P. ISSN: 0971-8184 II E. ISSN: 0976-1926
DOI: 10.61949/0976-1926.2024.v37i01.10

Indian Journal of
Plant Genetic Resources

RESEARCH ARTICLE

Variability, Heritability, and Correlation Studies for Economic Traits in Grain Amaranth (*Amaranthus* spp.)

Ved Prakash, Gajala Ameen, Vivek K. Sandilya and Jitendra K. Tiwari*

Abstract

Grain amaranth is a potential nutri-cereal and has high demand in the market due to its nutritional status. An experiment was conducted to evaluate different agro-morphological characteristics of grain amaranth. For this purpose, 102 grain amaranth (*Amaranthus* spp.) genotypes were taken to estimate different genetic components. The characters like leaf length (cm), stem thickness (cm), petiole length (cm), seed yield (q/ha) and seed test weight (g/10 mL) showed high genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) values. The highest GCV and PCV were recorded with seed test weight (g/10 mL) (40.57 and 45.40%). The estimated high heritability in different characters studied ranged from 77 to 99%. Heritability was observed to be high in consequence for days to 50% flowering, petiole length (cm), stem thickness (mm), seed test weight (g/10 mL), leaf width (cm), seed yield (q/ha), leaf length (cm), plant height (cm), and inflorescence length (cm). Days to 50% flowering showed a highly significant positive correlation with days to 80% maturity (rg = 0.8897, rp = 0.7931) and plant height (cm) highly significant positive correlation with petiole length (cm) (rg = 0.3202, rp = 0.2821). Petiole length significantly correlated with leaf width (rg = 0.1909, rp = 0.1918). Seed yield (q/ha) had a positive but not significant correlation with inflorescence length, leaf width, and petiole length. The Euclidean distance range 0 to 8. In pair-wise comparison, the maximum distance was obtained between IC444100 and IC444105 with the Euclidean distance of 8, whereas IC340823 and IC356023 (1.7%) showed least Euclidean distance with other genotypes. This study will help the utilization of diverse amaranth germplasm in future grain amaranth breeding programs to develop desired variety.

Keywords: Cluster analysis, Correlation coefficient, Genetic variability, Genetic advance, Grain amaranth, Heritability.

Department of Genetics and Plant Breeding, RMD, College of Agriculture and Research Station, IGKV, Ambikapur, Chhattisgarh, India.

***Author for correspondence:**

tiwarijk5@gmail.com

Received: 08/04/2020 **Revised:** 28/12/2020

Accepted: 29/09/2021

How to cite this article: Prakash V, G Ameen, VK Sandilya and JK Tiwari. (2024) Variability, Heritability, and Correlation Studies for Economic Traits in Grain Amaranth (*Amaranthus* spp.). *Indian J. Plant Genetic Resources*. 37(1): 80-89. **DOI:** 10.61949/0976-1926.2024.v37i01.10

Introduction

Grain amaranth is a fast-growing, dicotyledonous plant belonging to the genus *Amaranthus* and the family Amaranthaceae. The word "Amaranth" is mostly derived from the Greek word "Anthos" which means "everlasting," according to Sankaran (1943). The group amaranth is dibasic with x = 16 and x = 17 chromosomes. At the present time it is also called a 3rd millennium crop plant. The group amaranth is chiefly composed of about to 70 species (Sauer, 1967). The distribution of *Amaranthus* species is based on their usage as grain, vegetable, ornamental, and weedy amaranth (Sauer, 1967). Grain amaranths are widely scattered in Asia (Pagi *et al.* 2017) and it contribute greatly to the nutritional well-being of rural and economically weak people by providing the essential nutrients required for body growth and for the prevention of diseases associated with nutritional deficiencies such as iron and vitamin A (Dua *et al.*, 2009). *Amaranthus* are adapted to different environments, as it can be cultivated in poor soils and highly elevated regions. The grain amaranth species are considered by many as the crop of the future because of the diversification purposes and superior nutritional quality of grain with high protein content in the range 13 to 18% and relatively high lysine content is comparison with common cereals (Pandey *et al.*, 2015). Amaranth has the potential for a useful and bioactive additive in food products.

The knowledge about the nature and consequence of association of yield with various component characters is a prerequisite to bring improvement in the desired direction. Genetic variability in grain amaranth will provide the foundation for designing the breeding program. However, reports on genetic diversity and morphological variation in grain amaranth are scanty. There will be greater chances of producing a desired type with more variability. Selection based on the phenotype would be ambitious for polygenetic character. Observation of the correlation between yield and its given traits is a basic need to find plant selection guidelines. The present study was, therefore, undertaken for variability, heritability, and correlation studies for economic traits of grain amaranth's germplasm.

Materials and Methods

Plant Material

The materials for present investigation comprise of 102 germplasm lines and 5 check varieties (GA-2, BGA-2, RMA-7, SUVARNA and CG Rajgira-1) of grain amaranth from the National Bureau of Plant Genetics Resources, New Delhi for this study (Table 1).

Experimental Method

About 102 germplasm lines and 5 check varieties were grown in an augmented randomized complete block design during two rabi seasons of the year 2018 and 2019. The study was taken with four blocks, each block consisting of 25 genotypes and five check varieties. All the checks are randomly replicated in all the blocks, while the germplasm lines were unreplicated. Each genotype was sown in two rows, each with a spacing of 45 cm between the rows. Recommended agronomic practices were followed throughout the crop season during both years.

Data Recording

Observations were reported on five plants in each genotype for the 11 quantitative characters *viz*., leaf length (cm), leaf width (cm), days to 50% flowering, stem thickness (mm), number of branches per plant, plant height (cm), Inflorescence length (cm), days to 80% maturity, petiole length(cm), seed yield (q/ha) and seed test weight (g/10 mL) and 11 qualitative characters viz., early plant vigor, plant growth habit, leaf color, inflorescence color, inflorescence compactness, stem color, stem surface, inflorescence shape, inflorescence spininess, popping ability of seed and seed color. The data was analyzed for genotypic and phenotypic coefficients of variation and heritability (in a broad sense), and cluster analysis was done with PBT 1.4 and STAR software version 2.0.1 for Windows.

Table 1: List of grain amaranth genotypes used in this study

Germplasm lines from NBPGR, New Delhi	
S. No.	*Accession name*
1	IC 444156
2	IC 444159
3	IC 444167
4	IC 444193
5	IC 356085
6	IC 436948
7	IC 436953
8	IC 436957
9	IC 383647
10	IC 383578
11	IC 436974
12	IC 340823
13	IC 340825
14	IC 340861
15	IC 340803
16	IC 340971
17	IC 317517
18	IC 317549
19	IC 317631
20	IC 391433
21	IC 391468
22	IC 391517
23	IC 391561
24	IC 392498
25	IC 392525
26	IC 429977
27	IC 469777
28	IC 469803
29	IC 469805
30	IC 469820
31	IC 469837
32	IC 469858
33	IC 355992
34	IC 356012
35	IC 356023
36	IC 356027
37	IC 356041
38	IC 356046
39	IC 360827
40	IC 360834
41	IC 356070
42	IC 337341
43	IC 360858

44	IC 265008
45	IC 264805
46	IC 265980
47	IC 266778
48	IC 266812
49	IC 524215
50	IC 279807
51	IC 279363
52	IC 279413
53	IC 279462
54	IC 279511
55	IC 279512
56	IC 279567
57	IC 279612
58	IC 279631
59	IC 279652
60	IC 279670
61	IC 279760
62	IC 279832
63	IC 444099
64	IC 444100
65	IC 444105
66	IC 317427
67	IC 506604
68	IC 506605
69	IC 506611
70	IC 506612
71	NC 59949
72	IC 506514
73	IC 506519
74	IC 506520
75	IC 506521
76	IC 506524
77	IC 506528
78	IC 506529
79	IC 506531
80	IC 506534
81	IC 506535
82	IC 506575
83	IC 361327
84	IC 382640
85	IC 362257
86	IC 341452
87	IC 255428
88	IC 255555
89	IC 255419
90	IC 255481
91	IC 264854
92	IC 266835
93	IC 268885
94	IC 266937
95	IC 255482
96	IC 338640
97	IC 393022
98	IC 266754
99	IC 282786
100	IC 281749
101	IC 506555
102	IC 506573
CH-1	GA-2
CH-2	BGA-2
CH-3	RMA-7
CH-4	SUVARNA
CH-5	CG Rajgira-1

Results and Discussion

Genetic improvement in grain amaranth crop depends on the extent of genetic variability for yield and its components. The present investigation aims to determine the magnitude and extent of variability among genotypes for 11 different quantitative traits. The analysis of variance for grain yield and its attributing characters among blocks, treatments, checks and checks *vs* varieties revealed presence of significant variation in the genotypes studied. However, with respect to checks and checks vs varieties, non-significant differences were recorded for plant height and inflorescence length (Table 2).

Variability and Genetic Parameters

The nature and magnitude of variation for individual traits was assessed by range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance as a percentage of the mean (Table 3).

A high magnitude of GCV was recorded for trait, seed test weight (40.57), and seed yield (34.66), while high magnitude PCV was recorded for characters such as, seed test weight (45.40), seed yield (35.50) and leaf length (29.02). Moderate GCV was recorded for traits such as, petiole length (15.09), stem thickness (13.45) and leaf width (10.20), moderate PCV was recorded for traits such as, petiole length (15.14), stem thickness (13.58) and Leaf width (10.33). GCV and PCV are estimates as low (0–10%), moderate (10–20%) and high (>20%) categorized by Johnson *et al.* (1955). A high estimate of GCV and PCV indicates the high variability of characters in the germplasm. A similar result was reported for moderate GCV and PCV in petiole length and leaf blade width by

Table 2: Augmented design analysis of variance for yield and its attributing characters in grain amaranth

	DF	*Leaf length (cm)*	*Leaf width (cm)*	*Petiole length (cm)*	*Days to 50 %flowering*	*Stem thickness (mm)*	*No. of branches per plant*	*Plant height (cm)*	*Inflorescence length (cm)*	*Days 80% maturity*	*Seed yield (q/ha.)*	*Seed test weight (g/10 mL)*
Block (ignoring treatments)	3	1.42***	0.34***	0.18***	39.43***	0.16***	2.20***	12.48**	1.51**	2.17	15.05***	0.58***
Treatment (eliminating blocks)	106	0.44***	0.21***	0.19***	23.14***	0.08***	0.99***	14.98***	1.42***	7.63**	9.57***	0.76***
Checks	4	0.33***	0.76***	0.11***	7.37***	0.15***	0.42**	7.56*	0.33	8.25*	3.10***	0.25***
Checks+Var *vs*. Var.	102	0.44***	0.19***	0.20***	23.76***	0.08***	1.02***	15.27***	1.46***	7.60**	9.82***	0.78***
ERROR	12	0.02	0.01	0.01	0.57	0.01	0.07	1.52	0.24	1.55	0.26	0.011
Block (eliminating Check+Var.)	3	0.13*	0.01	0.01	0.45	0.01	0.85***	4.26	0.19	2.47	0.43	0.02
Entries (ignoring Blocks)	106	0.48***	0.22***	0.20***	24.24***	0.09***	1.03***	15.21***	1.46***	7.62**	9.98***	0.78***
Checks	4	0.33***	0.76***	0.11***	7.37***	0.17***	0.42**	7.56	0.33	8.25*	3.10***	0.25***
Varieties	101	0.47***	0.15***	0.19***	23.09***	0.08***	0.59***	15.59***	1.51***	7.48**	8.57***	0.68***
Checks *vs*. Varieties	1	1.33***	5.06***	1.38***	207.71***	0.20***	48.25***	7.18	0.37	19.81**	180.64***	12.39***
ERROR	12	0.03	0.01	0.01	0.57	0.01	0.07	1.52	0.24	1.55	0.26	0.01
Ci - Cj	1	0.25	0.12	0.07	1.17	0.05	0.42	1.90	0.75	1.92	0.79	0.16
BiVi - BiVj	1	0.49	0.24	0.14	2.34	0.11	0.84	3.80	1.50	3.84	1.57	0.32
BiVi - BjVj	1	0.54	0.26	0.15	2.56	0.12	0.92	4.17	1.64	4.20	1.72	0.35
Ci - VI	1	0.43	0.21	0.12	2.02	0.09	0.73	3.29	1.30	3.32	1.36	0.27

*Significant at 5% level, ** Significant at 1% level, , *** Significant at 0.1% level DF- degrees of freedom.

Table 3: Genetic parameters for yield and its attributing characters in grain amaranth

Characters	*General mean*	*Range*		*PCV (%)*	*GCV (%)*	*h^2 (%)*	*Genetic advance*	*GA as % of mean*
		Min	Max					
Leaf length (cm)	7.05	5.60	8.54	29.02	7.48	91	3.87	54.89
Leaf width (cm)	3.67	2.92	4.88	10.33	10.20	97	0.75	20.43
Days to 50% flowering	54.27	42.00	61.00	8.47	8.41	99	9.65	17.78
Stem thickness (mm)	4.39	3.64	5.16	13.58	13.45	98	0.57	12.98
Number of branches per plant	5.73	4.00	8.60	10.44	6.26	62	0.76	13.26
Plant height (cm)	89.07	76.40	101.50	7.32	6.87	90	8.50	16.87
Inflorescence length (cm)	38.46	28.20	51.60	5.73	5.21	85	1.98	10.02
Petiole length (cm)	2.84	1.94	4.08	15.14	15.09	99	0.87	30.63
Days to 80% maturity	128.41	122.00	132.00	1.86	1.56	77	3.79	2.95
Seed yield (q/ha)	20.62	14.50	26.60	35.50	34.66	96	5.58	27.06
Seed test weight (g/10 mL)	5.70	4.10	7.58	45.40	40.57	98	5.22	91.57

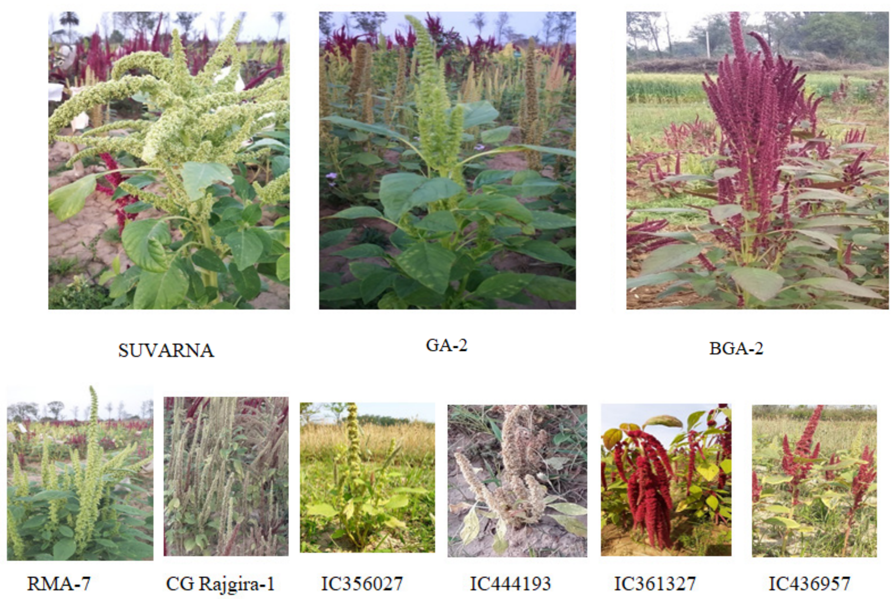


Figure 1: Morphological variation in different genotypes in grain amaranth sequence of picture Suvarna, GA-2, BGA-2, RMA-7, IC356027, IC 444193, IC 361327, IC 436957, CG Rajgira-1

Rashmi Yadav *et al.* (2014). The characteristics that showed high GCV and PCV are of economic importance, and there is scope for improvement of these characteristics through selection.

The high heritability was reported for the character's petiole length (99%), days to 50% flowering (99%), stem thickness (98%), seed test weight (98%), leaf width (97%), seed yield (96%), leaf length (91%), plant height (90%), Inflorescence length (85%), and days to 80% maturity (77%). Moderate heritability was observed for a number of branches per plant (62%). Rabinson *et al.* (1949) categorized the heritability measure as low (0– 30%), moderate (30–60%) and high (>60%). However, the heritability value provides no indication of the amount of genetic improvement that would result from the selection of superior genotypes. Pictures of check varieties and some potential lines dipicted through Figure 1.

Genetic advance as a percentage of mean was observed high seed test weight (91.57%), leaf length (54.89%), petiole length (30.63%), seed yield (27.06%) and leaf width (20.43%). The moderate GA as a percentage of mean was observed for days to 50% flowering (17.78%), plant height (16.87%), number of branches per plant (13.26%), stem thickness (12.98%), and Inflorescence length (10.02%) and low GA as a percentage of mean was observed for days to 80% maturity (2.95%).The genetic advance as % of mean was classified as below, medium or high following Johnson *et al.*, (1955) 0–10%: low, 10–20%: medium, >20% or above: high. Additive

Table 4: Estimation of genotypic (G) and phenotypic (P) correlation coefficient among various characters in grain amaranth

Character		*Leaf length (cm)*	*Leaf width (cm)*	*Petiole length (cm)*	*Days to 50% flowering*	*Stem thickness (mm)*	*Number of branches per plant*	*Plant height (cm)*	*Inflorescence length (cm)*	*Days to 80% maturity*	*Seed yield (q/ha)*	*Seed test weight (g/10 mL)*
Leaf length (cm)	(G)	1.00	0.29**	0.06	-0.04	0.16	-0.08	-0.03	0.03	-0.07	-0.09	0.07
	(P)	1.00	0.30**	0.07	-0.05	0.16	0.01	0.01	0.07	-0.12	-0.09	0.05
Leaf width (cm)	(G)		1.00	0.19*	0.15	0.12	-0.23*	-0.06	0.10	0.18	0.09	-0.06
	(P)		1.00	0.19*	0.14	0.15	-0.10	-0.04	0.08	0.15	0.09	-0.06
Petiole length (cm)	(G)			1.00	-0.12	-0.09	-0.22*	0.32**	-0.01	-0.02	0.05	-0.01
	(P)			1.00	-0.05	-0.09	-0.16	0.28**	0.01	-0.01	0.051	-0.01
Days to 50% flowering	(G)				1.00	0.15	0.11	0.13	0.03	0.89**	-0.07	-0.01
	(P)				1.00	0.14	0.05	0.11	0.01	0.79**	-0.06	-0.02
Stem thickness (mm)	(G)					1.00	-0.01	0.02	0.06	0.04	-0.02	0.03
	(P)					1.00	-0.01	0.04	0.05	0.06	-0.02	0.02
Number of branches per plant	(G)						1.00	-0.06	-0.09	-0.11	-0.04	-0.04
	(P)						1.00	0.06	-0.08	-0.12	-0.01	-0.03
Plant height (cm)	(G)							1.00	-0.01	0.06	-0.09	0.10
	(P)							1.00	-0.02	0.06	-0.08	0.10
Inflorescence length (cm)	(G)								1.00	0.13	0.11	0.10
	(P)								1.00	0.02	0.11	0.11
Days to 80% maturity	(G)									1.00	-0.04	-0.03
	(P)									1.00	-0.05	-0.02
Seed yield (q/ha)	(P)										1.00	0.10
	(G										1.00	0.09
Seed test weight (g/10 mL)	(P)											1.00
	(G											1.00

*5% level of significance, ** 1% level of significance

Table 5: Sources and clustering of 102 genotypes of grain amaranth in four clusters

Clusters	*Number of accessions*	*Name of the genotypes*
I	44	IC 444156, IC 444167,IC 444193, IC 356085, IC 436948, IC 436953, IC 436974, IC 340825, IC 34086, IC 34080, IC 391517, IC 391561, IC 392498, IC 392525, IC 429977, IC 469777, IC 469803, IC 469837, IC 469858, IC 355992, IC 356046, IC 360827, IC 356070, IC 265008, IC 266778, IC 279807, IC 279413, IC 279631, IC 279670, IC 279760, IC 444100, IC 317427, IC 506611, IC 506521, IC 255481, IC 266835, IC 268885, IC 266937, IC 255482, IC 338640, IC 393022, IC 266754, IC 506555, IC 281749
II	39	IC 444159, IC 383578, IC 340823, IC 317517, IC 317549, IC 317631, IC 391468, IC 469805, IC 469820, IC 356023, IC 356041, IC 360834, IC 337341, IC 264805, IC 265980, IC 524215, IC 279462, IC 279567, IC 279612, IC 444099, IC 506605, IC 506612, NC 59949, IC 506514, IC 506520, IC 506528, IC 506529, IC 506531, IC 506534, IC 506535, IC 506575, IC 361327, IC 382640, IC 362257, IC 341452, IC 255555, IC 255419, IC 264854, IC 506573
III	7	IC 436957, IC 340971, IC 391433, IC 360858, IC 279652, IC 279832, IC 506604
IV	12	IC 383647, IC 356012, IC 356027, IC 266812, IC 279363, IC 279511, IC 279512, IC 444105, IC 506519, IC 506524, IC 255428, IC 282786

Table 6: Cluster means of different quantitative traits of grain amaranth using Gower's coefficient

Characters	*Cluster 1*	*Cluster 2*	*Cluster 3*	*Cluster 4*
Leaf length (cm)	7.06	6.98	6.20	7.78
Leaf width (cm)	3.58	3.60	3.74	4.21
Petiole length (cm)	2.90	2.67	2.80	3.17
Days to 50% flowering	52.11	54.92	58.43	57.67
Stem thickness (mm)	4.34	4.40	4.55	4.43
Number of branches per plant	6.00	5.60	5.29	5.43
Plant height (cm)	91.84	84.77	93.99	90.34
Inflorescence length (cm)	38.97	38.93	40.03	34.14
Days to 80% maturity	127.23	128.64	131.00	130.50
Seed yield (q/ha)	20.43	18.77	24.83	21.56
Seed test weight (g/10 mL)	5.83	5.42	6.35	5.72

genes govern the high-value GA for these characters, and selection will be rewarding for the further improvement of such characters. Moderate genetic advance for the traits suggests that both the additive and nonadditive variance are operating in these traits.

Correlation Coefficient Analysis

Genotypic and phenotypic coefficients among 11 quantitative characters are presented in Table 4. A positive significance correlation of leaf length was noticed with leaf width. Days to 80% maturity showed a positive and significant correlation with days to 50% flowering. Petiole length showed a positive and significant correlation with leaf width. Leaf width showed a positive and significant correlation with leaf length. Plant height showed a positive and significant correlation with petiole length at the genotypic level only. Diwan *et al.* (2017) also reported a similar association, who considered leaf length showed a positive correlation with leaf width. Although phenotypic variation was considered, it is likely that this variation is largely genetic and, therefore, directly usable in breeding programs.

Cluster Analysis

Agglomerative cluster analysis was performed using the STAR software version 2.0.1 to calculate from quantitative data to generate a dendrogram for 102 genotypes (Figure 2). The Euclidean distance ranges from 0 to 8. The genotypes group four major clusters (Table 5). In pair-wise comparison, the maximum distance was obtained between IC444100 and IC444105 with the Euclidean distance of 8, whereas IC340823 and IC356023 (1.7%) showed least Euclidean distance with other genotypes. The cluster means of different quantitative traits of grain amaranth are given in Table 6. Cluster I included 44 genotypes with the highest mean value for the number of branches per plant (6.00). In this group, mean values for leaf width, days to 50% flowering, stem thickness and days to 80% maturity were minimum. Cluster II included 39 genotypes with the lowest mean values for petiole length, plant height, seed yield, and seed test weight. The mean value days to 50% flowering was minimal, showing early maturity. Cluster III, comprising of 7 genotypes having the highest mean values for days to 50% flowering (58.43), stem thickness (4.55), plant height (93.99), inflorescence length (40.03), days to 80% maturity (131.00), seed yield (24.83) and seed test weigh (6.35). This group has the lowest mean values for leaf length and number of branches per plant. Cluster IV comprises of 12 genotypes having the highest mean values for leaf length (7.78), leaf width (4.21) and petiole length (3.17). In this group, mean values for Inflorescence length (cm) was lowest. Cluster analysis helps in grouping accessions sharing similar characters in different clusters and identifying genetically diverse and desirable genotypes.

However, the dendrogram generated from similarity or genetic distance matrix based on morphological traits has provided an overall pattern of variation as well as

Table 7: Number of genotypes in different categories for different traits

S.N.	*Traits*	*Category*	*No. of genotype*
1	Early plant vigour	1 Poor 2 Good 3 Very good	17 45 40
2	Plant growth habit	1 Erect 2 Spreading 3 Drooping	59 39 4
3	Leaf color	2 Yellowish orange 3 Yellowish green 5 Green 8 Pinkish green 10 Redish green 11 Red	1 2 53 20 22 4
4	Inflorescence color	4 Yellowish green 6 Pink 7 Pinkish green 8 Purple 9 Red 10 Reddish green 11 Green 99 Dark red	16 20 10 9 15 2 28 2
5	Inflorescence compactness	3 Lax 5 Intermediated 7 Dense	47 46 9
6	Stem color	1 Yellow 2 Yellowish green 4 Pink 6 Reddish green 7 Reddish orange	19 34 22 15 12
7	Stem surface	1 Smooth 2 Ridged	35 67
8	Inflorescence shape	1 Globose 2 Semi drooping 3 Completely drooping 4 Straight 99 Others	7 68 13 14
9	Inflorescence spininess	1 Smooth 2 Glabrous 3 Prickly 4 Spiny	44 10 28 20
10	Popping ability of seed	3 Poor 5 Medium 7 Good	36 54 12
11	Seed color	2 Creamish 3 Pale yellow 7 Black 8 Golden	76 8 8 10

the degree of relatedness among genotypes. Genotypes showing maximum dissimilarity could be used in a hybrid breeding program.

Qualitative Character

The frequency of eleven qualitative characters in one 100 two grain amaranth accessions has been shown in Table 7, which shows a variable range of characters. Early plant vigor genotypes IC436953, IC340803, IC469803, IC469805, IC469820 and IC265980 were very good. The majority of the entries were erect type with spreading type and drooping type plant habit. The inflorescence color varied from yellowish green, pink, pinkish green, purple, red, reddish green and green. Genotypes IC355992, IC356046, IC360827 were yellowish green, IC436948, IC383647, IC469858 were pink, IC356085, IC383578, IC356023 were pinkish green, IC436957, IC392525, IC360858 were purple, IC444167, IC469805, IC279760 were red, IC444156, IC444159, IC340803 were reddish green. The inflorescence shape from globose, semi-drooping, completely drooping and straight genotypes IC444159, IC436953, IC337341 were globose, IC444156, IC444193, IC356085 were semi-drooping, IC436948, IC383647, IC340803 were completely drooping, IC356023, IC356027, IC356041, IC279511 were straight. The popping ability of seed genotypes IC436957, IC317549,

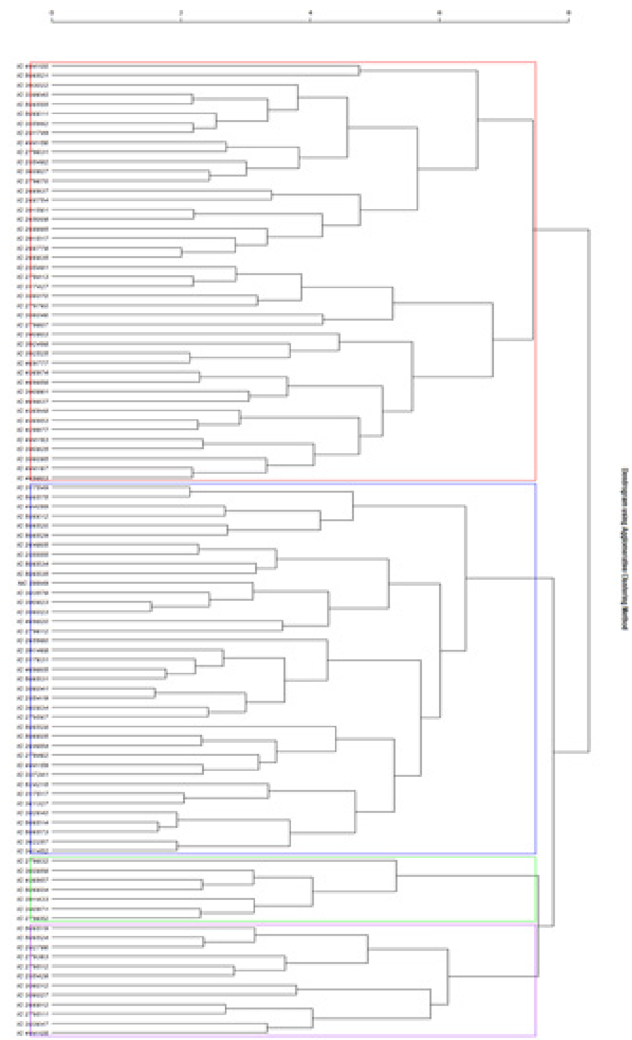
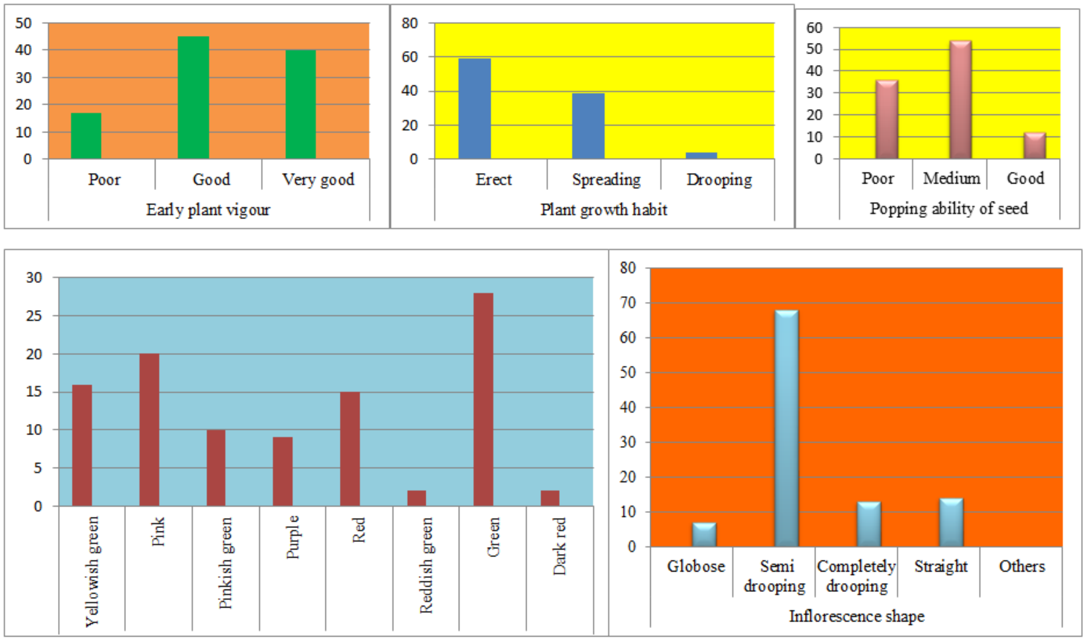


Figure 2: Dendrogram for morphological characters using Gower's Coefficient



Graph 1: Bar chart of different qualitative traits of grain amaranth

IC429977, IC360834, IC524215 were good. The distribution of the accessions for levels of qualitative characters showed that the growth habit of most of the genotypes was predominantly erect type (59%). Inflorescence color showed a marked variability in colors and about 28% of accessions were green, 20% pink 16% yellowish green and 15% had red color. Leaves color were of green, 53% of the accessions, redish green, 22% of the accessions and 20% had pinkish green color, inflorescence while 47% have lax type inflorescence compactness, 46% intermediate and about 9% have dense type of inflorescence. The inflorescence spininess presented a marked variability. The seed's color presented a marked variation, although 76% were creamish with different intensities. Similar results were reported by Rashmi Yadav *et al.* (2014) for qualitative characters in grain amaranth (Graph 1).

Conclusion

Grain amaranth has extensive variation for selected traits, and high heritability and genetic advances existed among the traits of further genetic improvement in this crop. The mean performance for yield (q/ha) of IC392525, IC279832, IC340825, IC279652 and IC360858 was superior among all the genotypes. Genotypes IC469803, IC392525, IC279807, IC279760 and IC506575 were early maturity. Therefore, the enormous variation in the grain amaranth germplasm would continue to provide breeders with good opportunities for breeding and selection. Exploitation of the genetic variability available in grain amaranth germplasm for yield components will continue to be emphasized in cultivar development. These characters are effectively used in a breeding program and these important characters will decide the future of amaranth. It may be concluded that the morphological descriptor can effectively be used for identifying and grouping of germplasm. However, morphological description also may not be sufficient for characterization criteria. Hence, some other markers/ descriptors must be considered to complement the morphological descriptor.

Acknowledgment

The authors thank the IGKV, Raipur and AICRN authorities on potential crops for providing necessary facilities and support for conducting research.

References

Ahammed AU, MM Rahman and MAK Mian (2012) Genetic Variability, Heritability and Correlation in Stem Amaranth (*Amaranthus tricolor*). *Bangladesh J. Pl. Breed. Genet.* 25(2): 25-32.

Barrio DA and MC Anon (2010) Potential antitumor properties of a protein isolate obtained from the seeds of *Amaranthus mantegazzianus*. *Eur. J. Nutr.* 49: 73- 82.

Chandravanshi D, PK Sharma, C Banjare and D Chandravanshi(2018) Genetic Diversity of *Amaranthus dubius* Mart. (Khedha) Used Tribal Place in Chhattisgarh, India. *Int. J. Bioresour. Stress Manag.* 9(5): 634-640.

Diwan IS, N Shukla and V Kurrey (2017) Genetic Studies in Amaranthus Germplasm. *Int. J. Curr. Microbiol. Appl. Sci.* 6(8): 2459-2470.

Dua RP, HL Raiger, BS Phogat and SK Sharma (2009) Underutilized Crops: Improved Varieties and Cultivation Practices. National Bureau of Plant Genetics Resources, New Delhi, India, p 66.

Gelotar MJ, DT Dharajiya, SD Solanki, NN Prajapati and KK Tiwari (2019) Genetic diversity analysis and molecular characterization of grain amaranth genotypes using inter simple sequence repeat (ISSR) markers. *Bull. Natl. Res. Cent.* 43: 103.

Johnson HW, HP Robinson and RE Comstock (1955) Estimate of genotypic and environmental variability in soybean. *Agron J.* 47: 314-318.

Joshi DC, S Sood, R Hosahatti, L Kant, A Pattanayak, A Kumar, D Yadav, MG Stetter (2018) From zero to hero: the past, present and future of grain amaranth breeding. *Theor. Appl. Genet.* 131(9): 1807-1823.

Kumar Y, R Prasad and PR Singh (2018) Studies on collection and evaluation of genetic variability available in Amaranthus (*Amaranthus* spp.) under Chhattisgarh plain condition. *Int. J. Curr. Microbiol. Appl. Sci.* 7(11): 3540-3547.

Lokesh kumar BM and N Murthy (2017) Genetic Variability and Divergence Studies for Yield Component Traits in Grain Amaranth (*Amaranthus* spp.). *Int. J. Curr. Microbiol. Appl. Sci.* 6(12): 1276-1285.

Pagi N, N Prajapati, K Pachchigar, D Dharajiya, SD Solanki, N Soni and P Patel (2017) GGE biplot analysis for yield performance of grain amaranth genotypes across different environments in western India. *J. Exp. Biol. Agric. Sci.* 5(3): 368–376.

Pandey CD, A Kak, S Pandey and V Gupta (2015) Trait-specific Amaranth Gemplasm- Potentialities to Combat Climate Change. *Indian J. Plant Genetics Resour*ces 28(3): 321-328.

Rai N and DS Yadav (2005) Advances in vegetable production. Research Co Book Centre, New Delhi, pp 530-531.

Rastogi A and S Shukla (2013) Amaranth: A New Millennium Crop of Nutraceutical Values. *Crit. Rev. Food Sci. Nutr.* 53: 109-125.

Robert YN, K Hiroe and K Yotaro (2008) Antioxidant activity of various extracts and fraction of Chenopodium quinoa and *Amaranthus* Spp. Seed, Analytical, nutritional and clinical methods. *Food Chem.* 106: 760-766.

Robinson HF, RE Comstock and PH Harvey (1949). Estimates of heritability and degree of dominance in Corn. *Agron. J.* 41: 353-359.

Sagar KP (2018) Genotypic Correlation Coefficients among Growth, Yield and Quality Parameters in Amaranthus Genotypes (*Amaranthus tricolor* L.). *Int. J. Curr. Microbiol. Appl. Sci.* 7(8): 2319-7706.

Sankaran A (1943) Cultivation of leafy vegetables in the northern circars. *Madras Agri. J.* 31: 285-286.

Sauer JD (1967) The grain Amaranthus and their relative: A revised taxonomic and geographic survey. *Ann. Mo. Bot. Gard.* 54: 103-137.

Sood Salej, RS Pal, A Sharma, L Kant and A Pattanayak (2018) Characterization of amaranth genetic resources for agro morphological and nutritional traits in submontane Himalayan region of India. *Electron. J. Plant Breed.* 9(4): 1484-1496.

Tiwari JK (2018) Variability and genetic parameter for different yield contributing traits in grain amaranths. *J. Res. ANGRAU.* 46(4): 11-16.

Yada Rashmi, JC Rana and JK Ranjan (2014) Analysis of variability parameters for morphological and agronomic traits in grain amaranth (*Amaranthus* sp.) genotypes. *Bio Scan.* 9(4): 1661-1665.