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Studies on growth and seed yield of grain Amaranthus (*Amaranthus hypochondriacus* L.)

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Abstract
The present investigations were carried out during rabi 2017-18 at AICRN on Potential Crops, M.P.K.V. Rahuri for testing the qualitative and quantitative characters of sixteen grain amaranthus genotypes. All sixteen genotypes differed for qualitative characters *viz*. plant growth habit (spreading, erect and drooping), leaf colour (pinkish green, yellowish green, green and reddish green), inflorescence colour (yellowish green, pink and yellow), stem colour (yellow, yellowish green and reddish green), stem surface (ridged and smooth), inflorescence shape (globose, straight and semidrooping), inflorescence spininess (smooth and spiny) and seed colour (creamish, pale yellow and brown). The results on quantitative characters revealed that genotype RHGA 13-4 gave better performance for yield and yield contributing characters followed by RGAG 12-8 and RGAG 16-11. Among the genotypes, RHGA 13-4 recorded significantly for leaf length, stem thickness, inflorescence length, plant height and seed yield per hectare while the genotype RGAG 12-27 showed early flowering days and days to maturity.

Keywords: Grain amaranthus, *Amaranthus hypochondriacus* L.

Introduction
Amaranthus is a annual or short-lived perennial plants, including domesticated and endangered species, restricted endemics and widespread weeds (Sauer, 1950) [15]. Amaranthus is cultivated as a minor food crop in Central and South America, Mexico and parts of Asia and Africa (Iturbide and Gispert, 1994) [5]. Grain amaranth belongs to the order *Caryophyllales*, family *Amaranthaceae*, sub-family *Amaranthoideae*, genus *Amaranthus* (Sauer, 1967) [16]. There are different types of species, *A. hypochondriacus* (prince's father) and *A. cruentus* (purple amaranth) which are commonly grown for grain and *A. tricolor* (tampala) grown primarily for the leaves. A fourth *A. caudatus* (love-lies-bleeding) is third type of grain species, although is often grown more as an ornamental (O'Brien and Price, 1983) [11]. Amaranth, a C_4 plant, is one of a few dicots in which the first product of photosynthesis is a four carbon compound. The combination of anatomical features in amaranth and C_4 metabolism, results in increased efficiency to use CO_2 under wide range of both temperate and moisture stress environments. This contributes to the plant's wide geographic adaptability to diverse environmental conditions (Wyn. Williams *et al.* 1985) [20].
In addition to proteins, carbohydrates, dietary fiber and lipids, grain amaranth also contains high levels of calcium, iron, magnesium, phosphorus, copper, manganese cobalt, chromium, iodine, selenium, zinc, molybdenum and sodium like other cereals (Becker *et al.* 1981) [2] which are also required by the human body in very small quantities (generally less than 100 micrograms/day).
Underutilized crops like amaranth have recently gained worldwide attention in this respect as this crop contain abundant amount of all the common nutrients required for normal human growth. The high nutritional value of Amaranthus seeds, functional potential, short lifecycle, rapid growth, adaptability to unfavorable climate and soil condition, drought tolerance and the food use of the entire plant is the reason for increasing research interest in this pseudocereal. This is a food for future crop for many developing countries, particularly in drought-prone areas of Africa and Asia. However, genus Amaranthus consists of some of the troublesome invasive or noxious weeds of the world which are known to compete with many economic crops in different parts of the world resulting in great yield losses. Hence, extensive research is required to choose between the good and bad Amaranths.
Thus, the production of good quality seed is the challenging work for this crop as it is difficult to maintain the genetic stability. It is the need for future to increase the qualitative yield of Amaranth for mitigating the nutritional need of increasing population. Keeping this view, the present investigation was carried out to morphologically characterize the grain amaranthus genotypes according to DUS guidelines and to evaluate for yield and yield contributing characters.

Materials and Methods

The experimental trail was conducted at AICRN on Potential Crops at M.P.K.V. Rahuri, during *rabi* 2017-18 to study the growth, seed yield and quality of grain amaranthus (*Amaranthus hypochondriacus* L.). The experiment consisted of sixteen genotypes grown in Randomised Block Design with three replications. The observations were recorded on five randomly selected plants from each genotype in each replication and averages were worked out. The qualitative observations of grain amaranthus was observed for plant growth habit, leaf colour, inflorescence colour, stem colour, stem surface, inflorescence shape, inflorescence spininess and seed colour as per the DUS guidelines developed by IIHR, Bangaluru which were finalized by the Task force committee of PPV & FRA (Anonymous, 2014) [1]. The quantitative observations were taken on leaf length, petiole length**,** days to 50 percent flowering, stem thickness, plant height, inflorescence length**,** days to maturity, seed yield /plant, seed yield/plot and seed yield/ha. The data was statistically analyzed as per the procedure given by Panse and Sukhatme (1967) [13]

Results and Discussion

Qualitative characters

The data on qualitative characters of grain amaranthus are presented in Table 1. The genotypes RGAG 12-8, RGAG 12-11, RGAG 12-28, RHGA 13-4 and RGAG 16-11 showed spreading type of growth habit whereas the RGAG 12-16, RGAG 12-27, RGAG 16-08, RGAG 16-12, RGAG 15-1 genotypes exhibited erect type of growth habit. The drooping type of growth habit was recorded in RGAG 14-2, RGAG 15-3, RGAG 16-05, RGAG 16-07, RGAG-16-10 and Phule Kartiki (C). Similar observations were recorded by Williams and Brenner (1995) [19] in different grain amaranthus. For leaf colour the genotypes RGAG 12-8, RGAG 12-11, RGAG 12-27, RGAG 14-2, RGAG 16-07 and RGAG 16-08 showed pinkish green colour of leaf whereas yellowish green leaf colour was exhibited in the genotypes RGAG 12-16, RGAG 16-10, RGAG 16-12. The green colour of leaf was recorded in RGAG 12-28, RHGA 13-4, RGAG-16-05 and Phule Kartiki (C) however the RGAG 15-3, RGAG 16-11 and RGAG 15-1 genotypes showed reddish green leaf colour. Similarly, for inflorescence colour the genotypes RGAG 12-8, RGAG 12-11, RHGA 13-4, RGAG 16-11 and Phule Kartiki (C) showed yellowish green inflorescence colour whereas, RGAG 12-16, RGAG 12-27, RGAG 15-3, RGAG 16-07 and RGAG 16-10 exhibited pink colour of inflorescence. The yellow colour of inflorescence was recorded in RGAG 12-28, RGAG 16-05, RGAG 16-12 while RGAG 14-2, RGAG 16-08 and RGAG 15-1 genotypes showed purple colour of inflorescence. Similar observations were also reported by Chatarmal and Kute (2013) [3] in grain amaranthus. For stem colour the genotypes RGAG 12-8, RGAG 12-11, RHGA 13-4, RGAG 16-11 and Phule Kartiki (C) showed yellow stem colour whereas the RGAG 12-16, RGAG 12-28, RGAG 16-05, RGAG 16-10 and RGAG 16-12 exhibited yellowish green stem colour. The reddish green stem colour was observed in RGAG 12-27, RGAG 14-2, RGAG 15-3, RGAG 16-07, RGAG 16-08 and RGAG 15-1.

The genotypes RGAG 12-16, RGAG 12-28, RHGA 13-4, RGAG 16-05, RGAG 16-10 and RGAG 16-12 showed smooth type of stem surface whereas RGAG 12-8, RGAG 12-11, RGAG 12-27, RGAG 14-2, RGAG 15-3, RGAG 16-07, RGAG 16-08, RGAG 16-11, RGAG 15-1 and Phule Kartiki (C) exhibited ridged type of stem surface. For inflorescence shape the genotypes RGAG 12-8, RGAG 12-11, RGAG 12-28, RHGA 13-4 and RGAG 16-11 showed globose type of inflorescence shape whereas the RGAG 12-16, RGAG 12-27, RGAG 14-2, RGAG 15-3, RGAG 16-05, RGAG 16-08 and RGAG 16-12 genotypes exhibited straight type of inflorescence shape. The semidrooping type of inflorescence shape was observed in RGAG 16-07, RGAG 16-10, RGAG 15-1 and Phule Kartiki (C). Similar type of observations was also recorded by Kunj Chandra and Kute (2017) [9]. Further, the genotypes RGAG 12-8, RGAG 12-11, RGAG 12-27, RGAG 16-07 and RGAG 16-11 showed smooth type inflorescence spininess whereas the spiny type inflorescence was exhibited in the genotypes RGAG 12-16, RGAG 12-28, RGAG 14-2, RGAG 15-3, RHGA 13-4, RGAG 16-05, RGAG 16-08, RGAG 16-10, RGAG 16-12, RGAG 15-1 and Phule Kartiki (C). For seed colour the genotypes RGAG 12-8, RGAG 16-12, RGAG 15-1 and Phule Kartiki (C) showed pale yellow type of seed colour whereas the RGAG 12-11, RGAG 12-16, RGAG 12-27, RGAG 12-28, RGAG 14-2, RGAG 15-3, RHGA 13-4, RGAG 16-05, RGAG 16-08, RGAG 16-10 and RGAG 16-11 exhibited creamish type of seed colour. The brown type of seed colour was recorded in the genotype RGAG 16-07. Williams and Brenner (1995) [19] also observed different seed colour in grain amaranthus. Variability was observed in all the genotype for plant growth habit, leaf colour, inflorescence colour, stem colour, stem surface, inflorescence shape, inflorescence spininess and seed colour.

Table 1: Characterization of sixteen grain amaranthus genotypes for qualitative characters

Sr. No.	Genotypes	Plant growth habit	Leaf colour	Inflorescence colour	Stem colour	Stem surface	Inflorescence shape	Inflorescence spininess	Seed colour
1.	RGAG 12-8	Spreading	Pinkish green	Yellowish green	Yellow	Ridged	Globose	Smooth	Pale yellow
2.	RGAG 12-11	Spreading	Pinkish green	Yellowish green	Yellow	Ridged	Globose	Smooth	Creamish
3.	RGAG 12-16	Erect	Yellowish green	Pink	Yellowish green	Smooth	Straight	Spiny	Creamish
4.	RGAG 12-27	Erect	Pinkish green	Pink	Reddish green	Ridged	Straight	Smooth	Creamish
5.	RGAG 12-28	Spreading	Green	Yellow	Yellowish green	Smooth	Globose	Spiny	Creamish
6.	RGAG 14-2	Drooping	Pinkish green	Purple	Reddish green	Ridged	Straight	Spiny	Creamish
7.	RGAG 15-3	Drooping	Reddish green	Pink	Reddish green	Ridged	Straight	Spiny	Creamish
8.	RHGA 13-4	Spreading	Green	Yellowish green	Yellow	Smooth	Globose	Spiny	Creamish
9.	RGAG 16-05	Drooping	Green	Yellow	Yellowish green	Smooth	Straight	Spiny	Creamish
10.	RGAG-16-07	Drooping	Pinkish green	Pink	Reddish green	Ridged	Semi drooping	Smooth	Brown
11.	RGAG 16-08	Erect	Pinkish green	Purple	Reddish green	Ridged	Straight	Spiny	Creamish

12.	RGAG 16-10	Drooping	Yellowish green	Pink	Yellowish green	Smooth	Semi drooping	Spiny	Creamish
13.	RGAG 16-11	Spreading	Reddish green	Yellowish green	Yellow	Ridged	Globose	Smooth	Creamish
14.	RGAG 16-12	Erect	Yellowish green	Yellow	Yellowish green	Smooth	Straight	Spiny	Pale yellow
15.	RGAG 15-1	Erect	Reddish green	Purple	Reddish green	Ridged	Semi drooping	Spiny	Pale yellow
16.	Phule Kartiki (C)	Drooping	Green	Yellowish green	Yellow	Ridged	Semi drooping	Spiny	Pale yellow

Quantitative characters

The data on quantitative characters of grain amaranthus are presented in Table 2. From the results, it was revealed that the all genotypes were early in flowering (<70 days) except RHGA 13-4 whereas the RHGA 13-4 recorded medium (70-80 days) for days to 50% flowering. None of the genotypes under study were found for late flowering (>80 days). Such earliness in flowering behavior might be related to faster emergence and better growth of plants. Harmones are also involved in flower behaviour and their active role in various physiological and bio-chemical processes of plants. Similarly less days to 50% flowering was recorded by Pushpa Rekha (1986) [14], Maruthi (1987) [10] and Vasapari *et al*. (2012) [18]. For leaf length, it is revealed that the genotypes RGAG 12-16, RGAG 12-27, RGAG 14-2, RGAG-15-3, RGAG 16-07, RGAG 16-08, RGAG 16-10, RGAG 16-12, RGAG 15-1 and Phule Kartiki had short leaf length (<18 cm). The medium leaf length (18-22 cm) was recorded in the genotypes RGAG 12-8, RGAG 12-11, RGAG 12-28, RHGA 13-4 and RGAG 16-11. Similar results were also observed by Joshi (1985) [6] and Oslusegun *et al.* (2016) in grain amaranthus. For petiole length, the genotype RHGA-13-4 (12.61 mm) showed maximum petiole length. Highest stem thickness was recorded in genotypes RHGA 13-4 (16.35 mm) while genotype RGAG 12-27 (11.80 mm) recorded lower stem thickness. For inflorescence length, it was revealed that the genotypes RGAG 12-16, RGAG 12-27, RGAG 16-08, RGAG 16-12 and RGAG 15-1 had short inflorescence length (<40 cm). The medium inflorescence length (40-70 cm) was recorded in the genotypes RGAG 12-8, RGAG 12-11, RGAG 12-28, RGAG 14-2, RGAG 15-3, RHGA 13-4, RGAG 16-05, RGAG 16-07, RGAG 16-10, RGAG 16-11 and Phule Kartiki (C). For plant height it is revealed that the genotypes RGAG 12-27, RGAG 16-08 and RGAG 15-1 had short plant height (<150 cm) while other genotypes had medium plant height. For days to maturity, the genotype RHGA 13-4 recorded 139.12 days while less days to maturity was observed in RGAG 12-27 i.e.102.59 days. For seed yield per plant, the genotype RHGA 13-4 (35.26 g) recorded significantly maximum seed yield per plant followed by RGAG 12-8 (33.27 g) and RGAG-16 11 (33.20 g). However, lowest seed yield per plant was recorded in the genotype RGAG 12-27 (22.06 g). Similar results were also found for seed yield per plant by Kumari Anjali *et al.* (2013) [8] in different grain amranthus. The data on seed yield/plot and seed yield per hectare of different grain amaranthus genotypes revealed that significantly higher seed yield/plot was recorded in genotype RHGA 13-4 while the lowest seed yield per plot was observed in genotype RGAG 12-27. Similar results were recorded for seed yield/ha by Spehar (2003) [17] and Gimplinger *et al.* (2007) [4] in grain amaranthus. It is concluded that the genotype RHGA 13-04 followed by RGAG 12-08 and RGAG 16-11 have shown better performance for seed yield and can be further utilized in breeding programme for improving the seed yield of grain amaranthus.

Table 2: Performance of sixteen Grain amaranthus genotypes for quantitative characters

S. N.	Genotypes	Days to 50% flowering (days)	Leaf length (cm)	Petiole length (cm)	Stem thickness (mm)	Inflorescence length (cm)	Plant height (cm)	Days to maturity (days)	Seed yield/plant (g)	Seed yield/plot (kg)	Seed yield/ha (qtl)
1	RGAG 12-8	Early (65.50)	Medium (18.59)	Short (11.81)	16.02	Medium (55.27)	Medium (187.20)	132.27	33.27	1.56	24.13
2	RGAG 12-11	Early (62.88)	Medium (18.43)	Short (11.67)	14.99	Medium (53.78)	Medium (181.40)	128.97	32.84	1.48	22.84
3	RGAG 12-16	Early (55.00)	Short (14.85)	Short (10.35)	13.16	Short (39.47)	Medium (153.20)	111.75	26.61	1.20	18.47
4	RGAG 12-27	Early (51.46)	Short (16.06)	Short (9.05)	11.80	Short (37.32)	Short (134.27)	102.59	22.06	1.04	16.00
5	RGAG 12-28	Early (62.63)	Medium (18.00)	Short (11.44)	14.96	Medium (49.07)	Medium (172.40)	128.30	29.73	1.40	21.55
6	RGAG 14-2	Early (61.36)	Short (17.70)	Short (11.25)	14.54	Medium (45.73)	Medium (165.87)	122.19	28.66	1.34	21.91
7	RGAG 15-3	Early (59.50)	Short (17.57)	Short (10.98)	14.44	Medium (45.18)	Medium (162.73)	118.90	28.59	1.34	20.68
8	RHAG 13-4	Medium (71.92)	Medium (19.48)	Short (12.61)	16.35	Medium (58.33)	Medium (187.47)	139.12	35.26	1.66	25.56
9	RGAG 16-05	Early (62.20)	Short (17.83)	Short (11.46)	14.63	Medium (46.63)	Medium (166.53)	127.28	28.67	1.35	20.78
10	RGAG 16-07	Early (59.00)	Short (16.75)	Short (10.69)	14.16	Medium (44.75)	Medium (159.27)	118.32	28.52	1.31	20.27
11	RGAG 16-08	Early (53.63)	Short (14.65)	Short (9.78)	12.46	Short (38.37)	Short (137.87)	106.37	23.20	1.09	16.82
12	RGAG 16-10	Early (57.01)	Short (15.12)	Short (10.48)	13.45	Medium (41.60)	Medium (157.00)	114.71	27.17	1.27	19.55
13	RGAG 16-	Early (64.77)	Medium	Short	15.73	Medium (54.33)	Medium	129.87	33.20	1.54	23.82

	11		(18.44)	(11.73)			(185.73)				
14	RGAG 16-12	Early (56.14)	Short (15.49)	Short (10.41)	13.43	Short (39.74)	Medium (154.60)	112.96	26.96	1.25	19.29
15	RGAG 15-1	Early (54.34)	Short (14.73)	Short (10.02)	13.12	Short (38.74)	Short (138.47)	108.70	24.13	1.13	17.49
16	Phule Kartiki (C)	Early (58.21)	Short (16.35)	Short (10.49)	13.56	Medium (44.49)	Medium (154.47)	116.14	27.93	1.28	19.70
	Mean	Early (59.60)	Short (16.88)	Short (10.89)	14.18	Medium (45.79)	Medium (162.40)	119.90	28.55	1.33	20.55
	SE (±)	2.12	0.90	0.38	0.19	2.41	11.24	4.31	1.69	0.08	1.25
	CD at 5%	6.13	2.60	1.10	0.55	6.98	32.47	12.46	4.89	0.23	3.62

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