducted in 2010 main cropping season at Adet Agricultural Research Center using randomized complete block design with three replications. Correlation and path coefficient analyses were conducted for nine traits at genotypic, phenotypic and environmental levels. Negative and highly significant ($p<0.01$) correlations were observed between days to heading and grain filling period both at phenotypic and environmental levels. Grain filling period and number of productive tillers per plant were positively and strongly correlated (r=0.78) at genotypic level. Grain filling period showed significant correlation with biomass yield (rp=0.40), grain yield (rp=0.45 and rg=0.75) and harvest index (rg=0.85 and rp=0.35). Biomass yield, number of productive tillers per plant and grain filing period exerted positive and substantial direct effect on grain yield at the genotypic level. Number of productive tillers per plant exerted the highest indirect and positive effect through its direct effect on biomass yield. Generally, biomass yield, number of productive tillers per plant and harvest index can be used as morphological markers for grain yield.

Key words: Correlation % Tef % Path coefficient

INTRODUCTION

Tef [*Eragrostis tef* (Zucc.)Trotter] is an allotetraploid (2n=4x=40) cereal which has its genetic origin and diversity in Ethiopia [1]. Tef belongs to the family Poaceae, subfamily Eragrostoideae, tribe Eragrosteae and genus *Eragrostis* [2]. It is a C4, self-pollinated, chasmogamous annual cereal [3]. The genus contains about 350 species of which tef is the only cultivated species.

Research to improve tef was underway for the last 40 years in Ethiopia with a primary focus on yield [4]. However, yield being a complex trait, its inheritance is influenced by many genes which are actually linked to various traits [5]. As a result, these traits show association in their expression. Association can also be manifested by genes which are pleotropic. Thus, results based on univariate analysis do not show the exact nature of variation and the potential of improvement expected as the assumptions are as if the traits are varying sole.

Correlation coefficient is the measure of the degree for linear association between two variables [6]. Knowledge of correlations among important characters may facilitate selection of desired traits directly or indirectly based on the nature of the correlation. The practical utility of selecting for a given character as a means of improving another depends on the extent to which they are correlated to the major trait under consideration [7].

Grain yield in tef showed a strong positive phenotypic and genotypic correlation with harvest index, shoot biomass, lodging index, panicle length, plant height, panicle weight and yield per panicle indicating the possibility of improving yield indirectly through selecting these traits [8-12].

Correlation estimates are helpful in determining the components that affect a character either positively or negatively. However, they do not provide exact pictures of the relative importance of direct and indirect influences of component traits in complex traits such as yield. As a result there was a need to devise a way of partitioning the correlation coefficients into direct and indirect components. Path coefficient analysis is statistical tool useful to reveal the path along which direct and indirect effects of a trait on another trait can be depicted in the relationships among variables [13].

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Shoot biomass (0.49), panicle weight (0.19), plant height (0.15) and lodging index (0.12) showed positive direct effects [14]. Shoot biomass (0.83) and harvest index (0.48) showed the highest positive direct effects on grain yield and substantial amount of indirect effects were exerted by plant height and panicle length through biomass yield [9, 12]. As it is evident from the above findings, the degree of association varies based on the test materials and the environment they were raised in. Therefore, the objectives of the present study were (1) to assess the nature of association between characters, (2) to estimate the direct and indirect effects of independent characters on grain yield and (3) to identify traits contributing more to yield.

MATERIALS AND METHODS

Experimental Site: The field experiment was conducted at Adet Agricultural Research Center which is located at 37°29 ´E and 11°16 ´N in the Amhara National Regional State, Ethiopia. Adet is found 45km from Bahir Dar along the main road that runs from Bahir Dar to Addis Ababa through Mota. It is located at 2240 masl and receives an average annual rain fall of 1230mm.

Experimental Materials: Landraces from Gojam, Gondar and Wollo, were accessed from Debrezeit Agricultural Research Center (National Tef Improvement Center). Improved varieties from both late (Dz-Cr-387, Dz-01-3186, Dz-01-2423) and early (Dz-Cr-37) sets were included totaling the test materials to 37 (Table 1).

The experiment was laid out in randomized complete block design with three replications. A plot size of 0.2 (1 x 0.2) m^2 was used with 1m and 2m inter rows and blocks spacing, respectively. With a seed rate of 30kg ha^{-1}, 0.6g of seed was broadcasted on the surface of the specified plot. Fertilization was also done on a rate of 40/60 N/P_2O_5kg ha^{-1}. All the DAP and 50% of Urea were applied at planting and the remaining 50% of the Urea at tillering. Land preparation and all other agronomic practices were at their optimum.

Data Collected: Main tillers of five randomly selected plants in each accession were tagged and evaluated for 14 quantitative traits. Days to 50% heading, days to 50% maturity and grain filling period were evaluated on plot basis. Plant height, panicle length, culm length, peduncle length, first basal internode length second basal internode length, number of nodes per culm and number of productive tillers per plant were measured at physiological maturity. Grain yield per plant, biomass yield per plant and harvest index were measured after harvest.

Table 1: Tef germplasm lines and their areas of collection in Amhara region, Ethiopia.

N	Code	Zone	District	N	Code	Zone	District
1	Dz-01-2580	N/Gondar	Dabat	20	Dz-01-2705	E/Gojam	Bichena
2	Dz-01-2721	N/Wolo	Kobo	21	Dz-01-2609	S/Gondar	A/Zemen
3	Dz-01-2613	S/Gondar	D/Tabor	22	Dz-01-2688	E/Gojam	Bichena
4	Dz-01-2608	S/Gondar	A/Zemen	23	Dz-01-2708	E/Gojam	Bichena
5	Dz-01-2611	S/Gondar	A/Zemen	24	Dz-01-2781	N/Wolo	Degem
6	Dz-01-2572	N/Gondar	A/Arkay	25	Dz-01-2629	Gondar	-
7	Dz-01-2610	S/Gondar	A/Zemen	26	Dz-01-2619	S/Gondar	A/Giorgis
8	Dz-01-2706	E/Gojam	Bichena	27	Dz-01-2666	S/Gondar	D/Tabor
9	Dz-01-2606	S/Gondar	A/Zemen	28	Dz-01-2598	W/Gojam	Dembecha
10	Dz-01-2582	N/Gondar	Dabat	29	Dz-01-2594	S/Gondar	Ebinat
11	Dz-01-2631	S/Gondar	Ebinat	30	Dz-01-2686	E/Gojam	Bichena
12	Dz-01-2602	S/Gondar	Ebinat	31	Dz-01-2614	S/Gondar	D/Tabor
13	Dz-01-2729	N/Wolo	Kobo	32	Dz-01-2643	W/Gojam	Adet
14	Dz-01-2691	E/Gojam	Bichena	33	Dz-01-2678	E/Gojam	Lumame
15	Dz-01-2653	W/Gojam	Mecha	Improved varieties			
16	Dz-01-2627	S/Gondar	D/Tabor	34	Dz-Cr-387 (Quncho)		
17	Dz-01-2576	N/Gondar	A/Arkay	35	Dz-01-3186 (Etsub)		
18	Dz-01-2654	W/Gojam	Mecha	36	Dz-01-2423 (Dima)		
19	Dz-01-2569	S/Gondar	A/Arkay	37	Dz-Cr-37 (Tsedey)		

*N=north, S=south, E=east, W=west

Statistical Analysis: The phenotypic, genotypic and environmental correlation coefficients were calculated using the environmental correlation coefficients were calculated following formula: $r_{xy} = \frac{COV_{xy}}{\sqrt{s^2 x^* s^2 y}}$.

Coefficients of correlation at phenotypic level were tested for significance using the formula [15]: $t = \frac{r}{\sqrt{\left(1-r^2\right)/n-2}}$ at (n-2) degree of freedom, where 'n' is number of accessions while the genotypic correlation coefficients were tested with the following formula [16]: $t = \frac{rg_{xy}}{SErg_{xy}}$, where $SErg_{xy} = \sqrt{\frac{(1-gr^2{}_{xy})}{2*h^2x*h^2y}}$ and h^2x and h^2y are the respective broad sense heritability values of traits x and y. Environmental correlation coefficients were tested at [(g-1) (r-1) - 1] degrees of freedom, where g is the number of genotypes and r replications.

The path coefficients were estimated by the formula [13]: $R_{ij}=p_{ij} + \sum r_{ik} p_{jk}$, Where: R_{ij} =Mutual association between independent variable (i) and dependent variable (j) as measured by genotypic correlation coefficient. P_{ij} = component of direct effect of independent variable (i) on the dependent variable (j) as measured by the genotypic path coefficient and $\sum r_{ik} p_{jk}$ = summation of components of indirect effects of a given independent variable (i) on a given dependent variable (j) via all other independent variables. The residual factor was estimated as described in [17]: $1 = p^2R + \sum piY^r iY$, where i=any trait in the model, Y=dependant variable (grain yield) and r=correlation coefficient between any trait i and the dependant variable. Residual (R), is the square root of non determination; known as coefficient of alienation which measures the lack of association between variables [18]

RESULTS AND DISCUSSION

Phenotypic, Genotypic and Environmental Correlations: Correlation analysis was conducted for nine traits at genotypic, phenotypic and environmental levels. Correlation between days to heading and days to maturity seemed to be controlled by non additive genes and the environment in that its genotypic correlation value was not significant. Negative and highly significant ($p<0.01$) correlation was observed between days to heading and grain filling period both at phenotypic and environmental levels, which is literally predictable in that a line spending much time in vegetative stage may get little time for grain filling. This was in agreement with the findings by [19] in tef RILs in which days to heading was negatively correlated with days to maturity at phenotypic level. Similarly in sesame, filling period was negatively correlated with days to 50% flowering in sesame at all levels of correlations [20].

Correlation between days to maturity and grain filling period was positive and highly significant ($p<0.01$) at phenotypic (rp=0.39) and environmental (re=0.69) levels while the genotypic component (rg=0.23) was positive in direction and non significant in magnitude (Table 2). Unlike days to heading, days to maturity showed positive correlation with most of the traits except number of productive tillers and harvest index at environmental level. Grain filling period and plant height showed negative and non significant correlation both at genotypic and phenotypic levels while the environmental component was positive and significant (r=0.28). The genotypic correlation between grain filling period and number of productive tillers per plant was positive while the environmental component was negative. Grain filling period and number of productive tillers per plant were positively and highly correlated (r=0.78) at genotypic level indicating the presence of additive genes responsible for these two traits. Grain filling period showed significant correlation with biomass yield (rp=0.40), grain yield (rp=0.45 and rg=0.75) and harvest index (rg=0.85 and rp=0.35). Therefore, selection for grain yield in this set of germplasm is marked by earlier heading and longer period of grain filling in terms of phenological markers.

Plant height and panicle length were significantly and positively correlated at all the three correlation components. Correlations between plant height and number of productive tillers per plant were negative which may arise from competition for photo assimilates directing it to the tillers than to height. But correlations between plant height and biomass yield and plant height with grain yield were positive except environmental correlation with biomass yield indicating the differential reaction to changes in environment. Panicle length showed positive significant phenotypic correlation (r=0.32) with biomass yield while its correlation with grain yield was not significant but positive in all the three correlation levels.

Number of productive tillers per plant showed positive and significant ($p<0.01$) correlations with biomass yield, grain yield and harvest index (Table 2). Correlation between biomass yield and grain yield were highly significant at all three correlation levels (rp=0.97, rg=0.93 &re=0.87). Correlation of harvest index with biomass yield and grain yield was also highly ($p<0.01$) significant at all levels of correlation.

Table 2: Genotypic, phenotypic and environmental correlations of nine quantitative traits on 37 tef genotypes.

		DH	DM	GFP	PH	PL	NPT	BMY	GY
DM	g	0.58	1						
	p	0.48**	1						
	e	0.23*	1						
GFP	g	-0.66	0.23	1					
	p	-0.61**	0.39**	1					
	e	-0.54**	0.69**	1					
PH	g	0.55	0.26	-0.42	1				
	p	0.33**	0.21	-0.16	1				
		-0.25*	0.12	0.29*	1				
PL	g	0.67**	0.49	-0.36	0.84**	1			
	p	0.40**	0.32*	-0.13	0.81**	1			
	e	-0.18	0.07	0.19	0.78**	1			
NPT	g	-0.26	0.45*	0.77**	-0.34	0.02	1		
	p	-0.03	0.16	0.18	-0.17	-0.03	1		
	e	0.21	-0.03	-0.18	-0.08	-0.06	1		
BMY	g	-0.09	0.51	0.59	0.07	0.22	0.94**	1	
	p	-0.03	0.40*	0.40*	0.11	0.26	0.61**	1	
	e	0.12	0.22	0.10	0.16	0.32**	0.49**	1	
GY	g	-0.24	0.46	0.72*	-0.004	0.18	0.93**	0.97**	1
	p	-0.11	0.37*	0.45**	0.03	0.20	0.63**	0.93**	1
	e	0.18	0.23	0.06	0.08	0.22	0.53**	0.87**	1
HI	g	-0.62**	0.11	0.85**	-0.18	-0.02	0.64**	0.62**	0.78**
	p	-0.29	0.05	0.35*	-0.07	0.06	0.35*	0.39*	0.65**
	e	0.12	-0.02	-0.11	0.03	0.14	0.25*	0.19	0.56**

*, ** indicate significant ($p<0.05$) and highly significant ($p<0.01$) correlations respectively.

*DH=days to heading, DM days to maturity, GFP=grain filling period, PH=plant height, PL=panicle length, PDL=peduncle length, CL=culm length, BMY=biomass yield, GY=grain yield, HI=harvest index, NPT=number of productive tillers per plant, NNC=number of nodes per culm, FIL=first internode length, SIL=second internode length.

Table 3: Direct (Diagonal) and indirect (off diagonal) effects of eight characters on grain yield at genotypic level

	DH	DM	GFP	PH	PL	NPT	BMY	HI	rgGY
DH	-0.070	0.004	-0.129	0.035	0.000	-0.007	-0.078	0.004	-0.240
DM	-0.041	0.007	0.044	0.017	0.000	0.013	0.420	-0.001	0.459
GFP	0.046	0.002	0.196	-0.027	0.000	0.020	0.483	-0.005	0.715*
PH	-0.038	0.002	-0.081	0.064	0.000	-0.009	0.058	0.001	-0.004
PL	-0.047	0.062	-0.070	0.053	0.000	0.001	0.183	0.000	0.182
NPT	0.018	0.003	0.151	-0.023	0.000	0.026	0.775	-0.004	0.933**
BMY	0.007	0.003	0.115	0.005	0.000	0.025	0.821	-0.004	0.972**
HI	0.043	0.001	0.167	-0.011	0.000	0.017	0.511	-0.006	0.784**

R= 0.15

*DH=days to heading, DM days to maturity, GFP=grain filling period, PH=plant height, PL=panicle length, BMY=biomass yield, GY=grain yield, HI=harvest index, NPT=number of productive tillers per plant.

Table 4:Direct (Diagonal) and indirect (off diagonal) effects of eight characters on grain yield at phenotypic level

	DH	DM	GFP	PH	PL	NPT	BMY	HI	rpGY
DH	-0.577	0.266	0.344	-0.004	-0.013	-0.001	-0.026	-0.102	-0.113
DM	-0.279	0.550	-0.223	-0.002	-0.010	0.005	0.311	0.016	0.368*
GFP	0.353	0.218	-0.562	0.002	0.004	0.005	0.309	0.121	0.450**
PH	-0.191	0.116	0.088	-0.012	-0.026	-0.005	0.082	-0.025	0.027
PL	-0.231	0.178	0.072	-0.009	-0.032	-0.001	0.203	0.021	0.200
NPT	0.015	0.091	-0.100	0.002	0.001	0.030	0.470	0.120	0.629**
BMY	0.020	0.222	-0.225	-0.001	-0.008	0.018	0.771	0.134	0.930**
HI	0.171	0.025	-0.198	0.001	-0.002	0.010	0.301	0.343	0.651**

R= 0.18

DH=days to heading, DM days to maturity, GFP=grain filling period, PH=plant height, PL=panicle length, BMY=biomass yield, GY=grain yield, HI=harvest index, NPT=number of productive tillers per plant.

Table 5: Direct (Diagonal) and indirect (off diagonal) effects of eight characters on grain yield at environmental level

	DH	DM	GFP	PH	PL	NPT	BMY	HI	reGY
DH	0.474	-0.112	-0.349	0.002	0.015	0.008	0.092	0.047	0.177
DM	0.109	-0.486	0.444	-0.001	-0.005	-0.001	0.174	-0.007	0.226
GFP	-0.258	-0.336	0.642	-0.002	-0.015	-0.007	0.082	-0.041	0.064
PH	-0.120	-0.056	0.184	-0.008	-0.062	-0.003	0.128	0.010	0.075
PL	-0.088	-0.033	0.126	-0.006	-0.079	-0.003	0.250	0.056	0.224
NPT	0.098	0.014	-0.114	0.001	0.005	0.041	0.385	0.101	0.529**
BMY	0.056	-0.108	0.067	-0.001	-0.025	0.020	0.782	0.080	0.870**
HI	0.055	0.009	-0.065	-0.0002	-0.011	0.010	0.152	0.412	0.561**

R= 0.265

DH=days to heading, DM days to maturity, GFP=grain filling period, PH=plant height, PL=panicle length, BMY=biomass yield, GY=grain yield, HI=harvest index, NPT=number of productive tillers per plant.

Genotypic Path Coefficient: Biomass yield per plant, number of productive tillers per plant and grain filling period exerted positive and substantial direct effect on grain yield at the genotypic level (Table 3). On the other hand days to heading and harvest index showed negative and direct effect but smaller in magnitude. Grain filling period did also show substantial indirect effect on grain yield through its positive effect on biomass yield per plant, days to heading and number of productive tillers per plant. Of all indirect effects the one exerted by productive tillers per plant on biomass yield was the highest value recorded. Plant height showed positive direct effect while at the same time exerting negative indirect effect through its association with days to heading, grain filling period, number of productive tillers per plant and harvest index. Panicle length exerted negligible direct effect due to counterbalancing of indirect effects through other traits. Positive and substantial indirect effect was exerted by panicle length via biomass yield, days to maturity and plant height. The positive correlation between grain yield and number of productive tillers was largely due to its positive indirect effect of the later on biomass yield. Biomass yield affected grain yield directly and also its indirect effect on grain filling period and number of productive tillers per plant was also relatively larger. Harvest index showed negative direct effect on the dependant trait. However, its indirect effect on biomass yield was large and positive. Similarly, harvest index showed a substantial positive indirect effect through its influence on grain filling period.

Phenotypic Path Coefficient: Days to heading (-0.58) exerted substantial amount of negative direct effect on grain yield, however this direct effect was diluted by its positive and indirect effects through days to maturity (0.27) and grain filling period (0.34). Similarly, grain filling period exerted negative direct effect (-0.56), but positive indirect effects through days heading (0.35), days to maturity (0.22) and biomass yield (0.31) which finally rendered highly significant and positive phenotypic correlation with grain yield. Plant height and panicle length were having negative direct effects on grain yield (Table 4). Days to maturity exerted substantial positive direct effect on the dependant trait. It did also influence grain yield indirectly through its effects on biomass yield and harvest index. Days to maturity exerted negative indirect effect on grain yield via days to heading, grain filling period, plant height and panicle length. The positive and significant correlation of number of productive tillers per plant with grain yield was mainly due to the positive indirect effect of the former with biomass yield and harvest index. Number of productive tillers per plant, biomass yield per plant and harvest index were having positive direct effects on grain yield. The greater proportion of correlation between biomass yield and grain yield was due mainly to its direct positive effect. It also affects grain yield indirectly via its positive effect on days to maturity and harvest index. Harvest index has exerted positive direct effect and also all of its indirect effects were positive except on panicle length. However, much of the correlation was due to the direct effect and indirectly via days to heading and biomass yield. The residual (R) indicates that more than 80% of the variation is explained by the variates in the model.

Environmental Path Coefficient: At environmental level, days to maturity, plant height and panicle length were having direct but negative effects on grain yield. Grain filling period showed positive direct effect; however it was affecting yield negatively through its indirect influence on all other traits except biomass yield. Plant height and panicle length were affecting grain yield negatively and directly and also indirectly through their negative association with all other traits except biomass yield, number of productive tillers per plant and harvest index (Table 5).

All the direct and indirect effects of number of productive tillers per plant were positive except its indirect effect on grain filling period. Much of the association was accounted by its indirect effect on biomass yield. Biomass yield showed similar patterns of direct effects (positive and substantial) on yield which accounted much of the correlations at all levels. Environmental correlation of grain yield and harvest index was largely due to the direct effect of the later. Generally it can be concluded that selecting for high values in grain filling period, biomass yield, number of productive tillers per plant and harvest index can improve yield both directly and indirectly.

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REFERENCES

1. Gugsa, L., G. Belay and S. Ketema, 2001. The cytogenetics of tef. Narrowing the Rift: Tef Research and Development. Pp. 49-57. Tefera, H. Belay, G. and Sorrells, M. (Eds). pp: 16-19.
2. Ketema, S., 1997. Tef. [*Eragrostis tef* (Zucc.) Trotter.] Promoting the conservation and use of underutilized and neglected crops. Institute of Plant Genetics and Crop Plant Research, Gatersleben/ International Plant Genetic Resources Institute, Rome, Italy.
3. Ayele, M., 1999. Genetic diversity in tef (*Eragrostis tef* (Zucc) Trotter) for osmotic adjustment, root traits and Amplified Fragment Length Polymorphism. PhD Thesis, Texas Tech University, USA.
4. Tefera, H. and S. Ketema, 2001. Production and importance of tef in Ethiopian agriculture. Narrowing the Rift: Tef Research and Development. pp: 3-7. Tefera, H. Belay, G. and Sorrells, M. (Eds). pp: 16-19.
5. Assefa, K., J.K. Yu, M. Zeid, G. Belay, H. Tefera and M. E. Sorrells, 2010. Review: Breeding tef [*Eragrostis tef* (Zucc.) Trotter]: conventional and molecular approaches. Plant Breeding.
6. Gomez, K.A. and R.A. Gomez, 1984.Staitical Procedures for Agricultural Research. 2nd Edition. John Wiley & Sons Inc. New York, Chichester, Brisbane, Toronto, Singapore.
7. Johnson, H.W., H.F. Robinson and R.F. Comstock, 1955. Genotypic and phenotypic correlation in soybean and their implication in selection. Agronomy J., 47: 477-483.
8. Assefa, K., H. Tefera and A. Merker, 2002. Variation and inter-relation ships of quantitative traits in tef [*Eragrostis tef* (zucc.) Trotter] germplasm from western and southern Ethiopia. Hereditas. 136: 116.
9. Chanyalew, S., 2007. Phenotypic Evaluation and Molecular Study of Parents and Recombinant Inbred Lines of Tef [*Eragrostis tef* (Zucc.) Trotter]. PhD Thesis. Haramaya University.
10. Hundera, F., Nelson, P.S. Baenziger, E. Bechere and H. Tefera, 2000.Association of lodging and some morph-agronomic traits in tef [*Eragrostis tef* (Zucc). Trotter]. Tropical Agriculture. 77(3): 169-17.
11. Tefera, H., K. Assefa, F. Hundura, T. Kefyalew and T. Tefera, 2003. Heritability and genetic advance in recombinant inbred lines of tef [*Eragrostis tef*]-Euphyteca, 131: 91-96.
12. Debebe, A., 2005. Performance of f4 progenies and associations among yield and yield related traits in tef (*Eragrostis tef*). MSc thesis, Alemaya University.
13. Dewey, D.R. and K.H. Lu, 1959. A correlation and path coefficient analysis of components of crested wheat grass and seed production. Agron. J., 51: 515-7.
14. Hundera, F., E. Bechere and H. Tefera, 1999. Interrelation ships of grain yield, lodging and agronomic traits in tef, Eragrostis tef. Tropical Sci., 39: 63-69.
16. Robertson, G.E., 1959. The sampling variance of the genetic correlation coefficient. Biometrics, 15: 469-485.
17. Singh, R.K. and B.D. Chaudhary, 1985. Biometrical Methodes in Quntitative Genetic Analysis Kalyani Publishers, New Delhi-Ludhianam, India.
18. Sokal, R.R. and F.J. Rohlf, 1995. BIOMETRY. The Principles and practices of Statistics in Biological Research. State University of New York at Stoney Brook. W.H.Freeman And Company. New York.
19. Chanyalew, S., H. Tefera and H. Singh, 2009. Genetic variability, heritability and trait relationships in recombinant inbred lines of tef (*Eragrostis tef* (Zucc.) Trotter). Res. J. Agric. and Bio. Sci., 5(4): 474-479.
20. Menzir, A., 2008. Genetic variability and association of characters in sesame (*Sesamum indicum* l.) Genotypes. An MSc thesis, Alemaya University.