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ANALYSIS OF VARIABILITY PARAMETERS FOR MORPHOLOGICAL AND AGRONOMIC TRAITS IN GRAIN AMARANTH (*AMARANTHUS SP*) GENOTYPES

RASHMI YADAV*, J. C. RANA[1] AND J. K. RANJAN[2]
*National Bureau of Plant Genetic Resources, Pusa Campus - 110 012, New Delhi, INDIA
[1]NBPGR, Regional Station, Shimla - 171 001, Himachal Pradesh
[2]Indian Institute of vegetable Research, Varansi 221 002, UP, INDIA
e-mail: rashmigbp@gmail.com

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***Corresponding author**

ABSTRACT

This study was aimed to evaluate genotypic variability and character association in grain amaranth genotypes for agronomically useful and yield contributing traits. The characters like leaf blade width, lateral spikelet length and grain yield per plant showed high GCV and PCV values. Genotypic coefficient of variation for different characters ranged from 11.60 to 42.73%. The highest GCV was recorded with grain yield per plant (42.73%). High heritability exhibited for all the characters studied ranged from 97.81 to 99.98%. The estimates of heritability were observed to be high in magnitude for days to 80 % maturity, days to 50 % flowering, leaf blade width, inflorescence length and plant height. At genotypic level, seed yield per plant showed highly significant positive correlation with days to 80% maturity (rg = 0.696) and plant height (rg = 0.403) and significant positive correlation with days to 50% flowering (rg = 0.338). Inflorescence length had significant positive correlation with lateral spikelet length.

INTRODUCTION

Grain Amaranth is a very versatile pseudo-cereal crop and grown in a wide range of agro-climatic conditions (temperature 20-40ºC, elevation 500-2500m amsl and rainfall 800 mm to 1500 mm). The genus *Amaranthus* consists of approximately 60 species out of which about 18 species are occurring in India. There are three major grain producing *Amaranthus* species, *A. caudatus*, *A. cruentus* and *A. hypochondriacus*, all believed to originate from Central and South America; and three major leafy vegetable species, *A. tricolor*, *A. dubius* and *A. blitum* (*A. lividus*), of which *A. tricolor* is thought to originate from India or Southern China, *A. blitum* from Central Europe and *A. dubius* from Central America (National Research Council, 1984; Sreelathakumary and Peter, 1993; Grubben, 1993). They grow vigorously, resist drought, heat, and pests; and adapt readily to new environments, including some that are inhospitable to conventional cereal crops. It is one of those rare plants whose leaves are eaten as a vegetable while the seeds are used as cereals. Besides, it is also used as fodder, ornamental, organic red dye and for industrial purposes. The genus *Amaranthus* is receiving increasing attention because of the nutritional properties of the grain and leaves and can now be found throughout the world (Stallknecht and Schulz-Schaeffer, 1993). It's high in protein, particularly in the amino acid, Lysine, which seeds is low in the cereal grains. Amaranth is one of the highest grains in fiber content. This makes Amaranth an effective agent against cancer and heart disease. Amaranth is also rich in many vitamins and minerals. However, Amaranth contains no gluten and because of this, it's not good for making yeast breads by itself (O'Brien and Price, 1983). The wide geographical spread of the genus has resulted in the evolution of many landraces in widely separated areas forming a huge gene pool.

In India, *Amaranthus* is mainly cultivated in the rural areas and is well adapted to diverse the climatic conditions, highly resistance to stresses (including diseases and pests), and high quality for specific purposes. *Amaranths* crop also have very high variability in leaf size, leaf shape, branching, flower colour and flowering pattern. Khurana *et al*. (2013) also reported the phenotypic variability in the Amaranth germplasm. Germplasm is the basic raw material in any and characterization and evaluation are pre-requisites for its effective utilization for crop improvement program for obtaining high yielding varieties. On the other hand, yield is a complex character and is associated with some yield contributing characters. Progress in any crop improvement venture depends mainly on the magnitude of genetic variability and heritability present in the source material. Genetic variability studies provide basic information regarding the genetic properties of the population based on which breeding methods are formulated for further improvement of the crop.

Therefore, In order to explore the potential of domestic *Amaranthus* genetic resources, a large-scale collection and evaluation of *Amaranthus* in India has been carried out over the past 15 years. However, few genotypes with favorable agronomic traits were identified. Hence, this experiment was conducted to enhance the pool of agronomically useful *Amaranthus* resources available for crop improvement programme in India. The aim was to screen agronomic traits and assess growth response of Amaranth Collection available at National Bureau of Plant Genetic Resources, New Delhi, India and to find out the genetic variation, magnitude of heritability, expected genetic advance and to identify the important traits for selection of superior genotypes in grain amaranth landraces.

MATERIALS AND METHODS

The experiment was conducted at National Bureau of Plant Genetic Resources, Regional Station, Shimla, Himachal Pradesh during 20013-2014. The material of the study consists of 27 grain amaranth germplasm accessions. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each genotype was sown in three rows of 4m length plot and having spacing of 50cm between lines and 15cm between plants. Normal cultural practices and plant protection measures were followed to raise a good crop. A morphological characterization was carried out in these accessions and observations were recorded for five randomly selected plants in each genotype for twenty three characters. The characteristics evaluated are listed in Table 1.

Plant traits

The observations recorded for plant traits, counted from the sowing time, were: days to 50% of flowering (DF); days to physiological maturity (DM); and plant height at maturity (PH).

Table 1: Morphological and phenological characters recorded observed in different organs (see " Materials and methods" for details)

Organ	Character	Abbreviation
Plant	Growth habit	GH
	Plant Height	PH
	Stem colour	SC
	Stem surface	SS
	Days to flowering	DF
	Days to physiological maturity	DM
	Time of flowering	TF
Leaf	Anthocyanin coloration of basal leaf sheath	AC
	Shape	LS
	Length	LL
	Width	LW
	Colour	LC
	Petiole length	PL
Inflorescence	Inflorescence colour	FC
	Inflorescence compactness	IC
	Inflorescence shape	IS
	Inflorescence length	IL
	Inflorescence spininess	IS
	Lateral spikelet length	LSL
Seed	Colour of seed	CS
	Seed transparency	ST
	Seed shattering	SSH
	Seed Yield	SY

Growth habit (GH) was scored as: 1 erect; 3 semi-erect; 5 drooping. Time of flowering (TF): 1 very early; 3 early; 5 medium; 7 late; 9 very late.

Colour of the stem (SC): 1 yellow; 2 yellowish green; 3 orange; 4 pink; 5 red; 6 reddish green; 7 reddish orange. Stem surface (SS): 1 smooth; 9 ridged.

Leaf traits

Anthocyanin coloration of basal leaf sheath (AC): 1 absent or weak; 2 Medium; 3 Strong.

Maximum leaf length (LL) and width (WL) were measured in cm.

Colour (LC): 3 light green; 5 medium green; 7 dark green.

Petiole length (PL): 3 short; 5 medium; 7 long.

Flower traits

Inflorescence colour (FC): 1 Light yellow; 2 Yellow; 3 Yellowish green; 4 orange; 5 pink; 6 pinkish green; 7 purple; 8 red; 9 reddish green; 10 green.

Inflorescence compactness (IC): 3 lax; 5 intermediate; 7 dense.

Inflorescence shape (IS): 1 globose; 2 semi drooping; 3 completely drooping; 4 straight.

Inflorescence length (IL): 3 short; 5 medium; 7 long.

Inflorescence spininess (ISN): 1 smooth; 2 glabrous;3 prickly; 4 spiny.

Lateral spikelet length (LSL): 3 short; 5 medium; 7 long.

Seed traits

Colour of seed (CS): 1 white; 2 creamish; 3 pale yellow; 4 pink; 5 red; 6 brown; 7 black; 8 golden.

Seed transparency (ST): 1 translucent, 9 opaque.

Seed shattering (SS): 3 low (%), 5 intermediate (10-50%), 7 high (50%).

The data were subjected to statistical analysis. The estimation of mean, variance, standard deviation, standard error, variance, coefficient of variation, phenotypic and genotypic variances were estimated by using the computer software SAS Ver.9.2 (2011). Association among all observed traits was computed by calculating correlation coefficient by using the standard methods Gomez KA, Gomez AA (1984).

RESULTS AND DISCUSSION

Qualitative Characters

The distribution of the accessions for levels of qualitative characters (Table 2) showed that the growth habit of most of the genotypes was predominantly erect type (96.4%). Stem colour showed a marked variability in colours and about 39% of accessions were yellowish, 21.4% yellowish green, 17.9% reddish green, 14.3% pink and rest 7.14% had red colour of stem predominantly ridged type of stem surface (53.6%).

In most cases basal leaf sheath had weak or absent (71.4%) anthocyanin colouration, 25% had medium and one accession had strong anthocyanin pigmentation. Leaves colour were of a medium green, 71.4 % of the accessions,

Table 2: Distribution of the 27 studied accessions for levels of qualitative characters

Organ	Abbriviation	Levels 1	2	3	4	5	6	7	8	9	10
Plant	DF										
	GH	27	1								
	TF		1	10		11		3		3	
	SC	11	6		4	2	5				
	SS	11	2							15	
Leaf	AC	20	7	1							
	LC			2		20		6			
Inflorescence	FC		4	4		13	1		3	2	1
	IC			3		19		5			
	IS	9			17	2					
	IS	11	1	3	13						
Seed	CS	3	22	2					1		
	ST	12								16	
	SSH			5		2		18		2	

See " Materials and methods" for details of the levels and Table 1 for abbreviations of characters

Table 3: Estimates of phenotypic and genotypic coefficient of variation, heritability, genetic advance and genetic gain for different horticultural traits in amaranths (pooled data)

Character	Mean±SE	Range	GCV (%)	PCV (%)	Heritability (%)	GA	GA as % of mean
Leaf blade length (cm)	21.14±0.23	12.23-25.47	14.1	14.2	98.29	6.09	1.29
Leaf blade width (cm)	13.11±0.25	9.43-22.83	21.8	22.1	97.81	5.83	0.76
Petiole length (cm)	14.30±8.70	10.33-21.57	11.9	91.4	1.71	0.53	0.09
Plant height (cm)	228.57±2.11	91.40-289.00	19.0	19.1	99.30	89.35	204.23
Infl length (cm)	73.03±0.35	56.03-96.73	16.2	16.2	99.72	24.31	17.75
Lateral spikelet length (cm)	16.37±0.26	11.43-23.10	21.3	21.5	98.41	7.12	1.17
Days to 50% flowering	83.73±0.13	65.00-107.00	12.6	12.6	99.96	21.68	18.15
Days to 80% maturity	123.85±0.13	98.00-180.00	15.2	15.2	99.98	38.78	48.03
1000 seed wt (g)	0.73±0.01	0.50-.80	11.6	11.7	98.36	0.17	0.00
Seed yield/plant (g)	40.05±0.24	21.85-105.83	42.7	42.7	99.94	35.24	14.11

Table 4: Estimates of Genotypic Correlations coefficients for different agro-morphological characters of grain amaranth

	Leaf blade length (cm)	Leaf blade width (cm)	Petiole length (cm)	Plant height (cm)	Inflorescence length (cm)	Lateral spikelet length (cm)	Days to 50% flowering	Days to 80% maturity	1000 seed wt (g)	Seed yield/plant (g)
Leafblade length (cm)	1.00	-0.54**	0.25	0.22	0.01	0.07	0.10	0.20	0.03	0.25
Leafblade width (cm)		1.00	0.07	-0.53	-0.23	-0.07	-0.34*	-0.25	-0.01	-0.08
Petiole length (cm)			1.00	0.26	0.35*	0.64**	-0.56**	-0.45**	-0.53**	-0.48**
Plant height (cm)				1.00	0.57**	0.08	0.68**	0.48**	0.23	0.40**
Inflorescence length (cm)					1.00	0.34*	0.46**	0.14	0.38**	0.05
Lateral spikelet length (cm)						1.00	0.22	0.11	-0.03	-0.14
Days to 50% flowering							1.00	0.73**	-0.18	0.34*
Days to 80% maturity								1.00	-0.30	0.70**
1000 seed wt (g)									1.00	-0.09
Seed yield/plant (g)										1.00

and 21.4% had dark green colour leaves. Inflorescence colour was pink in 46.4 % of the accessions, 14.3% have yellow and yellowish green each, 20 % of them had red and reddish green inflorescence while 46% have intermediate type inflorescence compactness, 17.9% dense and about 10% have lax type of inflorescence. The inflorescence spininess presented a marked variability. The seeds were medium sized and of low weight in at least 80 % of the accessions. They were uniform in almost all accessions and about 57 % of them opaque and rest translucent or semi-translucent in seed transparency. The colour presented a marked variation, although 78.6 % were yellow with different intensity.

Mean values were subjected to statistical analysis to study the descriptive statistics like mean, range, standard error, coefficient of variation (Table 3). Wide range was observed for characters like plant height, petiole length, leaf blade length and width, inflorescence length and grain yield per plant in the evaluated germplasm which indicates the extent of variability of these characters. The plant height ranged from 91.4 to 289cm with a mean height of 228.5cm. Leaf blade width ranged from 9.43 to 22.8cm with a mean of 13.1cm. Inflorescence length ranged from 56 to 96.7cm with a mean

Table 5: Estimates of Phenotypic Correlations coefficients for different agro-morphological characters of grain amaranth

	Leaf blade length (cm)	Leaf blade width (cm)	Petiole length (cm)	Plant height (cm)	Inflorescence length (cm)	Lateral spikelet length (cm)	Days to 50% flowering	Days to 80% maturity	1000 seed wt (g)	Seed yield/ plant (g)
Leafblade length (cm)	1.00	-0.52**	0.14	0.22	0.01	0.07	0.10	0.20	0.03	0.25
Leafblade width (cm)		1.00	-0.06	-0.52*	-0.23	-0.07	-0.34*	-0.24	-0.02	-0.08
Petiole length (cm)			1.00	0.03	-0.17	0.09	-0.07	-0.06	-0.06	-0.06
Plant height (cm)				1.00	0.57**	0.08	0.68**	0.48**	0.23	0.40**
Inflorescence length (cm)					1.00	0.34*	0.46**	0.14	0.38**	0.05
Lateral spikelet length (cm)						1.00	0.22	0.11	-0.02	-0.13
Days to 50% flowering							1.00	0.73**	-0.17	0.34*
Days to 80% maturity								1.00	-0.30	0.70**
1000 seed wt (g)									1.00	-0.09
Seed yield/plant (g)										1.00

Table 6: Environmental Correlations coefficients for different agro-morphological characters of grain amaranth.

	Leaf blade length (cm)	Leaf blade width (cm)	Petiole length (cm)	Plant height (cm)	Inflorescence length (cm)	Lateral spikelet length (cm)	Days to 50% flowering	Days to 80% maturity	1000 seed wt (g)	Seed yield/ plant (g)
Leafblade length (cm)	1.00	0.16	-0.14	-0.12	0.12	0.22	0.02	-0.03	0.02	0.12
Leafblade width (cm)		1.00	-0.44**	-0.18	-0.09	0.05	-0.30	-0.24	-0.30	-0.16
Petiole length (cm)			1.00	-0.05	0.03	0.06	0.05	0.06	0.05	0.19
Plant height (cm)				1.00	0.31	0.12	0.26	0.25	0.26	0.16
Inflorescence length (cm)					1.00	0.27	0.41*	0.36*	0.41**	0.28
Lateral spikelet length (cm)						1.00	0.29	0.25	0.29	0.14
Days to 50% flowering							1.00	0.94**	1.00	0.63**
Days to 80% maturity								1.00	0.94**	0.59**
1000 seed wt (g)									1.00	0.63**
Seed yield/plant (g)										1.00

of 73cm. Grain yield per plant ranged from 21.9 to 105.8 g with a mean of 40 g.

Genetic Variability and Correlation Analysis

Estimation of genotypic and phenotypic co-efficient of variation, heritability and genetic advance as percent of mean are presented in Table 4&5. The differences between phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were very less for all the characters studied. This showed the close resemblance between the corresponding estimates of PCV and GCV in almost all the characters except petiole length, suggested that there was a very little influence of environment on the expression of these characters and variability was due to genetic constitution only. This inferred phenotypic variability to be a reliable measure of genotypic variability. The traits viz., plant height, petiole length, leaf blade length, inflorescence length, 1000 seed weight, days to 50% flowering and days to physiological maturity showed moderate GCV and PCV values. The characters like leaf blade width, lateral spikelet length and grain yield per plant showed high GCV and PCV values. Genotypic coefficient of variation for different characters ranged from 11.60 to 42.73%. The highest GCV was recorded with grain yield per plant (42.73%) followed by leaf blade width. The lowest GCV was observed with 1000-seed weight (11.70%). GCV and PCV estimates classified as low (0-10%), moderate (10-20%) and high (>20%) classified by Johnson *et al*. (1955). High estimate of GCV and PCV indicates the high variability of characters in the germplasm. Similar results were reported for high genotypic and phenotypic variability in most of the yield contributing traits by Venkata Subbaiah *et al*. (2011) and Singh *et al*. (2011).

GCV values only are not enough to determine the genetic variability, this could be done with the help of heritability and genetic advance estimates to assess the heritable portion of total variation and extent of genetic expected gain for selection. Rabinson *et al*. (1949) classified the heritability estimates as low (0- 30%), moderate (30-60%) and High (>60%). A very less differences were observed for all the characters over seasons with regard to heritability. High heritability exhibited for all the characters studied ranged from 97.81 to 99.98%. The estimates of heritability were observed to be high in magnitude for days to 80 % maturity, days to 50 % flowering, leaf blade width, inflorescence length and plant height. Since high heritability does not always indicate high genetic gain, heritability with genetic advance should be used in predicting selection of superior genotypes (Ali *et al*. 2002). High estimate of heritability coupled with high genetic advances were observed for the characters viz., plant height, days to 80 % maturity and inflorescence length which suggested that these characters can be considered as favourable attributes and as an indication of additive gene action and the consequent high extended genetic gain from selection of superior genotypes. Similar results also reported by Mulugeta Syoum *et al*., (2012).

At genetic level, a positive correlation occurs due to coupling phase of linkage and negative correlation occurs due to repulsive phase of linkage of genes controlling two different traits (Salini *et al*., 2010). In the present investigation, at genotypic level, seed yield per plant showed highly significant positive correlation with days to 80% maturity (rg = 0.696) and plant height (rg = 0.403) and significant positive correlation with days to 50% flowering (rg = 0.338) whereas rest of the characters showed non-significant correlation (Table 4).

Most of the characters had positive inter correlation with each other. Days to 50 per cent flowering recorded positive and highly significant inter correlation with plant height and inflorescence length. Plant height showed positive highly significant correlation with inflorescence length, days to 50 per cent flowering and days to 80 per cent maturity. Inflorescence length had significant positive correlation with lateral spikelet length. From the above results, it is evident that most of the traits were associated with grain yield and inter correlated among themselves. Kumar *et al*., (2014) also reported that the grain yield/plant, days to maturity, number of grains/spike, effective tillers/plant and test weight were important components and these should be taken into account while breeding in wheat.

At phenotypic level, seed yield per plant showed highly significant positive correlation with days to 80% maturity (rp = 0.696), plant height (rp = 0.402) and significant positive correlation with days to 50% flowering (rp = 0.339) whereas, rest of the characters showed non-significant correlation (Table 5). Positive and significant association of seed yield per plant with number of siliquae, plant height and days to 50% flowering in mustard was also reported by Shekhawat *et al*., (2014). Chidambaram and Palanisamy (1995) and Singh & Yadava (2000) also reported similar findings for different parameters in soybean. These results revealed that the selection in any one of these yield attributing traits will lead to increase in the other traits, thereby finally boosting the grain yield. Hence, primary selection for traits like plant height, inflorescence length, lateral spikelet length and days to 50 per cent flowering may be given importance in selection to obtain genotypes with increased grain yield per plant. In addition the significant associations between these component traits suggest the possibility of simultaneous improvement of these traits by single selection. Khurana *et al*., (2013) also suggested that high values of heritability coupled with high genetic gain for the characters like plant height, total green yield and leaf area index were obtained indicating the preponderance of additive gene effect and desired improvement in these characters can be brought through direct selection for these component traits.

Plant height, inflorescence length, lateral spikelet length and days to 50 per cent flowering were recorded high GCV, PCV, heritability, genetic advance % of mean, suggested that maximum emphasis should be given on the above characters in selecting grain amaranth with higher seed yield. These characters could be transmitted to the progeny when hybridization and phenotypic based selection is effective. On the other hand, concomitant selection based on high Inflorescence length, plant height and high leaf blade width would be effective selection method for improvement of grain amaranth.

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Cont. .... P. 1672