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Principal Component Analysis of Morphological Traits in Thirty-Six Accessions of Amaranths (Amaranthus Spp.) Grown in a Rainfed under Mizanand Tepe Condtions, South West Ethiopia

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Abstract
Amaranthus is one of the most dominantly consumed vegetable in the pastoralist area of Ethiopia. However this crop has received less research attention and little or nothing has been done on extent variability. Hence, 36 accessions of Amaranthus spp. were evaluated in 6x6 simple lattices design at Tepi and Mizan experimental sites during 2012 cropping season under rain fed condition. The overall objective was to assess the contribution of morphological traits to variability in some accessions of Amaranthus there by determine the extent of accession near to each other in relation to genetic variability. Variances component method was used to estimate genetic variation and relationship among traits was also estimated by using standard method. Analysis of variance revealed that there was a significant difference ($p < 0.01$) among thirty six germplasm accessions for all the characters studied except for thousand seed weight which was non-significant ($p > 0.05$). The principal components (PC) analyses indicated that most of the 80.75% of the variation were more explained by seven principle components (PC1, PC2, PC3, PC5, PC6, PC5 and PC5) from this the major of 47.2% of the variation were elucidate by PC1 and PC2. The overall study confirmed the presence of trait variability in amaranths germplasm accessions and this could be exploited in the genetic improvement of the crop through hybridization and selection
Keywords: Variation, principal component, Amaranthus, accessions.

1.INTRODUCTION

Amaranthus belongs to the family Amaranthaceae and the genus *Amaranthus* has more than fifty species, including both cultivated and wild are eaten as greens. Because of the large number of species diversity available in the world, there is a considerable variability in growth habit, inflorescence color, inflorescence attitude, leaf color, leaf shape and utilization (Rubaihyo, 1995). The availability of genetic variation among different germplasm of amaranths provides great scope for improvement through selection and breeding to develop the desired genotypes (Revanappa and Madalageri, 1998).

Amaranths plant grows as wild in Ethiopia but some are cultivated as a food crop in southern part of the country. The crop is mostly grown and consumed in the humid area of Oromiya, Benashangule Gomez, Gambella and SNNPRS (extensively in Benche Maji area). The crop has wide adaptability area and grows successfully in every ecological part of the country. Presently the production of amaranths is 2125 hectare while the zone of Bench Magi takes the lion share 612 hectares from the total (ARBMZ, 2010).

As far as variability studies among characters in amaranths are concerned little or nothing has been done in the country (Kebu and Fassil, 2006). To do agronomic and other related research on this crop to know the genetic differences and identify the groups of similarities between germplasm was considered an important area of study. Therefore this study is conducted to show variation among the varieties and identify traits that contribute to variability in this population and for their possible exploitation in breeding programs.

2. MATERIALS AND METHODS

2.1. Experimental Site

The experiment was conducted in two experimental sites in South Bench and Tepi National Spices Research Center. South Bench (Appendix plate 2) is found in Bench Magi Zone of SNNPRS and located at latitude from 5.33° to 7.21°N and longitudes from 34.88° to 36.14°E with an elevation ranging from 1200 to 1959 meters above sea level. The area receives mean annual rainfall ranging from 1500 to 1800mm (an average 1692mm) per year and has 15°C to 27°C range of temperature annually and the soil is loam or silty-loam soil type (SNNPR, 2009). The research site is located at 1280 meter altitude above sea level and 580 km away from Addis Ababa.

The second site is Tepe National Spices Research Center (Appendix plate 1) (TNSRC) is located in the South Western part of the country 611 km away from the capital city Addis Ababa. Tepe situated in Yeki woreda, Sheka zone of SNNPRS and located at approximate geographic coordinates of latitude 7°3' N and longitude of 35°E. It is is located an altitude of 1200 m.a.s.l. and it receives annual average rainfall of 1688 mm (ranging from 1560 to 1790 mm) and has mean maximum and minimum temperatures of 29.5 and 15.4°C, respectively. The soil type is Distric Nitosoil with a pH ranging from 4.5–6.5(TNSRC, 2011).

2.2. Experimental Materials

In this study thirty six accessions of amaranths were obtained from the Institute of Biodiversity Conservation of Ethiopia and these accessions were grown in the experimental sites during 2012 cropping season under rain fed condition. The details of the accessions used in the experiment are given in Table 1.

Table 1. List of Amaranths germplasm accessions that were used in the study

No	Accessions	Species	Region	Zone	Woreda	Locality	Latitude	Longitude	Altitude(m)	Source
1	Am.91001	*A.tricolor*	SNNPRS	Konso	Konso	Fesha	05-17-00-N	37-20-00-E	1890	IBCE
2	Am91002	*A.tricolor*	Oromiya	East Wellga	Gida kiramu	Atera, South Alibo	09-49-00N	37-00-00-E	2480	IBCE
3	Am 91003	*A.tricolor*	Oromiya	East Wellga	Diga leka	Tolle kebele	09-02-00-N	37-04-00-E	1200	IBCE
4	Am.91005	*A.tricolor*	Oromiya	Jimma	Seka Chekorsa	AlroTebara kebele	07-33-00-N	36-35-00-E	2040	IBCE
5	Am.202108	*A.tricolor*	Oromiya	Jimma	Sokoru	Keshe	-	-	-	IBCE
6	Am.204644	*A.tricolor*	SNNPRS	North Omo	Arbaminch	Siele kebele	-	-	1200	IBCE
7	Am204645	*A.tricolor*	SNNPRS	Konso	Konso	Konso town	--	--	1600	IBCE
8	Am.205139	*A.tricolor*	SNNPRS	North Omo	Sodo	Dalbow agna	-	-	2240	IBCE
9	Am208025	*A.tricolor*	Amhara	North Gonder	Dmbia	Gorgora town	12-15-00-N	37-10-00-E		IBCE
10	Am 208683	*A.tricolor*	Oromiya	East Harrga	Deder	Gende Osman	09-26-00-N	41-21-00-E	2270	IBCE
11	Am.208764	*A.tricolor*	Oromiya	West wellga	Sayo	Dembi Delo	---	--	1850	IBCE
12	Am209057	*A.tricolor*	SNNPRS	North Omo	Sodo	Wachi	----	--	1660	IBCE
13	Am209057	*A.tricolor*	SNNPRS	North Omo	Offa	Sere Esho	----	--	1580	IBCE
14	Am.211455	*A.tricolor*	SNNPRS	North Omo	Arba Minch	Sele	05-50-00-N	37-27-00-E	1150	IBCE
15	Am.211456	*A.tricolor*	SNNPRS	North Omo	Bonke	Arfiti	----	---	1570	IBCE
16	Am211457	*A.tricolor*	SNNPRS	Konso	Konso	Durayie	----	--	1560	IBCE
17	Am.212581	*A.tricolor*	Amhara	South Wolo	Werebabu	Hadeeno	11-16-00-N	39-45-00-E	2920	IBCE
18	Am.212582	*A.tricolor*	Amhara	South Wolo	Tehuledere	Wune	11-10-00-N	39-40-0–E	1840	IBCE
19	Am.212583	*A.tricolor*	Amhara	South Wolo	Tehuledere	Abasomile	----	---	1640	IBCE
20	Am212890	*A.tricolor*	SNNPRS	Kebatatembro	Kedid	Hambo	37-56-00-N	07-12-00-E	2180	IBCE
21	Am212892	*A.tricolor*	SNNPRS	Dierashe	Dierashe	Afya	37-20-00-N	05-38-00-E	2200	IBCE
22	Am.212893	*A.tricolor*	SNNPRS	Dierashe	Dierashe	Gato	37-25-00-N	05-41-00-E	1380	IBCE
23	Am. 202109	*A.tricolor*	SNNPRS	Kefiecho	Melgewa	-	07-08-00-N	36-11-00-E	1940	IBCE
24	Am.214617		SNNPRS	North Omo	Damote dale	-	-	-	-	IBCE
25	Am215560	*A.tricolor*	SNNPRS	Gedeo	Yirgacifa	Deboca	06-07-00-N	38-13-00-E	2080	IBCE
26	Am215567	*A.tricolor*	SNNPRS	North Omo	Damot	Gidiobodti	06-57-00-N	37-51-00-E	2100	IBCE
27	Am215567	*A.tricolor*	SNNPRS	North Omo	Blososori	Arka road	07-05-00-N	37-43-00-E	1750	IBCE
28	Am219284		SNNPRS	North Omo	Borda abaya	Sodo road	06-17-00-N	37-47-00-E	1300	IBCE
29	Am225712	*A.tricolor*	SNNPRS	North Omo	Arbaminch	Kemba	05-45-00-N	37-22-00-E	1100	IBCE
30	Am225713	*A.tricolor*	SNNPRS	North Omo	Zalau baamale	Kemba	06-18-00-N	37-00-00-E	1600	IBCE
31	Am225714	*A.tricolor*	SNNPRS	North Omo	Gofa zuria	Sawla road	06-17-00-N	36-53-00-E	1570	IBCE
32	Am225715	*A.tricolor*	SNNPRS	North Omo	Gofa zuria	Bulki road	06-18-00-N	36-49-00-E	1780	IBCE
33	Am225716	*A.tricolor*	SNNPRS	North Omo	Kucha	Selamber	06-28-00-N	37-30-00-E	-	IBCE
34	Am240812	*A.tricolor*	SNNPRS	North Omo	Damote dale	Koysha	-	-	1880	IBCE
35	Am240815	*A.tricolor*	SNNPRS	Gurage	Sodo	Shola	-	-	950	IBCE
36	Am242530	*A.tricolor*	Benishangule	Asosa	Kurmuk	Sheflyul	10-33-18-N	34-30-94-E	1250	IBCE

IBCE= Institute of Biodiversity Conservation of Ethiopia

2.3. Experimental Design and plant Management

The experiment was carried out during 2012 cropping season in two locations in 6x6, simple Lattices design with two replications. The experimental flied was well prepared by ploughing three times. Plot size of 3m length and 2.7m width and 0.5meter path between plot with one meter path between block and with a three meter distance between replication were prepared. Seeds of different accession were sown uniformly in rows at 40 cm and 30 cm distances between plants. The quantity of seed applied was calculated based on seed rate 2 kg/ hectare (Tindall, 1983). Normal cultural practices such as 15 days interval weeding after germination were followed during the experimental period (Palada and Chang, 2010).

2.4. Statistical Analysis

2.4. 1. Analysis of variance

To perform a combined statistical analysis across location, testing for homogeneity of error variance (Bartlett, 1937a) test was carried out.

The data collected for each quantitative character were subjected to analysis of variance (ANOVA) for simple lattices design. The relative efficiency of simple lattice design over RCBD (Randomized Complete Block Design) was estimated and found that the use of the 6x6 simple lattice design estimated had increased the experimental precision over that of RCB design. Analysis of variance was done by Statistical soft ware SAS Version 9.2(SAS Institute, 2008). LSD was used to separate means with the significance difference by using 5% probability levels of significance for the characters studied.

2.4.2. Principal component analysis

Principal component analysis was performed using correlation matrix by SAS 9.2 version software in order to evaluate the relation of characters between genotypes. Eigenvalues of one and above were considered as significant. The contribution of each character in PCA is determined by eigenvector that is greater than half divided by the square root of the standard deviation of the eigenvalue of the respective PCA as suggested by Johnson and Wikhern (1992).

According to Hollmen (1996), below is the general formula to compute scores on the first component extracted in a principal component analysis:

$$C1 = b\,11(X1) + b12(X\,2) + \ldots\, b1p\ (Xp)$$

Where: *C1* = The subject's score on principal component 1 (the first component extracted)

b1p=The regression coefficient (or weight) for observed variable *p*, as used increasing principal component 1 and *Xp* = the subject's score on observed variable *p*.

3. RESULTS AND DISCUSSION

The computed homogeneity error variance test and the combined analysis of variance for the two locations showed no significant differences between two locations. This indicated that genotype by environment interactions are not important sources of variation for the tested germplasm accession of amaranths. As the result the combined analysis of variance was computed for two location showed highly significant difference (P<0.01) among amaranths accessions for all the characters studied except thousand seed weight which was non-significant (Table 2).This indicated that the existence of genetic variability among the tested germplasm accession of amaranths.

Appendix plate 1. Partial view of Tapi site

Appendix plate 2. Partial view of Mizan Site

Appendix plate 3. Terminal inflorescence amaranths

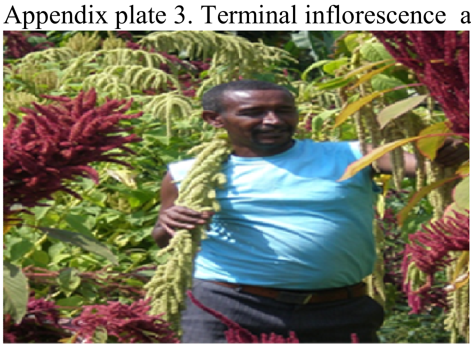

Table 2. Analysis of variance (Pooled) for 24 quantitative characters of in 36 Amaranths accessions tested at Mizan and Tapi (2010)

Source of Variation	Degree of freedom	Mean square: Dyes to emergence	Days to green harvest	Green leaf yield	Stem diameter	Biomass per plant	Internode length	Plant height	Length of basal branch
Replications	3	7.2477	37.21	2977.8	0.346	1409523	1.3437	5777.7	1523.6
Blocks within Replications (Adj.)	20	0.4125	1.336	63.879	0.122	17287.0	0.2541	86.939	30.689
Component A	10	0.4681	2.530	5.2757	0.212	16660.0	0.1427	103.86	26.928
Component B	10	0.3569	0.1375	122.48	0.033	17914.0	0.3656	70.02	34.450
Treatments (Unadj.)	35	7.9165	45.39	4220.5	1.45	462955	2.8578	1624.4	2579.6
Treatments(Adj.)	35	7.1214**	41.80**	3758.9**	1.36**	399327.4**	2.40**	1529.7**	2344.7**
Location x Treatment	35	1.2878 ^{ns}	2.340 ^{ns}	7.300^{ns}	0.185 ^{ns}	2.91^{ns}	0.2010^{ns}	97.53^{ns}	39.88^{ns}
Intra block Error	85	0.7030	0.781	59.25	0.103	12102.0	0.1499	96.720	21.630
Randomized Complete block error	105	0.6477	0.886	60.130	0.106	13089	0.1698	97.860	23.35
Efficiency Relative to RCBD		105.12	106.9	104.30	105.6	109.70	105.85	105.07	106.6
Replications	3	608.09	200.69	575.70	32.300	210.73	35.365	11.517	2301.8
Blocks within Replications (Adj.)	20	28.050	26.70	21.890	1.6246	25.810	4.2874	0.6633	103.50
Component A	10	20.967	10.62	10.020	0.6894	6.8179	1.9457	0.3304	85.620
Component B	10	35.138	42.78	33.750	2.5590	44.813	6.6291	0.9962	121.30
Treatments (Unadj.)	35	2568.8	859.22	1213.8	63.058	126.76	15.155	7.5706	988.89
Treatments(Adj.)	35	162.46**	38.04**	1114.7**	55.230**	116.70**	14.35**	6.950**	949.08**
Location x Treatment	35	27.93^{ns}	14.38 ^{ns}	34.96^{ns}	0.763 ^{ns}	3.128^{ns}	0.840 ^{ns}	0.437^{ns}	52.07^{ns}
Intra Block Error	85	16.827	18.865	24.050	0.8025	13.220	2.0732	0.5915	62.496
Randomized complete block error	105	18.965	20.357	23.630	0.9588	15.620	2.4949	0.6052	70.306
Efficiency relative to RCBD		108.60	106.62	105.29	107.1	106.34	107.56	100.17	103.50
Replications	3	4908.8	21.71	5.109	1.270	0.127	6.50	0.0018	14.10
Blocks within replications (Adj.)	20	390.05	1.720	2.040	1.170	0.223	1.14	0.0012	2.410
Component A	10	292.78	3.067	0.612	0.534	0.018	2.273	0.0012	1.770
Component B	10	487.31	0.379	3.470	1.800	0.428	0.007	0.0012	3.060
Treatments(Unadj.)	35	14879	444.7	215.9	169.9	13.33	499.7	0.008	66.00
Treatments(Adj.)	35	13210**	413.4**	205.1**	159.2 **	11.77**	458.5**	0.008^{ns}	64.5**
Location x Treatment	35	406.95^{ns}	4.31^{ns}	0.64 ^{ns}	0.494 ^{ns}	0.024 ^{ns}	470.9*	0.003 ^{ns}	2.62 ^{ns}
Intra block error	85	269.62	1.990	1.643	0.883	0.110	1.060	0.008	1.720
Randomized complete block error	105	292.56	1.930	1.710	0.930	0.130	1.078	0.009	1.860
Efficiency Relative to RCBD		108.83	107.4	110.6	111.1	107.3	111.1	106.30	101.6

** = Highly significant at 1% , *= significant at 5% probability level and ns= Non significant at 5% probability level

3.1. Range and Mean of the Different Characters

The range and mean for the 23 quantitative characters of the accession showed the presence of wide variability among the amaranths accessions. The results of range revealed a wide range of variation in characters like biomass per plant (548.68-1820.5 gm/plant), number of leaf per plant(191.7-408.8), green leaf yield per plant (83.2-216.6 gm / plant), length of top branch (12.54-75.4cm), length of middle branch (35.38-136.8cm), axillary inflorescences length (0-8.6cm), length of top branch (12.54-75.4cm) and seed yield (9.7-28.28 gm/plant) (Table 4). Moreover, the differences between the minimum and maximum mean values for other characters were also high, indicating the availability of variation for improvement through selection. In addition the average mean value was almost three times more than from the minimum mean value for characters like, axillary inflorescences length, terminal inflorescences length, lateral inflorescences length, seed yield per plant, green leaf yield per plant and also almost twice for characters like biomass per plant and length of basal branch. This indicating that these characters play a great role to the total variability observed among the amaranths accessions (Table 3). Similarly Priya *e al*. (1999) reported high range and means difference in yield, plant height, stem girth and leaf size in amaranths accession.

Table 3. Mean performance of 36 amaranths accession for 24 quantitative characters

No	Accession	Days to 50% emergence	Days to green harvest	Green leaf yield	Stem diameter	Biomass per plant	Inter node Length	Plant height
1	Am212582	9.20	27.5	114.3	2.79	826.20	5.60	180.9
2	Am91002	11.7	37.0	161.9	2.90	1333.3	5.00	188.1
3	Am91001	13.0	37.0	177.1	3.19	881.40	5.70	197.5
4	Am202108	10.3	27.5	92.30	2.70	751.70	4.80	176.9
5	Am91005	12.2	28.5	83.20	2.20	548.60	3.20	137.7
6	Am240815	13.0	36.0	201.2	3.30	1262.5	4.40	163.2
7	Am211455	13.5	30.5	158.0	2.40	806.00	3.60	152.4
8	Am214617	13.7	35.5	199.0	3.23	1454.8	4.40	167.0
9	Am212893	10.5	28.5	137.7	3 .50	846.70	4.10	164.1
10	Am219284	13.7	35.5	188.7	3.30	1527.0	2.79	135.4
11	Am215567	11.7	37.5	165.6	2.60	1549.0	4.30	174.9
12	Am215560	13.2	36.5	179.6	2.60	1505.0	3.60	177.3
13	Am225713	14.5	38.5	216.6	5.30	1820.5	6.66	208.7
14	Am225712	12.5	37.0	171.8	3.60	1659.0	5.20	206.8
15	Am240812	13.2	35.5	203.5	3.30	1787.5	4.70	177.4
16	Am212892	14.0	35.0	152.3	5.10	1182.3	4.40	170.5
17	Am212890	10.7	30.3	160.6	2.80	590.30	4.80	176.9
18	Am212583	12.50	30.75	127.2	3.10	1133.7	4.47	171.6
19	Am211456	11.00	37.00	182.7	3.50	1104.0	5.56	208.6
20	Am242530	12.75	30.75	110.6	3.10	1184.5	5.30	207.2
21	Am225716	13.25	36.50	173.8	2.80	1604.5	4.90	184.9
22	Am225715	11.25	29.00	123.7	2.60	608.80	5.60	189.3
23	Am225711	11.25	30.50	141.1	2.40	1115.4	4.30	162.2
24	Am225714	10.50	28.50	143.0	2.70	773.00	3.40	136.1
25	Am205139	9.750	31.25	127.5	2.60	860.40	5.40	202.6
26	Am208025	13.75	31.25	135.0	3.45	1182.0	5.50	201.7
27	Am204645	9.750	31.25	119.8	2.40	1012.5	5.60	200.1
28	Am204644	11.25	31.25	125.4	2.80	1038.7	5.80	201.8
29	Am202109	10.50	30.50	140.5	3.40	881.80	4.70	179.0
30	Am91003	12.70	37.50	182.0	2.70	925.60	4.40	176.4
31	Am209057	13.00	35.50	184.7	2.50	832.9 0	4.80	180.4
32	Am211457	11.00	30.50	109.5	2.80	919.40	4.90	181.9
33	Am212581	10.20	31.25	118.3	2.70	927.30	4.40	172.5
34	Am209056	13.50	30.75	123.4	2.60	1076.6	5.50	201.2
35	Am208764	12 .00	30.50	115.0	3.00	870.70	3.90	169.5
36	Am208683	12.25	29.00	129.2	3.20	819.20	4.60	175.2
	Mean	12.04	32.80	145.9	3.06	1089.0	4.65	181.7
	CV (%)	4.930	1.860	6.451	8.5	8.0700	8.29	5.344
	LSD (5%)	1.170	1.230	10.79	4.44	154.20	0.54	13.78

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Table 3. (Continued)

No	Accession	Length of basal branch	Length of middle branch	Length of top branch	Average branch length	Leaf length	Leaf width	Leaf area	Number of leaf per per plant
1	Am212582	53.4	85.90	41.09	60.13	19.20	10.8	74.3	305.8
2	Am91002	43.5	36.20	19.48	33.00	20.70	10.4	96.3	343.0
3	Am91001	53.1	72.20	60.60	58.00	21.80	12.0	98.5	380.0
4	Am202108	56.5	67.50	54.74	48.60	16.20	11.5	56.2	253.2
5	Am91005	58.0	54.03	36.71	49.60	18.00	7.80	54.7	235.2
6	Am240815	67.9	41.80	30.20	41.60	22.00	13.0	95.8	324.7
7	Am211455	49.9	70.60	50.74	51.10	20.10	10.3	87.5	229.4
8	Am214617	67.3	52.10	18.81	46.10	19.70	12.7	94.7	373.9
9	Am212893	47.6	67.59	32.96	49.40	21.65	9.70	80.2	191.8
10	Am219284	42.8	44.00	27.30	38.05	19.75	10.5	90.9	365.9
11	Am215567	76.1	106.5	36.60	73.00	20.70	11.6	79.6	361.0
12	Am215560	57.1	72.10	39.89	56.30	17.80	10.3	70.0	339.4
13	Am225713	98.0	58.70	27.94	68.50	22.40	13.3	115	408.8
14	Am225712	96.9	136.8	50.90	94.90	22.80	10.7	88.2	328.8
15	Am240812	29.9	39.70	25.30	31.60	21.10	12.0	114	386.6
16	Am212892	57.7	69.90	44.79	54.50	24.50	12.2	111.1	327.1
17	Am212890	59.7	57.20	44.43	59.70	22.50	12.5	107.1	323.3
18	Am212583	36.4	39.50	32.40	36.10	15.90	10.2	66.9	326.1
19	Am211456	84.1	67.00	53.40	65.20	20.30	11.5	88.8	333.5
20	Am242530	95.6	123.4	37.30	75.40	20.50	10.6	83.4	191.7
21	Am225716	41.3	48.16	28.10	39.20	19.80	12.2	92.0	350.0
22	Am225715	101.6	101.6	75.40	92.90	22.50	11.6	98.5	258. 0
23	Am225711	113.75	81.05	58.7	84.50	22.6	8.30	70.9	258.2
24	Am225714	71.80	78.40	55.2	67.50	20.7	11.1	87.3	270.4
25	Am205139	72.40	34.40	31.4	27.60	21.0	9.30	74.5	246.7
26	Am 208025	85.40	79.15	35.5	66.60	23.5	10.8	96.3	249.8
27	Am 204645	30.04	43.80	24.5	32.80	21.4	9.40	81.1	288.5
28	Am 204644	72.38	43.01	21.6	45.60	20.8	9.00	71.5	214.4
29	Am 202109	67.02	42.60	12.5	40.70	20.8	10.2	81.5	266.8
30	Am 91003	32.00	53.70	37.7	41.10	22.4	11.0	94.0	214.0
31	Am 209057	73.30	80.30	27.3	60.31	19.9	11.3	109.3	210.6
32	Am211457	76.90	84.60	29.8	70.40	21.4	9.60	79.0	287.0
33	Am212581	72.03	102.2	49.9	74.70	21.2	8.50	68.7	302.8
34	Am 209056	99.60	62.00	33.9	61.00	24.5	10.5	89.6	234.0
35	Am208764	36.90	43.10	19.0	29.00	22.4	9.00	57.0	199.0
36	Am 208683	80.40	35.35	27.2	29.00	20.7	9.00	80.4	306.3
	Mean	62.85	66.03	40.3	53.83	20.7	10.7	85.78	289.1
	CV (%)	5.884	5.760	12.1	8.016	8.93	7.56	10.21	5.355
0	LSD (5%)	6.520	5.750	6.08	6.870	2.14	1.07	141.1	23.02

Table 3. (Continued)

No	Accession	Primary branch per plant	Secondary branch per plant	Terminal inflorescences length	Lateral inflorescences length	Axillary inflorescences length	Days to flowering	Days to seed harvest	Seed yield	Thousand seed weight
1	Am212582	14.40	51.70	24.7	16.4	2.00	44.0	77.50	9.90	0.9464
2	Am 91002	19.40	56.12	24.5	8.5	2.70	71.5	100.0	10.5	0.9567
3	Am91001	25.20	63.42	32.6	18.2	4.07	79.5	109.2	9.90	0.9815
4	Am202108	16.50	55.60	34.8	20.1	2.37	40.5	73.50	9.70	0.9584
5	Am 91005	15.50	54.40	24.1	25.1	3.00	40.5	74.00	11.5	0.9810
6	Am240815	25.40	56.75	21.3	7.00	2..01	72.0	105.0	10.2	0.9585
7	Am 211455	15.00	53.90	31.3	25.2	5.10	59.2	90.00	10.7	0.9770
8	Am214617	24.60	51.10	13.1	5.12	0.00	70.5	100.0	28.2	0.9640
9	Am 212893	20.30	54.10	28.9	18.7	0.00	40.0	74.50	25.6	1.0100
10	Am219284	22.30	60.90	8.02	3.92	0.00	73.0	100.0	15.6	1.0017
11	Am 215567	20.27	63.80	33.0	14.2	4.10	70.5	100.0	13.3	0.9715
12	Am 215560	18.40	64.30	17.1	8.87	3.00	71.5	109.5	12.0	0.9859
13	Am 225713	25.12	68.00	21.2	21.2	4.10	81.2	124.0	10.2	1.0210
14	Am225712	22.25	64.67	21.02	9.40	2.55	70.5	100.0	12.2	0.9845
15	Am240812	28.90	61.80	11.8	4.10	2.07	73.5	105.0	10.7	0.9302
16	Am212892	15.20	51.90	12.9	3.60	1.90	69.7	100.0	12.5	0.9655
17	Am212890	15.30	56.80	34.0	10.8	5.60	58.0	90.00	14.6	0.9578
18	Am212583	21.05	62.80	20.4	9.60	4.70	60.0	90.00	18.0	1.0000
19	Am 211456	27.05	56.50	21.5	7.20	3.90	73.3	105.0	11.4	0.9446
20	Am 242530	17.27	45.60	16.0	17.3	4.70	58.0	80.00	17.0	0.9800
21	Am225716	28.9	58.0	7.9 0	9.70	2.20	74.2	105	10.60	0.932
22	Am225715	19.2	45.6	31.8	18.4	6.80	43.5	74.0	11.00	0.971
23	Am 225711	16.4	64.37	22.5	23.2	8.60	58.5	90.0	11.27	0.964
24	Am225714	18.5	49.5	24.0	20.25	5.10	49.5	85.0	15.77	0.967
25	Am 205139	19.3	55.8	12.0	7.30	5.10	57.7	90.0	15.10	0.976
26	Am 208025	19.0	50.97	18.1	18.3	3.03	62.0	90.0	15.80	0.969
27	Am204645	19.5	58.6	18.3	15.8	3.22	61.2	90.0	14.90	1.009
28	Am 204644	18.1	57.1	16.8	13.0	2.30	60.5	90.0	16.25	0.971
29	Am202109	17.7	55.5	13.8	7.35	2.80	60.5	90.0	14.75	1.016
30	Am 91003	17.3	49.0	15.5	15.1	2.70	61.0	90.0	13.20	0.965
31	Am 209057	19.0	58.0	14.7	7.70	1.90	64.0	100	11.30	1.003
32	Am 211457	21.6	56.5	16.3	7.70	1.9 0	60.5	90.0	10.60	0.993
33	Am212581	17.5	53.6	16.7	13.75	3.75	60.0	90.0	14.70	0.968
34	Am 209056	19.3	43.9	24.5	22.40	2.70	60.2	90.0	15.60	1.010
35	Am208764	16.4	61.4	14.9	5.30	5.70	60.5	90.0	17.00	0.965
36	Am 208683	14.6	55.5	18.9	7.42	2.55	59.0	90.0	13.90	0.934
	Mean	19.8	56.7	20.5	13.0	3.30	62.0	93.2	13.7	0.97
	CV (%)	4.85	7.87	7.42	7.76	12.3	1.43	1.88	9.60	5.29
	LSD (5%)	0.45	5.33	1.79	1.31	0.49	1.98	1.44	1.84	0.80

3.2. Principal Component Analysis (PCA)

Principal component analysis based on 36 genotypes of amaranths in 23 quantitative characters is presented in Table 4. The result indicated that the first seven principal components accounted for about 80.75 % of the total variation. The first principal components (PC1), which accounts for 31.75 % of total variability among accessions, were attributed to dissimilarity traits such as, days to flowering, days to maturity of seed harvest, days to green harvest and biomass per plant and green leaf yield. The second principal component (PC2) accounted for 15.77 % of the variability among accessions originated from variation for internode length, length of middle branch, length of top branch and average branch length. Likewise, 9.0 % of the total variability among the tested accessions accounted for the third PCA (PC3), originated from leaf width, days to emergence and length of basal branch. Similarly, PC4, which explained 7.71% of the total variation, was obtained from variation of days to emergence, length of middle branch and seed yield. PC5 also accounts 6.94%, originated from number of leaf per plant and length of basal branch. The sixth principal component (PC6), was expressed 4.64% of the variability; length of average branch, stem diameter and days to emergence made the variability. Seed yield per plant and primary branch per plant contributed chiefly to the variation of the seventh principal component which explained 4.62 % of the variation. The findings in agreement with this observation were reported by Vena (2005), Shukla *et al*.(2010) and Rubaihayo (1995) on selection criteria of amaranths. The present study confirmed that amaranths genotypes showed wider amount of variation for the character studied.

Table 4. Eigen values, total variance, cumulative variance and eigenvectors for 24 characters of amaranths genotypes

Characters	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Days to emergence	-0.0889	-0.1029*	0.3750*	0.3967*	0.0229	0.3001*	0.2183*
Days to green harvest	0.2268*	0.0617	0.0386	0.0976	-0.1623	0.0691	-0.1449
Green leaf yield per plant	0.3199*	0.0180	-0.0086	0.1184	0.1530	0.1393	0.1373
Biomass per plant	0.2969*	0.0515	-0.1932	-0.0375	-0.1013	0.1366	0.1209
Internode length	-0.0542	0.4632*	-0.0243	0.2146	-0.0340	-0.0505	-0.0525
Plant height	0.3200	0.0334	-0.0343	0.0504	0.1656	0.1814	0.0930
Length of basal branch	0.0126	0.1187	0.3997*	-0.0309	0.4681*	-0.2237	-0.0261
Length of middle branch	-0.0028	0.4065*	0.0971	0.2478*	0.0292	-0.0845	-0.1145
Length of top branch	-0.0715	0.3688*	-0.0560	0.2842	-0.0726	-0.2066	-0.0937
Average branch Length	-0.1282	0.3562*	-0.2055	-0.1098	-0.0542	0.2657*	0.1408
Primary branch per plant	0.1974	0.1846	0.2792	-0.2597	-0.2199	0.0204	0.2761*
Secondary branch per plant	0.2636	0.0295	-0.0298	-0.0123	0.0575	-0.1015	0.1339
Stem diameter	-0.1407	0.1905	-0.0938	0.1238	0.2652	0.5186*	0.1531
Leaf length	0.0256	0.0214	0.2837	-0.3452	0.5155*	-0.0695	-0.1013
Leaf width	0.0659	0.2620*	0.3900*	-0.0760	-0.1192	0.1139	0.1974
Leaf area	0.2044	0.1707	0.0401	-0.3139	-0.2128	-0.1383	0.1611
Number of leaf per plant	0.1835	-0.0577	-0.3070	0.0918	0.3235*	0.0677	0.0152
Days to flowering	0.3130*	0.0574	-0.0032	0.0165	0.0948	0.0499	0.1179
Terminal inflorescences length	0.2167	0.0941	-0.2309	-0.1870	0.0504	-0.0608	0.0460
Lateral inflorescences length	-0.1514	0.2567	-0.2647	-0.2918	0.1234	-0.1198	0.1013
Axillary inflorescences length	-0.1876	0.2536	-0.0719	-0.0685	0.1222	-0.0853	-0.1824
Days to seed harvest	0.3021*	0.0387	-0.0475	0.1975	0.0732	-0.1298	-0.2362
Seed yield per plant	-0.0218	-0.0691	-0.0222	0.2985*	-0.0236	-0.5203	0.5424*
Thousand seed weight	0.1656	0.0423	0.2334	-0.0791	-0.2826	0.1081	-0.4228
Eigenvalue	7.9800	3.9400	2.2700	1.9200	1.7300	1.1600	1.1500
%Cumulative variance	31.950	47.720	56.900	64.520	71.450	76.090	80.750
Total variance explained	31.950	15.770	9.0000	7.7100	6.9400	4.6400	4.6200

*=Significant contributors to the total variation

4. SUMMARY AND CONCLUSION

The present study comprises 36 Amaranths germplasm accessions that were evaluated at Tapi and Mizan locations in 6x6 simple lattices design with the objective of assessing the genetic variability and characters association for 24 characters.

The ANOVA showed highly significant difference ($p<0.01$) among amaranths germplasm accessions for all the characters studied except thousand seed weight which was none significant ($P>0.05$). The range of mean values for most of the characters showed the existence of variation among the tested germplasm accessions. This explains the variation existing among the accessions studied.

The principal components (PC) indicated that there were a greatest variability among the accessions and then the relative contribution of each individual variable to variability was more explained by seven principle components (PC1, PC2, PC3, PC4, P5, PC6 and PC7) which account 80.75 % from the total variation. Among the others PC_1 and PC2 take the great shier 47.72 %(31.95% and 15.77% respectively).Characters which had a highest positive coefficient were attributed to the variability of PC1 were, days to flowering, days to seed harvest, days to maturity of green harvest, biomass per plant and green leaf yield per plant, while in PC2 length of basal branch, length of top branch and average branch length had strong impact on the variation. Characters with high variability are expected to provide high level of gene transfer during breeding programs (Gana, 2006; Aliyu et al., 2000). Therefore high level of variability existing within the accessions and the characters will make for further improvement of the cultivars in breeding programs

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