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Research Article

Genetic variability, correlation and principal component analyses in grain amaranth under water limited conditions of Bundelkhand region

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Abstract

Two hundred amaranth (*Amaranthus* sp.) germplasm accessions were evaluated for nine quantitative and ten qualitative traits with five checks under water limited conditions of Bundelkhand region during *kharif*, 2019. The accessions, IC35373, IC583610 and IC38039 showed early inflorescence emergence *i.e.* 28.0, 28.0 and 29.0 days, respectively. Out of 200 germplasm accessions, 64.88% showed green inflorescence colour followed by red and light yellow colours. High heritability estimates were observed for 1000 grain weight (81.94%), followed by grain yield per plant (67.04%) and leaf length (66.94%), whereas, leaf length, leaf width, lateral spikelet length and 1000 grain weight exhibited moderate range for genetic advance as per cent of mean. Grain yield per plant revealed positive and significant correlation with plant height (0.345), followed by lateral spikelet length (0.220**), leaf length (0.199**) and 1000 grain weight (0.143*). In principal component analysis the first principal component (PC1) showed the highest contribution of 73.5% followed by PC2 (11.10%) and PC3 (9.30%), respectively. Petiole length, lateral spikelet length and inflorescence length were identified as contributors towards genetic variation in PCA analysis. The genotypes, EC146534, IC38193, IC289386, IC396963, IC540832 and IC415314 were found promising under water limited conditions of Bundelkhand region.**

Key words: Amaranth, Correlations, PCA, DUS

1. Introduction

Amaranth (*Amaranthus* sp.) is underutilised and genetically potential orphaned crop mainly grown in the tropical and subtropical regions of the world. The edible amaranth is a cosmopolite genus of annual herb family Amaranthaceae and order Caryophillales (Miguel, 2018). Amaranth is an important subsistence and commercial food crop in the parts of central and South America and its cultivation has been reported more than 8,000 years ago before the Pre-Colombian civilization in Central and South America (Thapa and Blair, 2018). It is a *pseudocereal*, cultivated over a wide range of agro-climatic conditions with temperature range of 20 - 40°C, elevation of 500-2500 meter above mean sea level and rainfall between 800 mm to 1500 mm (Yadav *et al.,* 2014). Amaranth spp. are nutritious *pseudocereal* an utilized as food crops, leaves and edible grains (Ozimede *et al.,* 2019). Dietary fibre, vitamins and precursors of vitamins (ascorbic acid, riboflavin and carotenoids), as well as minerals (Ca, Fe, Mg, K, Cu, Zn, and Mn) are important nutrients present in the grains and leaves of amaranth (Karamac *et al.,* 2019). Amaranth is an excellent source of iron and ß-Carotene and can help in alleviating iron and vitamin A deficiencies. It has better balanced amino acid compositions and maximum amount of glutamic acid (2.259 g) followed by glycine (1.636 g) and aspartic acid (1.261 g) per 100 grams of amaranth grains (Mota *et al.,* 2016; Maurya and Arya, 2018). Amaranth seed oil has 8% Squalene, a powerful antioxidant which has anti-cancerous and hypocholestromic effect (Kaur *et al.,* 2010). The regular dietary intake of amaranth has proven positive health effects particularly in lowering blood pressure and cholesterol levels, in turn helpful for the people suffering from hypertension and cardiovascular ailments. Amaranth flour is gluten free and receiving considerable attention as an interesting source for the formulation of gluten free products (Da Silva *et al.,* 2019).

Grain amaranth is widely cultivated in India under the common name of Rajdana or Rajgira in the sub-Himalayan regions and in the Nilgiri Hills of South India. It is mostly cultivated in the Indian states of Uttarakhand, Himachal Pradesh, Tamil Nadu, Karnataka, Kerala and Andhra Pradesh. Bundelkhand region of Uttar Pradesh and Madhya Pradesh is one of the vulnerable areas in central India, is prone to frequent drought and crop failure due to low annual rainfall variability. The region is home of 18.3 million population with an area of 2.95 m ha in Uttar Pradesh and 4.12 m ha in Madhya Pradesh. Nearly 75% population of Bundelkhand region stay in rural areas, where agriculture and allied sectors contributes up to 80-84% in rural livelihood. This region is well known for climatic adversities, undulated topography, low fertility, different soil types and water limited conditions. Pulses such as mung bean and urd bean and oilseed crops like groundnut and sesame are the most commonly grown crops during *kharif* season in this region. Due to water scarcity and *Anna Pratha* (stray animals) most of the land remains fallow during *Kharif* season. Amaranth has low water and fertilizer requirements and highly nutritious in nature, it has adaptation to survive well under adverse conditions, including poor soils and lack of water availability. Therefore, amaranth can be considered as potential crop for crop diversification, soil protection and a useful option to fulfil the nutritional requirement in Bundelkhand region. Amaranth is one of the hardy crops but there is no prior knowledge about the adaptable amaranth genotypes and combination of yield and yield attributes in Bundelkhand region. The contribution of agro-morphological traits of amaranth towards grain yield enhancement under limited water condition of Bundelkhand region is still unknown. Therefore, the present study was undertaken to evaluate amaranth germplasm accessions for agro-morphological traits and grain yield in Bundelkhand region.

2. Materials and Methods

The present study was conducted at Research Farm, Rani Lakshmi Bai Central Agricultural University, Jhansi during *kharif,* 2019. The experimental site is geographically located at 25.51°N latitude, 78.56°E longitude and at an altitude of 227m above mean sea level. The experimental materials comprised of 200 grain amaranth accessions and five checks, Annapurna, Durga, PRA-2, PRA-3 and Amaranth VL-44. Out of 200 germplasm accessions, 135 were of indigenous origin and rest 65 genotypes were exoticin nature. The summary of the germplasm accessions is presented in the Table 1.

Table 1: Details of amaranth germplasm accessions

Sr. No.	Number	Indigenous	Sr. No.	Number	Exotic
1	05	Chhattisgarh	13	01	Benin
2	01	Goa	14	05	China
3	05	Gujarat	15	13	Germany
4	20	Himachal Pradesh	16	01	Hungary
5	01	Jammu & Kashmir	17	01	Italy
6	02	Karnataka	18	03	Latvia
7	10	Madhya Pradesh	19	02	Nepal
8	34	Maharashtra	20	02	Netherlands
9	03	Meghalaya	21	03	Poland
10	01	Rajasthan	22	11	Russia
11	03	Sikkim	23	22	USA
12	28	Uttarakhand	24	23	Others

The germplasm accessions along with checks were grown in the augmented block design (ABD) during *Kharif*, 2019. The 200 germplasm accessions were grown in to 8 blocks under restricted water conditions and each block consisted of 25 genotypes and randomly distributed 05 checks. The row to row spacing was of 40cm and plant to plant distance was maintained of 20 cm by carrying out thinning operations, 20 to 25 days after sowing (DAS). The observations were recorded for nine quantitative traits *viz.*, days to 50% flowering, leaf length, leaf width, petiole length, plant height, Inflorescence length, lateral spikelet length, 1000 grain weight and grain yield per plant. In addition, the data on 10 qualitative traits were also recorded as per DUS guidelines of amaranth (DUS guideline, PPV&FRA, GOI). The analysis of variance for ABD was carried out as per standard procedure given by Federer (1961). The genotypic and phenotypic coefficients of variation, heritability, correlations, genetic advance per cent of mean and principal components (PCs) were computed as per standard procedures.

3. Results and Discussion

The analysis of variance revealed significant genetic differences for all the characters *viz.*, days to 50 % flowering, leaf length, leaf width, petiole length, plant height, inflorescence length, lateral spikelet length, 1000 grain weight and grain yield per plant. The significant differences for all the quantitative characters indicated the presence of adequate genetic variations among the evaluated germplasm accessions. General mean for days to 50% flowering was observed as 51 days, which ranged from 28 to 66 days. The germplasm accessions, IC35373 (28 days), IC583610 (28 days) and IC38039 (29 days) showed early inflorescence emergence. The maximum leaf length was recorded in the germplasm accession IC20306 (24.05 cm) followed by IC41998 (22.33 cm), EC146534 (21.72 cm) and IC21804 (21.45 cm). The average plant height was estimated of 136.61 cm with the minimum and maximum plant height of 77.47cm (EC467910) to 213.07 cm (IC540866). The wide range of variation was observed among the genotypes for inflorescence length, which varied from 19.70cm to 68.50cm with the average mean value of 38.31cm. The germplasm accessions, EC130389 (68.50cm), EC157418 (67.84cm) and IC20306 (64.92cm) showed maximum inflorescence length, whereas, the germplasm lines, EC146536, IC35428 and EC467910 were recorded with minimum inflorescence length.

The mean 1000 grain weight was observed as 0.87 g, which ranged from 0.38g to 1.22 g. The highest 1000 grain weight was recorded for the germplasm accessions IC289386 and IC38163 (1.22g) followed by the genotype IC383571 (1.21g). Grain yield per pant ranged from 0.70 g to 14.15 g with mean grain yield of 3.73 g. The germplasm accession EC146534 showed the highest grain yield per plant (14.15g) followed by IC38193 (12.35g) and IC289386 (10.55g). The grain yield per plant ranged from 3.13 g (Annapurna) to 9.23g (Durga) for check varieties. The checks PRA-2, PRA-3 and Amaranth VL-44 showed grain yield per plant of 3.47 g, 3.63 g and 3.83 g, respectively. The promising genotypes over the best check for each quantitative character of amaranth are presented in Table 2. The germplasm accessions, namely EC146534 (14.15 g), IC38193 (12.35 g), IC289386 (10.55 g), IC396963 (10.47 g), IC540832 (10.23 g) and IC415314 (10.12 g) showed grain yield advantage over the best check Durga (9.23 g).

Table 2: List of promising genotypes for various traits in amaranth

Days to 50% flowering	Leaf length (cm)	Leaf width (cm)	Petiole Length (cm)	Plant height (cm)	Inflorescence length (cm)	Lateral spikelet length (cm)	1000 grain weight (g)	Grain yield per plant (g)
IC35373 (28)*	IC20306 (24.05)	EC328879 (12.20)	EC146506 (19.28)	IC540866 (213.07)	EC130389 (68.50)	IC35363 (33.71)	IC289386 (1.22)	EC146534 (14.15)
IC583610 (28)	IC41998 (22.33)	EC338767 (12.05)	IC20306 (17.76)	IC38193 (198.59)	EC157418 (67.84)	IC35379 (29.89)	IC38163 (1.22)	IC38193 (12.35)
IC38039 (29)	EC146534 (21.72)	-	EC16328 (17.42)	IC35492 (195.47)	IC20306 (64.92)	IC38164 (29.64)	IC383571 (1.21)	IC289386 (10.55)
IC21938 (30)	IC21804 (21.45)	-	IC35365 (16.79)	-	IC35363 (58.68)	IC415314 (29.22)	IC289378 (1.21)	IC396963 (10.47)

IC35365 (31)	EC328885 (21.42)	-	IC21947 (16.50)	-	EC16328 (57.90)	IC36833 (27.97)	IC444192 (1.19)	IC540832 (10.23)
IC20304 (32)	EC146538 (21.41)	-	EC146494 (16.39)	-	-	IC35415 (26.10)	IC38301 (1.17)	IC415314 (10.12)
PRA-3 (48)	Durga (20.03)	Durga (10.35)	Amaranth VL44 (11.61)	Durga (171.86)	PRA-3 (50.66)	PRA-3 (18.24)	PRA-2 (0.96)	Durga (9.23)

*Mean performance within parenthesis

The genotype IC289386 was observed with superior mean performance over the checks for multiple traits *viz.,* days to 50 % flowering, lateral spikelet length, 1000 grain weight and grain yield per plant. The genotypes IC396963 and IC415314 had better performance for lateral spikelet length and grain yield per plant. The accessions EC130389 and EC16328 were recorded with maximum petiole length and inflorescence length than the check variety. The genotype IC20306 exhibited superior performance for multiple traits, namely days to 50% flowering, leaf length, petiole length and Inflorescence length.

For DUS features five classes for stem colour *viz*, green, pink, red, purple and whitish were observed, however, green stem colour (56.10%) was prevalent among the genotypes (Table 3). Green (64.88%) was the predominant classes for inflorescence colour followed by red (13.66%) and light yellow (9.27%), however pink, yellowish-green, purple and reddish-green inflorescence colours were also observed. Most of the genotypes were having intermediate (70.73%) type inflorescence density followed by lax (26.83%) with a few having dense type inflorescences (2.44%). Varalakshmi (2004) also observed high variability in case of inflorescence colour and stem colour. Similarly, Akaneme and Ani (2013) reported differences between accessions for stem colour. Comparatively equal proportions of genotypes were observed for smooth (54.15%) and rigid (45.85%) stem surface. The shape of the inflorescence was straight for most of the genotypes with some having semi drooping, globose and dropping type of inflorescence shapes. The most of the genotypes (85.37%) were observed with inflorescence spines and remaining genotypes were observed without inflorescence spines. Based on ten morphological characters considered for the study the most of the germplasm accessions showed medium to late germination, good seedling vigour and absence of leaf blade blotch. Further, primarily the germplasm accessions exhibited green smooth stem coupled with green colour spiny inflorescence. These findings are in agreement with Wu *et al.* (2004), Akaneme and Ani (2013) and shah *et al.* (2018).

Table 3: Details of qualitative characters recorded in amaranth

Sr. No.	Character	Class	Frequency	Per cent of total
1.	Anthocyanin coloration of hypocotyl	Present	96	46.83
		Absent	109	53.17
2.	Germination in days	10 days	29	14.15
		15 days	83	40.49
		20 days	93	45.37
3.	Seedling vigour	1	0	0.00
		2	7	3.41
		3	62	30.24
		4	95	46.34
		5	41	20.00
4.	Leaf blade blotch	Present	09	4.39
		Absent	196	95.61
5.	Stem colour	Green	115	56.10
		Pink	20	9.76
		Red	31	15.12
		Purple	5	2.44
		Light green	34	16.59

6.	Stem surface	Smooth	111	54.15
		Ridged	94	45.85
7.	Inflorescence colour	Light yellow	19	9.27
		Yellow	-	-
		Yellowish green	4	1.95
		Purple	1	0.49
		Green	133	64.88
		Pinkish green	2	0.98
		Pink	8	3.90
		Reddish green	10	4.88
		Orange	-	-
		Red	28	13.66
		Mottling	-	-
8.	Inflorescence density	Lax	55	26.83
		Intermediate	145	70.73
		Dense	5	2.44
9.	Inflorescence shape	Globose	12	5.85
		Straight	147	71.71
		Semi- dropping	45	21.95
		Dropping	1	0.49
10.	Inflorescence spines	Present	175	85.37
		Absent	30	14.63

In the present investigation, the PCV and GCV ranged from 6.09 to 26.85 % and 5.08 to 21.98 %, respectively. The highest estimates of PCV were observed for grain yield per plant (26.85%), followed by petiole length (18.65%), leaf width (17.09%) and lateral spikelet length (14.64%). The highest GCV was recorded for grain yield per plant (21.98%) followed by lateral spikelet length (10.37%), leaf width (10.21%), leaf length (8.37%) and inflorescence length (7.11%). High magnitude (>20%) of genotypic and phenotypic coefficients of variation for grain yield per plant were also reported by Patial *et al.* (2014). Mobina and Jagatpati (2015) Oduwaye *et al.* (2017) and Diwan *et al.* (2017) also reported high GCV and PCV for leaf length and Rani *et al.* (2019) for plant height in amaranth.

High heritability was exhibited by 1000 grain weight (81.94%) followed by grain yield per plant (67.04%) and leaf length (66.94%), which suggested that these characters were determined by the underlying genetic mechanism with the environmental influence. Days to 50% flowering, leaf width and lateral spikelet length found to have a moderate range of heritability, whereas, petiole length, plant height and inflorescence length exhibited a low range of heritability. Similar results were also reported by Sravanthi *et al.* (2012), Chattopadhyay *et al.* (2013) and Mobina and Jagatpati (2015). High estimates of genetic advance as per cent of mean (more than 20%) were depicted for grain yield per plant (37.08%), which revealed prevalence of the additive gene action in the expression of the character. Thus, selection based on phenotypic performance for this character would likely to be effective. Leaf length, leaf width, lateral spikelet length and 1000 grain weight exhibited a moderate range of genetic advance as per cent of mean, whereas, days to 50% flowering, petiole length, plant height and inflorescence length were observed with low range of genetic advance per cent of mean. Rana *et al.* (2005) and Prasantha and Nagaraja (2011) also reported high (>20%) genetic advance per cent of mean for grain yield.

1000 grain weight showed positive associations with grain yield per plant (0.143*) and lateral spikelet length (0.061), where it was negatively associated with days to 50% flowering (-0.179*), petiole length (-0.177*) and leaf width (-0.145*). Leaf length depicted positive correlations with leaf width (0.646**), plant height (0.457**), petiole length (0.260**), grain yield per plant (0.199**) and lateral spikelet length (0.145*). Similar results were also reported by Diwan *et al.* (2017), Akaneme and Ani (2013), Sood *et al.* (2018) and Rani *et al.* (2019). Grain yield per plant revealed the highest positive and significant correlation with plant height (0.345**), followed by lateral spikelet length (0.220**), leaf length (0.199**) and 1000 grain weight (0.143*) indicated that increase in these component traits simultaneously will help in improving economic grain yield per plant in amaranth. Patial *et al.* (2014) and Sood *et al.* (2018) also identified the above characteristics as an important component of grain yield in amaranth. The results revealed that grain yield in amaranth can be maximized by improving lateral spikelet length, leaf length, plant height and 1000 grain weight. The positive association of grain yield with plant height and leaf length suggested that more number of leaves led to the increased photosynthetic area with increased plant height and played significant role in higher grain yield realization.

In PC analysis, the first principal component (PC1) showed the highest contribution of 73.5% followed by PC2 (11.10%) and PC3 (9.30%), respectively. Petiole length had the highest Eigen vector of 0.994 in PC1 followed by plant height (0.070) and inflorescence length (0.046), while 1000 grain weight exhibited the least (-0.001) followed by days to 50% flowering (0.003). Lateral spikelet length showed maximum contribution (0.951) followed by leaf width (0.198) and days to 50% flowering (0.090), while inflorescence length exhibited the least variability (-0.218) followed by petiole length (-0.027).The traits *viz*., petiole length, lateral spikelet length, inflorescence length, leaf width and plant height (0.800) were significant in defining variability in the present set of amaranth germplasm accessions. Gerrano *et al.* (2014), Gueco *et al.* (2016) and Ogechi and Joseph (2017), also reported contributions of plant height, leaf length, plant height and dry weight of leaves in variations in amaranth.

In the nutshell, six germplasm lines, namely EC146534, IC38193, IC289386, IC396963, IC540832 and IC415314 were found promising under the water limited conditions of Bundelkhand region. The selected genotypes exhibited earliness and the germplasm accession IC289386 was observed promising for multiple traits *viz.,* days to 50 % flowering, lateral spikelet length and 1000 grain weight. Similarly, IC20306 was promising for days to 50% flowering, leaf length, petiole length and Inflorescence length. The germplasm accession, IC35363 depicted with desirable inflorescence length, lateral spikelet length and 1000 grain weight. The results revealed that grain yield in amaranth can be maximized by improving lateral spikelet length, leaf length, 1000 grain weight with optimum plant height. The traits, petiole length, plant height, inflorescence length, lateral spikelet length and leaf width contributed significantly in the present germplasm accessions.

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Conflict of Interest

Authors declares that they do not have any conflict of interest

Ethical Compliance Statement: NA

Authors Contribution

Conceptualization of research, designing of experiments and conduction (AK, SY, SKC, VK), Data recording (SY, MP, VK), Preparation of manuscript (VK, SY).

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