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Genetic Variation, Heritability and Path-Analysis in Ethiopian Finger Millet [*Eleusine coracana* (L.) Gaertn] Landraces

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ABSTRACT

A total of 66 finger millet accessions constituted of 64 landraces and two standard varieties were evaluated for 15 morpho-agronomic characters in randomized complete block design with three replications at Aresi-Negele Research Sub-Center in Ethiopia during 2004 main cropping season. The objectives were to assess the variability and association of characters. The mean squares of genotypes were highly significant for all characters. Relatively, grain yield per plant exhibiting the highest range (4.87-21.21g) and days to maturity showed the lowest range (143-200 days) of 336 and 40% where maximal values were greater than the corresponding minimal values, respectively. For all characters, the phenotypic and genotypic coefficients of variations varied in the orders of 8.05-31.23% and 6.52-24.21% in both cases for days to maturity and grain yield per plant, respectively.

Heritability estimates ranged from 20% for grain-filling duration to 84% for days to heading. Values of expected genetic advance varied from 6.67-44.14% for grain-filling duration and finger width, respectively. Finger width and length exhibited high heritability coupled with high genetic advance. The strongest positive association was observed between culm thickness and leaf blade width while the strongest negative association was found between 1,000-grain weight and finger number. Grain yield per plant associated positively with productive tillers, 1,000-grain weight, the number of grains per spikelet and finger number and negatively associated with days to heading and maturity. The genotypic correlation and path-coefficient analysis showed 1,000-grain weight, finger number and productive tillers as a major contributor to grain yield per plant. Generally, the result revealed the existence of variability for the characters studied in finger millet landraces. Hence, this is a potential character of interest which could be used in the genetic improvement of finger millet through hybridization and/or selection.

Key words: finger millet, *Eleusine coracana*, Ethiopia, landrace, genetic variation, heritability

INTRODUCTION

Finger millet (*Eleusine coracana* subsp. c*oracana)* and its wild relatives are the member of Chloridoidea, one of the primary subfamilies of the grass (Poaceae) family. The cultivated *E. coracana* is a tetraploid species (2n=4x=36) derived from its wild ancestor *E. coracana* subsp.

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africana (Zeven and de Wet, 1982). East Africa is recently reported as the center of origin and diversity of finger millet (FAO, 1998).

Finger millet is one of the few species that currently support the world food supplies. It is grown over four million hectares and is the primary food source for millions of poor people in the dry land regions of east Africa, central Africa and southern India (OIA, 1996). It is indigenous to Ethiopia and occupies 304,758 ha of land with production of 305,101 tons (CSA, 2004). It is grown more or less throughout the country though mainly cultivated in the mid and low altitude of regions of Gonder, Gojam, Wollega and Tigray where it constitutes 10 to 20 percents of the total cereal production (Kebede and Menkir, 1986).

In Ethiopia, finger millet utilization is deep-rooted in the culture of the people. The grain is used for making the native bread, injera, porridge and genfo (thick porridge) alone or in mixture with teff (*Eragrostis tef*), maize and barley. It is also popular for preparing local beer and distilled spirit (areki). The straw is used for animal feed or thatching. It is valued for its drought, stresses tolerance and nutritional value (Barbeau and Hilu, 1993). The great merit of finger millet is that it can be stored for period of up to ten years or more without deterioration and weevil damage. Consequently, it has traditionally played an important role as reserve crop. It is also being considered to be free of the major pests and diseases and the growing crops suffer little from bird damage (Purseglove, 1972).

In spite of all this, the national average grain yield of finger millet is low, 1 ton/ha (CSA, 2004), although it has a potential to yield up to 3 ton/ha (Taddesse *et al*., 1995). Its low productivity has, among the others, been due to lack of improved varieties, drought in lowlands and unimproved traditional cultural practices. Currently most of the farmers grow local varieties (landraces), but about three improved varieties have been released and disseminated in some parts of the country for production in place of the landraces.

Replacement of landraces by modern pure-line cultivars (and wide spread production of single, superior cultivars) generally reduce the genetic variation in cropping programs. Besides, finger millet is being pushed to the more marginal areas; therefore, it is believed that this would aggravate the danger of loss of genetic variation (genetic erosion). Nevertheless, germplasm collection has been undertaken from different areas of the country by the Ethiopian Institute of Biodiversity Conservation (EIBC) and other organizations. Some reports indicated to have about 2,051 finger millet accessions collected and preserved in the gene bank.

Regardless of the vast materials available and the urgent need to improve finger millet unit productivity through genetic manipulation, little is known about their variability, major characters and the potential usefulness of the individual accessions stored in the bank. Therefore, investigating and identifying plants for the genetic variation available in the breeding materials is the first step of plant breeding and so vital for successful crop improvement program. In this line, Ghiorgis (1993), Daba (2000) and Yemne and Fassil (2002) made some attempts to measure the genetic variability in the collection of finger millet based on morphological and agronomic characters. However, this was not extensive and considerable amounts of accessions are left untouched. Hence, this study was undertaken to assess the variability and association among finger millet landraces and to determine the genetic potential of these materials for future use in the breeding program.

MATERIALS AND METHODS

The experiment was conducted at Aresi-Negelle Research Sub-Center (Altitude, 1960m asl, 7°30′N and 39°00′E) in Ethiopia during 2004 main cropping season. It represents highland and serves as a breeding center for finger millet improvement program. Sixty-six finger millet accessions consisting of 64 landraces and two standard varieties (Padet and Tadesse) were used in this study. The landraces were obtained from Ethiopian Institute of Biodiversity Conservation (EIBC) with their passport data. The improved varieties were provided by Melakasa Agricultural Research Center (MARC).

The experiment was laid down in randomized complete block design (RCBD) with three replications. The seeds of each accession were drilled on a plot of 4 m long in a single row with spacing of 75 cm between rows (plots) and 15 cm between plants within a row, which was maintained by thinning. Each plot received 100 kg diamonium phosphate at planting and 50 kg urea at early tillering stage on hectare basis. Weeding and other field management were made as frequent as required.

Five plants from each accession and replication were randomly selected for data recording except for days to heading, maturity and grain-filling duration where they were on plot basis. Data were recorded using the descriptors for finger millet (IBPGR, 1985) on plant height, days to heading, days to maturity, grain-filling duration, productive (basal) tillers, culm thickness, finger length, finger width, finger number, leaf number, leaf blade length, leaf blade width, 1,000-grain weight, the number of grains per spikelet and grain yield per plant.

All measured data were subject to analysis of variance. The genotypic (σ^2_g), phenotypic (σ^2_p) and error (σ^2_e) variances were computed using the formulae of Burton and De Vane (1953) as σ^2_g= (MSg-MSe)/r; $\sigma^2_p = \sigma^2_g+\sigma^2_e$ and σ^2_e=MSe, where MSg=genotypic mean square, MSe=environmental variance (error mean square) and r=the number of replications. The phenotypic (PCV), genotypic (GCV) and error (ECV) coefficients of variability were estimated following the procedure of Kumar *et al*. (1985): PCV=100(σ_p)/ $\bar{x}$; GCV=100(σ_g)/ $\bar{x}$ and ECV=100 (σ_e)/ $\bar{x}$, where σ_p= phenotypic standard deviation σ_g= genotypic standard deviation, σ_e= environ-mental standard deviation and $\bar{x}$= character mean. Heritability (h^2) in a broad sense was estimated by the formulae of Allard (1960): $h^2=\sigma^2_g/\sigma^2_p$. Expected genetic advance (GA), assuming a selection intensity of 5% was estimated according to the method of Johnson *et al*. (1955): GA=$kh^2\sigma_p$, where k was selection intensity. Phenotypic (r_{pxy}), genotypic (r_{gxy}) and environmental (r_{exy}) correlation coefficients were estimated by employing the formulae of Al-Jibouri *et al*. (1958): $r_{pxy}=CoV_{pxy}/(\sigma^2_{px}\sigma^2_{py})^{1/2}$; $r_{gxy}=CoV_{gxy}/(\sigma^2_{gx}\sigma^2_{gy})^{1/2}$ and $r_{exy}=CoV_{exy}/(\sigma^2_{ex}\sigma^2_{ey})^{1/2}$, where CoV_{pxy}= phenotypic covariance of characters of x and y; CoV_{gxy}= genotypic covariance of characters of x and y and CoV_{exy} = environmental covariance of characters of x and y. Direct and indirect path coefficients were calculated as described by Dewey and Lu (1959). MSTATC and Agres-1 statistical package were employed for analysis.

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance (Table 1) for the 15-selected characters indicated that the genotypic mean square values were highly significant for all characters, implying that the landraces tested were highly variable. Substantial variations in finger millet have been also reported in previous studies (Naik *et al*., 1994; Prasad Rio *et al*., 1994; Daba, 2000).

Most of the characters except productive tillers, finger width, leaf blade length, finger number and grain yield per plant also showed highly significant differences due to environmental effects (replication). The coefficient of variation ranged from 4.72% for days maturity to 19.73% for grain yield per plant.

Estimates of mean and range

The performance of most populations for characters of grain filling duration, productive tillers, finger length and finger number and some accessions for plant height, days to heading, leaf number, leaf blade length, leaf blade width, the number of grains per spikelet and grain yield per plant exceeded the performance of the commercial varieties (Padet and/or Tadesse) (data not shown). This situation ensured the existence of base population for improving the character of interest.

The ranges and the means for the 15 finger millet characters studied are summarized in Table 2. Regardless of the variation in the relative magnitude of the ranges, the means of the genotypes generally displayed considerable differences between the minimal and maximal values for all traits evaluated.

Grain yield per plant exhibited the widest range (4.87–21.21g) followed by finger length (3.67–14.6cm) and finger width (3.13–9.13cm) with the values of 336, 298 and 192% where maximum values exceeded the corresponding minimal values, respectively. Relatively, low ranges with 40, 53, 60, 61 and 69% differences between the corresponding minimal and maximal values were recorded for days to maturity, leaf blade width, grain filling duration, days to heading and leaf blade length, respectively. Similar to the result of this study, a wide range of variations for plant height and grain yield per plant (Narasmba Rao and Parathasarathi, 1968), for finger length and number (Kebede and Menkir, 1986), for plant height and productive tillers (Prasada Rao *et al*., 1994) and for most traits studied (Daba, 2000), were reported. Such broad diversity apparent among the finger millet landraces tested would provide ample opportunities for the genetic improvement of the crop through selection directly from the landraces and/or following traits recombination through intra-specific hybridization of desirable traits.

Table 1 Mean square values and coefficient of variations in morpho-agronomic characters of finger millet.

Character	Mean squares			C.V.%
	Replication (df=2)	Genotyp (df=65)	Error (df=130)	
Plant height (cm)	1902.98**	536.78**	134.50	13.49
Days to heading	129.96**	448.47**	26.98	4.94
Days to maturity	592.75**	429.61**	63.80	4.72
Grain-filling duration	701.09**	151.79**	87.12	14.57
Productive tillers	2.92NS	15.53**	3.76	17.38
Finger length (cm)	7.50**	11.17**	1.35	13.93
Finger width (mm)	0.50NS	3.41**	0.27	12.21
Culm thickness (mm)	6.43**	2.67**	0.46	14.24
Leaf number	14.94**	5.42**	1.34	14.03
Leaf blade length (cm)	31.96NS	41.57**	14.44	10.17
Leaf blade width (cm)	0.13**	0.04**	0.01	9.84
Finger number	2.68NS	4.52**	1.80	15.12
Number of grains per spikelet	9.79**	2.10**	0.77	16.14
Thousand-grain weight (g)	0.96**	0.33**	0.10	13.35
Grain yield per plant (g)	9.04NS	32.86**	5.95	19.73

*, ** Significant at 5% and 1%, respectively; NS, non-significant

Numbers in parenthesis are degree of freedom

Estimates of phenotypic, genotypic and environmental variability

As shown in Table 3, high phenotypic and genotypic variances were depicted by plant height, days to maturity and days to heading whereas the lowest ones were found for leaf blade width followed by 1,000-grain weight. In characters such as days to heading, finger width,

Table 2 Mean, maximum, minimum and difference values of morpho-agronomic characters in finger millet.

Character	Mean	Minimum	Maximum	Difference	Difference as % of minimum
Plant height (cm)	86.0	61.3	116.7	55.4	90
Days to heading	105	84	135	51	61
Days to maturity	169	143	200	57	40
Grain-filling duration	64	48	77	29	60
Productive tillers	11.15	8.00	17.33	9.33	117
Finger length (cm)	8.33	3.67	14.60	10.93	298
Finger width (mm)	4.26	3.13	9.13	6.00	192
Culm thickness (mm)	4.75	3.47	7.87	4.40	127
Leaf number	8.26	6.07	11.07	5.00	82
Leaf blade length (cm)	37.4	27.3	46.1	18.8	69
Leaf blade width (cm)	1.09	0.93	1.42	0.49	53
Finger number	8.87	5.87	12.00	6.13	104
Number of grains per spikelet	5.44	3.93	7.20	3.27	83
Thousand- grain weight (g)	2.41	1.53	3.20	1.67	109
Grain yield per plant (g)	12.37	4.87	21.21	16.34	336

Table 3 Phenotypic, genotypic and error variance of morpho-agronomic characters in finger millet.

Character	Phenotypic variance(σ^2_p)	Genotypic variance(σ^2_g)	Error variance(σ^2_e)
Plant height (cm)	268.595	134.092	134.503
Days to heading	167.477	140.497	26.980
Days to maturity	185.734	121.937	63.797
Grain filling duration	108.676	21.559	87.117
Productive tillers	7.680	3.925	3.755
Finger length (cm)	4.623	3.276	1.347
Finger width (mm)	1.317	1.046	0.271
Culm thickness (mm)	1.196	0.739	0.457
Leaf number	2.700	1.358	1.342
Leaf blade length (cm)	23.484	9.042	14.442
Leaf blade width (cm)	0.020	0.008	0.012
Finger number	2.703	0.907	1.796
Number of grains per spikelet	1.213	0.442	0.772
Thousand-grain weight (g)	0.179	0.075	0.104
Grain yield per plant (g)	14.923	8.968	5.954

finger length, days to maturity, culm thickness and grain yield per plant, a large portion of the phenotypic variance was accounted by the genetic component with the values of 84, 80, 71, 66, 62 and 60%, respectively (Table 3). This indicated the existence of immense inherent variability that remained unaltered by environmental conditions among the genotypes, which in turn was more useful for exploitation in hybridization and/or selection.

The phenotypic (PCV) and genotypic (GCV) coefficient of variations of the various finger millet characters computed based on analysis of variance presented in Table 4. For all 15 traits, the PCV and GCV ranged in the orders of 8.05 to 31.23% and 6.52 to 24.21% in both cases for days to maturity and grain yield per plant, respectively. Generally, the PCV estimates were higher than the GCVs as found by Daba (2000) showing that the apparent variation was not only due to genotypes but also to the influence of environment. However, for majority of the traits the environmental coefficients of variation (ECV) estimates were lower than from both genotypic and phenotypic coefficient of variations. This implied that the environmental role was less for the expression of such characters (Singh and Narayana, 1993). Relatively, the PCV estimates were high in culm thickness, productive tillers, finger length and width and grain yield per plant, which varied from 23.05–31.23%. Grain filling duration, 1,000-grain weight, finger number, plant height, leaf number and the number of grains per spikelet exhibited moderate PCV estimates from 16.27 to 20.24%, whereas, the low PCV (8.05-12.88%) estimates were recorded for days to heading and maturity, leaf blade length and width.

Three of the traits namely finger length, finger width and grain yield per plant exhibited relatively high GCV values of 21.72, 23.99 and 24.21%, respectively. In contrast, low GCV values ranging from 6.52 to 12.21% were recorded for days to maturity, grain filling duration, leaf blade length and width, finger number, days to heading, 1,000-grain weight and the number of grains per spikelet, whereas plant height, leaf number, productive tillers and culm thickness exhibited intermediate (13.47–18.12%) GCV values. Similarly, high genotypic and phenotypic coefficient of variation were also found for

Table 4 Phenotypic, genotypic and error coefficient of variability, heritability and genetic advance of morpho-agronomic characters in finger millet.

Character	Phenotypic coefficient of variability (PCV)	Genotypic coefficient of variability (GCV)	Error coefficient of variability (ECV)	Heritability broad sense (h^2)	Genetic advance GA	(GA) as % of mean
Plant height (cm)	19.07	13.47	13.49	50	16.88	19.63
Days to heading	12.30	11.27	4.94	84	22.40	21.33
Days to maturity	8.05	6.52	4.72	66	18.46	10.92
Grain-filling duration	16.27	7.25	14.57	20	4.27	6.67
Productive tillers	24.85	17.77	17.38	51	2.92	26.20
Finger length (cm)	25.81	21.72	13.93	71	3.14	37.73
Finger width (mm)	26.92	23.99	12.21	80	1.88	44.14
Culm thickness (mm)	23.05	18.12	14.24	62	1.39	29.35
Leaf number	19.90	14.12	14.03	50	1.70	20.64
Leaf blade length (cm)	12.97	8.05	10.17	39	3.85	10.29
Leaf blade width (cm)	12.88	8.32	9.84	41	0.12	10.71
Finger number	18.55	10.74	15.12	34	1.14	12.83
Number of grains per spikelet	20.24	12.21	16.14	37	0.83	15.22
Thousand-grain weight (g)	17.52	11.34	13.35	42	0.37	15.17
Grain yield per plant (g)	31.23	24.21	19.73	60	4.79	38.72

productive tillers, finger length and grain weight per plant (Abraham *et al*., 1989), for finger length (Goswami and Asthana, 1984) and for grain weight per plant (Prabhakar and Prasad, 1983). In contrast to the current findings, high genotypic coefficients of variations were reported for finger number and 1,000-grain weight (Abraham *et al*., 1989) and for days to flowering and maturity (Patniak and Jana, 1973).

Estimates of heritability in broad sense and expected genetic advance

Heritability which is the heritable portion of phenotypic variance is a good index of transmission of characters from parents to offspring (Falconer, 1981). In this study, heritability (h^2) estimates ranged from 20% for grain filling duration to 84% for days to heading (Table 4). Overall, comparatively days to maturity, finger length, finger width and days to heading revealed high h^2 values ranging from 66-84%, as opposed to low h^2 values of 20-41% recorded for grain filling duration, finger number, the number of grains per spikelet, and leaf blade length and leaf blade width. The values were intermediate (42-62%) for 1,000-grain weight, plant height, leaf number, productive tillers, grain yield per plant and culm thickness. Likewise, high heritability estimates for days to flowering and maturity (Dhagate *et al*., 1972) and finger length (Daba, 2000) and low for 1000-grain weight, finger number (Patnaik, 1968) were reported. On the other hand, low heritability estimates for days to flowering and high heritability estimates for finger number (Daba, 2000) and for 1,000-grain weight (Abraham *et al.*, 1989) were also reported.

Estimates of genetic advance (as percentage of the mean) expected from selecting 5% of the best genotypes are given in Table 4. Percentage of mean, the genetic advance estimates varied from 6.67-44.14% for grain-filling duration to finger width, respectively. On the whole, grain-filling duration, leaf blade length, days to maturity, leaf blade width, finger number, 1,000-grain weight and the number of grains per spikelet demonstrated relatively low genetic advance estimates of 6.67-15.22%. In contrast, comparatively high values (37.73-44.14%) were observed for three of the characters involved: finger length, grain yield per plant and finger width. Intermediate estimates of 19.63-26.20% were obtained for plant height, leaf number, days to heading and productive tillers.

Heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimates alone. However, it is not necessary that a character showing high heritability will also exhibit high genetic advance (Johnson *et al.,* 1955). High heritability with high genetic advance (as percentage of the mean) was observed for finger length and width as found by Daba (2000) for productive tillers, ear weight per plant and biomass per plant. Such conditions were most likely caused by additive gene action, thereby, reflecting the efficiency of selection for the improvement of these traits.

Correlation among characters

The phenotypic correlation (r_p) among traits is influenced by genotypes and environment. Genotypic correlation (r_g) is usually attributed to pleiotropy (Falconer, 1981) whereas environmental correlation (r_e) is entirely due to environment and is not heritable and stable. It reflects a similarity or dissimilarity in the response of the two traits to a common environment. The estimates of phenotypic, genotypic and environmental correlation coefficients are displayed in Table 5. The strongest positive association was observed between leaf blade width and culm thickness (r_g=0.98) while the strongest negative association between 1,000-grain weight and finger number (r_g=-0.77).

Grain yield per plant, a trait of primary interest, had highly significant positive associations with productive tillers (r_g= 0.493), number of grains per spikelet (r_g=0.454) and

Table 5 Phenotypic (r_p), genotypic (r_g) and environmental (r_e) correlations among 15 morpho-agronomic characters in finger millet.

		DTH	DTM	GFD	PRT	FL	FW	CT	LENU	LEBL	LEBW	FNU	NGPSP	TGW	GYPPL
PH	r_p	0.34**	0.32**	0.01	-0.14	0.25*	-0.01	-0.02	0.32*	0.45**	-0.06	0.27*	-0.27*	-0.11	-0.01
	r_g	0.52**	0.63**	0.18	0.06	0.37**	0.07	0.02	0.28*	0.73**	0.00	0.22	-0.53**	-0.37**	-0.14
	r_e	0.06	-0.09	-0.08	-0.34**	0.08	-0.16	-0.07	0.35**	0.25**	-0.10	0.31**	-0.07	0.11	0.09
DTH	r_p		0.70**	-0.34**	-0.15	-0.19	0.23	0.31*	0.52**	0.42**	0.27*	0.13	-0.30	-0.31*	-0.36**
	r_g		0.92**	-0.36**	-0.25*	-0.27*	0.30*	0.41**	0.79**	0.69**	0.44**	0.31*	-0.45**	-0.50**	-0.46**
	r_e		0.04	-0.52**	0.04	0.08	-0.03	0.05	0.04	0.09	0.03	-0.11	-0.17	-0.04	-0.12
DTM	r_p			0.45**	-0.02	0.07	-0.01	0.12	0.37**	0.40**	0.12	0.15	-0.39**	-0.34**	-0.30*
	r_g			0.23**	-0.03	0.08	0.00	0.14	0.58**	0.71**	0.22	0.36**	-0.71**	-0.62**	-0.49**
	r_e			0.03	-0.01	0.05	-0.05	0.09	0.10	0.09	0.01	-0.05	-0.09	-0.03	0.02
GFD	r_p				0.16	0.33**	-0.30*	-0.22	-0.17	0.00	-0.18	0.03	-0.13	-0.05	0.05
	r_g				0.56**	0.87**	-0.74**	-0.72**	-0.64**	-0.07	-0.61**	0.07	-0.54**	-0.18	0.02
	r_e				-0.04	0.00	-0.03	0.05	0.06	0.02	0.00	0.02	0.02	0.00	0.08
PRT	r_e					0.22	-0.08	-0.21	-0.27*	-0.15	-0.20	-0.07	-0.07	0.06	0.50**
	r_g					0.22	-0.19	-0.37**	-0.39**	-0.26*	-0.54**	-0.14	-0.24	0.17	0.49**
	r_e					0.03	0.11	-0.02	-0.26*	-0.06	0.08	-0.03	0.06	-0.05	0.50**
FL	r_p						-0.52**	-0.34**	-0.36**	0.21	-0.24	0.11	-0.23	-0.03	0.05
	r_g						-0.72**	-0.58**	-0.57**	0.15	-0.57**	0.20	-0.40**	0.01	0.10
	r_e						0.07	0.13	-0.07	0.30**	0.16	0.03	-0.07	-0.07	-0.06
FW	r_p							0.68**	0.40**	0.17	0.51**	-0.13	0.21	0.20	0.20
	r_g							0.89**	0.68**	0.27*	0.84**	-0.21	0.39**	0.37**	0.24
	r_e							0.22	-0.09	0.05	0.07	-0.07	0.01	-0.05	0.11
CT	r_p								0.47**	0.30*	0.65**	0.05	0.30*	0.13	0.11
	r_g								0.89**	0.46**	0.98**	0.21	0.43**	0.15	0.18
	r_e								-0.05	0.15	0.33**	-0.09	0.17	0.11	0.02
LENU	r_p									0.31*	0.35**	0.17	0.04	-0.03	-0.07
	r_g									0.58**	0.86**	0.26*	0.21	-0.23	-0.25*
	r_e									0.10	-0.08	0.10	-0.10	0.14	0.16
LEBL	r_p										0.30	0.20	-0.21	-0.14	-0.02
	r_g										0.57**	0.38**	-0.50**	-0.36**	-0.04
	r_e										0.12	0.10	-0.03	0.01	0.00
LEBW	r_p											0.07	0.15	0.04	0.07
	r_g											0.23	0.33**	0.11	0.01
	r_e											-0.03	0.03	0.00	0.12
FNU	r_p												-0.07	-0.24	0.14
	r_g												-0.17	-0.77**	0.25*
	r_e												0.07	0.09	0.05
NGPSP	r_p													0.21	0.22
	r_g													0.46**	0.45**
	r_e													0.04	0.01
TGW	r_p														0.16
	r_g														0.38**
	r_e														-0.07

*, ** Significant at 5% and 1%, respectively.

PH=Plant height, DTH=days to heading, DTM=days to maturity, GFD=grain-filling duration, PRT=no. of productive tillers, FL=finger length, FW=finger width, CT=culm thickness, LENU=leaf no., LEBL=leaf blade length, LEBW=leaf blade width, FNU=finger no., NGPSP=no. of grains per spikelet, TGW= thousand-grain weight, GYPPL=grain yield per plant

1,000-grain weight (r_g=0 380) and significant positive association with finger number (r_g= 0.254). The high association of grain yield per plant with productive tillers was considered to occur due to favorable influence of the environment as the value of r_e between them was greater than both r_p and r_g. Such association would probably change with a change in environment. It was also associated highly significantly but negatively with both days to heading (r_g= -0.463) and maturity (r_g= -0.487).

Likewise, positive associations of grain yield per plant with 1,000-grain weight (Dhagate *et al*., 1972) and with productive tillers (Gowda, 1977; Daba, 2000) were reported. In contrast to the result of this study, significant and positive associations of grain yield per plant with days to maturity and ear length (Daba, 2000), with plant height (Dhanakodi, 1988; Daba, 2000) and finger number and ear length (Gowda, 1997; Daba, 2000) were also reported. Generally, the correlation results revealed that besides selection for grain yield per plant *per se*, indirect selection for 1,000-grain weight, the number of grains per spikelet, finger number and productive tillers might lead to the improvement of grain yield per plant since they exhibited significantly positive correlation with the grain yield per plant. However, there should be a balance among characters in selection particularly between 1,000-grain weight and finger number as they had strong inverse association.

Most of the materials tested including the commercial varieties were late in maturity, which required an average 169 days to mature (Table 2) and finger millet was cultivated in the area where moisture stress was prevalent and the growing period was not so long as required for late maturing varieties. Hence, the very strong negative association between days to maturity and grain yield per plant gives an opportunity to develop relatively early maturing varieties with better yield potential.

Path-coefficient analysis

Path-coefficient analysis is simply a standardized partial regression coefficient, which splits the correlation coefficient into the measures of direct and indirect effects (Singh and Narayanan, 1993). The information obtained by this technique helps in indirect selection for genetic improvement of yield.

In this investigation, the genotypic correlation coefficient was further divided into direct and indirect effects using path-coefficient analysis. In computing the path-analysis, grain yield per plant was considered as resultant (dependable) variable while the rest of the variables that were significantly correlated with grain yield per plant were used as causal (independent) variables.

As shown in Table 6, among the seven causal (independent) variables, five of them including days to heading (0.670), productive tillers (0.701), the number of leaf (0.659) and finger (1.212), and 1,000-grain weight (0.858) had positive direct effect whereas days to maturity (-1.932) and the number of grains per spikelet(-0.784) showed negative direct effect.

Finger number exerted the highest positive direct effect (1.212) upon grain yield per plant. It also had positive indirect effect via days to heading (0.208), leaf number (0.170), and the number of grains per spikelet (0.129). However, the positive direct effect of number of finger was counterbalanced by relatively high negative indirect effect via days to maturity (-0.703), thousand-grain weight (-0.663), and productive tillers (-0.10) which resulted in lesser correlation with grain yield (r_g=0.254) as compared with its highest positive direct effect.

Thousand-grain weight as an important component of yield exerted the second highest positive direct effect (0.858) on grain yield per plant. It also exhibited very highly positive indirect effect (1.192) via days to maturity and negligibly positive indirect effect (0.119) through productive tillers. Though, 1,000-grain weight exhibited negatively indirect effect through majority of the characters, its association with grain yield per plant remained positive and highly significant (r_g=0.380). Regardless of the unfavorably indirect effect of productive tillers, its association with grain yield per plant was positive and highly significant due to its highly positive direct effect (0.701) and indirect effect through the number of grains per spikelet (0.186), 1,000-grain weight (0.145) and days to maturity (0.052).

Days to heading had high favorable direct effect (0.670) and high favorable indirect effect via leaf number (0.518), finger number (0.377) and the number of grain per spikelet (0.353). However, it exerted the highest indirect effect (-1.777) via days to maturity. This along with the negatively indirect effect via 1,000-grain weight (-0.432) and productive tillers (-0.172) contributed to its highly negative significant association with grain yield per plant (-0.463).

Similar to days to heading, the high favorably direct effect (0.659) of the number of leaf and its favorably indirect effect via days to heading (0.526) and finger number (0.313) was counterbalanced by relatively higher of unfavorably indirect effect through days to maturity (-1.111), productive tillers (-0.271), 1,000-grain weight (-0.198) and the number of grains per spikelet (-0.164) and resulted in negative association between leaf number and grain yield per plant (-0.246).

In line to the finding of the present study, strong direct effect on grain yield per plant were reported for productive tillers (Mahudeswaran and Marugesan, 1973), productive tillers and 1,000-grain weight (Prabhakar and Prasad, 1983), productive tillers and finger number (Ravindran *et al*., 1996), productive tillers and 1,000-grain weight (Daba, 2000). However, as opposed to this Reddy *et al*. (1995) recorded negatively direct effect for productive tillers and Daba (2000) for days to heading.

The direct effect of days to maturity on grain yield per plant was negative and very high (-1.932). Besides, it exerted negatively indirect effect via 1,000-grain weight (-0.529) and productive tillers (-0.019). Hence, these effects led to negative and highly significant association with grain yield per plant (-0.487). Regardless of positive association with grain yield per plant, negatively direct effect of days to maturity on grain yield per plant was reported by Daba (2000). The other character which exerted highly and negatively direct effect (-0.784) on grain yield per plant was the number of grains per spikelet. It also exhibited negatively indirect effect via days to

Table 6 Direct and indirect genetic effects via various paths of seven characters on grain yield per plant.

Character	Direct effect	Indirect effect via: Days to heading	Days to maturity	Productive tillers	No. of leaf	No. of finger	No. of grains/ spikelet	1,000-grain weight	Total correlation with grain yield / plant
Days to heading	0.670	-	-1.777	-0.172	0.518	0.377	0.353	-0.432	-0.463
Days to maturity	-1.932	0.616	-	-0.019	0.379	0.441	0.557	-0.529	-0.487
Productive tillers	0.701	-0.164	0.052	-	-0.255	-0.172	0.186	0.145	0.493
No. of leaf	0.659	0.526	-1.111	-0.271	-	0.313	-0.164	-0.198	-0.246
No. of finger	1.212	0.208	-0.703	-0.100	0.170	-	0.129	-0.663	0.254
No. of grains/ spikelet	-0.784	-0.301	1.372	-0.166	0.138	-0.200	-	0.396	0.454
Thousand-grain weight (g)	0.858	-0.337	1.192	0.119	-0.152	-0.937	-0.362	-	0.380

Residual effect (h) =0.304

heading (-0.301), finger number (-0.200) and productive tillers (-0.166). The favorably indirect effect particularly via days to maturity (1.372) counterbalanced its unfavorable effect and its association with grain yield per plant was found to be highly significant and positive (0.454).

In this study, the positively direct effect of 1,000-grain weight, finger number and productive tillers on grain yield per plant and their significantly positive association at genotypic level with grain yield per plant revealed that these characters were the major contributors to grain yield per plant.

CONCLUSION

The success of genetic improvement in any character depends on the nature of variability present for that character. Hence, an insight into the magnitude of variability present in the gene pool of a crop is of utmost important to a plant breeder for starting judicious plant breeding program. Variability in the population is important for disease resistance, varietal adaptability and effective selection. An effort was made in this study to further substantiate the earlier limited studies that indicated Ethiopian finger millet of having wide variability. Regardless of the magnitude, all characters studied showed wide range of variability. This ensured the existence of ample variability and potential in the landraces to offer a particular character of interest. This could be employed in the genetic improvement of finger millet through hybridization and/or selection.

The correlation and path-coefficient analyses clearly indicated apart from selection for grain yield per plant *per se*; indirect selection for 1,000-grain weight, finger number and productive tillers could be applied in the improvement of finger millet. Moreover, the result of this experiment also showed a possibility of developing relatively early maturing varieties with a better performance. Based on the result of the present study, it can be concluded that Ethiopian finger millet has tremendous variability that can be used for the improvement of finger millet.

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