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Variability of Ginger (*Zingiber officinale* Rosc.) Accessions for Morphological and Some Quality Traits in Ethiopia

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ABSTRACT

Genetic variability study generates very relevant information on the possibility of genetic improvement of crops for yield and quality attributes. The study was objectively designed to assess the genetic variability of thirty six ginger (*Z. officinale* Rosc.) accessions. The experiment was laid out in a 6×6 simple lattice design with two replications during 2009-2010 main cropping seasons at two locations i.e., Tepi and Bahir Dar. Variances component method was used to estimate genetic variation, broad sense heritability and genetic advance. Number of plants per plot, fresh rhizome yield and dry rhizome yield showed high Genetic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) at both locations. Relatively high heritability and genetic advance was obtained for oleoresin content, volatile oil content, fiber content, fresh rhizome yield and dry rhizome yield. The D^2 analysis showed the 36 genotypes grouped into 7 and 11 clusters at Tepi and Bahir Dar, respectively. This makes the genotypes to become highly divergent. The overall assessment showed that there is wide variability among ginger accessions in Ethiopia which has an important implication for breeding ginger for yield, morphological and quality attributes.

Key words: *Zingiber officinale* Rosc., variability, heritability, genetic divergent, genetic advance

INTRODUCTION

Spices have been a profound influence on the course of history and civilization. They hold a high and very special place in the exploration in the middle ages and the Renaissance. Internationally, there are about 70 plant species that have been grown for spices, the majority of which are in Asia (Purseglove *et al*., 1981). Ginger (*Zingiber officinale* Rosc.) is one of the widely cultivated and consumed spices worldwide. It belongs to the family *Zingberaceae* cultivated all over tropical and subtropical countries. Ginger has been used throughout history as an aid for many for its gastrointestinal disturbances and to relieve inflamed joints (Katzer, 2007).

In Ethiopia, ginger is grown in an area of 45,164 ha with production of 716,550 t ha^{-1}) (Ministry of Agriculture and Rural Development (MoARD, 2007a)). Ginger yield on farmers field is very low i.e., 15.87 t ha^{-1} which is far less than the crops potential. This is attributed to several factors; of which shortage of improved varieties, poor agronomic practices and poor soil fertility are the most important ones (Hailemichael *et al*., 2008; MoARD, 2007b).

In Ethiopia, ginger breeding has been going on as part of coffee diversification, since the inception of coffee research in 1969 (Girma *et al*., 2000). Some preliminary research conducted in the country indicated that both the local and exotic ginger germplasms showed variability in their morphological characters, fresh rhizome yield, oil and oleoresin contents (Hailemichael and Tilahun, 2004). According to Hailemichael *et al*. (2008), high variability among cultivars and/or accessions was observed for plant height, rhizome yield, volatile oil content and oleoresin yield. A study conducted in India at molecular level showed the existence of variation in the genetic makeup, rhizome yield and quality in eight ginger cultivars (Palai and Rout, 2007).

In Ethiopia, the study conducted using three cultivars and nine accessions indicated that the oleoresin content varied from 6.5 to 10.88% (Hailemichael and Tilahun, 2004). Moreover, studies on genetic variability for yield and yield components in ginger indicated the existence of only moderate variability in the germplasms (Citation is required). Little variability exists among the genotypes that are grown in the same area; however, high variability has been reported among cultivars that came from widely divergent areas (Ravinderan *et al*., 2005).

There is location difference in the oleoresin and volatile oil content depending on environmental differences. Similarly, Michelle (2009) reported that soil chemistry was the most important factor in determining the essential oil constituent in 48 Helichrysum italicum plants (a plant having strong smelled leaves used for medicinal purposes) specifically grown in different locations and harvested at different times. The author also reported that composition of essential oil showed chemical variability depending on vegetation cycle, environment and geographic origins. According to Tiwari (2003a), Phenotypic Coefficients of Variation (PCV) were more than the Genotypic Coefficients of Variation (GCV). A narrow range of GCV and PCV was observed for almost all the characters. The same author reported that leaf length had comparatively high estimates of GCV, heritability and genetic advance.

Due to the very long tradition of consumption and cultivation of ginger, it is believed that a fair amount of germplasms base is available in the country. Currently, more than 40 locally collected and introduced ginger accessions are being maintained at Tepi National Spice Research Center (TNSRC) for further research purposes (Hailemichael *et al*., 2008).

The knowledge of the extent of genetic variability present in the population is essential for further improvement of the crop. Apart from some observations on variety trials, the extent and pattern of variability present in the crop is not yet systematically assessed. Therefore, this study was undertaken to estimate the extent of variability, heritability (in the broad sense) and the genetic advance expected under selection.

MATERIALS AND METHODS

Experimental site: The experiment was conducted during 2009-2010 at two locations representing mid to high agro-ecologies i.e., Tepi National Research Center (TNRC) (7°3' N, 35°E, 1200 masl) and Bahir Dar (12°31' N, 37°3' E, 1890 masl) in Southwest and Northwest of Ethiopia, respectively (Hailemichael and Tesfaye, 2008; Adam, 2008). The soil type is Dystric Nitosol at Tepi and sandy at Bahir Dar. Bahirdar receives an annual average rainfall of 1545 mm. The mean monthly minimum and maximum temperatures of the sites are 12.2 and 25.8°C., respectively. Tepi receives the annual average rainfall of 1688 mm and has mean maximum and minimum temperatures of 29.5 and 15.4°C, respectively.

Experimental materials: Thirty six diverse ginger accessions representing the germplasms of the crop in the country were used for the study. The planting materials were kindly provided by

Table 1: Locally collected and introduced ginger accessions that were used in the experiment

Accessions	Locally collected/introduced	Origin	Year of collection/introduction
Ging28 Introduced	Mauritius	1979	
Ging41 Introduced	Riodejonero (Brazil)	1979	
Ging316	Introduced	Surinam	1973
Ging296	Introduced	Rafinfua	1979
Ging25 Locally collected	Gamu Gofa	1986	
Ging61 Locally collected	Gamu Gofa	1986	
Ging10 Locally collected	Gamu Gofa	1986	
Ging57 Locally collected	Gamu Gofa	1986	
Ging84 Locally collected	BenchMaji	2000	
Ging70 Locally collected	Kafa-Yeki	2000	
Ging74 Locally collected	Kafa-Sheko	2000	
Ging47 Locally collected	Kafa-Benchi maji	1986	
Ging141	Introduced	Australia	1973
Ging190	Locally collected	Maji	1973
Ging24 Locally collected	Gamu Gofa	1986	
Ging85 Locally collected	Gamu Gofa	1986	
Ging45 Locally collected	Gamu Gofa	1986	
Ging60 Locally collected	Gamu Gofa	1986	
Ging64 Locally collected	Kafa-Yeki	2000	
Ging305	Locally collected	Wolaita	1972
Ging61(Ging63 for analysis)	Locally collected	Kafa-Yeki	2000
Ging26 Locally collected	Gamu Gofa	1986	
Ging54 Locally collected	Gamu Gofa	1986	
Ging56 Locally collected	Gamu Gofa	1986	
Ging59 Locally collected	Gamu Gofa	1986	
Ging53 Locally collected	Gamu Gofa	1986	
Ging181	Locally collected	Gamogofa	1973
Ging39 Introduced	Australia	1979	
Ging40 Introduced	Riodjenero (Brazil)	1979	
Ging75 Locally collected	Kafa-Sheko	2000	
Ging62 Locally collected	Kafa-Yeki	2000	
Ging01 Locally collected	Gamu Gofa	1999	
Ging180	Locally collected	Mizan Teferi	1973
Ging16 Introduced	Main land (China)	1986	
Ging15 Locally collected	Gamu Gofa	1986	
Ging38 Introduced	Australia	1979	

TNSRC. Of these, twenty seven were local collections; while the other nine were introduced from abroad (Brazil, China, Rafinfua, Surinam and Mauritius). Details of the accessions that were used in the experiment are given in Table 1.

Experimental design and management: The experiment was laid out in 6×6 Lattice Design with two replications. The spacing was 30×15 cm between rows and plants, respectively, 50 cm between plots and 1 m between replications in plot size of 1.2×1.5 m with 4 rows per plot. Three to five centimeter long one-year-old rhizomes having at least one active bud were used as planting materials for all accessions. Fertilizer was not applied at TNSRC; as there were non-significant results from fertilizer trials (Hailemichael *et al.*, 2008). At Bahir Dar, a recommended rate of fertilizer i.e., 100 and 200 kg ha^{-1} DAP and urea, respectively, was applied at planting. Other agronomic practices, such as planting, weeding and harvesting were carried out according to the recommendations of Agricultural and Rural Development Office (MoARD, 2007a) of the site.

Data collection: For data collection, five plants were randomly selected from each inner two rows. The parameters recorded included date of planting, number of plants/plot (nppp), days taken to maturity (dm), fresh rhizome yield (q ha^{-1}), dried rhizome yield (dry in q ha^{-1}), oleoresin content (oc in w/w%), volatile oil content (voc in v/w%) and fiber content (fb) (1 = having less fiber and 5 = having higher fiber content), leaf area (cm^2) which was calculated using length×width multiplied by adjustment factor (K = 1.426) (Anteneh *et al.*, 2008). Oleoresin content (w/w%), volatile oil content (v/w%) and fiber content were determined as described by Toure and Zhang (2007).

Data analysis: Analysis of variance for each character was computed using the standard statistical procedure of Gomez and Gomez (1984), using statistical software SAS 9.1 (SAS, 2002). Means were separated using LSD value at p = 0.05 level of significance. Test of homogeneity of variances of each character for the tow locations were performed by Cochran's test (Cochran and Cox, 1957) and the test showed heterogeneity of the two locations for almost all characters considered. The experiment was conducted using lattice design with two replications. However, Randomized Complete Block Design (RCBD) was used for the genetic variability analysis, because RCBD was more efficient than lattice for estimating the variance components of the different characters considered.

Genotypic (σ^2g) and phenotypic (σ^2p) variances were computed using the procedures of Burton and de Vane (1953). The genetic advance was computed as per the method reported by Johnson *et al.* (1955). Non-significant characters of the two sites were not taken in calculations of genetic variations.

Cluster analysis for genetic divergence among the genotypes was estimated by D^2 (Mahalanobis, 1936). Principal component analysis was performed by using correlation matrix by employing procedure printcomp corr of SAS version 9.2 (SAS, 2008) in order to examine the relationships among the quantitative characters that are correlated among each others by converting into uncorrelated characters called principal components.

RESULTS

Analysis of variance, range and mean values: Separate analysis of variance (Table 2) for individual location was made for each parameter. Number of plants per plot, days taken to maturity, fresh rhizome yield, dry rhizome yield, oleoresin, volatile oil and fiber content showed highly significant differences at both locations. Other characters, like number of leaves per plant, leaf length, leaf width, leaf area, plant height, number of fingers per rhizome, rhizome length and rhizome width were non-significant between accessions at Tepi and highly significant at Bahir Dar. Number of tillers per hill showed non-significant difference between accessions at both locations.

At Tepi, fresh rhizome yield ranged from 60.00 to 366.7 kg ha^{-1}. More than 33.3% of the accessions gave above the grand mean fresh rhizome yield i.e., 181.10 q ha^{-1} (Table 3). At Bahir Dar, fresh rhizome yield ranged from 50.5 to 228.6 kg ha^{-1}. At Bahir Dar, though the range was as wide as that of Tepi, the grand mean was lower (10661 kg ha^{-1}). Fifty percent of the accessions gave above the grand mean. At Tepi, dry rhizome yield ranged from 11.30 to 69.9 kg ha^{-1} and at Bahir Dar, the same character ranged from 9.3 to 53.2 kg ha^{-1}.

Table 2: Analysis of variance for 16 characters of Ginger accessions grown at Tepi and Bahir Dar during 2009-2010 cropping season

	Mean squares					
	Tepi			Bahir Dar		
Character	Replication	Genotype	Error	Replication	Genotype	Error
No. of leaves per plant	4.109^{ns}	7.976^{ns}	7.057	0.87	14.10**	2.01
Leaf length (cm)	51.34**	2.822^{ns}	4.563	1.68	4.17**	0.25
Leaf width (cm)	0.161^{ns}	0.041^{ns}	0.039	0.01	0.081**	0.02
Leaf area (cm^2)	62.61^{ns}	49.76^{ns}	65.453	3.93	68.49**	9.67
Plant height (cm)	754.60**	63.39^{ns}	67.96	0.35	22.67**	0.43
No. of fingers per rhizome	2.722^{ns}	2.378^{ns}	3.289	3.56	11.17**	1.87
Rhizome length (cm)	5.336^{ns}	3.80^{ns}	2.585	0.30	2.871**	0.10
Rhizome width (cm)	0.094^{ns}	2.42^{ns}	2.235	0.00	0.816**	0.05
No. of tillers per hill	70.014*	22.42^{ns}	16.127	0.06	1.948ns	1.42
No. of plants per plot	28.13^{ns}	97.37**	27.904	0.89	54.30**	5.08
Days taken to maturity	5.014^{ns}	172.02**	26.51	10.89	175.071**	3.15
Fresh rhizome yield (kg ha^{-1})	102.70^{ns}	9111.61**	50.22	0.605	3360.30**	1.18
Dry rhizome yield (kg ha^{-1})	35.280*	353.108**	6.80	0.008	159.57**	0.637
Oleoresin content (w/w%)	0.000^{ns}	1.117**	0.05	0.008	0.90**	0.023
Volatile oil content (v/w%)	0.095*	0.13**	0.031	0.002	0.06**	0.007
Fiber content (1-5 scale)	-	0.248**	-	-	0.438**	-

**and * indicate significant differences at 1 and 5%, respectively, ns: Not significant

Table 3: Estimates of ranges and standard deviation for char acres of ginger accessions grown at Tepi and Bahir Dar during 2009-2010 main cropping season

	Bahir Dar			Tepi		
	Range			Range		
Characters	Min.	Max.	SD	Min.	Max.	SD
NLPP	5.0	19.0	2.926	8.0	21.0	2.89
NPPP	6.0	35.0	5.539	3.0	38.0	7.968
PH (cm)	18.0	35.9	3.620	20.1	36.1	3.392
LL (cm)	11.0	17.3	1.578	13.1	19.3	1.568
LW (cm)	1.1	2.2	0.226	1.3	2.2	0.198
LA (cm^2)	21.8	54.27	6.330	23.223	65.34	9.167
NFPR	4.0	17.0	2.573	8.0	19.0	2.496
RL (cm)	4.5	10.7	1.225	5.7	13.5	1.567
RW (cm)	2.3	5.3	0.666	2.5	5.3	0.632
DM	241.0	273.0	9.977	251.0	285.0	10.337
OC (w/w%)	2.4	5.0	0.686	2.7	6.0	0.769
VOC (v/w%)	0.5	1.6	0.195	0.6	2.0	0.288
FB(1-5 scale)	1.0	2.0	0.508	1.0	2.0	0.382
DRY (kg ha^{-1})	9.3	53.2	9.602	11.3	69.9	14..532
FRY (kg ha^{-1})	50.5	228.6	44.284	60.00	366.7	72.433

NLPP: No. of leaves per plant, NPPP: No. of plants per plot, LL: Leaf length, LW: Leaf width, LA: Leaf area, NFPR: No. of fingers per rhizome, RL: Rhizome length, RW: Rhizome width, DM: Days taken to maturity, FRY: Fresh rhizome weight, DRY: Dry rhizome weight, OC: Oleoresin content, VOC: Volatile oil content and FB: Fiber content

Table 4: Estimates of variances, coefficients of variations, heritability in broad sense (H%) and genetic advance as percent of mean (GAM) of ginger accessions grown at Tepi

Characters	$\partial^2 g$	$\partial^2 e$	$\partial^2 p$	GCV%	PCV%	H%	GA	GAM (%)
No. of plants per plot	32.24	33.33	65.57	33.33	47.99	49.17	8.20	48.608
Days taken to maturity	65.67	41.86	107.52	3.03	3.87	61.07	13.044	4.869
Oleoresin content (w/w%)	0.48	0.09	0.570	16.99	18.46	84.74	1.327	32.221
Volatile oil content (v/w%)	0.06	0.01	0.073	21.45	23.44	83.68	0.471	40.414
Fiber content (1-5 scale)	0.15	0.01	0.162	33.33	34.86	91.40	0.766	65.639
Fresh rhizome yield (kg ha^{-1})	4530.70	50.00	4580.90	37.17	37.37	98.90	88.31	48.760
Dry rhizome yield (kg ha^{-1})	173.15	6.80	179.95	34.85	35.53	96.22	26.59	70.427

Table 5: Estimates of variances, coefficients of variations, heritability in broad sense (H%) and genetic advance as percent of mean (GAM) of ginger accessions grown at Bahir Dar

Characters	$\partial^2 g$	$\partial^2 e$	$\partial^2 p$	GCV%	PCV%	H%	GA	GAM
No. of leaves per plant	4.05	4.62	8.67	23.80	26.83	78.70	4.651	43.492
Leaf length (cm)	2.20	0.30	2.50	10.49	11.52	82.91	2.679	19.667
Leaf width (cm)	0.03	0.02	0.05	10.25	12.93	62.80	0.263	16.733
Leaf area (cm^2)	32.06	9.48	41.53	16.13	18.47	76.30	10.013	29.034
Plant height (cm)	12.90	0.38	13.28	15.75	15.99	97.11	7.390	31.980
No. of fingers per rhizome	4.50	1.73	6.66	20.51	23.83	74.08	3.939	36.364
Rhizome length (cm)	1.42	0.10	1.52	15.82	16.38	93.23	2.37	31.462
Rhizome width (cm)	0.38	0.17	0.54	18.56	19.56	90.07	1.25	36.286
No. of plants per plot	26.19	5.28	31.46	29.37	31.92	84.65	9.72	55.657
Days taken to maturity	97.12	3.70	100.82	3.89	3.96	96.33	19.93	7.866
Oleoresin content (w/w%)	0.50	0.17	0.67	17.58	18.04	94.96	1.35	35.287
Volatile oil content (v/w%)	0.04	0.00	0.04	18.97	20.92	82.28	0.33	35.455
Fiber content	0.22	0.002	0.22	14.67	14.80	99.10	0.61	40.740
Fresh rhizome weight (kg ha^{-1})	1679.85	1.18	1681.03	38.78	38.79	99.90	49.45	46.613
Dry rhizome weight (kg ha^{-1})	79.47	0.64	80.10	39.20	39.36	99.21	11.02	48.444

At Tepi, oleoresin content ranged from 2.7 to 6.0 w/w while at Bahir Dar it ranged from 2.4 to 5.0 w/w. At Tepi, volatile oil content ranged from 0.6 to 2.0 v/w; while at Bahir Dar, volatile oil content ranged from 0.5 to 1.6 v/w. The fiber content ranged from 1.0 to 2.0 at both sites. At Tepi days taken to maturity ranged from 251 to 285 and at Bahir Dar 241 to 273.

Genotypic and phenotypic variation: Characters such as number of plants per plot, fresh rhizome yield, fiber content, volatile oil content and dry rhizome yield produced high GCV and PCV at Tepi (Table 4). However, days taken to maturity showed the least GCV and PCV values.

At Bahir Dar number of plants per plot, fresh rhizome yield, number of fingers per rhizome and dry rhizome yield produced high GCV and PCV (Table 5). Here also days taken to maturity showed the least GCV and PCV values.

Heritability in the broad sense: Broad sense heritability was estimated at Tepi for all agronomic traits and it ranged from 49.17 to 98.90% (Table 4). The values of heritability were high for all characters measured at Tepi.

At Bahir Dar heritability values were ranged between 62.80 and 99.90% (Table 5). The values of heritability were high for all characters measured at this particular location.

Table 6: Eigen values, total variance, cumulative variance and eigen vectors for 16 characters of 36 ginger accessions grown at Tepi during 2009-2010 main cropping season

Characters	PC1	PC2	PC3	PC4	PC5	PC6
NLPP	-0.023	0.047	-0.448	0.039	-0.170	0.013
LL (cm)	0.626	0.032	-0.534	-0.335	0.084	0.187
LW (cm)	0.447	-0.152	-0.477	-0.295	0.363	0.400
LA	0.612	-0.071	-0.530	-0.364	0.272	0.334
PH (cm)	0.659	0.064	-0.605	-0.202	-0.354	-0.160
NTPH	0.175	0.198	0.153	-0.087	0.217	-0.084
NPPP	0.483	-0.129	0.045	0.030	-0.090	-0.003
NFPR	0.483	-0.100	-0.109	0.040	-0.342	-0.054
RL (cm)	0.154	0.011	-0.311	-0.167	0.573	-0.704
RW (cm)	0.668	0.233	-0.374	0.586	0.113	0.037
FRY (kg ha^{-1})	0.000	0.995	0.052	-0.083	0.009	0.008
DRY (kg ha^{-1})	0.999	-0.003	0.007	-0.004	0.004	-0.000
DM	0.983	0.039	0.011	0.078	-0.102	0.002
OC (w/w%)	0.025	0.098	-0. 121	-0.008	-0.016	0.158
VOC (v/w%)	0.001	-0.178	0.199	-0.151	-0.181	0.395
FB (1-5 scale)	-0.303	0.241	0.034	0.138	0.025	0.006
Eigen value	5.374	1.824	1.665	1.271	1.189	1.103
% Total variance explained	33.591	11.405	10.407	7.945	7.430	6.896
Cumulative variance	33.591	44.996	55.403	63.348	70.778	77.674

NLPP: No. of leaves per plant, NTPH: Number of tillers per hill, NPPP: No. of plants per plot, LL: Leaf length, LW: Leaf width, LA: Leaf area, NFPR: No. of fingers per rhizome, RL: Rhizome length, RW: Rhizome width, DM: Days taken to maturity, FRY: Fresh rhizome weight, OC: Oleoresin content and VOC: Volatile oil content

Estimates of genetic advance: Genetic advance was relatively high for dry rhizome yield (48.760%) and fresh rhizome weight (70.427%) and this was coupled with high heritability and high GCV at Tepi location (Table 4).

Similarly, genetic advance was relatively high for dry rhizome yield (48.760%) and fresh rhizome weight (70.427%) and this was coupled with high heritability and high GCV at Bahir Dar (Table 5).

Principal component analysis: At Tepi, the first six principal components explained 77.7% of the total variation (Table 6). The first PC which accounted for 33.6% of the total variation, was the average effect of traits, such as leaf length (0.626), leaf area (0.612), plant height (0.659), rhizome width (0.668), dry rhizome yield (0.999) and days to maturity (0.983). This perhaps emphasizes the significance of these characters for the overall genetic diversity in PC1. The second PC which accounted for 11.4%, of the variability among accessions was the average effect of traits such as rhizome width (0.233), fiber content (0.241) and fresh rhizome yield (0.995).

Similarly at Bahir Dar, the five principal components with eigenvalues greater than one explained for 67.7% of the total variations among accessions (Table 7). The first PC explained 23.3% of the variation among accessions was highly influenced by fresh rhizome yield. The second PC that explained 15% of the variation among accessions was highly influenced by days taken to maturity (-0.993).

Cluster analysis: At Tepi, the germplasm were grouped into 7 cluster (Table 8) whereas at Bahir Dar the germplasm were classified into 11 clusters (Table 9) based on the morphological and quality traits associated with them.

Table 7: Eigen values, total variance, cumulative variance and eigen vectors for 16 characters of 36 ginger accessions grown at Bahir Dar during 2009-2010 main cropping season.

Characters	PC1	PC2	PC3	PC4	PC5
NLPP	-0.006	0.061	-0.060	0.168	-0.617
LL (cm)	0.017	-0.020	0.025	0.132	0.031
LW (cm)	0.002	0.001	0.019	0.013	-0.010
LA	0.076	0.003	0.518	0.693	-0.012
PH (cm)	0.019	-0.027	-0.219	0.403	0.676
NTPH	-0.000	-0.011	-0.057	0.039	-0.009
NPPP	-0.020	-0.017	-0.799	0.296	-0.160
NFPR	0.013	-0.006	-0.170	0.209	0.081
RL (cm)	0.040	-0.012	-0.055	-0.019	-0.111
RW (cm)	0.001	0.008	-0.001	-0.006	-0.031
FRY (kg ha^{-1})	0.977	0.071	-0.053	-0.134	0.046
DRY (kg ha^{-1})	0.189	-0.066	0.005	0.397	0.334
DM	0.056	-0.993	0.016	-0.044	-0.028
OC (w/w%)	0.02	-0.006	-0.023	-0.025	-0.019
VOC (v/w%)	0.001	0.002	0.001	-0.011	-0.010
FB (1-5 scale)	0.001	0.003	0.035	0.008	0.024
Eigen value	3.373	2.396	1.949	1.504	1.255
% Total variance explained	23.321	14.973	12.186	9.398	7.845
Cumulative%	23.321	38.285	50.471	59.869	67.714

NLPP: No. of leaves per plant, NTPH: No. of tillers per hill, NPPP: No. of plants per plot, LL: Leaf length, LW: Leaf width, LA: Leaf area, NFPR: No. of fingers per rhizome, RL: Rhizome length, RW: Rhizome width, DM: Days taken to maturity, FRY: Fresh rhizome weight, OC: Oleoresin content and VOC: Volatile oil content

Table 8: Clustering patterns of 36 ginger accessions grown at Tepi during 2009-2010 main cropping season.

Clusters	Accessions	Total No.	Proportion in (%)
I	Ging 41, Ging 141, Ging 25, Ging 01, Ging 28, Ging 74, Ging 84, Ging 40, Ging 70, Ging 190, Ging 305, Ging 47	12	33.33
II	Ging 45, Ging 64, Ging 54, Ging 62, Ging 10, Ging 59	6	16.67
III	Ging 316, Ging 16, Ging 61, Ging 75, Ging 57	5	13.89
IV	Ging 296, Ging 39, Ging 61, Ging 24, Ging 60	5	13.89
V	Ging 85, Ging 56, Ging 181, Ging 26, Ging 53	5	13.89
VI	Ging 180, Ging 15	2	5.56
VII	Ging 38	1	2.78

Table 9: Clustering patterns of 36 ginger accessions grown at Bahir Dar during 2009-2010 main cropping season

Clusters	Accessions	Total No.	Proportion in (%)
I	Ging 25, Ging 61, Ging 26, Ging54, Ging 74, Ging 305, Ging 41, Ging 40, Gin 28,	9	25.00
II	Ging 60, Ging 64, Ging 15, Ging 38, Ging 181, Ging 180	6	16.67
III	Ging 296, Ging 61, Ging 84, Ging 01, Ging 45, Ging 56, Ging 47	7	19.44
IV	Ging 70, Ging 53	2	5.56
V	Ging 316, Ging 85, Ging 57, Ging 16	4	11.11
VI	Ging 24, Ging 75	2	5.56
VII	Ging 10, Ging 59	2	5.56
VIII	Ging 141	1	2.78
IX	Ging 190	1	2.78
X	Ging 62	1	2.78
XI	Ging 39	1	2.78

Table 10: Generalized square distance (D^2) among the clusters of accessions grown at Tepi during the growing season of 2009-2010 main cropping season

	Cluster No.						
	I	II	III	IV	V	VI	VII
I		126.209**	93.237**	22.941**	194.947**	463.261**	893.569**
II			394.738**	57.44**	614.715 **	1040.00**	1644.00**
III				169.122**	33.391**	169.616**	470.243**
IV					311.873 **	635.543**	1130.00**
V						68.217**	289.169**
VI							103.822**
VII							

* and ** significance at X^2 of p<0.01% and p<0.05% are 30.58 and 25.00

Table 11: Generalized square distance (D^2) among the clusters of accessions grown at Bahir Dar during the growing season of 2009-2010 main cropping season

	Cluster No.										
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
I		218.073**	136.537**	250.359**	33.144 **	821.795**	85.277**	531.404**	448.317**	1284.00**	263.015**
II			47.890**	65.660**	157.980**	222.031**	119.848**	137.379**	95.358**	525.529**	544.813**
III				67.255**	74.939**	351.073**	150.044**	248.853**	117.205**	665.34**	342.788**
IV					152.031**	240.424**	212.666**	135.612**	76.107**	467.22**	529.772**
V						675.759**	112.494**	430.679**	322.336**	1046.00**	288.607**
VI							119.666**	238.912**	99.528**	144.72**	1145.00**
VII								347.60**	380.585**	1022.00**	416.972**
VIII									146.684**	237.701**	807.458**
IX										320.903**	724.796**
X											147.00**
XI											

* and ** significance at X^2 of p<0.01% and p<0.05% are 30.58 and 25.00

Genetic distances: Based on Mahalanobis's statistics, highly significant inter-cluster distances were obtained at Tepi (Table 10). At Tepi Cluster II showed the maximum and significant distance (1644.00) from cluster VII whereas cluster VI revealed the maximum genetic distance (1145.00) from cluster XI. These distances indicated that the germplasm in the above clusters are significantly divergent from each other.

At Bahir Dar, there was a significance difference between all clusters (Table 11). The maximum distance was found between C I and C X (D^2 = 1284.0). The second most divergent distance was between C VI and C XI (D^2 = 1145.0). The third most divergent distance was C VII and C X (D^2 = 1022.0). The genetic divergence distance between the rest of the clusters was also highly significant.

DISCUSSION

The existence of significant difference among ginger germplasm accession for most of the characters studied at both Tepi and Bahirdar locations indicates the existence of sufficient genetic variability among the studied accessions. This finding is in-line with results of Chandra *et al.* (1999). Parthiban *et al.* (2011) observed significant variability among plant height, basal diameter, sturdiness quotient, number of primary and secondary branches and seed yield in jatropha hybrids. However, this is not in line with the findings of Dar and Sharma (2011) who reported significant variation between quantitative character among 60 tomatoes genotypes. Further, Gichimu and Omondi (2010) reported that morphological characterization of five newly developed lines of arabica coffee as compared to commercial cultivars in Kenya and they found non significant difference for internodes length.

At Tepi, fresh rhizome yield ranged from 366.7 to 60.0 kg ha^{-1}. At Bahir Dar, fresh rhizome yield ranged from 228.6 to 50.0 kg ha^{-1}. At Bahir Dar, though the range was as wide as that of Tepi the grand mean was lower (10661 kg ha^{-1}). This may be attributed to long growing period of the crop and lower rain shower, especially late in the season at Baihr Dar. The average fresh rhizome yield in all Indian accessions varied from 7000.0 to 10000.0 kg ha^{-1}; despite up to 40000.0 kg ha^{-1} report from experimental plots (Pruthi, 1998). Weiss (2002) reported average fresh rhizome yield in India up to 150.0 t ha^{-1} from selected cultivars of ginger. Similar work done under Ethiopian condition confirmed that the average fresh rhizome yield varied between 11600.0 to 21440 kg ha^{-1} (Hailemichael and Tilahun, 2004). Jansen (1981) also reported rhizome yield of up to 38000.0 kgq ha^{-1} in Ethiopia. At Tepi, dry rhizome yield ranged from 69.9 to 13.3 kg ha^{-1}. Similarly, at Bahir Dar dry rhizome yield ranged from 6990 to 1130 kg ha^{-1}, indicating that there was a considerable difference between accessions for the character. The existence of variation in yield of accessions may be considered during varietal development selection process.

At Tepi, the maximum oleoresin content was obtained from Ging 141/73; while at Bahir Dar it was recorded from Ging 84/00. At Tepi, the highest volatile oil content was obtained from Gin 141/73; while at Bahir Dar, it was obtained from Ging 74/86. An experiment conducted in India using 14 popular ginger cultivars showed that the oleoresin content varied from 3.6 to 10.4% (Pruthi, 1998). In a similar experiment conducted in India using 24 genotypes found that the highest oleoresin content was 5.31% (Tiwari, 2003b). This study demonstrates a high level of intraspecific differences in oil composition due to environmental factors and, more particularly, soil characteristics.

In this study, wide range in days to maturity was recorded. Such a wide range in days taken to maturity of accessions offers a great opportunity for the development of ginger varieties suitable for various agro-ecological zones of Ethiopia; experiencing diversities in precipitation and length of growing period. The accessions differ significantly for most of the characters and relatively wide range of mean values for most of the characters indicated the existence of variation among the tested accessions.

Genetic variability is a prerequisite for response to selection and knowledge of the extent and nature of phenotypic variability is, then, one of the basic needs for the breeders for further improvement of the crop (Adam, 2006). The amount of genotypic and phenotypic variability that exists in a species is essential in developing better varieties and in initiating a breeding program. The estimates of components of variance, phenotypic and genotypic variances, heritability in the broad sense, genetic advance for Tepi and Bahir Dar are presented in Table 7 and 8, respectively. Deshmukh *et al.* (1986) classified Genotypic Coefficients of Variation (GCV) and Phenotypic Coefficients of Variation (PCV) estimates as high (>20%), medium (10-20%) and low (<10).

Selection based on traits with high PCV and GCV is effective and the phenotypic expression of such characters is a good indication of the genotypic potential. Progress from selection depends on genetic variability existing in the population and selection is more effective when the genetic variation is higher than environmental variation (Allard, 1960). According to Moll and Stuber (1974) genetic effects are dependant on non-genetic effects such as physiological factors.

Generally, the differences between GCV and PCV for almost all the corresponding characters were small, indicating thereby these characters were less influenced by the environment. Similar findings were reported by Jalata *et al.* (2011) in field pea. However, this finding contradicts with the findings of Singh *et al.* (2011) who reported the magnitude differences to be medium to low in PCV and GCV for most of the characters studied in field pea. For all characters studied, PCV value was greater than GCV at both sites similar with the findings of Tiwari (2003b).

Broad sense heritability was high for all characters measured. Dabholkar (1992) categorized heritability estimates as low (5-10%), medium (10-30%) and high (>30%). Garedew (2006) also found high heritability with high phenotypic and genotypic coefficient of variation in tuber weight/hill and tuber number/hill for (common name) *Plectranthus edulis* (Vatke) Agnew. Chattopadhyay *et al.* (2004) reported maximum heritability (88.5%) for weight of secondary rhizome followed by plant height (83.3%), total fresh rhizome yield (79.9%) and number of secondary finger (72.1%) in ten turmeric cultivars studied in India. In addition to this, Abera (1998) reported high heritability (79.06%) of marketable root yield in medium maturing sweet potato cultivars. The value of heritability is affected by the breeding material, the character under consideration and environmental conditions to which the genetic materials are exposed (Dabholkar, 1992). In this study, relatively high heritability values were obtained may be due to favorable growing conditions and adaptability of the ginger germplasms used.

Since heritability estimates show only the effectiveness with which selection of genotypes can be based on phenotype, their utilities increased when used only with estimates of genetic advance (Johnson *et al.*, 1955; Allard, 1960). Besides, Genetic advance was relatively high for dry rhizome yield (48.760) and fresh rhizome weight (70.427) and this was coupled with high heritability and high GCV at both locations (Table 4, 5). This high heritability coupled with GCV estimates also gives a reliable estimate of the amount of genetic advance through selection which indicates the effectiveness with which selection of genotype can be based on phenotypic performance (Johnson *et al.*, 1955).

At Tepi the maximum variation showed by the first principal component was based on traits leaf length, leaf area), plant height, rhizome width, dry rhizome yield and days to maturity. Similar finding was reported by Kebede and Bellachew (2008) for leaf area. The largest value for fresh rhizome yield in the first PC at Bahir Dar displayed that this trait was mainly responsible for explaining 23.32% of the total variance. This emphasizes the importance to these traits for assessment genetic diversity in ginger.

The 36 ginger grermplasm accessions were grouped into 7 clusters (Table 8). Six are real clusters and one is solitary. This solitary is also considered as cluster, even if it consists of one accession. This indicates the tested ginger germplasm were highly divergent. Cluster I contained one accession (Ging 28/79) from Mauritius and the rest from Ethiopia. Cluster II was characterized by accessions from Ethiopia (Gamogofa and Kafa-Sheko). The third cluster was characterized by accessions from Surinam, Ethiopia and Kenya. Cluster IV was characterized by accessions from Ranifua, Ethiopia and Australia. Clusters V and VII were characterized by accessions from Ethiopia only. The introduced germplasm were concentrated in four clusters. The germplasm from Gamo Gofa district (Ethiopia) were distributed in five different clusters. Similarly, accessions from Kafa district (Ethiopia) were distributed in three clusters. Generally the germplasm from Ethiopia were concentrated in 10 clusters, even if most of them are concentrated in cluster I. This indicated that there was more genetic variability in Ethiopian accessions.

At Bahir Dar cluster I consisted of nine accessions from Mauritius, Brazil and Ethiopia. Clusters II and VIII were mainly characterized by the accessions from Ethiopia and Australia, whereas Cluster III was characterized by accessions from Rafintua and Ethiopia. Clusters IV, VI, VII, IX and X were characterized by accessions from Ethiopia. The last cluster (cluster XI) contained accession from Australia only. Similarly, accessions from Kafa district (Ethiopia) were distributed six clusters. Generally the germplasm collected from different major ginger growing zones of Ethiopia were scattered over 10 clusters out 11 clusters at Tepi and all over clusters at Bahir Dar, displaying possibility of exchange of planting materials among farmers from different zones. Further, this result also suggested that the accessions from Ethiopia were more variable.

In addition, we recorded overlapping of clustering patterns in germplasm in the majority of origin. This could be explained as lack of differentiation among origins, probably arising partly due to gene flow among regions (Ayana and Bekele, 1999). In general, it is observed that accessions from Ethiopia are relatively more variable in their clustering patterns, compared to those from abroad. This indicates that due emphasis must be given to Ethiopian germplasm to improve most of the attributes in the crop. Nevertheless, the ginger accession found in Ethiopia have to be classified accurately by using molecular markers , qualitative traits, etc.

The study has revealed highly significant inter-cluster genetic distances at both locations (Table 10, 11). At Tepi Cluster II showed the maximum and significant distance (1644.00) from cluster VII whereas cluster VI revealed the maximum genetic distance (1145.00) from cluster XI at Bahir Dar). These distances indicated that the germplasm in the above clusters are significantly divergent from each other. Since, the magnitude of heterosis largely depends upon the degree of genetic diversity among the parental lines, the progenies of those accessions belonging to the pairs of distant clusters could be useful in a hybridization program for obtaining a wide spectrum of variation among the segregants (Peeters and Martinelli, 1989). Thus, it may be concluded that the germplasm accessions from cluster II and VII at Tepi and VI and XI at Bahir Dar could offer relatively better parental lines that, when intercrossed, could produce hybrids with high heterotic effect, even though other clusters with significant genetic distances are also good sources of parental lines.

Dissimilarities recorded in this study revealed a wide variation in land races of ginger. Greater diversity may be obtained if a more collections from geographically distant areas was included in the study. Nevertheless, the information on the genetic relationships will be vital to utilize available germplasm for crop improvement.

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REFERENCES

Abera, G., 1998. Variability and association of characters in sweet potato. Proceedings of the 3rd Conference of the Agronomy and Crop Physiology Society of Ethiopia: Crop Management Options to Sustain Food Security, May 29-30, 1997. Addis Ababa, Ethiopia, pp: 169-176.

Adam, A., 2006. Evaluation of ethiopian black cumin (*Nigella sativa* L.) land races for agronomic characters and oil content at Adet and Woreta, North West Ethiopia. M.Sc. Thesis, Alemaya University, Alemaya.

Adam, A., 2008. Evaluation of ginger accessions for yield from the Southwestern parts of the country at Weramit. Progress report for the period 2007/08, Adet Agricultural Research Center, Adet, Ethiopia.

Allard, R.W., 1960. Principles of Plant Breeding. 2nd Edn., John Willey and Sons, Inc., New York, pp: 96.

Anteneh, N., H. Girma and T. Endale, 2008. Leaf area estimation models for ginger (*Zingiber officinale* Rosc.). East Afr. J. Sci., 2: 25-28.

Ayana, A. and E. Bekele, 1999. Multivariate analysis of morphological variation in sorghum (*Sorghum bicolor* (L.) Moench) germplasm from Ethiopia and Eritrea. Genet. Resour. Crop Evol., 46: 273-284.

Burton, G.W. and E.H. de Vane, 1953. Estimating heritability in tall fescue (*Festuca arundinacea* L.) from replicated clonal material. Agron. J., 45: 478-481.

Chandra, R., S. Govind and A.R. Desai, 1999. Growth, yield and quality performance of turmeric (*Curcuma longa* L.) genotypes in mid altitudes of Meghalaya. J. Applied Hortic., 1: 142-144.

Chattopadhyay, N., J.K. Hore and A. Bandyopadhyay, 2004. Studies on character association and genetic variability in turmeric. Hortic. J., 17: 259-266.

Cochran, W.G. and G.M. Cox, 1957. Experimental Designs. 2nd Edn., John Wiley and Sons, Canada.

Dabholkar, A.R., 1992. Elements of Biometrical Genetics. Concept Publishing Company, New Delhi, India.

Dar, R.A. and J.P. Sharma, 2011. Genetic variability studies of yield and quality traits in tomato (*Solanum lycopersicum* L.). Int. J. Plant Breed. Genet., 5: 168-174.

Deshmukh, S.N.N., M.S. Basu and P.S. Reddy, 1986. Genetic variability, character association and path coefficient analysis of quantitative traits in *Virginia bunch* varieties of ground nut. Indian J. Agric. Sci., 56: 515-518.

Garedew, W., 2006. Morphological characterization and divergence analysis of *Plectranthus edulis* (Vatke) agnew collection in Ethiopia. M.Sc. Thesis, Hawassa University, Awassa, Ethiopia.

Gichimu, B.M and C.O Omondi, 2010. Morhpological characterization of five newly developed lines of Arabica coffee as compared to commercial cultivars in Kenya. Int. J. Plant Breed. Genet., 4: 238-246.

Girma, A., B. Bayette, S. Tesfaye and K. Taye, 2000. Coffee diversity and knowledge. Proceedings of National Work Shop. Four Decades of Coffee Research and Development in Ethiopia. Addis Ababa. Ethiopia.

Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedure for Agricultural Research. 2nd Edn., John Wiley and Sons, New York, USA., ISBN-10: 0471870927, pp: 704.

Hailemichael, G. and D. Tilahun, 2004. Current status of spice research. Ethiopian Agricultural Research Organiztion, Jimma Agricultural Research Center, Tepi Agricultural Research Sub-Center.

Hailemichael, G. and K. Tesfaye, 2008. The effects of seed rhizome size on the growth, yield and economic return of ginger (*Zingiber officinale* Rosc.). Asian J. Plant Sci., 7: 213-217.

Hailemichael, G., D. Tilahun, E. Etissa, B. Yemanebirhan and W. Garedew, 2008. Spices Research Achievements. Revised Edn., EIARO., Addis Ababa. Ethiopia.

Jalata, Z., A. Ayana and H. Zeleke, 2011. Variability, heritability and genetic advance for some yield and yield related traits in ethiopian barley (*Hordeum vulgare* landraces and crosses. Int. J. Plant Breed. Genet., 5: 44-52.

Jansen, P.C.M., 1981. Spices, Condiments and Medicinal Plants in Ethiopia, Their Taxonomy and Agricultural Significance. Centre for Agricultural Publishing and Documentation, Wageningen, The Netherlands, pp: 327.

Johnson, H.W., H.F. Robinson and R.E. Comstock, 1955. Estimates of genetic and environmental variability in soybeans. Agron. J., 47: 314-318.

Katzer, G., 2007.. Spice pages. http://www.uni-graz.at/~katzer/engl/index.html.

Kebede, M. and B. Bellachew, 2008. Phenotypic diversity in the Hararge coffee (*Coffea arabica* L.) germplasm for quantitative traits. East Afr. J. Sci., 2: 13-18.

Mahalanobis, P.C., 1936. On the generalized distance in statistics. Proc. Nat. Inst. Sci., 2: 49-55.

Michelle, T., 2009. Essential oil composition affected by plant growing conditions. The Ananda Apothecary, http://www.anandaapothecary.com/aromatherapy-essential-oils.html

MoARD, 2007a. Annual yield assessment report 2007. Results on area, production and yield of coffee, tea and spices. Statistical Bulletin 150. Addis Ababa, Ethiopia.

MoARD, 2007b. Crop Variety register 2007/2008. Statistical Bulletin 11. Addis Ababa, Ethiopia.

Moll, R.H. and C.W. Stuber, 1974. Quantitative genetics: Empirical results relevant to plant breeding. Adv. Agron., 26: 277-331.

Palai, S.K. and G.R. Rout, 2007. Identification and genetic variation among eight varieties of ginger by using random amplified polymorphic DNA markers. Plant Biotechnol., 24: 417-420.

Parthiban, K.T., R. Kirubashankkar, M. Paramathma, V. Subbulakshmi and P. Thiyagarajan *et al.*, 2011. Genetic association studies among growth attributes of jatropha hybrid genetic resources. Int. J. Plant Breed. Genet., 5: 159-167.

Peeters, J.P. and J.A. Martinelli, 1989. Hierarchical cluster analysis as a tool to manage variation in germplasm collections. Theor. Applied Genet., 78: 42-48.

Pruthi, J.S., 1998. Major Spices of India: Crop Management and Post Harvest Technology. Indian Council of Agricultural Research, India.

Purseglove, J.W., E.G. Brown, C.L. Green and S.R.J. Robbins, 1981. Spices. Longman, Inc., New York, 1: 331-439.

Ravinderan, P.N., B.K. Nirmal and K.N. Shiva, 2005. Botany and Crop Improvement of Ginger. In: Ginger: The Genus Zingiber, Ravinderan, P.N. and B.K. Nirmal (Eds.). CRC Press, New York, pp: 15-86.

SAS., 2002. Statistical Analysis System (SAS 9.1). SAS Institute, Cary, North Carolina, USA.

SAS, 2008. STAT Users Guide (Version 9.2). SAS Institute, Cary, N.Carolina, USA.

Singh, A., S. Singh and J.D.P. Babu, 2011. Heritability, character association and path analysis studies in early segregating population of field pea (*Pisum sativum* L. var. *arvense*). Int. J. Plant Breed. Genet., 5: 86-92.

Tiwari, S.K., 2003a. Evaluation of ginger genotypes for yield and quality attributes under rainfed and irrigated conditions. Ann. Agric. Res., 24: 512-515.

Tiwari, S.K., 2003b. Genetic variability and correlation studies in ginger (*Zingiber officinale* Rosc.). Ann. Agric. Res., 24: 261-265.

Toure, A. and X. Zhang, 2007. Gas chromatographic analysis of volatile components of Guinean and Chinese ginger oils (*Zingiber officinale*) extracted by steam distillation. J. Agron., 6: 350-355.

Weiss, E.A., 2002. Spice Crops. CABI Publishing, London, UK.