Correlation and Path Coefficient Analysis of Quantitative Traits in Tef [*Eragrostis tef (Zucc*.) Trotter] Germplasm Accessions from Different Regions of Ethiopia

***Dagnachew Lule and Girma Mengistu**

Bako Agricultural Research Center, PO. Box: 03, Tel: +251-911-813638, E-mail: *hawinok@gmail.com, Bako, Ethiopia

ABSTRACT

Seed yield is a complex character and considered as the ultimate product of its components and hence a thorough knowledge on the nature of interrelationship prevalent between contributory characters and grain yield is a pre- requisite to plan a meaningful crop improvement program. To this end, seventy nine tef landraces collected from ten administrative zones were planted with two improved varieties in simple lattice design at Bako Agricultural Research Center during 2008 main cropping season to assess the genotypic and phenotypic association of quantitative traits and the direct and indirect effect of these traits on grain yield. About 80.83% of the total traits association showed positive genotypic association. This positive correlation could be resulted from the presence of common genetic elements that controls the characters to the same direction. Harvest index (0.548), days to panicle emergency (0.412) and culm diameter (0.399) showed relatively high and positive genotypic direct effect on grain yield per plant. Such result implies any genetic improvement on those traits could improve grain yield per plant. Lodging index showed strong negative genotypic correlation to plant height (-0.366), panicle length (-0.319) and culm length (-0.310). Besides, it is negatively associated to grain yield both phenotypically and genetically. All quantitative traits except harvest index (0.671) showed minimum phenotypic direct and indirect effect on grain yield through each other. Panicle length, days to 50% maturity and biomass weight per plant showed positive genotypic correlation, but the negative direct effects on grain yield per plant. This implies that the indirect effects of other polygenic traits through those traits seem to be the cause of positive correlation and hence selection for grain yield should consider such important traits simultaneously.

Key words and phrases: *Eragrostis tef*, correlation, path coefficient

{**Citation:** Dagnachew Lule and Girma Mengistu. Correlation and path coefficient analysis of quantitative traits in tef [*Eragrostis tef (Zucc*.) Trotter] aermplasm accessions from different regions of Ethiopia. American Journal of Research Communication, 2014, 2(2): 194-204} www.usa-journals.com, ISSN: 2325-4076.

INTRODUCTION

Tef [*Eragrostis tef* (Zucc.) Trotter] is an indigenous cereal to Ethiopia. The abundance of several species of *Eragrostis* in Ethiopia and also the presence of wider genetic diversity for tef in Ethiopia than the other part of the world indicate that tef originated and domesticated in Ethiopia (Vavilov, 1951). Tef is grown in almost all regions of Ethiopia since it is the preferred grain for local consumption, highly valued by farmers and consumers and fetches the highest grain price compared with other cereals (Ketema, 1997). Its special adaptation to diverse biotic and abiotic stresses has made it a “low risk” crop for cultivation (Ketema, 1993). Some other specific merits of tef are; the higher prices for its grain, more nutritious straw for feed, better adaptation to moisture stress and also water-logging, less susceptibility to disease & insect pests, stored for longer period of time and often it is sown as a rescue crop (Ketema, 1997; Tefera and Ketema, 2001).

Despite its food, feed and economic importance, the productivity of tef is relatively low in the country primarily due to the low yielding ability of unimproved local cultivars and other biotic and abiotic factors. Landrace populations are naturally variable in seed yield and yield components. The selection imposed on these populations can directionally improve yield and yield components. Determination of the interrelationships between various agronomic characters and their direct and indirect effect on grain yield could provide good information necessary for breeders in improving the productivity of crops and also a pre- requisite to plan a meaningful breeding program.

The association among traits can be measured by genotypic and/or phenotypic coefficients of correlation. The path coefficient analysis is used to partition the correlation coefficients in to direct and indirect effects and to clarify the relationship between different morphological characters with the grain yield. In path coefficient analysis, grain yield is considered as dependent variable and the remaining traits are considered as independent variables (Singh and chaundhary, 1977). Lenka and Mishra (1973) suggested the scales for path coefficients in rice with values 0.00 to 0.09 as negligible, 0.10 to 0.19 low, 0.20 to 0.29 moderate and 0.30 to 0.99 high path coefficients. Therefore, the present study was to assess the correlation between different agronomic traits and their direct and indirect effect on grain yield of tef.

MATERIALS AND METHODS

A total of 79 tef landraces and two improved varieties (Gibe and Guduru) were evaluated in simple lattice design at Bako Agricultural Research Center during 2008 main cropping season. These landraces were collected from the major tef producing regions of Ethiopia, particularly from Arsi, Bale, East Gojam, East Wollega, Horro Guduru Wollega, Illuababor, Jimma, South Wello, West Shewa and West Wollega administrative zones. The altitude classes of collection were ranging from 1390-2750m.a.s.l. (Table 1).

Eight individual plants were selected randomly per plot, marked before panicle emergency and used as a sample for some quantitative data collected. Data were recorded for days to 50% panicle emergence, days to 50% maturity, plant height (cm), panicle length (cm), culm length (cm), lodging index, culm diameter(cm), fertile floret per spikelet (at top of the panicle), fertile floret per spikelet (at the base of the panicle), biomass weight per plant (g), grain yield per plant (g) and harvest index per plant (HI %). Genotypic and phenotypic correlation coefficient between all possible pairs of quantitative traits and the direct and indirect effect of the independent variables on grain yield per plant at genotypic and phenotypic level were analyzed using SPAR-1 (Doshi, S. R. and Gupta, K. C., 1991) computer software

RESULT AND DISCUSSION

Genotypic and phenotypic correlation coefficient

The result of analysis of genotypic correlation coefficients based on the mean of 79 tef population and two improved varieties for 15 quantitative traits showed that about 80.73% of the total traits association showed positive (Table 2). This positive correlation could be resulted from the presence of common genetic elements that controls the characters to the same direction. Positive significant correlation due to effect of genes can be the result of the presence of strong coupling linkage between their genes or the characters may be the result of pleiotropic genes that control these characters in the same direction (Kearsey and Pooni, 1996). Similar results were reported by Lule et al. (2012) for finger millet and Ayana (2001) for sorghum.

Polygenic traits such as days to panicle emergency, days to maturity, culm diameter, fertile floret per spikelet at the top of the panicle, biomass weight and harvest index showed relatively higher positive genotypic and phenotypic correlation with grain yield. This implies the possibility to combat the low yielding ability of tef accessions by improving and selecting for these important agronomic traits. Similarly, Tefera (1988) reported that grain yield per plant showed positive correlation coefficient with plant height, spikelet per main panicle, days to heading, hundred seed weight and grain yield per main panicle. In the contrary, Assefa et al. (2002) found that grain yield per plant was correlated negatively with days to maturity, harvest index and number of primary branches. Tefera (1988) also reported grain yield per plant showed negative correlation with days to maturity, panicle length and days to heading.

Lodging index showed strong negative genotypic correlation with plant height (-0.366), panicle length (-0.319) and culm length (-0.310). Besides, it is negatively associated to grain yield both phenotypically and genetically. Assefa et al. (2002) indicated that lodging resistance was positively correlated ($P \leq 0.05$) with culms diameter, plant height, panicle and peduncle length.

Morphological traits such as days to panicle emergence, days to maturity, plant height, panicle length and culm diameter revealed strong positive correlation with each other both genetically and phenotypically. This positive correlation could be resulted from the presence of common genetic elements or micro environments (or both) that controls the characters to the same direction. Supportive results in agreement to the present study were reported by Worku (2005) for linseed, Assefa et al. (2002) for tef and Ayana (2001) for sorghum. Fertile floret per spikelet at the base of the panicle showed negative correlation to grain yield per plant. This could probably be explained as the available resources were used up in the production of profuse vegetative growth as the expense of material production that should be stored in the seeds. It could also be due to the effect of different genes or pleiotrophic genes that have dominance on the characters and control the characters in different directions (Kearsey and Pooni, 1996).

Path coefficient analysis

Relatively high and positive genotypic direct effects on grain yield per plant were recorded for harvest index (0.548), days to 50% panicle emergency (0.412), culm diameter (0.399) and panicle length (0.387) (Table 3). Panicle length, culm diameters and days to 50% panicle emergency were also reported as the major contributor for the variation observed among landraces (Lule et al., 2013). This indicated that any genetic improvement on those traits can increase grain yield per plant. Similarly, Chanyalew et al. (2006) reported that harvest index and shoot biomass has high and positive direct effect on grain yield of tef recombinant inbred lines. Temesgen (2002) also noted high and positive genotypic direct effect of biomass weight, number of panicle branch and harvest index. Mengesha et al. (1965) reported panicle length has strong and positive direct effect on grain yield. Days to 50% maturity, lodging index and biomass weight per plant in the present study showed negative direct on grain yield per plant. In the contrary, Adnew (2002) noted high and positive direct effect of days to maturity on grain yield, but high and negative direct effect of days to panicle emergence and thousand grain weights on yield of tef landraces.

Lodging index was negatively correlated to plant height (Table 2). Though not strong, genotypically it has negative direct effect on grain yield. Lodging index has also negative indirect effect on grain yield through first culm diameter. This implies that accessions with thick culm diameter resist lodging and hence give good grain yield per plant.

All traits have negative indirect effect on grain yield per plant through days to 50% maturity (except for number of fertile floret per spikelet and lodging index). This implies that in addition to the negative direct effect of days to 50% maturity on grain yield, several traits influence grain yield per plant indirectly through days to 50% maturity. Days to 50% panicle emergence, Days to 50% maturity and fertile floret at the top and bottom of panicle has negative direct effect on grain yield. Overall, most of morphological traits considered in the present study showed positive but very low phenotypic direct and indirect effect on grain yield per plant.

Days to 50% panicle emergence and days to 50% maturity showed no indirect effect on grain yield through number of fertile floret per spikelet at top of the panicle and vice verse. Similarly, an increase or a decrease in lodging index, harvest index and days to panicle emergency have no indirect effect on grain yield through number of fertile floret per spikelet at top of the panicle. The genotypic correlation coefficient between traits such as panicle length, days to 50% maturity and biomass weight per plant is positive, but their direct effect on grain yield is negative. In such cases, the indirect effect seems to be the cause of correlation and hence, these indirect causal factors (traits) should be considered simultaneously for selection (Singh and chaundhary, 1977).

Table 1: List of experimental materials with their respective region of origin, soil type of collection area and altitude

No.	Acc.	Admin. Regions	District	Soil type	Altitude
1	229966	Arsi	Sherka	Sandy-loam	2550
2	229971	Arsi	Ziway Dugda	Sand	1730
3	231217	Arsi	Chole	Clay loam	1540
4	231219	Arsi	Jeju	NI	1600
5	236952	Arsi	Dodotana Sire	Sandy-loam	2710
6	232245	Arsi	Sherka	Clay loam	2550
7	236942	Arsi	Gedeb	Sandy-loam	2350
8	236944	Arsi	Tiyo	Loam	2000
9	55014	Bale	Sinanana Dinisho	NI	2565
10	55015	Bale	Agarfa	Clay	2500
11	55016	Bale	Goro	NI	1710
12	237737	Bale	Adaba	Clay loam	2400
13	229981	Bale	Sinanana Dinisho	Clay	2560
14	229982	Bale	Mennana Herena Bulu	Loam	1440
15	55018	Bale	Ginir	Loam	1630
16	55019	Bale	Gaserana Gololcha	Clay	1980
17	55022	Bale	Gaserana Gololcha	NI	2300
18	55045	East Gojam	Hulet Ej Enese	Clay	2260
19	55046	East Gojam	Hulet Ej Enese	NI	1920
20	55047	East Gojam	Goncha Siso Enese	Clay	2670
21	222174	East Gojam	Dejen	NI	1500
22	229754	East Gojam	Hulet Eju Enese	Loam	1790
23	55172	East Gojam	Machakel	NI	2440
24	55267	East Gojam	Dejen	Sandy-loam	1570
25	55062	East Gojam	Enemay	Clay	2560
26	203010	East Wollega	Bila Seyo	Clay loam	1600
27	202991	East Wollega	Arjo	Clay	2420

28	237704	East Wollega	Sibu Sire	Clay loam	1760
29	237706	East Wollega	Guto Wayu	Clay loam	1620
30	237707	East Wollega	Gida Kiremu	Clay loam	1450
31	237700	East Wollega	Bila Seyo	Clay loam	2470
32	236364	East Wollega	Diga Leka	Loam	2420
33	236365	East Wollega	Jimma Arjo	Loam	2470
34	55261	East Wollega	Limu	Clay loam	2210
35	239391	East Wollega	Gatama	Loam	2260
36	236359	East Wollega	Guto Wayu	Loam	2100
37	239384	Horro Guduru	Jimma Horo	Sandy-loam	2500
38	203030	Horro Guduru	Jimma Horo	Clay	2210
39	236357	Horro Guduru	Guduru	Loam	2200
40	239376	Horro Guduru	Guduru	Loam	2300
41	236326	Horro Guduru	Abay Chomen	Loam	2420
42	236336	Horro Guduru	Jimma Horo	Clay	2520
43	236328	Horro Guduru	Jimma Horo	Loam	2480
44	239379	Horro Guduru	Abay Chomen	Loam	2300
45	55253	Illubabor	Bedele	Clay loam	2000
46	55254	Illubabor	Bedele	Clay loam	1910
47	55248	Illubabor	Yayu	NI	1750
48	202979	Illubabor	Gechi	Clay loam	2140
49	202972	Illubabor	Bedele	Clay loam	1710
50	202952	Jimma	Sokoru	Clay loam	1920
51	202966	Jimma	Kersa	Clay	1770
52	202950	Jimma	Sokoru	Clay loam	1390
53	239396	Jimma	Kersa	Clay loam	1790
54	239398	Jimma	-	NI	1750
55	212597	South Wello	Legambo	Clay	2360
56	212599	South Wello	Legambo	Clay loam	2450
57	212608	South Wello	Kutaber	Clay loam	2400
58	212615	South Wello	Tehuledere	Clay loam	1690
59	212616	South Wello	Ambasel	Clay	1460
60	55101	South Wello	Dessie Zuria	NI	2500
61	203034	West Shewa	Bako Tibe	Clay loam	1610
62	203036	West Shewa	Cheliya	Clay	1680
63	228666	West Shewa	Ambo	NI	1500
64	55091	West Shewa	Jeldu	NI	2470
65	239375	West Shewa	Cheliya	Sandy-loam	2410
66	236752	West Shewa	Dendi	Clay	2160
67	236756	West Shewa	Cheliya	Clay loam	2100
68	236757	West Shewa	Adda Berga	Loam	2600
69	236758	West Shewa	Wonchi	Loam	2280
70	236340	West Shewa	Bako Tibe	Clay loam	1710
71	236754	West Shewa	Ambo	Clay loam	2150

72	55131	West Wollega	Gimbi	NI	1900
73	208753	West Wollega	Ayra Guliso	Clay loam	1800
74	202997	West Wollega	Jimma Gidami	Clay loam	2190
75	237712	West Wollega	Gimbi	Clay loam	1800
76	237713	West Wollega	Gimbi	Clay loam	1800
77	55156	West Wollega	Nejo	NI	2750
78	55147	West Wollega	Jarso	NI	2000
79	55154	West Wollega	Nejo	NI	2000
80	DZ-01-1880	Released	-		-
81	DZ-Cr-255	Released	-		-

Key: NI= Not Identified

CONCLUSIONS

The high and positive correlation and also genotypic direct effect of traits such as panicle length, harvest index and culm diameter on grain yield per plant.The minimum value of direct and indirect phenotypic effect of majority of polygenic traits on grain yield per plant observed in the present study indicated that genetic manipulations of tef accessions for several quantitative characters are more important to improve the productivity of tef than management practices. Susceptibility to lodging is the major bottleneck to increase the productivity of tef. It has significant negative correlation with some lodging tackling traits such as culm diameters, plant height, culm and panicle length. This implies the possibility to minimize yield loss due to lodging through targeted breeding approaches with main emphasis on those traits. Besides, quantitative characters having genetically positive direct effect on grain yield should be given due attention when collection, conservation and selection of landraces targeted for yield improvement is be planned.

Table 2. Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficient for 12 quantitative traits of 79 tef populations and two improved varieties

Traits	DPE	DM	PLH	PAL	CL	LOG	CD	FFT	FFB	BIOP	GYPL	HI
DEP	**1.000**	0.934	0.901	0.928	0.629	-0.517	0.763	0.154	0.218	0.541	0.516	0.200
DM	0.727	**1.000**	0.917	0.808	0.827	-0.438	0.834	0.201	-0.072	0.561	0.443	0.112
PLHT	0.350	0.356	**1.000**	0.892	0.839	-0.366	0.725	-0.464	0.414	0.247	0.350	0.142
PAL	0.368	0.397	0.697	**1.000**	0.385	-0.319	0.803	-0.273	0.267	0.396	0.341	0.082
CL	0.175	0.149	0.800	0.164	**1.000**	-0.310	0.366	-0.917	0.566	0.021	0.281	0.232
LOG	-0.442	-0.371	-0.147	-0.210	-0.026	**1.000**	-0.175	-0.444	0.354	-0.320	-0.306	-0.097
CD	0.213	0.314	0.494	0.494	0.294	-0.070	**1.000**	0.369	-0.262	0.482	0.671	0.038
FFT	0.056	0.048	0.003	0.165	-0.094	-0.043	0.167	**1.000**	-0.603	0.443	0.565	0.267
FFB	0.002	0.062	0.204	0.259	0.103	0.029	0.116	-0.062	**1.000**	-0.054	-0.138	-0.016
BIOP	0.294	0.369	0.269	0.357	0.075	-0.239	0.404	0.295	0.007	**1.000**	0.693	0.025
GYPL	0.344	0.383	0.257	0.267	0.132	-0.235	0.383	0.212	-0.033	0.666	**1.000**	0.623
HI	0.131	0.121	-0.061	-0.095	-0.023	-0.072	-0.061	-0.169	0.012	-0.098	0.484	**1.000**

Table 3. Estimate of direct (bold and diagonal) and indirect effect of 11 quantitative traits on grain yield per plant on the basis of genotypic correlation

TRAITS	DPE	DM	PLHT	PAL	CL	LOG	CD	FFT	FFB	BIOP	HI
DPE	**0.412**	0.181	0.035	-0.359	0.217	0.074	0.304	0.009	0.046	-0.034	0.109
DM	0.385	**-0.193**	0.035	-0.313	0.285	0.062	0.332	0.012	-0.015	-0.035	0.061
PLHT	0.371	-0.177	**0.039**	-0.345	0.289	0.052	0.289	-0.027	0.088	-0.015	0.078
PAL	0.382	-0.156	0.035	**0.387**	0.133	0.045	0.320	-0.016	0.057	-0.025	0.045
CL	0.259	-0.160	0.032	-0.149	**0.345**	0.044	0.146	-0.053	0.121	-0.001	0.127
LOG	-0.231	0.085	-0.014	0.123	-0.107	**-0.143**	-0.070	-0.026	0.075	0.020	-0.053
CD	0.314	-0.161	0.028	-0.310	0.126	0.025	**0.399**	0.021	-0.056	-0.030	0.021
FFT	0.063	-0.039	-0.018	0.105	-0.316	0.063	0.147	**0.057**	-0.129	-0.027	0.146
FFB	0.090	0.014	0.016	-0.103	0.195	-0.050	-0.105	-0.035	**0.231**	0.003	-0.009
BIOPL	0.223	-0.109	0.010	-0.153	0.007	0.046	0.192	0.025	-0.011	**-0.062**	-0.065
HI (%)	0.082	-0.022	0.005	-0.032	0.080	0.014	0.015	0.015	-0.003	0.007	**0.548**

Table 4. Estimate of direct (bold and diagonal) and indirect effect of 11 quantitative traits on grain yield per plant on the basis of phenotypic correlation

TRAITS	DPE	DM	PLHT	PAL	CL	LOG	CD	FFT	FFB	BIOPL	HI
DPE	**0.046**	-0.014	-0.029	0.006	0.013	-0.011	0.005	0.000	0.000	0.023	0.088
DM	0.033	**-0.020**	-0.030	0.006	0.011	-0.009	0.007	0.000	-0.001	0.029	0.081
PLHT	0.016	-0.007	**-0.083**	0.011	0.059	-0.004	0.012	0.000	-0.004	0.021	-0.041
PAL	0.017	-0.008	-0.058	**0.015**	0.012	-0.005	0.012	-0.001	-0.004	0.028	-0.063
CL	0.008	-0.003	-0.067	0.003	**0.074**	-0.001	0.007	0.001	-0.002	0.006	-0.016
LOG	-0.020	0.007	0.012	-0.003	-0.002	**0.025**	-0.002	0.000	0.000	-0.019	-0.049
CD	0.010	-0.006	-0.041	0.008	0.022	-0.002	**0.024**	-0.001	-0.002	0.032	-0.041
FFT	0.003	-0.001	0.000	0.003	-0.007	-0.001	0.004	**-0.009**	0.001	0.023	-0.114
FFB	0.000	-0.001	-0.021	0.004	0.008	0.001	0.003	0.001	**-0.016**	0.001	0.008
BIOPL	0.014	-0.007	-0.022	0.005	0.006	-0.006	0.010	-0.003	0.000	**0.079**	-0.066
HI (%)	0.006	-0.002	0.005	-0.001	-0.002	-0.002	-0.001	0.001	0.000	-0.008	**0.671**

KEY: *DPE= days to 50% panicle emergence, DM= days to 50% maturity, PLHT= plant height, PNL= panicle length, CL= culm length, LOG= lodging index, CD= culm diameter, FFT=fertile floret per spikelet at top of the panicle, FFB= fertile floret per spikelet at the base of the panicle, BIOPL= biomass weight per plant and, HI= harvest index.*

ACKNOWLEDGEMENTS

The authors would like to acknowledge Bako Agricultural Research Center for funding the research work. My great thanks also render to the Institute of Biodiversity Conservation of Ethiopia for kindly providing tef landraces with their passport data.

REFERENCE

Adnew, T. (2002). Genetic diversity and association among quantitative traits in tef germplasm. MSc. thesis. Alemaya University.

Assefa, K., Tefera, H.and Arnulf, M. (2002). Variation and interrelationship of quantitative trait in tef (*Eragrostis tef* (Zucc.) Trotter) germplasm from western and south western Ethiopia. *Hereditas* 136: 116-125.

Ayana, A. (2001). Genetic diversity in sorghum [*Sorghum bicolor* (L.) Moench] germplasm from Ethiopia and Eritrea. Ph.D thesis, Addis Ababa University.

Chanyalew, S., Tefera, H., Zelleke, H. and Singh, H. (2006). Correlation and path coefficient analysis of yield related traits in recombinant inbred lines of tef (*Eragrostis tef*).

Doshi, S. R. and Gupta, K. C. (1991). SPAR (Statistical Package for Agricultural Research). ICRA, New Delhi, 110012.

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

Ketema, S (1997). Tef. *Eragrosties tef (Zucc.)* Trotter. Promoting the conservation and use of underutilized & neglected crops, bulletin no.12. Institute of Plant Genetics & Crop Plant Research, Gatersleben (International Plant Genetic Resources Institute). Rome, Italy.

Ketema S. (1993). Tef *(Eragrostis tef): Breeding, Genetic Resources, Agronomy, Utilization and Role in Ethiopian Agriculture*. Ethiopian Agricultural Research Institute, Addis Ababa.

Lenka, D. and B.Mishra (1973). Path coefficient analysis of yield in rice varieties. Ind. J. Agric. Sci., 43: 376-379.

Lule, D., Bekele, E. and Ayana, A. (2013). Phenotypic diversity in tef [*Eragrostis tef* (zucc.) Trotter] germplasm accessions from various ragions of Ethiopia. *Ethiopian Journal of crop science.* 3 (1):15-32

Lule, D., Tesfaye, K., Fetene, M. and Santie De Villiers (2012). Inheritance and Association of Quantitative Traits in Finger Millet (Eleusine coracana Subsp. Coracana) Landraces Collected from Eastern and South Eastern Africa. *Inte. J. of Genetics 2(2): 12-2.*

Mengesha, M.H., Picket, R.C. and Davis, R.I.(1965). Genetic variability and interrelationships of characters in tef [*E. tef* (Zucc.) Trotter]. *Crop Sci.* 5:155-157.

Negash, W., Asfaw, Z. and Yibra, H. (2005). Variation and association analysis on morphological characters of Linseed (*Linum usitatissimum* (L.) in Ethiopia. *SINET: Ethiop. J.Sci*., 28(2):129-140.

Singh, R.K and Chaundhary, B. D. (1977*). Biometrical Methods in Quantitative Genetic Analysis*. Kalyani publishers, New Delhi, p 304.

Tefera, H. (1988). Variability and association of characters in tef [*Eragrostis tef* (Zucc.) Trotter] cultivars. MSc. Thesis. Alemaya University, Ethiopia.

Tefera, H. and Ketema S. (2001). Production and importance of tef in Ethiopian agriculture. In: *Narrowing the Rift: Research and Development in Tef: Workshop Proceedings*, pp. 3-7, (Tefera, H., Belay, G. and Mark, S. eds). Ethiopian Agricultural Research Institute, Addis Ababa.

Vavilov, N. (1951). The origin, variation, immunity and breeding of cultivated plants, pp. 37-38. Ronald press, NewYork, [Translated from the Rusian by K. Starrchester].