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**Shailendra Tiwari**
Assistant Professor, Department of Agriculture, Dolphin (P.G.) Institute of Biomedical and Natural Sciences, Dehra Dun, Uttarakhand, India

**Naveen Chandra Pant**
Assistant Professor, Department of Agriculture, Dolphin (P.G.) Institute of Biomedical and Natural Sciences, Dehra Dun, Uttarakhand, India

**Anuj Gupta**
Assistant Professor, Department of Agriculture, Dolphin (P.G.) Institute of Biomedical and Natural Sciences, Dehra Dun, Uttarakhand, India

**Upendra Dwivedi**
Assistant Professor, Department of Agriculture, Dolphin (P.G.) Institute of Biomedical and Natural Sciences, Dehra Dun, Uttarakhand, India

**Jitendra Kumar Meena**
Assistant Professor, Department of Agriculture, Dolphin (P.G.) Institute of Biomedical and Natural Sciences, Dehra Dun, Uttarakhand, India

**CS Pandey**
Associate Professor (Head), Department of Agriculture, Dolphin (P.G.) Institute of Biomedical and Natural Sciences, Dehra Dun, Uttarakhand, India

**Rakesh Dhoundiyal**
Assistant Professor, Department of Chemistry, Shri Guru Ram Rai P.G. College, Dehradun, Uttarakhand, India

**Arun Bhatt**
Assistant Professor, Govind Ballabh Pant Engineering College, Pauri-Garhwal, Uttarakhand, India

**Correspondence**
**Shailendra Tiwari**
Assistant Professor, Department of Agriculture, Dolphin (P.G.) Institute of Biomedical and Natural Sciences, Dehra Dun, Uttarakhand, India

# Genetic variability and genetic divergence for seed yield and its component characters in grain amaranth (*Amaranthus hypochondriacus* L.) germplasms

**Shailendra Tiwari, Naveen Chandra Pant, Anuj Gupta, Upendra Dwivedi, Jitendra Kumar Meena, CS Pandey, Rakesh Dhoundiyal and Arun Bhatt**

**Abstract**
The research was conducted during Kharif (2013) at Crop Improvement Research Block of Uttarakhand University of Horticulture and Forestry, Ranichauri Campus with 54 diverse genotypes of grain amaranth. The 54 genotypes including four checks viz., Annapurna, Durga, PRA-2 and PRA-3 were planted in an augmented design during under rainfed condition. Genetic variability and genetic divergence was studied for characters viz., days to 50% flowering, days to maturity, plant height, inflorescence length, spikelet length, number of spikelets per plant, stem thickness, 1000 seed weight and seed yield per plant. Analysis of variance reviled that differences among the entries were highly significant for days to 50% flowering, days to maturity, plant height (cm), inflorescence length (cm), spikelet length (cm), number of spikelets per plant, stem thickness (mm) and non significant for 1000 seed weight (g) and seed yield per plant (g). Adjusted mean for earliest flowering (63.20 days) and maturity (128.00 days) minimum in Durga. The maximum plant height (148.00 cm) was noticed in IC-95339. The genotype IC-82625 recorded highest seed yield per plant (46.69 g). Using the Non-hierarchical Euclidean cluster analysis, the 54 genotypes were group into eight different non-overlapping clusters. The highest inter cluster distance was observed between cluster III and cluster VIII (67.39) followed by cluster IV and cluster VII (64.30) suggesting wide diversity among these groups. Considering cluster mean and genetic distance, crossing between genotypes of cluster IV (IC-82625 and IC-95247) with cluster VIII (Durga) were likely to recombine the genes for high seed yield in temperate conditions mid hills of Uttarakhand.

**Keywords:** amaranthus, correlation, path coefficient analysis

## Introduction
Amaranth belongs to the family Amaranthaceae and genus *Amaranthus*. There are two chromosome groups in Amaranth, n=16 and n=17. The species with n=16 are *A. hypochondriacus* and *A. caudatus* and with n=17 are *A. tricolor, A. spinosu, A. virdis, A. cruentus and A. bilatum*. *Amaranthus* species have different centre of domestication and origin, being widely distributed in North America, Central America, and the South America Andes, where the greatest genetic diversity is found (Sun *et al*. 1999; Xu and Sun, 2001). It is estimated that there are 87 species of Amaranthus: 17 in Europe, 14 in Australia and 56 in America (Mujica and Jacobsen, 2003) [10]. The production of *Amaranthus* (Ramdana) in Uttarakhand is cultivated in a wide range of soils and under diverse climate conditions. The production and productivity of amaranthus crops is approximately 2939 mt and 4.840 quintal per ha from approximately 6072 ha area reported by Khamgonkar *et al*. 2013. Grain amaranth is an important multifarious-utility cash crop of the higher hills where, it is grown mainly as a pure crop. Amaranth seed is having protein (15-18%) and contains respectable amounts of lysine (Marx, 1997) [9], and methionine, two essential amino acids that are not frequently found in grains. Favorable composition of grain amaranth flour helps in prevention of certain disease like heart condition, diabetes, brain stoke etc. Also, the high content of fiber and starch has a positive effect on digestion disorder (Peterka *et al*. 2001) [15].
Amaranth is one of the most important underutilized crops for Himalayan agriculture and is often considered as 'minor crops'. However, it was once grown more widely or intensively, but failed into disuse for a variety of agronomic, genetic, economics and cultural reasons.

Use of this crop by farmers and consumers are less in practice because it is not competitive enough with other species for same agro climatic zone. Consequently, this species has been neglected and genetic erosion of their gene pools has become severe.

These crops are usually characterized by local importance in consumption and production systems, receives scarce attention by national agricultural setup and biodiversity conservation board, which are mainly consisting of local types or landraces and being cultivated with indigenous knowledge. Genetic variability plays an important role in the selection of best genotypes for rapid improvement in yield, and economic trait along with potential parent for hybridization programmes.

## Materials and Methods

### Plant Material

The seed material of 50 genotypes and four checks used in the present investigation was obtained from Project Coordinator Unit of All India Coordinator Research Project on Under Utilized Crop, NBPGR, regional station Shimla while the check PRA-2 and PRA-3 was received from Department of Crop Improvement. Ranichauri. Durga and Annapurna was received from NBPGR, Shimla.

The 54 genotypes including four checks (Annapurna, Durga, PRA-2 and PRA-3) were planted in an augmented design during Kharif- 2013 under ranifed condition. There were 5 blocks, each block with 10 genotypes. The checks were randomly allocated along with the new genotypes in block. Each block comprises of 10 genotypes and each genotypes sown in single row with four checks.

## Results and Discussion

The analysis of variance for all nine characters under investigation is showed in Table 1. The analysis of variance released that mean sum of squares. The observation of 5 plants randomly selected in each entry for seed yield and its component characters were used for analysis the mean performance. The mean performance of 54 genotypes for various characters studied is given in Table 2. The results for the plant growth and seed yield characters was summarized All the genotypes take for investigation showed days to 50% flowering between 63.20 (Durga) to 87.40 (EC-519523 and EC-519556), The general mean of 50% flowering was 77.67 days. A wide range of variability in days to 50 % flowering has also been reported by Lokeshkumar and Murthy (2017) [8] (29 days to 44 days); Kumar and Yassin (2013) [6] (31.12 days to 59.79 days); Sravanthi *et al*. (2012) [18] from 22.67 days to 78.67 days and Varalakshmi (2012) [20] from 69 days to 89 days in amaranth.

Wide range of variability was found for day to maturity which range from 128.00 days to 142.80 days. Lowest value for day to maturity was found in Durga (128.00 days). The overall mean for day to maturity was 140.28 days. Differences in days to maturity in grain amaranth genotypes have also been expressed by Diwan *et al*. (2017) [2] (100.25 days to 117.48 days) and Patial *et al*. (2014) [14] from 129.33 days to 145.33 days.

Plant height was found in the range of 81.83 cm to 148.00 cm. Significantly higher plant height 148.00 cm was observed in IC-95339 and minimum value was observed for IC-42421 (81.83 cm). The general mean of population for plant height was 132.12 cm. Variability in plant height of amaranth has also been reported by Diwan *et al*. (2017) [2] 8.39 cm to 12.15 cm, Lokeshkumar and Murthy (2017) [8] 23.37 cm to 140.72 cm, Panda *et al*. (2017) 34.52 cm to 70.18 cm, Patial *et al*. (2014) [14] from 154.10 cm to 200.35 cm, Hasan *et al*. (2013) 77.5 cm to 143.9 cm Kumar and Yassin (2013) [6] from 60.72 cm to 96.21 cm, Ahammed *et al*. (2012) [1] from 101.3 cm to 145.00 cm Erum *et al*. (2012) [3] from 67 cm to 116.7 cm, Sravanthi *et al*. (2012) [18] from 58.47cm to 172.53, Smitha and Krishnahakumary (2011) (138 cm maximum in variety GA-22) and Pandey *et al*. (2010) from 15.16 cm to 87.2 cm.

Wide range of variability was observed among the genotypes for Inflorescence length i.e., in IC-82625 (84.12 cm) and minimum length was observed in IC-42421 (23.08 cm). The overall mean for inflorescence length was 57.23 cm. Such a large extent of variability in inflorescence length might have also resulted due to diverse origin of accession coupled with environmental effect. Differences in inflorescence length of amaranth genotypes have also been expressed by Kumar and Yassin (2013) [6] from 32.46 cm to 51.97 cm, Sravanthi *et al*. (2012) [18] from 3.97 cm to 55.07 cm and Oweree *et al*. (2010) found that the maximum inflorescence length for amaranth was 52.81 cm.

Spikelet length was found in the range of 7.17 cm to 28.21 cm. The maximum and minimum range of spikelet length of spikelet was recorded in IC-42402 (28.21 cm) and IC-42421 (7.17 cm). The overall mean for spikelet length was 15.20 cm. Spikelet length is principal yield contributing character in grain amaranths. The spikelet length mainly governed by genetic constitution of the genotype but environmental effect is also supposed to play crucial role in increasing the length of spikelet. Spikelet length of grain amaranth genotypes have also been expressed by Diwan *et al*. (2017) [2] from 9.75 cm to 14.70 cm and Patial *et al*. (2014) [14] from 56.39 cm to 65.27 cm. Sravanthi *et al*. (2012) [18] from 3.97 cm to 55.07 cm.

The mean number of spikelets per plant varied from 16.44 (IC-42352) to 58.39 (IC-107144) with an overall mean of 45.60. While studding variability in amaranth genotypes, Erum *et al*. (2012) [3] have also noticed a range of 1 to 19.6 spikelets per plant.

Stem thickness ranged from 5.73 mm to 16.57 mm. The genotypes IC-95339 had highest mean stem thickness (16.57 mm). While genotypes IC-47436 exhibited minimum stem thickness (5.73 mm). The general mean for stem thickness was 11.57 mm. Stem thickness is also important in the view of selecting the population resistant to lodging. A wide range of variability among the genotypes included in this investigation could offer better opportunity of population improvement for this character through selection breeding. Variability in stem thickness of amaranth has also been reported by Panda *et al*. 2017 2.56 cm to 4.87 cm, Venkatesh *et al*. (2014) [21] 1.02 cm to 3.99 cm, Hasan *et al*. (2013) 11.80 mm to 33.20 mm Ahammed *et al*. (2012) 16.71 mm to 27.63 mm and Sravanthi *et al*. (2012) [18] have also observed a wide range of variability in stem thickness of grain amaranth genotypes with minimum 1.91 cm and maximum 5.57 cm.

Thousand seed weight of 54 grain amaranth genotypes including four checks ranged between 0.684 g (IC-95304) to 1.388 g (IC-43715) while the overall mean for thousand seed weight was 0.896 g. Seed yield per plant ranged from 2.545 g (IC-42421) to 46.69 g (IC-82625) with an overall mean 25.90 g. Lokeshkumar and Murthy (2017) had also reported a wide range of variability in 1000 seed weight from 0.23 g to 1.27 g in grain amaranth and Sravanthi *et al*. (2012) [18] Shubpreet *et al*. (2010) [16] observed a range of 0.62 g to 0.88 g kernel weight in A. hypocandriacus whereas 1000 kernel weight varied from 0.46 g to 0.70 g in A. caudatus.

**Genetic Divergence**

Using the Non- hierarchical Euclidean cluster analysis, The 54 genotypes were group into 8 different non-overlapping clusters (Table 4). Cluster II$^{nd}$ was maximum number of 21 genotypes followed by cluster I$^{st}$ with 8 genotypes and cluster VI$^{th}$ with 7 genotypes. Cluster III$^{rd}$ possessed 6 genotypes while cluster VII$^{th}$ were represented by 4 entries. Cluster IV$^{th}$ having 2 genotypes and cluster VIII$^{th}$ had only one genotype (Durga). Earlier workers have also reported existence of substantial genetic divergence in grain amaranth materials (Shukla and Singh 2002; Verma *et al*. 2002: Kusuma *et al*. 2007 [7]; Pandey and Singh 2011; Ahmmed *et al*. 2013 and Hasan *et al*. 2013; Lokeshkumar and Murthy 2017) [8, 22].

Intra cluster distance (Table 5) was observed out of eight clusters, cluster VII$^{th}$ had maximum intra cluster distance (13.32) followed by VI$^{th}$ (11.67), cluster IV$^{th}$ (10.03), cluster V$^{th}$ (9.56), cluster I$^{st}$ (8.28), cluster II$^{nd}$ (5.98) and Cluster III$^{rd}$ (4.39). High Intra-cluster genetic distance is a measure of genetic heterogeneity of genotypes included in that cluster. High intra-cluster genetic in cluster VII$^{th}$ was because of heterogeneous composition of that cluster.

Inter-cluster genetic distance was recorded between III$^{rd}$ and VII$^{th}$ (67.39) followed by IV$^{th}$ and VII$^{th}$ (64.30), IV$^{th}$ and VIII$^{th}$ (61.75), VII$^{th}$ and VIII$^{th}$ (58.22) and cluster V$^{th}$ and VII$^{th}$ (53.07). Selection of genotypes belonging to clusters with maximum inter-cluster distance for hybridization had also been proposed by Verma *et al*. 2002 [22]; Kusuma *et al*. 2007 [7]; Pandey and Singh 2011 and Ahmmed *et al*. 2013 Lokeshkumar and Murthy 2017 [8].

**Cluster means**

A close perusal of these cluster means (Table 6) for different characters indicated that considerable differences existed among the cluster for all the nine characters. Cluster I$^{st}$ having 8 genotypes, showed highest cluster means for stem thickness (13.48 mm), cluster II$^{nd}$, having 21 genotypes, exhibit highest cluster means for number of spikelet per plant (52.28). Cluster IV$^{th}$ having 2 genotypes exhibited highest cluster means for plant height (145.04 cm), inflorescence length (82.75 cm), spikelet length (20.59 cm) and thousand seed weight (1.26 mg). Cluster V$^{th}$ having 5 genotypes exhibited highest cluster means for seed yield per plant (33.05 mg). Cluster VII$^{th}$ having one genotype (Durga) showed lowest cluster means for days to 50% flowering (63.20) and days to maturity (128).

**Table 1:** Analysis of variance (ANOVA) for different characters of grain amaranths genotypes.

| S. No. | Characters DF | Mean of squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | Block | Entries | Checks | Varieties | Checks vs. Varieties | Error |
| | | 4 | 53 | 3 | 49 | 1 | 12 |
| 1. | Days to 50% flowering | 52.82** | 33.93** | 131.38** | 9.38 | 944.24** | 4.25 |
| 2. | Days to maturity | 2.30 | 16.04** | 163.38** | 2.61 | 232.01** | 2.63 |
| 3. | Plant height (cm) | 28.71 | 239.41** | 493.90** | 189.22** | 1935.56** | 25.10 |
| 4. | Inflorescence length (cm) | 215.65** | 148.58** | 22.00 | 155.66** | 181.07* | 29.35 |
| 5. | Spikelet length (cm) | 11.45* | 18.32** | 10.48 | 18.37** | 39.34** | 3.30 |
| 6. | No. of spikelets per plant | 11.72 | 135.02** | 322.15** | 104.76** | 1056.57** | 3.75 |
| 7. | Stem thickness (mm) | 16.51** | 6.39** | 2.50 | 6.67** | 4.13 | 1.78 |
| 8. | 1000 seed weight (g) | 0.05 | 0.01 | 0.04 | 0.01 | 0.04 | 0.04 |
| 9. | Seed yield per plant (g) | 31.34 | 81.12 | 8.15 | 86.12 | 55.16 | 54.09 |

* Significant at 0.05 % level; **Significant at 0.01 % level

**Table 2:** Adjusted mean for different field parameters of grain amaranth.

| S. No. | Characters | Days to 50% flowering | Days to maturity | Plant height (cm) | Inflorescence length (cm) | Spikelet length (cm) | No. of spikelet per plant | Stem thickness (mm) | 1000 Seed weight(g) | Seed yield per plant (g) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Genotypes | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1. | IC-42346-6 | 77.65 | 140.80 | 142.69 | 61.52 | 20.25 | 45.64 | 14.31 | 0.866 | 38.60 |
| 2. | IC-42352 | 84.65 | 141.80 | 132.35 | 37.60 | 16.01 | 16.44 | 6.57 | 0.726 | 5.70 |
| 3. | IC-42353 | 76.65 | 139.80 | 138.81 | 60.94 | 20.81 | 31.64 | 11.01 | 0.942 | 25.10 |
| 4. | IC-42356 | 77.65 | 138.00 | 136.93 | 56.92 | 13.69 | 52.04 | 13.87 | 0.822 | 12.75 |
| 5. | IC-42358 | 76.65 | 140.80 | 109.09 | 41.68 | 11.13 | 36.24 | 9.29 | 0.830 | 35.20 |
| 6. | IC-42397 | 76.65 | 141.80 | 137.93 | 52.68 | 20.59 | 31.64 | 14.82 | 0.870 | 33.30 |
| 7. | IC-42402 | 78.65 | 137.80 | 142.87 | 59.70 | 28.21 | 35.24 | 14.01 | 0.810 | 36.95 |
| 8. | IC-42415 | 77.65 | 141.80 | 133.75 | 62.38 | 13.53 | 50.64 | 15.44 | 0.874 | 23.45 |
| 9. | IC-42421 | 77.65 | 141.80 | 81.83 | 23.08 | 7.17 | 34.04 | 8.53 | 0.882 | 2.54 |
| 10. | IC-42776-2 | 79.65 | 139.80 | 140.57 | 69.68 | 17.11 | 36.84 | 12.76 | 0.946 | 27.75 |
| 11. | IC-42987-4 | 76.15 | 139.30 | 144.21 | 67.52 | 18.12 | 34.84 | 11.64 | 0.968 | 43.14 |
| 12. | IC-43715 | 78.15 | 140.30 | 139.83 | 60.90 | 10.14 | 31.04 | 11.35 | 1.388 | 27.69 |
| 13. | IC-47434 | 81.15 | 141.30 | 126.33 | 56.14 | 12.92 | 30.24 | 9.40 | 1.092 | 24.94 |
| 14. | IC-47436 | 82.15 | 141.30 | 95.87 | 45.10 | 11.98 | 39.64 | 5.73 | 0.936 | 13.99 |
| 15. | IC-82625 | 78.15 | 141.30 | 146.35 | 84.12 | 20.52 | 47.04 | 11.02 | 1.320 | 46.69 |
| 16. | IC-93946 | 78.15 | 138.30 | 140.45 | 82.82 | 13.54 | 56.04 | 10.31 | 1.164 | 25.14 |
| 17. | IC-94656 | 76.15 | 139.30 | 139.03 | 61.46 | 13.26 | 56.24 | 12.42 | 1.176 | 45.44 |
| 18. | IC-94661 | 78.15 | 140.30 | 111.21 | 48.70 | 11.74 | 44.64 | 6.53 | 1.128 | 15.49 |
| 19. | IC-95247 | 68.15 | 137.30 | 143.73 | 81.38 | 20.66 | 46.44 | 13.41 | 1.200 | 36.12 |
| 20. | IC-95249 | 75.15 | 141.30 | 140.33 | 56.26 | 9.46 | 54.24 | 12.57 | 1.208 | 44.19 |
| 21. | IC-95250 | 76.40 | 139.30 | 135.55 | 69.37 | 16.67 | 55.34 | 13.16 | 0.900 | 23.29 |
| 22. | IC-95251 | 76.40 | 141.30 | 129.45 | 64.91 | 10.63 | 55.94 | 10.72 | 1.140 | 22.79 |
| 23. | IC-95253 | 77.40 | 139.30 | 123.19 | 51.73 | 15.83 | 55.34 | 9.87 | 0.896 | 28.19 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 24. | IC-95277 | 76.40 | 140.30 | 135.23 | 54.03 | 24.19 | 56.34 | 11.83 | 0.984 | 27.85 |
| 25. | IC-95279 | 77.40 | 140.30 | 139.05 | 62.37 | 14.17 | 54.74 | 12.55 | 0.716 | 31.04 |
| 26. | IC-95284 | 69.40 | 139.30 | 134.21 | 47.17 | 13.45 | 53.14 | 8.35 | 1.000 | 28.09 |
| 27. | IC-95286 | 74.40 | 141.30 | 136.57 | 45.97 | 17.39 | 55.94 | 11.76 | 0.872 | 24.04 |
| 28. | IC-95292 | 78.40 | 140.30 | 138.87 | 52.11 | 11.15 | 55.94 | 11.19 | 0.816 | 25.12 |
| 29. | IC-95299 | 74.40 | 141.30 | 139.83 | 61.35 | 17.75 | 55.34 | 11.77 | 0.788 | 26.44 |
| 30. | IC-95301 | 77.40 | 141.30 | 138.15 | 49.59 | 13.07 | 53.94 | 11.63 | 0.872 | 23.63 |
| 31. | IC-95302 | 72.40 | 140.80 | 130.47 | 53.36 | 17.08 | 56.59 | 12.55 | 0.812 | 25.12 |
| 32. | IC-95304 | 72.40 | 140.80 | 134.91 | 52.80 | 15.90 | 54.19 | 13.37 | 0.684 | 24.67 |
| 33. | IC-95308 | 76.40 | 141.80 | 137.31 | 70.02 | 16.84 | 56.39 | 14.29 | 0.872 | 30.22 |
| 34. | IC-95313 | 76.40 | 142.80 | 131.91 | 78.24 | 15.44 | 53.59 | 14.63 | 0.792 | 19.58 |
| 35. | IC-95315 | 78.40 | 140.80 | 130.51 | 60.54 | 14.44 | 54.99 | 8.15 | 0.820 | 18.52 |
| 36. | IC-95316 | 71.40 | 141.80 | 138.55 | 56.96 | 20.08 | 50.59 | 11.58 | 0.752 | 31.22 |
| 37. | IC-95321 | 74.40 | 142.80 | 136.35 | 61.56 | 17.10 | 40.79 | 11.95 | 0.844 | 25.77 |
| 38. | IC-95322 | 75.40 | 141.80 | 137.09 | 54.80 | 14.04 | 49.39 | 11.74 | 0.884 | 23.72 |
| 39. | IC-95326 | 78.40 | 140.80 | 120.09 | 52.12 | 10.48 | 32.79 | 8.72 | 0.828 | 19.52 |
| 40. | IC-95330 | 79.40 | 142.80 | 131.41 | 50.30 | 13.82 | 41.99 | 8.51 | 0.852 | 21.72 |
| 41. | IC-95334 | 84.40 | 142.80 | 144.58 | 61.44 | 13.60 | 52.99 | 13.17 | 0.755 | 33.73 |
| 42. | IC-95339 | 82.40 | 140.80 | 148.00 | 60.44 | 17.82 | 41.79 | 16.57 | 0.831 | 21.38 |
| 43. | IC-107127 | 86.40 | 142.80 | 137.66 | 59.92 | 12.88 | 46.39 | 13.54 | 0.779 | 22.38 |
| 44. | IC-107144 | 84.40 | 142.80 | 147.64 | 57.36 | 16.44 | 58.39 | 15.07 | 0.783 | 30.58 |
| 45. | EC-146543 | 86.40 | 139.80 | 91.26 | 62.38 | 13.70 | 38.19 | 8.57 | 0.743 | 5.48 |
| 46. | EC-146546 | 85.40 | 140.80 | 140.16 | 46.52 | 13.30 | 47.99 | 12.88 | 0.703 | 29.98 |
| 47. | EC-519512 | 86.40 | 141.80 | 126.96 | 48.40 | 13.42 | 56.19 | 12.43 | 0.699 | 21.28 |
| 48. | EC-519523 | 87.40 | 139.80 | 139.16 | 59.30 | 14.88 | 50.59 | 10.54 | 0.819 | 20.03 |
| 49. | EC-519556 | 87.40 | 135.80 | 138.00 | 53.28 | 18.60 | 31.99 | 12.69 | 0.911 | 26.72 |
| 50. | EC-524457 | 75.40 | 135.80 | 133.02 | 45.56 | 11.30 | 33.39 | 11.89 | 0.731 | 14.34 |
| 51. | ANNAPURNA | 69.40 | 140.00 | 119.98 | 54.04 | 14.62 | 29.56 | 10.30 | 0.700 | 29.06 |
| 52. | PRA-2 | 74.40 | 139.00 | 122.41 | 56.15 | 14.52 | 45.72 | 11.04 | 0.914 | 26.29 |
| 53. | PRA-3 | 73.60 | 139.20 | 133.60 | 54.44 | 13.99 | 43.24 | 10.95 | 0.901 | 28.48 |
| 54. | DURGA | 63.20 | 128.00 | 109.38 | 51.10 | 11.53 | 32.04 | 12.01 | 0.860 | 27.04 |
| Mean | | 77.67 | 140.28 | 132.12 | 57.23 | 15.20 | 45.60 | 11.57 | 0.896 | 25.90 |
| Std. Dev. | | 4.96 | 2.33 | 13.63 | 10.79 | 3.82 | 10.14 | 2.31 | 0.161 | 9.26 |
| Std. Error | | 0.67 | 0.31 | 1.85 | 1.47 | 0.52 | 1.38 | 0.31 | 0.022 | 1.26 |
| C.V. % | | 6.39 | 1.66 | 10.31 | 18.86 | 25.12 | 22.25 | 20.02 | 17.91 | 35.77 |
| C.D % | | 2.84 | 2.23 | 6.09 | 7.46 | 2.50 | 2.67 | 1.84 | 0.29 | 10.13 |
| Lowest | | 63.20 | 128.00 | 81.83 | 23.08 | 7.17 | 16.44 | 5.73 | 0.684 | 2.545 |
| Highest | | 87.40 | 142.80 | 148.00 | 84.12 | 28.21 | 58.39 | 16.57 | 1.388 | 46.69 |

**Table 3:** Contribution of different plant growth and seed yield characters to total divergence in grain amaranth.

| S. No. | Source | Number of times appearing first in ranking | Contribution % |
|---|---|---|---|
| 1. | Days to 50% flowering | 72 | 5.03% |
| 2. | Days to maturity | 1 | 0.07% |
| 3. | Plant height (cm) | 403 | 28.16% |
| 4. | Inflorescence length (cm) | 329 | 22.99% |
| 5. | Spikelet length (cm) | 29 | 2.03% |
| 6. | No. of spikelet per plant | 397 | 27.74% |
| 7. | Stem thickness (mm) | 1 | 0.07% |
| 8. | 1000 seed weight (g) | 0.01 | 0.00% |
| 9. | Seed yield per plant (g) | 199 | 13.91% |

**Table 4:** Clustering pattern of 54 genotypes of grain amaranth on the basic of genetic divergence.

| Cluster | Number of genotypes | Genotypes |
|---|---|---|
| I | 8 | IC- 42346-6, IC- 42397, IC- 95339, IC- 42353, IC- 42776-2, IC- 42987-4, IC- 42402, EC-519556 |
| II | 21 | IC-95250, IC-95308, IC-42415, IC-95279, IC-95313, IC-95299, IC-95316, IC-95321, IC- 95302, IC-95304, IC-95286, IC-95277, IC-95301, IC-95322, IC-95292, IC-95315, IC-42356, PRA-2, PRA-3, IC-95253, IC-95284 |
| III | 6 | IC-95334, IC-107144, EC-146546, EC-519512, IC-107127, EC-519523 |
| IV | 2 | IC-82625, IC-95247 |
| V | 5 | IC-93946, IC-95251, IC-43715, IC-94656, IC-95249 |
| VI | 7 | IC-42358, ANNAPURNA, IC-95326, IC-95330, IC-47436, EC-524457, IC-42352 |
| VII | 4 | IC-47436, IC-94661, EC-146543, IC-42421 |
| VIII | 1 | DURGA |

**Table 5:** Intra and inter cluster distance $D^2$ values among 54 genotypes of grain amaranth.

| | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| I | 8.28 | 12.72 | 14.43 | 19.67 | 20.17 | 20.38 | 41.79 | 50.91 |
| II | | 5.98 | 10.15 | 23.50 | 14.69 | 15.86 | 29.59 | 47.65 |
| III | | | 4.39 | 34.21 | 19.86 | 18.49 | 32.21 | 67.39 |
| IV | | | | 10.03 | 16.81 | 41.12 | 64.30 | 61.75 |
| V | | | | | 9.56 | 24.52 | 37.86 | 53.07 |
| VI | | | | | | 11.67 | 19.00 | 45.62 |
| VII | | | | | | | 13.32 | 58.22 |
| VIII | | | | | | | | 0.00 |

**Table 6:** Intra cluster group means for various components of grain amaranth.

| S. No | Characters | Cluster Mean | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | VI | VII | VIII |
| 1. | Days to 50% flowering | 79.40 | 75.33 | 85.73 | 73.15 | 76.80 | 77.86 | 81.08 | 63.20 |
| 2. | Days to maturity | 139.48 | 140.71 | 141.80 | 139.30 | 140.10 | 140.47 | 140.80 | 128.00 |
| 3. | Plant height (cm) | 141.63 | 134.50 | 139.36 | 145.04 | 137.82 | 124.61 | 95.04 | 109.38 |
| 4. | Inflorescence length (cm) | 60.72 | 57.72 | 55.49 | 82.75 | 65.27 | 48.21 | 44.82 | 51.10 |
| 5. | Spikelet Length (cm) | 20.19 | 15.73 | 14.09 | 20.59 | 11.40 | 12.90 | 11.15 | 11.53 |
| 6. | No. of spikelet per plant | 36.20 | 52.58 | 52.09 | 46.74 | 50.70 | 31.52 | 39.12 | 32.04 |
| 7. | Stem thickness (mm) | 13.48 | 11.98 | 12.94 | 12.22 | 11.47 | 9.24 | 7.34 | 12.01 |
| 8. | 1000 seed weight (g) | 0.89 | 0.84 | 0.75 | 1.26 | 1.21 | 0.82 | 0.92 | 0.86 |
| 9. | Seed yield per plant (g) | 31.62 | 25.12 | 26.33 | 41.41 | 33.05 | 21.50 | 8.60 | 27.04 |

**Contribution of different characters**

The relative contribution of different quantitative characters in stated that plant height (28.16%) near genetic divergence (22.99%), seed yield per plant (13.91%), days to 50% flowering (5.03%) and spikelet length (2.03%) show low contribution near genetic divergence, while remaining 3 character played negligently role less (<1%) in contributing genetic diversity (Table 3).

**Conflict of Interest**

We declare no conflict of Interest.

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