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Genetic variability and varietal performance in vegetable amaranthus (*Amaranthus* sp.)

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Abstract
Twelve genotypes of amaranthus collected from various sources and maintained at All India Co-ordinated Research Project (AICRP) on Vegetable Crops, Bhubaneswar were subjected to evaluation for 13 quantitative traits namely as plant height, number of nodes per plant, number of leaves per plant, number of inflorescence per plant, stem girth, leaf length, leaf breadth, petiole length, leaf area, stem weight, leaf weight, leaf: stem ratio and yield per plant. The results of the investigation revealed a wide range of variation for all the characters. Among the genotypes 2012/AMVAR-4 (V4), Bhigarpur Local (V11) and 2012/AMVAR-2 (V2) are the ideal genotypes for cultivation at Bhubaneswar (Odisha).Presence of minimum difference between phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for all the characters indicated that the phenotypes were true to the genotypes. Expression of high to moderate PCV and GCV for characters like number of inflorescence per plant, leaf: stem ratio, stem weight, yield per plant, leaf weight and plant height indicated the presence of good amount of variability among the materials evaluated. So selection for such characters would be effective in Amaranthus. High heritabilities (>80%) were observed for eight characters such as leaf: stem ratio, stem weight, number of inflorescence per plant, number of leaves per plant, yield per plant, petiole length, plant height and leaf weight. Moderate to high heritabilities (60-80%) were observed for rest of the five characters. Highest genetic advance as percentage of mean was observed in number of inflorescence per plant followed by leaf: stem ratio, stem weight, yield per plant and leaf weight. Rest of the characters showed low to moderate values for this genetic parameter. Considering the three genetic parameters together such as genotypic coefficient of variation (GCV), heritability estimates and genetic advance as percentage of mean altogether,it may be inferred that phenotypic selection for number of inflorescence per plant, leaf: stem ratio, stem weight, yield per plant, leaf weight and plant height may prove to be effective criteria for selection in Amaranthus since, these characters are due to additive gene effects and are less influenced by the environment.

Keywords: amaranthus, heritability, genetic advance, genetic variability

Introduction
Amaranth (*Amaranthus* sp.) is a widespread traditional vegetable throughout the tropics and the temperate zone of the world including India. It is one of the main leafy vegetables in this country and consumed as a pot herb. Amaranthus is recognized as an easy-to-grow and extremely productive and nutritious vegetable. The nutritional endowments of amaranths provide evidence that the plants deserve more scientific attention. Lysine and sulphur containing amino acids have been found in their leaves. Many vegetables and cereal grains lack these amino acids. Additionally, the leaves are high in carbohydrates, several vitamins including beta-carotene, vitamin C and minerals such as iron, calcium, manganese and zinc. It fits well in multiple and mixed cropping system because of its short duration with high yield potential of edible matter per unit area. It exhibits C4 type photosynthesis with more efficient photosynthetic ability and has a remarkable capacity of rejuvenation after each cut. Through collection and selection programmes a number of strains have been introduced and acclimatized in various parts of the world, but evaluation studies for yield and its contributing quantitative and qualitative traits are scarce in our country in Amaranthus. Considering the potentiality of this crop, there is a need to develop varieties suitable for cultivation under specific agro-ecological conditions. A thorough knowledge regarding the amount of genetic variability existing for various characters is essential for initiating the crop improvement programme. With limited variability, much improvement cannot be achieved, hence, the breeders will have to enrich the germplasm or he can restore to create greater variability through hybridization, mutation and polyploidy breeding. Development of productive and potentially ideal type is the main aim of any crop improvement programme. It is also necessary to become familiar with the detailed genetic structure of germplasm material to be

used in hybrid breeding. Such studies are also useful in selection of parents for hybridization to recover superior transgressive segregants. Since such studies are meagre particularly under Odisha conditions, the present investigation was carried out with a set of varieties and advanced lines of amaranthus.

Materials and Methods

The present investigation was carried out during rainy season of 2014-15 at All India Coordinated Research Project on Vegetable Crops, HRS, Orissa University of Agriculture and Technology, Bhubaneswar. The experiment was conducted in the randomized block design with 12 genotypes replicated thrice. Seeds were sown on 2nd August 2014. Spacing of 30 cm x 20 cm was uniformly adopted. A fertilizer dose of 50 kg N, 25kg P2O5 and 25 kg K2O per ha was applied. The total amount of phosphorus with 25 kg of nitrogen and 12.5 kg of K2O was applied to the soil before sowing. Remaining 25 kg of nitrogen and 12.5 kg of potash was applied in two-splits. All other cultural practices were uniformly adopted according to recommended packages. The data recorded for various characters were subjected to statistical analysis. The analysis was carried out separately for each trait following the procedure of randomized block design analysis (Panse and Sukhatme, 1954) [15]. The genotypic co-efficient of variation (GCV) and the phenotypic co-efficient of variation (PCV) were calculated by the formula given by Burton (1952). Heritability was worked out by using the formula suggested by Lush (1949) [13] and Burton and Devance (1953) [5] and expressed in percentage according to Weber and Moorthy (1952) [25]. Genetic advance was estimated as per the formula suggested by Johnson *et al* (1995).

Results and Discussion

A reference to Table 1 showed that the treatments significantly differed for all the characters showing that the material under study has sufficient genetic variability.

Table 1: Mean of performance of 12 amaranthus genotypes for 13 characters

Notation	Genotypes	Plant height (cm)	No. of nodes per plant	No. of leaves per plant	No. of inflorescence per plant	Stem girth (cm)	Leaf length (cm)	Leaf breadth (cm)	Petiole length (cm)	Leaf area (cm^2)	Stem weight (g)	Leaf weight (g)	Leaf : stem ratio	Yield per plant(g)
V1	2012/AMVAR-1	54.957	14.067	69.067	10.200	3.527	8.147	5.310	3.997	34.277	607.967	341.733	0.559	949.700
V2	2012/AMVAR-2	61.730	14.433	70.433	9.667	4.017	8.023	5.587	2.747	33.143	731.933	415.867	0.567	1147.800
V3	2012/AMVAR-3	70.183	14.033	69.600	12.267	3.370	8.240	4.433	4.313	27.360	791.233	147.200	0.184	938.433
V4	2012/AMVAR-4	67.827	18.700	93.100	5.300	4.867	9.510	5.607	4.667	44.317	1268.133	534.700	0.421	1802.833
V5	2012/AMVAR-5	58.147	14.567	62.933	8.433	3.540	7.887	5.417	4.557	35.600	648.467	398.467	0.616	1046.933
V6	2012/AMVAR-6	48.990	14.733	67.033	2.033	3.297	8.980	4.993	3.497	35.417	609.833	239.167	0.390	849.000
V7	2012/AMVAR-7	65.177	14.933	43.667	4.567	4.663	8.307	5.637	3.277	37.077	548.467	341.433	0.620	889.900
V8	Arka Suguna	51.763	14.933	76.400	1.467	3.647	7.503	5.457	3.487	33.553	391.567	506.500	1.302	898.067
V9	Arun	44.387	15.033	72.000	1.233	3.620	8.240	4.747	4.770	30.630	296.867	377.200	1.287	674.067
V10	Utkal Mayuri	34.523	11.967	72.433	1.367	2.567	6.573	5.690	3.297	29.993	102.733	142.967	1.399	245.700
V11	Bhingarpur (Local)	49.160	15.900	94.233	6.167	4.870	7.537	5.407	3.273	32.997	760.933	414.200	0.545	1175.133
V12	Salepur (Local)	39.840	12.700	72.067	2.367	4.177	7.733	5.057	2.840	31.113	340.467	255.133	0.749	595.600
SE m(±)	3.394	0.936	3.058	0.707	0.324	0.392	0.202	0.211	2.051	49.909	39.811	0.042	89.221	
C.D.(0.05)	7.039	1.941	6.342	1.465	0.672	0.812	0.419	0.438	4.253	103.505	82.564	0.086	185.035	

Plant height
A wide range of variability ranging from 34.523cm to 70.183cm was noticed with respect to plant height. Highest plant height was recorded in the genotype V3 (70.183cm) which was closely followed by V4 (67.827cm), V7 (65.177cm) and V2 (61.730cm). Lowest height was observed in V10 (34.523cm) followed by V12 (39.840cm) in ascending order.

Number of nodes per plant
A low range of variation from 11.967 to 18.700 was observed among the genotypes for this trait. The genotype V4 produced maximum number of nodes per plant (18.700) followed by the genotypes V11 (15.900) and V9 (15.033). Minimum numbers of nodes were observed in V10 (11.967).

Number of leaves per plant
A significant variation was visualized in number of leaves per plant among the genotypes ranging from 43.667 to 94.233. The genotype V11 recorded the highest number of leaves per plant (94.233) closely followed by V4 (93.100). The lowest number of leaves per plant (43.667) was observed in V7.

Number of inflorescences per plant
Among the genotypes evaluated, a wide range of variation was observed for number of inflorescences per plant ranging from 1.233 to 12.267. The highest number of inflorescences per plant (12.267) was recorded in V3 followed by V1 (10.200) whereas the lowest number of inflorescences per plant (1.233) was recorded in V9 followed by V10 (1.367).

Stem girth
A narrow range of variation was observed among the twelve genotypes with respect to stem girth. Maximum stem girth (4.870cm) was recorded in V11 followed closely by V4 (4.867cm). However the lowest stem girth (2.567cm) was recorded in V10 followed by V6 (3.297cm).

Leaf length
Leaf length recorded a moderate variation ranging from 9.510cm to 6.573cm. V4 (9.510cm) produced the maximum leaf length which was followed by V6 (8.980cm). The lowest value (6.573cm) was recorded in V10.

Leaf breadth
A narrow range of variation was observed among the twelve germplasm with respect to leaf breadth. Highest leaf breadth was observed in V10 (5.690cm) closely followed by V7 (5.637cm). However, the lowest leaf breadth (4.433cm) was recorded in V3 followed by V9 (4.747cm).

Petiole length
A moderate range of variation was recorded ranging from 4.770cm to 2.747cm among the twelve genotypes for this trait. The maximum value of petiole length was observed in V9 (4.770cm) closely followed by V4 (4.667cm). The minimum value of (2.747cm) was recorded in V2 closely followed by V12 (2.840cm) in higher magnitude.

Leaf area
The genotype V4 recorded the highest leaf area (44.317cm^2) followed by 37.077 (cm^2) in V7. The lowest leaf area (27.360cm^2) was recorded in V3 followed by (29.993 cm^2) in V10. The germplasm like V1 (34.277 cm^2), V6 (35.417 cm^2) and V5 (35.600 cm^2) have shown medium values for the character.

Stem weight
A significantly wide range of variation from 102.733g to 1268.133g was noticed with respect to stem weight. Stem weight was maximum for V4 (1268.133g). Minimum stem weight was observed in V10 (102.733g) followed by V9 (296.867g). However, V3 (791.233g), V11 (760.733g) and V2 (731.933g) were of medium type.

Leaf weight
The maximum leaf weight was observed in V4 (534.700g) followed by V8 (506.500g). However, the minimum value (142.967g) was recorded in case of V10 closely followed by V3 (147.200g).

Leaf: stem ratio
A significantly wide range of variation was observed among the twelve germplasm with respect to leaf: stem ratio. The highest value (1.399) was recorded in case of V10 which was closely followed by V8 (1.302). The lowest value (0.184) was observed in V3. The germplasm like V5 (0.616), V7 (0.620) and V12 (0.749) have shown medium value for the character.

Yield per plant
The data presented in the Table clearly showed distinct variation for yield per plant among the genotypes ranging from 1802.833g to 245.700g. Maximum yield per plant was observed in V4 (1802.833g) followed by V11 (1175.133g) and minimum yield per plant was recorded in V10 (245.700g) followed by V12 (595.600g).
The nature and magnitude of variability for 13 different quantitative characters indicate highly significant differences for all the characters under study, thereby suggesting existence of large amount of variations among the genotypes. So, there is a scope for considerable improvement in this crop through characters studied such as plant height, number of nodes per plant, number of leaves per plant, number of inflorescence per plant, stem girth, leaf length, leaf breadth, petiole length, leaf area, stem weight, leaf weight, leaf: stem ratio and yield per plant. Similar to the present findings investigation carried out earlier reported wide variation for various characters by Varalakshmi and Reddy (1994) [24], Revanappa and Madalgeri (1998) [20], Anuja and Mohideen (2007) [2], Pan *et al.* (2008) [14], Ahammed *et al.* (2012) [1], Khurana *et al.* (2013) [11], Parveen *et al.* (2014) [16] and Hailu *et al.* (2015) [8] in Amaranthus and Chander Parkash (2012) [6] in Chenopodium.

Co-efficient of variation (C.V)
The Co-efficient of variance with respect to different characters is presented in Table 2, which ranged from 4.69% to 15.96%. The highest variation (15.96%) was noticed in number of inflorescence per plant followed by leaf weight (14.22%) and yield per plant (11.69%). However, the lowest variation (4.69%) was recorded in leaf breadth followed by number of leaves per plant (5.21%) and leaf length (5.95%) in ascending order. Therefore, basing on the C.V value, the characters can be grouped into three classes such as:
Low variability (C.V. = 5% or less)
Moderate variability (C.V. = 5-10%)
High variability (C.V. = >10%)
Thus the only trait leaf breadth exhibited low variability. On the contrary, the traits like plant height, number of nodes per plant, number of leaves per plant, leaf length, petiole length,

leaf area and leaf: stem ratio recorded moderate variability. Number of inflorescences per plant, stem girth, stem weight, leaf weight and yield per plant exhibited high variability.

Estimation of genetic parameters

The estimates of genetic parameters *viz.*, phenotypic variance and genotypic variance are presented in Table 2. Further, their respective coefficient of variation i.e. PCV and GCV, heritability in broad sense, genetic advance and genetic advance as percentage of mean are presented in Table 3. On examining the data in Table 2, it was clearly observed that phenotypic variance was higher as compare to the genotypic variance for all the characters under study. The genotypic variance ranged from 0.134 for leaf breadth to 135841.906 for yield per plant. The phenotypic variance ranged from 0.157 for leaf: stem ratio to 147782.578 for yield per plant. In general, all the traits exhibited parallel values between those two variances showing lower value in the former than the latter.

The perusal of data in Table 3 revealed that the magnitude of phenotypic coefficient of variation (PCV) was greater than the corresponding genotypic coefficient of variation (GCV) for all characters. The PCV was highest (73.352) for number of inflorescence per plant followed by leaf: stem ratio (55.045). Traits like stem weight (51.172), yield per plant (41.140) and leaf weight (38.571) exhibited moderate value. While, other traits like plant height (21.728), stem girth (19.989), petiole length (19.849), number of leaves per plant (18.695), leaf area (14.053), number of nodes per plant (12.950) and leaf length (10.385) showed lower values having lowest value (8.365) for leaf breadth. More or less similar trend was observed in the estimate of GCV for all the traits with number of inflorescence per plant having the highest value (71.595) followed by leaf: stem ratio (54.587). The values were moderate in traits like stem weight (50.117), yield per plant (39.443) and leaf weight (35.853). Lower values were observed for traits like plant height (20.313), stem girth (17.120), petiole length (18.595), number of leaves per plant (17.955), leaf area (11.926), number of nodes per plant (10.327) and leaf length (8.509), recording the lowest value (6.930) by leaf breadth.

Table 2: General mean, range, co-efficient of variation, genotypic variance and phenotypic variance for 13 quantitative characters in Amaranthus germplasm

Sl. No.	Characters	General Mean	Range	Co-efficient of variation (%)	Genotypic Variance	Phenotypic Variance
1.	Plant height(cm)	53.890	34.523 - 70.183	7.71	119.831	137.113
2.	Number of nodes per plant	14.667	11.967 - 18.700	7.81	2.294	3.608
3.	Number of leaves per plant	71.914	43.667 - 94.233	5.21	166.730	180.756
4.	Number of inflorescence per plant	5.422	1.233 - 12.267	15.96	15.070	15.819
5.	Stem girth(cm)	3.847	2.567 - 4.870	10.32	0.434	0.591
6.	Leaf length(cm)	8.057	6.573 - 9.510	5.95	0.470	0.700
7.	Leaf breadth(cm)	5.278	4.433 - 5.690	4.69	0.134	0.195
8.	Petiole length(cm)	3.727	2.747 - 4.770	6.94	0.480	0.547
9.	Leaf area(cm2)	33.790	27.360 - 44.317	7.43	16.241	22.551
10.	Stem weight(g)	591.550	102.733 - 1268.133	10.33	87895.719	91632.023
11.	Leaf weight(g)	342.881	142.967 - 534.700	14.22	15113.305	17490.691
12.	Leaf : stem ratio	0.720	0.184 - 1.399	7.08	0.154	0.157
13.	Yield per plant(g)	934.431	245.700 - 1802.833	11.69	135841.906	147782.578

Table 3: Genotypic co-efficient of variation (GCV), Phenotypic co-efficient of variation (PCV), Heritability (in broad sense), Genetic advance and GA expressed in % of Mean for 13 quantitative characters studied in Amaranthus

Sl. No.	Characters	Phenotypic co efficient of variation (PCV)	Genotypic co efficient of variation (GCV)	Heritability (in broad sense) (%)	Genetic advance	GA Expressed in % of mean
1.	Plant height(cm)	21.728	20.313	87.40	21.08	39.118
2.	Number of nodes per plant	12.950	10.327	63.59	2.48	16.965
3.	Number of leaves per plant	18.695	17.955	92.24	25.54	35.524
4.	Number of inflorescence per plant	73.352	71.595	95.27	7.80	143.953
5.	Stem girth(cm)	19.989	17.120	73.35	1.16	30.204
6.	Leaf length(cm)	10.385	8.509	67.13	1.15	14.362
7.	Leaf breadth(cm)	8.365	6.930	68.63	0.62	11.826
8.	Petiole length (cm)	19.849	18.595	87.76	1.33	35.886
9.	Leaf area(cm^2)	14.053	11.926	72.02	7.04	20.850
10.	Stem weight(g)	51.172	50.117	95.92	598.15	101.116
11.	Leaf weight(g)	38.571	35.853	86.41	253.4	68.656
12.	Leaf : stem ratio	55.045	54.587	98.34	0.802	111.515
13.	Yield per plant(g)	41.140	39.443	91.92	734.94	77.900

Heritability

Heritability (broad sense) estimates (Table 3) ranged from 63.59% to 98.34%. Very high heritability above 85% were observed in traits like leaf: stem ratio (98.34%), stem weight (95.92%), number of inflorescence per plant (95.27%), number of leaves per plant (92.24%), yield per plant (91.92%), petiole length (87.76%), plant height (87.40%) and leaf weight (86.41%). High heritability above 60% were observed in rest of traits like stem girth (73.35%), leaf area (72.02%), leaf breadth (68.63%), leaf length (67.13%) and number of nodes per plant (63.59%).

Genetic advance

The genetic advance varied from 0.62 (leaf breadth) to 734.94 (yield per plant) (Table 3). High genetic advance was also observed in stem weight (598.15), leaf weight (253.4), number of leaves per plant (25.54) and plant height (21.08) were also observed. All the remaining characters showed low to very low value for genetic advance, being lowest in leaf breadth (0.62). The predicted genetic advance expressed as percent of population mean ranged from 143.953% for number of inflorescence per plant to 11.826% for leaf breadth. Highest expected genetic gain by selection was observed in the trait number of inflorescence per plant (143.953%). Other characters showing genetic gain of higher magnitude were leaf: stem ratio (111.515%) followed by stem weight (101.116%), yield per plant (77.900%) and leaf weight (68.656%) while rest of the traits showed moderate to low value being lowest in leaf breadth (11.826%).

Heritability which is an index of transmissibility is primarily of interest to a plant breeder. Poehlman and Borthakur (1972) [17] opined that the characters not influenced by environment will have high heritability. According to Randhawa *et al*. (1975) [18] higher the heritability value of a character, less will be the environmental influence for expression of that character, thereby indicating better opportunity for selecting a genetically good individual.

In the present experiment, very high to high heritability values above 80% have been obtained for eight characters such as leaf: stem ratio, stem weight, number of inflorescence per plant, number of leaves per plant, yield per plant, petiole length, plant height and leaf weight suggesting that these characters might be highly heritable and less influenced by environment and selecting genotypes on the basis of such characters would be worthwhile in Amaranthus improvement. The results obtained are in agreement with the findings of Reddy (1994) [24], Bhargava *et al.* (2003) [4], Shukla *et al.* (2006) [22] and Ahammed *et al.* (2012) [1] in Amaranthus and Chander Parkash (2012) [6] in bathua. It was suggested by Weber and Moorthy (1952) [25] that information concerning heritability of quantitative characters and their genetic and environmental variances when considered together might be useful for improving the efficiency of selection.

Considering the heritability estimates with genotypic coefficient of variation values (Table 3) it is observed that high values were obtained for both the parameters in case of leaf: stem ratio, stem weight, number of inflorescence per plant, number of leaves per plant, yield per plant and plant height. So, selection may be quite effective based on these characters. Similar results were reported by Revanappa and Madalgeri (1998) [20], Anuja and Mohideen (2007) [2] and Khurana *et al.* (2013) [11] in Amaranthus. On the other hand, deviations were noticed from the findings of previous worker in the present study which is due to difference in genetic stock and environmental variation.

Though the study of heritability estimates is important, their scope is limited since they are estimated in broad sense and are prone to change with change in environment and the testing material. Further, the heritability estimate alone by itself may not be an useful index of genetic potentiality of a character. According to Eswro *et al*. (1963) [7], genetic advance (GA) indicates the potentiality of selection at a particular level of selection intensity. Thus, heritability estimates along with genetic advance are more valuable than heritability alone in predicting the response of selection (Johanson *et al*., 1955; Robinson, 1963) [10, 21]. High heritability does not necessarily mean that the character will show high genetic advance, but when such compatible associations exist (high heritability and high GA) additive genes come into prominence because no genetic advance is due to non-additive genes. The selection based on a character showing high genetic gain (GA) may be desirable particularly case of directional selection, when the main aim of the selection is to change the mean value of a character to have better standards. On the other hand, high heritability accompanied with low genetic advance indicates the prominence of non-additive gene effect, suggesting heterosis breeding (hybridization) instead of direct selection.

In the present investigation, high estimates of heritability coupled with high genetic advance for characters such as number of inflorescence per plant, leaf: stem ratio, stem weight, yield per plant, leaf weight, number of leaves per plant and plant height may be ascribed to effect of additive genes (Panse and Sukhatme, 1954; Liang and Walter, 1968) [15, 12] which may be amenable for selection. The present findings are in conformity with the works of Varalakshmi and Reddy (1994) [24], Revanappa and Madalgeri (1998) [20], Shukla and Singh (2000) [23], Rani and Veeraragavathatham (2003) [19], Anuja and Mohideen (2007) [2], Pan *et al.* (2008) [14], Ahammed *et al.* (2012) [1], Anuja (2012) [3], Hasan *et al.* (2013) [9] and Khurana *et al.* (2013) [11] in Amaranthus.

Conclusion

Considering the three genetic parameters together such as genotypic coefficient of variation, heritability and predicted genetic gain together (Table 3) it is observed that characters like number of inflorescence per plant, leaf: stem ratio, stem weight, yield per plant, leaf weight and plant height showing high to moderate values for the above three important genetic parameters suggested that additive gene action is responsible for expression of these characters. So, direct selection through these characters will be effective in improvement programme of Amaranthus. This is in agreement with the findings of Revanappa and Madalgeri (1998) [20], Anuja and Mohideen (2007) [2] and Khurana *et al.* (2013) [11] in Amaranthus.

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