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Short Communication

Seed Yield and Quality of Grain Amaranthus (*Amaranthus hypochondriacus* L.)

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Amaranthus is an annual or short-lived perennial plants, including domesticated and endangered species, restricted endemics and widespread weeds [1]. Amaranthus is cultivated as a minor food crop in Central and South America, Mexico and parts of Asia and Africa [2]. Grain amaranth belongs to the order *Caryophyllales*, family *Amaranthaceae*, sub-family *Amaranthoideae*, genus *Amaranthus* [3]. There are different types of species, *A. hypochondriacus* (prince's father) and *A. cruentus* (purple amaranth) are commonly grown for grain and *A. tricolor* (tampala) is 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 [4]. 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 [5]. The seed is lenticular and relatively small (0.9 to 1.7 mm diameter) with 1000 seed weight from 0.6 to 1g. The colour of the seed of amaranth varies from white, gold, brown and pink to black [6].

Hand harvested yields have been as high as 4000 kg/ha in Montana [7] and 6000 kg/ha in Peru [8], between 2500 and 3300 kg/ha in southwest Germany [9] between 2100 and 2700 kg/ha in Slovak Republic [10] and 1200 kg/ha in India [11]. 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 [12] 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 unfavourable climate and soil condition, drought tolerance and the food use of the entire plant is the reason for increasing research interest in this pseudo-cereal. 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.

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 in view the present investigation was carried out on grain Amaranthus.

An experiment was conducted in the Department of Seed Science and Technology, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri during the year 2017-2019 to study the growth, seed yield and quality of grain amaranthus (*Amaranthus hypochondriacus* L.). The experiment consisted of following sixteen genotypes were given in Table 1.

The fresh seed were stored in container and the following seed quality parameters were tested at 3 and 9 months of storage.

Table 1

1.	RGAG 12-8	5.	RGAG 12-28	9.	RGAG 16-05	13.	RGAG 16-11
2.	RGAG 12-11	6.	RGAG 14-2	10.	RGAG 1-07	14.	RGAG 16-12
3.	RGAG 12-16	7.	RGAG 15-3	11.	RGAG 16-08	15.	RGAG 15-1
4.	RGAG 12-27	8.	RHGA 13-4	12.	RGAG 16-10	16	Phule Kartiki (C)

Germination

The germination was tested according to ISTA Rule [13]. Hundred seeds of each genotype were kept for germination in four replication in seed germinator at 25^0C temperature and at 95 percent relative humidity for 8 days using top paper method. Accordingly germination percentage was computed on normal seedling with the formula given below.

$$\text{Germination (\%)} = \frac{\text{Number of normal seedling}}{\text{Total numbers of seeds kept for germination}} \times 100$$

Seedling length

Ten normal seedlings were selected at random from each genotype on 8th day (final count day) of the germination test and used for measuring seedling length. The seedling length was measured from the base of the primary root to the first emerging leaf of seedling and the mean was expressed in centimeter.

Vigour Index I

Ten normal seedlings from each replication were selected for calculation of vigour index I [14] and was calculated as under:

Vigour index I = Average seedling length [(root + shoot (cm)] × Average germination percentage

Vigour index II

Immediately after germination test ten normal seedlings from each replication were selected randomly. The seedlings were dried in hot air oven at 60ºC temperature for 16 hrs. The dry weight of seedlings was weighed in milligram.

Vigour index II was assessed as under:

Vigour index II = Dry matter content of ten seedling (mg) × Germination (%)

Dry matter content of seedlings

Ten normal seedlings used for measuring root and shoot length were kept in tin plate and dried in hot air oven maintained at 60ºC temperature for 16 hours. Then seedlings were weighed after allowing them to cool in a desiccator for 30 minutes and expressed in milligram per ten seedlings.

Moisture content

Moisture content was determined by Hot Air Oven Method by grinding the 10 gm seeds on grinding mill and dried at 103±2 °C for 17±1 hours in hot air oven [15]. The percentage of moisture content was calculated on the weight basis.

$$\text{Moisture content (\%)} = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Where,

M1 = Weight of container with lid.

M2 = Weight of container with lid + seed before drying.

M3 = Weight of container with lid + seed after drying

Seed mycoflora

Standard blotter paper method recommended by International Seed Testing Association [16, 17] were used to detect the seed mycoflora of grain Amaranthus genotypes. Three discs of blotter paper was moistened with sterilized water, excess of water removed and was placed at the bottom of each petriplate and labeled. 25 seeds was placed at equidistance on blotter paper in each petriplate. For better growth and sporulation of fungal flora 12 hrs artificial light was provided by placing the plates below a tube light and alternately with 12 hrs darkness in a culture rack. Fungal growth was observed on 7 days after incubation under stereo binocular microscope.

The percent infection of seed borne pathogens on amaranth seed was calculated by taking the number of seed infected with pathogens, out of incubated seeds and multiplied with 100.

$$\text{Seedborne Pathogen Infection (\%)} = \frac{\text{Number of seeds infected}}{\text{Total number of seeds incubated}} \times 100$$

Electrical conductivity

5 gm of seeds in four replications were soaked in 25 ml distilled water and kept in incubator maintained at 25 ±1°C for 24 hrs. After soaking and gently swirling the solution.

The seeds was discarded and the leachates decanted and final volume made up to 25 ml by adding distilled water for measuring the electrical conductivity with help of Digital Electrical Conductivity Meter and expressed in dSm^{-1} [18].

Seed volume weight

After harvesting of the Amaranthus crop the seed was filled in 10 ml test tube at the 10 ml mark level. These seeds were then taken on a paper and weight of seed was recorded in grams.

The data on seed quality parameters of grain Amaranthus during the storage are presented in Table 2.

Germination percentage (%)

The genotypes differed significantly for germination percentage. At 3 months of storage the highest germination was recorded in the genotype RHGA 13-4 (70.33) which was at par with the genotypes RGAG 12-8 (66.67%) and RGAG 16-11(65.67%). The lowest germination was recorded in the genotype RGAG 12-27 (28.00%). After 9 months of storage the highest germination was recorded in the genotype RHGA 13-4 (85.69%) as compared to rest of the genotypes followed by RGAG 12-8 (70.33%). The lowest germination exhibited in the genotype RGAG 12-27 (47.98%).

The increase in germination was recorded in all the genotypes of grain Amaranthus after 9 months of storage as compared to 3 months of storage. This increase in germination might be due to breaking of dormancy in the Amaranth seed. Similar results in grain Amaranthus were reported [19].

Seedling length (cm)

The genotypes differed significantly for seedling length. At 3 months of storage the highest seedling length was recorded in the genotype RHGA 13-4 (6.97 cm) which was followed by the genotype RGAG 12-8 (6.24 cm) and RGAG 16-11 (6.16 cm). The lowest seedling length was recorded in the genotype RGAG 12-27 (3.94 cm). After 9 months of storage the highest seedling length was recorded in the genotype RHGA 13-4 (8.09 cm) as compared to rest of the genotypes followed by RGAG 12-8 (7.49 cm). The lowest seedling length exhibited in the genotype RGAG 12-27 (2.89 cm). It was revealed that the seedling length had increased after 9 months of storage as compared to 3 months of storage. Seedling length was observed 23.59 cm in Fennel [20].

Vigour index I and Vigour index II

The genotypes differed significantly for vigour index I. At 3 months of storage the highest vigour index I was

Table 2a. Seed quality of sixteen grain Amaranthus genotypes during storage

Sr. No.	Genotypes	Germination (%)		Seedling length (cm)		Vigour index I		Vigour index II	
		3	9	3	9	3	9	3	9
		Storage months							
1.	RGAG 12-8	66.67(54.75)	70.33(57.01)	6.24	7.49	208.01	256.23	559.93	1687.92
2.	RGAG 12-11	62.00(51.95)	64.65(53.54)	6.08	6.19	188.48	200.09	463.20	1485.87
3.	RGAG 12-16	42.00(40.39)	52.57(46.48)	5.07	3.60	106.47	94.62	174.70	857.37
4.	RGAG 12-27	28.00(31.95)	47.98(43.84)	3.94	2.89	55.16	69.33	44.20	673.36
5.	RGAG 12-28	59.00(50.19)	64.60(53.51)	6.00	6.03	110.	194.77	380.80	1468.57
6.	RGAG 14-2	53.89(47.23)	58.01(49.62)	5.69	4.88	153.31	141.54	276.45	1179.70
7.	RGAG 15-3	51.11(45.63)	57.42(49.27)	5.66	5.56	144.64	159.62	255.38	1147.83
8.	RHAG 13-4	70.33(57.01)	85.69(67.88)	6.97	8.09	245.10	346.61	652.03	2112.81
9.	RGAG 16-05	56.00(48.45)	60.11(50.84)	5.94	5.85	166.32	175.82	344.40	1299.20
10.	RGAG 16-07	49.00(44.43)	57.40(49.26)	5.61	4.79	137.44	137.47	237.53	1068.93
11.	RGAG 16-08	38.00(38.05)	48.97(44.40)	4.31	3.27	81.89	80.06	91.87	568.07
12.	RGAG 16-10	46.67(43.09)	53.52(47.02)	5.21	4.39	121.57	117.47	199.33	962.12
13.	RGAG 16-11	65.67(54.14)	68.12(55.84)	6.16	6.97	202.26	233.49	520.80	1617.37
14.	RGAG 16-12	44.33(41.57)	52.71(46.56)	5.09	3.99	112.81	105.15	171.57	896.71
15.	RGAG 15-1	40.00(39.23)	50.51(45.29)	4.89	3.70	97.80	93.44	104.07	640.72
16.	Phule Kartiki (C)	48.00(43.85)	57.30(49.20)	5.46	5.15	131.04	147.54	228.73	1052.51
	Mean	51.29	59.06	5.51	5.18	142.41	185.03	294.06	1158.09
	SE (±)	1.47	1.86	014	0.06	12.48	9.28	14.87	69.26
	CD at 5%	4.19	5.37	0.38	0.16	35.96	26.74	42.85	199.41

Table 2b. Seed quality of sixteen grain Amaranthus genotypes during storage

Sr. No.	Genotypes	Dry matter content of ten seedlings (mg)		Moisture content (%)	Seed mycoflora (%)	Electrical conductivity (dSm^{-1})	Seed volume weight (gm/10 ml)
		At 3 months	At 9 months				
1	RGAG-12-8	8.40	24.00	10.07(18.49)	6.67(14.80)	0.25	8.14
2	RGAG-12-11	7.47	23.00	10.40(18.82)	16.00(23.47)	0.26	8.11
3	RGAG-12-16	4.17	16.33	9.87(18.31)	26.67(31.91)	0.43	7.63
4	RGAG-12-27	1.57	14.00	10.87(19.34)	30.67(33.50)	0.47	7.52
5	RGAG-12-28	6.43	22.67	10.43(18.81)	20.00(24.49)	0.27	8.07
6	RGAG-14-2	5.13	20.33	10.43(18.81)	21.33(26.91)	0.34	8.02
7	RGAG-15-3	5.00	20.00	9.70(18.14)	21.58(28.17)	0.37	7.99
8	RHAG-13-4	9.27	24.67	9.50(17.95)	4.00(9.32)	0.24	8.15
9	RGAG-16-05	6.17	21.67	10.10(18.53)	21.33(26.91)	0.27	8.05
10	RGAG-16-07	4.83	19.00	10.27(18.69)	22.67(29.28)	0.39	7.80
11	RGAG-16-08	2.40	11.67	10.47(18.87)	28.00(31.91)	0.45	7.58
12	RGAG-16-10	4.27	18.00	10.17(18.59)	24.00(30.12)	0.42	7.71
13	RGAG-16-11	7.93	23.67	9.83(18.27)	16.00(23.47)	0.26	8.12
14	RGAG-16-12	3.87	17.00	10.00(18.43)	25.33(30.99)	0.42	7.65
15	RGAG-15-1	2.60	16.00	10.13(18.56)	28.00(31.91)	0.43	7.61
16	Phule Kartiki (C)	4.77	18.33	10.37(18.78)	24.00(30.12)	0.40	7.79
	Mean	5.27	19.40	10.12	21.58	0.35	7.87
	SE (±)	0.20	0.67	0.18	4.11	0.02	0.05
	CD at 5%	0.58	1.93	0.52	11.84	0.05	0.15

recorded in the genotype RHGA 13-4 (245.10) as compared to rest of the genotypes followed by RGAG 12-8 (208.01). The lowest vigour index I was recorded in the genotype RGAG 12-27 (55.16). At 9 months of storage the highest vigour index I was recorded in the genotype RHGA 13-4 (346.61) as compared to rest of the genotypes followed by RGAG 12-8 (256.23). The lowest vigour index I was exhibited in the genotype RGAG 12-27(69.33).

The difference in vigour index I after 3 and 9 months was observed due to variation in germination percentage, shoot length and root length after 9 months of harvest. Vigour index I was observed *i.e.* 1450 [21] in Mustard.

The genotypes differed significantly for vigour index II. At 3 months of storage the highest vigour index II was recorded in the genotype RHGA 13-4 (652.03) as compared to rest of the genotypes followed by RGAG 12-8 (559.93). The lowest vigour index II was exhibited in the genotype RGAG 12-27 (44.20). At 9 months of storage the highest vigour index II was recorded in the genotype RHGA 13-4 (2112.81) as compared to rest of the genotypes followed by RGAG 12-8 (1687.92). The lowest vigour index II was exhibited in the genotype RGAG 12-27 (673.36).

The difference in vigour index II after 3 and 9 months of storage was observed due to increase in germination percentage and increased dry matter content of seedlings after 9 month of harvest.

Dry matter content (mg)

The genotypes differed significantly for dry matter. At 3 months of storage the highest dry matter was recorded in the genotypes RHGA 13-4 (9.27 mg) followed by RGAG 12-8 (8.40 mg) as compared to rest of the genotypes The lowest dry matter was recorded in the genotype RGAG 12-27 (1.57 mg). After 9 months of storage the highest dry matter was recorded in the genotypes RHGA 13-4 (24.67 mg) which was at par with the genotypes RGAG 12-8 (24.00 mg), RGAG 12-11 (23.00 mg) and RGAG 16-11 (23.67 mg). The lowest dry matter exhibited in the genotype RGAG 12-27 (14.00 mg). It was observed that difference in dry matter content due to increased in thickness of seedlings even after there was variation in root and shoot length of seedling after 9 months of harvest.

Moisture content (%)

The genotypes differed significantly for moisture content. The highest moisture content was recorded in the genotype RGAG 12-27 (10.87 %) as compared to rest of the genotypes followed by RGAG 16-08 (10.47%). The lowest moisture content was exhibited in the genotype RHGA 13-4 (9.50%). The storage life of seed is halved

for each 1 per cent increase in moisture content [22]. The moisture content is of great importance in seed deterioration. Seed deterioration increases as the moisture content increased [23].

Electrical conductivity (dS/m)

The genotypes differed significantly for electrical conductivity. The highest electrical conductivity was recorded in the genotype RGAG 12-27 (0.47 dSm^{-1}) which was at par with the genotypes RGAG 12-16 (0.43 dSm^{-1}), RGAG 16-08 (0.45 dSm^{-1}), RGAG 16-10 (0.42 dSm^{-1}), RGAG 16-12 (0.42 dSm^{-1}) and RGAG 15-1 (0.43 dSm-1). The lowest electrical conductivity was exhibited in the genotype RHGA 13-4 (0.24 dSm^{-1}). Lower the electrical conductivity it might helps in increase the yield as well as storability of seed. In Soybean leaching of sugars and EC of the leachates showed a negative correlation with germinability and seedling vigour [24].

Seed volume weight (g/10 ml)

The genotypes differed significantly for seed volume weight. The highest seed volume weight was recorded in the genotype RHGA 13-4 (8.15 gm/10 ml) which was at par with RGAG 12-8 (8.14 gm/10 ml), RGAG 12-11 (8.11 gm/10 ml), RGAG 12-28 (8.07 gm/10 ml), RGAG 14-2(8.02 gm/10 ml), RGAG 16-05 (8.05 gm/10 ml) and RGAG 16-11 (8.12 gm/10 ml). The lowest seed volume weight was recorded in the genotype RGAG 12-27 (7.52 gm/10 ml).

The difference in seed volume weight was observed in different grain Amaranthus genotypes. Similar observations were also recorded in grain Amaranthus [25].

Seed mycoflora %

The genotypes differed significantly for seed mycoflora. The highest seed mycoflora was recorded in the genotype RGAG 12-27 (30.67%) which was at par with all the genotypes except in RGAG 12-8(6.67%) and RHGA 13-4 (4.00%) genotypes. The lowest seed mycoflora was recorded in the genotype RHGA 13-4 (4.00%).

Lower mycoflora infection of seed is required for its long storage life. The *Alternaria* and *Aspergillus spp* was observed in the studied genotypes. Similar observations i.e. 85 % *Alternaria* were reported in grain Amaranthus [26].

CONCLUSION

1. The genotype RHGA 13-4 performed well for seed quality as it was recorded highest germination (70.33%) and (85.69 %), seedling length (6.97 cm) and (8.09 cm), vigour index I (245.10) and 346.61) , vigour index II (652.03) and (2112.81), dry matter of seedlings (9.27 g) and (24.67 g) at 3 and 9 months of storage respectively. It also recorded the highest seed volume (wt.gm/10 ml) of seed *i.e.* 8.15g and lower moisture content (9.50%) and electrical conductivity (0.24 dS/m). It was less susceptible to fungal infection (4.00%) during storage of seed among all the genotypes.
2. It is concluded that the genotype RHGA 13-04 followed by RGAG 12-08 and RGAG 16-11 having better seed yield and seed quality can be utilized in breeding programme for improving the seed yield and quality of grain Amaranthus.

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