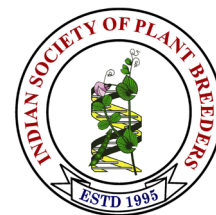


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Research Note

Estimation of genetic variability and association of yield and related traits in indigenous grain amaranth (*Amaranthus hypochondriacus* L.) genotypes

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Abstract

Twenty-five genotypes of grain amaranth (*Amaranthus hypochondriacus* L.) were tested during the *rabi* 2019-20, for genetic factors such as genetic variability, correlation, and path analysis. For each of the 13 characters under study, the results of the analysis of variance revealed a significant variation among the genotypes. Characteristics with high GCV and PCV were the leaf area, biological yield per plant, number of branches per plant, harvest index, plant height, stem diameter and grain yield per plant. The biological yield per plant, leaf area, number of branches per plant, harvest index, length of inflorescence, girth of inflorescence, stem diameter, plant height, grain yield per plant, days to 50% flowering, and days to maturity showed high estimates of heritability along with high genetic advance. Therefore, choosing such traits will be more beneficial. At the genotypic and phenotypic levels, there was a positive and highly significant correlation between the characters days to 50 per cent flowering, days to maturity, plant height, length of inflorescence, stem diameter, leaf area, biological yield per plant and grain yield per plant. Based on the results of the path co-efficient analysis high direct influence was observed between grain yield and the days to 50% flowering, plant height, inflorescence length and girth of inflorescence, number of branches per plant, and biological yield per plant.

Keywords: Correlation, Grain amaranth, Genetic variability, Heritability, Path co-efficient analysis

Amaranth, originating in America and Europe, has been grown for 8000 years as a grain (O'Brien and Price, 1983). Thousands of hectares of this pseudo-cereal were grown by Pre-Columbian civilizations. Grain amaranth is cultivated throughout India, from subtropical lowlands to the Himalayas at elevations of 3500 m. (Sauer, 1967). The Greek word "*amarantos*," which means "fading flower," is where the English term "amaranth" originated. Grain amaranth is a dicotyledonous crop and grows rapidly. Amaranthus is the vegetable of the poor man. Amaranth is an anemophilous (wind pollination) vegetable crop and it is often pollinated by bees because of their colorful inflorescence.

Possessing almost equal numbers of $x = 16$ and $x = 17$ chromosomes in the Amaranth section, the amaranth genus is dibasic. It has unisexual flowers, which might be purple, orange, red, or gold, emerge in branching flower clusters. The seeds range in size from 0.9 to 1.7 mm in diameter, weigh 1,000 to 3,000 per gram, and can be any colour from cream to gold to pink to black.

An efficient breeding programme, which often focuses on the selection of suitable parents, requires the existence of variability within the population for various economic characteristics. Most critical and primary steps in any crop improvement program are the collection, maintenance and

evaluation of germplasm. Many yield attributing characters control the dynamic character yield characteristics. It is challenging to determine whether the exhibited diversity is heritable or not, despite the fact that the majority of yield-attributing characteristics are quantitatively transmitted and influenced by environment.

The nature of inheritance of different characteristics can be determined by looking at factors like heritability, genetic advance, and genotypic and phenotypic coefficients of variation. The estimates of genotypic and phenotypic coefficients of variation, provide an idea of interplay of the genotype and environment that influences breeding results (Gopinath and Irene, 2017). Any crop plant could be improved by first choosing desired genotypes of the current cultivars, and then using the vastly outstanding different kinds in the breeding programme (Kerure *et al.* 2017). For the objective of selecting plants for a possible breeding programme, it is crucial to understand the relationship among grain yield and the contributing character. An effective method for elaborating the degree and extent of relationships between significant plant characteristics is correlation coefficient analysis.

Yield is a complex trait, composed of numerous components, some of which affect the yield directly while others contribute indirectly. Therefore, for the improvement of grain yield we need to identify characters playing direct or indirect role in the enhancement of the grain yield (Nezam *et al.*, 2018). It also demonstrates straightforward selection criteria that result in a directional model based on yield as well as its constituent parts in field experiments. On the other hand, path coefficient analysis is a powerful statistical method created specifically for measuring the relationships between different variables and their direct and indirect effects on yield. This methodology can be used to categorize the yield of contributing traits and

particular characteristics that generate a given correlation (Islam *et al.*, 2010). Hence a research was carried out with 25 grain amaranth genotypes to elucidate genetic variability and trait association.

The experiment was conducted in *rabi* 2019–20 at field unit of Centre for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. Sardarkrushinagar situated at 154.52 metres above mean sea level and is located around 24°N latitude and 72°E longitude. Twenty five grain amaranth genotypes were sown in a randomised block design with three replications ; Each plot had a single 3m-long row for each genotype, with a row-to-row spacing of 45cm and a plant-to-plant spacing of 15cm. Five random plants selected on plot basis were used to record the data *viz.*, days to 50 per cent flowering, leaf area per plant (cm²), length of inflorescence (cm), girth of inflorescence (cm), stem diameter (mm), number of branches per plants, plant height (cm), protein content (%), days to maturity, harvest index (%), biological yield per plant (g), grain yield per plant (g), test weight (g/10ml). Analysis of variance was carried out as per Panse and Sukhatme formula (1978). The genotypic as well as phenotypic co-efficients of variation were calculated based on the method proposed by Burton (1952). The formula proposed by Allard (1960) was used to compute the broad sense heritability (h^2). The genotypic (r_g), phenotypic (r_p) and environmental (r_e) correlation co-efficients for all potential characteristic combinations was calculated as per Al-Jibouri *et al.* (1958). The Wright (1921) approach was used for the path coefficient research, along with Dewey and Lu (1959).

Twenty-five grain amaranth genotypes were examined for growth and yield characteristics throughout the course of 2019–20 (**Table 1**). The mean performance level for each morphological trait demonstrated that there was

Table 1. List of genotypes selected for study

S. No.	Genotypes	S. No.	Genotypes
1.	SKGPA-61	14.	BGA-7-1
2.	SKGPA-74	15.	CGA-18-1
3.	SKGPA-150	16.	CGA-18-2
4.	SKNA-401	17.	GA-1
5.	SKNA-808	18.	GA-2
6.	SKNA-903	19.	GA-3
7.	SKNA-1313	20.	SUVARNA
8.	SKNA-1406	21.	ANNPURNA
9.	SKNA-1407	22.	IC-469820
10.	SKNA-1503	23.	IC-506575
11.	SKNA-1508	24.	IC-436953
12.	SKNA-1510	25.	IC-279511
13.	SKNA-1701		

Source: Indigenous collection of germplasm of grain amaranth from Center for Crop Improvement S.D.A.U, S.K. NAGAR.

Table 2. Mean, range, variability parameters, heritability and genetic advance for thirteen characters in grain amaranth

S.No.	Characters	Genetic parameters								
		Mean	Range	σ^2_p	σ^2_g	σ^2_e	PCV (%)	GCV (%)	h^2 (%)	GAM (%)
1	Days to 50 per cent flowering	50.28	34.77-65.00	75.88	73.25	2.62	17.32	17.02	96.54	34.44
2	Days to maturity	117.36	98.55-130.88	104.12	100.42	3.70	8.69	8.54	96.44	17.26
3	Plant height (cm)	102.17	48.20-147.13	787.90	761.59	26.31	27.47	27.01	96.66	54.70
4	Length of inflorescence (cm)	46.83	34.06-58.25	64.83	55.67	9.16	17.19	15.93	85.87	30.40
5	Girth of inflorescence (cm)	20.25	15.96-27.58	8.02	5.73	2.29	13.98	11.82	71.45	20.58
6	Stem diameter (mm)	10.52	5.61-13.81	6.84	5.87	0.97	24.85	23.02	85.86	43.95
7	Number of branches per plant	2.00	1.00-6.82	4.34	4.24	0.10	103.96	102.74	97.67	209.17
8	Leaf area (cm ²)	731.73	164.77-1422.00	132323.01	124106.42	8216.59	49.71	48.14	93.79	96.04
9	Biological yield per plant (g)	48.90	14.80-75.93	303.22	278.24	24.98	35.61	34.11	91.76	67.31
10	Grain yield per plant (g)	11.68	3.61-19.15	20.80	18.36	2.45	39.05	36.68	88.24	70.98
11	Harvest index (%)	25.04	7.44-39.06	68.77	48.70	20.07	33.12	27.87	70.82	48.31
12	Test weight (g/10 ml)	6.88	5.52-7.61	0.42	0.22	0.20	9.41	6.75	51.38	9.96
13	Protein content (%)	12.79	11.20-13.61	0.66	0.24	0.42	6.35	3.85	36.72	4.80

Where,

σ^2_g , σ^2_p and σ^2_e are the genotypic, phenotypic and environmental variance, respectively

GCV % and PCV % are genotypic and phenotypic co-efficient of variance, respectively

h^2 (%) and GAM are broad sense heritability and genetic advance expressed as per cent of mean, respectively

considerable variability among the genotypes. For all the attributes under study, genotype differences that were highly significant as per analysis of variance were observed. The genetic variability parameters, that are shown in **Table 2** as range (minimum and maximum), mean, phenotypic and genotypic coefficients of variation, heritability, and genetic advance as a percentage of mean, were estimated using an analysis of variance.

Significantly higher phenotypic coefficient of variation was found for every characteristic examined in the current study when compared to its equivalent genotypic coefficient of variation. In all of the features under examination, however, only marginal changes were found between some of these two coefficient variants. It also stated that selection might be successfully done based on phenotypic performance and that genetic factors are primarily responsible for the expression of those qualities. The same research results were revealed by Sheelamary and Phogat, (2016), Kumar and Murthy (2017), Shrivastav *et al.* (2017), Shah *et al.* (2018) and Tiwari (2018). The GCV (%) was equivalent to the PCV (%) for the preponderance of traits, showing a reduced environmental influence and a larger genetic influence on trait expression. The probability of improving these characteristics through phenotypic selection increases with the co-efficient of variance. The genotypic and phenotypic co-efficients of variation values across the environments revealed that high GCV (%) and PCV (%) were observed for leaf area, plant height, and stem diameter, harvest index, grain yield per plant, biological yield per plant, which were followed by number of branches per plant. These outcomes were in agreement with the report of Shrivastav *et al.* (2017)

for biological yield/plant, harvest index, Gelotar (2018) for number of branches per plant, plant height, leaf area and grain yield per plant Kumar *et al.* (2018) for number of branches per plant.

The effect of selection on phenotypic variation can be predicted by heritability analysis and genetic advance. With the exception of moderate in test weight, all the variables under examination showed high heritability. All of the studied traits seemed to have high heritability values, which meant that they were all less influenced by the environment. Because these characteristics are less affected by the environment, selection based on these traits is more likely to be successful because the phenotypes are reliable constituents of their genotypes. All of the studied attributes were less impacted by the environment due to the high heritability values for all the characters. As they are often less impacted by the environment, the phenotypes were the accurate representations of their genotype, demonstrating that selection based on such features would be reliable and efficient.

Genetic advancement is the genetic enrichment of the progeny above the original population driven about through selection, and it aids in the evaluation of the selection processes. Due to the characters' environments' masking effects, the worth of genetic advancement fluctuated significantly. Consequently, genetic advance as a percent mean was estimated to determine the genetic gain in order to obtain relative comparison of the characteristics in relationship to the environment. Genetic advancement divided into three categories **Table 2**: high (above 20%), medium (10%–20%), and low (below 10%).

Table 3. Genotypic (r_g) and phenotypic (r_p) correlation co-efficients among thirteen characters in grain amaranth

Characters		DM	PH	LI	GI	SD	NB	LA	BY	HI	TW	PC	GY
DF	r_g	1.0329**	0.8604**	0.3642	0.5125**	0.9297**	-0.8847**	0.8386**	0.9246**	-1.1003**	-0.933**	0.6217**	0.4064**
	r_p	0.8458**	0.802**	0.1921	0.2786*	0.8359**	-0.8330**	0.7033**	0.7294**	-0.4601**	-0.5677**	0.383**	0.3268**
DM	r_g		0.9856**	0.6051**	0.5343**	0.9519**	-0.9566**	0.928**	1.0019**	-0.9788**	-0.8396**	0.7289**	0.6267**
	r_p		0.7792**	0.2831*	0.1836	0.7846**	-0.8389**	0.6502**	0.7213**	-0.4392**	-0.5611**	0.345**	0.359**
PH	r_g			0.7679**	0.4272**	0.8892**	-0.9276**	0.9306**	0.9927**	-0.684**	-0.6146**	0.5328**	0.8529**
	r_p			0.5493**	0.271*	0.7545**	-0.8547**	0.7552**	0.7435**	-0.3343**	-0.3841**	0.2785*	0.5154**
LI	r_g				-0.228	0.476**	-0.621**	0.6086**	0.732**	0.4221**	0.3719	0.3949	1.323**
	r_p				0.0726	0.2331*	-0.4032**	0.2752*	0.3249**	-0.1245	-0.0225	0.2783*	0.3668**
GI	r_g					0.7369**	-0.4362**	0.7161**	0.7508**	-0.5725**	-0.8002**	-0.0844	0.4267**
	r_p					0.3908**	-0.2351*	0.3142**	0.2764*	-0.2031	-0.3996**	0.0691	0.0852
SD	r_g						-0.9007**	0.8926**	0.9445**	-0.9781**	-0.9179**	0.4817**	0.5675**
	r_p						-0.7916**	0.6765**	0.7829**	-0.4646**	-0.4952**	0.3042**	0.3419**
NB	r_g							-0.8255**	-0.9226**	0.7228**	0.6494**	-0.5302**	-0.7353**
	r_p							-0.6523**	-0.7237**	0.3502**	0.4769**	-0.3025**	-0.4794**
LA	r_g								0.9756**	-0.9059**	-0.8115**	0.3082	0.6017**
	r_p								0.6553**	-0.1958	-0.3367**	0.1795	0.5104**
BY	r_g									-0.8969**	-0.834**	0.5545**	0.7019**
	r_p									-0.4138**	-0.3988**	0.2503*	0.5532**
HI	r_g										1.192**	-0.2609*	-0.1721
	r_p										0.5961**	-0.1297	0.4169**
TW	r_g											-0.2793*	-0.0409
	r_p											-0.0354	0.0935
PC	r_g												0.4943**
	r_p												0.047

* and ** : Significant at 5 and 1 per cent levels of significance, respectively

DF : Days to flowering, DM : Days to maturity, PH : Plant height (cm), LI : Length of inflorescence (cm), GI : Girth of inflorescence (cm), SD : Stem diameter (mm), NB : Number of branches per plant, LA : Leaf area per plant (cm²), BY : Biological yield per plant (g), GY : Grain yield per plant (g), HI : Harvest index (%), TW : Test weight (g/10 ml) and PC : Protein content (%).

Heritability gives the contribution of genetic causes to the phenotypic variance and predicts the extent to which it is transmitted to further generations. High heritability does not always indicate a high genetic gain, heritability is recommended to be considered in association with genetic advance to identify the selection criteria (Chandana *et al.*, 2018).

Characters like days to 50 per cent flowering, plant height, length of inflorescence, stem diameter, number of branches per plant, leaf area, biological yield per plant, grain yield per plant and harvest index were found to have high genetic advance and high heritability. This suggested that these characteristics are governed by additive gene effects and have stronger selection responses. The results are consistent in grain amaranth with the reports of Venkatesh *et al.* (2014) for grain yield per plant. Shrivastav *et al.* (2017) for plant height, length of inflorescence and harvest index, biological yield per plant, Gelotar (2018) for plant height, days to 50 per cent flowering length of inflorescence and grain yield per plant.

High heritability was associated with moderate genetic advance (% mean) for days to maturity as was also reported by Kumar and Murthy (2017). The heritability for test weight as well as protein content was higher, although the genetic advance was lower. The findings were in tune with that of Shrivastav *et al.* (2017) for test weight and protein content. It was discovered that these characteristics' expression was influenced by environmental factors and the existence of non-gene action and as a result, simple selection would be less responsive for improvement of these attributes.

Studies of correlation provide precise details about the type and degree of character relationships in **Table 3**. According to assessments of the correlation between several variables' genotypic and phenotypic characteristics, seed yield per plant seemed to have a strongly substantial and favorable genotypic correlation on days to 50 per cent flowering, stem diameter, plant height, leaf area per plant, biological yield per plant and days to maturity at genotypic as well as phenotypic levels, respectively. Harvest index

Table 4. Direct and indirect effect of twelve causal variables on grain yield per plant based on path analysis

Characters	DF	DM	PH	LI	GI	SD	NB	LA	BY	HI	TW	PC	GY
DF	17.038	-2.312	20.133	0.505	1.936	-5.541	-11.899	-29.654	18.300	-1.072	-0.242	-6.784	0.406
DM	17.598	-2.242	23.063	0.839	2.018	-5.674	-12.868	-32.815	19.829	-0.954	-0.218	-7.954	0.627
PH	14.660	-2.206	23.420	1.065	1.614	-5.300	-12.476	-32.909	19.647	-0.667	-0.160	-5.814	0.853
LI	6.206	-1.355	17.968	1.384	-0.862	-2.837	-8.352	-21.520	14.488	0.411	0.097	-4.308	1.323
GI	8.733	-1.196	9.996	-0.316	3.781	-4.392	-5.868	-25.325	14.861	-0.558	-0.208	0.923	0.427
SD	15.840	-2.131	20.808	0.660	2.784	-5.961	-12.115	-31.563	18.694	-0.953	-0.238	-5.257	0.567
NB	-15.073	2.142	-21.704	-0.861	-1.648	5.369	13.461	29.192	-18.260	0.705	0.169	5.786	-0.735
LA	14.288	-2.077	21.776	0.844	2.705	-5.320	-11.103	-35.388	19.309	-0.883	-0.211	-3.363	0.602
BY	15.754	-2.243	23.228	1.015	2.836	-5.630	-12.410	-34.499	19.811	-0.874	-0.217	-6.051	0.702
HI	-18.747	2.191	-16.004	0.585	-2.163	5.830	9.722	32.033	-17.752	0.981	0.310	2.848	-0.172
TW	-15.898	1.880	-14.382	0.516	-3.023	5.471	8.735	28.696	-16.506	1.162	0.254	3.048	-0.041
PC	10.594	-1.632	12.468	0.548	-0.320	-2.872	-7.133	-10.899	10.977	-0.254	-0.073	-10.912	0.494

* and **: Significant at 5 and 1 per cent levels of significance, respectively

DF : Days to flowering, DM : Days to maturity, PH : Plant height (cm), LI : Length of inflorescence (cm), GI : Girth of inflorescence (cm), SD : Stem diameter (mm), NB : Number of branches per plant, LA : Leaf area per plant (cm²), BY : Biological yield per plant (g), GY : Grain yield per plant (g), HI : Harvest index (%), TW : Test weight (g/10 ml) and PC : Protein content (%)

and test weight were found non-significant and negatively correlated at genotypic level. Number of branches was found significant but negatively correlated at genotypic, phenotypic and environmental levels. Similar findings were reported by Shrivastav *et al.* (2017) for plant height, length of inflorescence and biological yield per plant. Gelotar *et al.* (2018) for length of inflorescence, days to 50 per cent flowering and plant height.

In order to determine the causal factor and the elements that cause it, path coefficient analysis was done for several features using genotypic and phenotypic correlation coefficients and considering seed yield per plant as a dependable variable. The studied supplementary traits had a high to moderate/low direct effect on the related characteristics, like the amount of seeds yield per plant, according to path analysis. The strongest direct impact on seed yield was shown by the plant height (23.420), biological yield per plant (19.811), days to flowering (17.038), number of branches per plant (13.461), girth of inflorescence (3.781) while leaf area per plant (-35.388), protein content (-10.912), stem diameter (-5.961) seemed to have a negative outcome direct effect on seed yield per plant (Table 4). Consequently, the path coefficient study showed that the days to flowering, plant height, number of branches per plant, girth of inflorescence and biological yield per plant represent the most important traits for selection, and selection individuals with these characteristics in view may result in better grain amaranth results for improvement as demonstrated by Oduwaye *et al.* (2016), Gelotar *et al.* (2018), Tiwari (2018) in amaranth.

Thus based on the study it could be concluded that there is a significant amount of variation among the genotypes for all the traits, indicating that there is a large amount of

opportunity for improving the grain amaranth genotypes *via* selection. Genetic parameters in correlation with genetic variability and path analysis showed number of branches per plant, length of inflorescence, girth of inflorescence, biological yield per plant and grain yield per plant are the traits of importance for yield improvement in this crop.

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