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Grain Amaranth (*Amaranthus hypochondriacus* L.): A New Millennium Crop of Pseudo-Cereals

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Thousands of traditional crops are well known, but have sustain little attention in the last century and breeding endeavour were limited. Grain amaranth (*Amaranthus hypochondriacus* L.) is such an underutilized indigenous potential pseudo cereals crop that is particular interest because of its balanced amino acid and micronutrient profiles. Genetic improvement of amaranth with high numbers of species manifest high degree of variability, may inflate biodiversity within cereal food supply and deliver essential ingredients as grain and vegetable crops worthy for variable climatic conditions and also for people with allergies. The future of amaranth is dependent on the vigilant recombinant selection of genotypes from the germplasm collections. Additionally, the C_4 photosynthetic pathway and ability to withstand environmental stress make the crop a suitable choice for future agricultural systems. Despite the potential of amaranth, efforts of genetic improvement lag considerably behind those of major crops. The primary purpose of genetic improvement is to develop varieties that are of high yielding with superior quality in relation to past and ease of cultivation, and to satisfy and fulfil the needs of the people for food. Goals in improving cultivars of grain amaranth are indistinguishable to those in other grain crops – improvement and stabilization of the yield, increasing pest resistance, and ameliorate harvestability. The progress in novel breeding methods and molecular techniques developed in model plants and major crops allow a rapid improvement of underutilized crop like amaranth.

Introduction

Amaranth is such a potential crop that is of particular interest because of its higher and quality protein and high micronutrients content. Grain amaranth possess C_4 pathway, which confers physiological advantage of high rate of photosynthesis. This crop can be grown even inhospitable environments. The Grain amaranth belongs to the family *Amaranthaceae*, subfamily *Amaranthoideae*, and genus Amaranthus.The genus amaranth is dibasic with (x = 16, 17) chromosomes, almost equally distributed in section amaranth. Grant (1959) has reported the information regarding the chromosome number of 30 species of *Amaranthus.* Among these, four have 2n = 32, while all others have 2n = 34. Among the 30 species, *Amaranthus caudatus* L. (2n = 32), *Amaranthus cruentus* L. (2n = 34) and *Amaranthus hypochondriacus* L. (2n = 32) are domesticated species and among these three species, *Amaranthus caudatus* L. is drooping type and rest two are erect type species.

The three principal species considered for grain production include: *Amaranth hypochondriacus* L., *Amaranthus cruentus and Amaranthus. caudatus.* In some of the Indian

languages it is known as *rajgara* in Gujarat ("king of seeds"), *ramdana* in Bihar ("seed sent by god"), *anardana* in Uttar Pradesh, *Chuka* in Bengal, *Kalaghesa* central India and *Bathu* in HP etc.

The height of mature plants varies between 0.3 m and 2.5 m, depending on the species, growth habit and environment. Some species have distinct markings on their leaves. Terminal and auxiliary inflorescences also occur. Most of the cultivated species are monoecious, wind pollinated, but the grain species with colourful inflorescence are occasionally visited by bees (Khoshoo and Pal, 1970).

Narrow genetic base of this self-pollinating crop (Schulz-Schaeffer *et al*., 1991) has been a main problem in its genetic improvement. Exploiting the gene pool from different geographic collections could increase diversity of the crop and the possibility of improving desirable characters in amaranth.

The proteins have a high sulphur containing essential amino acids (Lysine, Methionine and Cysteine), which makes it better than cereals crops. Its importance is in the quality of the leaves and tender stem for food, high biocompatibility, nutritional value, antioxidants, mineral contents and low cost of production and sale than cereal crops (FAO 2020). The nutritional qualities especially the higher protein, lysine, fiber and iron content as well as low in saturated fats and gluten free of grain amaranth was known and the crop started gaining importance and reemerged as one of the health care crops in many countries including India.

Subramaniam and Srinivasan (1952), while working on vegetable protein, observed that *Amaranthus cruentus* L., *Amaranthus hypochondriacus* L. contained 14.5 per cent to 16.0 per cent crude protein. Smith *et al*. (1959) have given amino acid profile of *Amaranthus hypochondriacus* L. grain, which contain 14.1 per cent crude protein. Other amino acid reported that, arginine 2.9 per cent, histidine 4.7 per cent, phenylalanine 4.3 per cent, threonine 6.9 per cent, soleunine 8.0 per cent, leucine 8.2 per cent, lysine 2.5 per cent, methionine 0.9 per cent, tryptophan and valine 6.0 per cent. They indicate contain highest in lysine and third highest in methionine amongst the various plant species. Leaf parts of amaranth contain 3 per cent protein, 0.3 per cent fat, 3.6 per cent mineral matter and about 8.1 per cent carbohydrates. All the mentioned reason, increases interest in the development of high yielding variety and thus Gujarat Amaranthus-2 has been released during 1998 for general cultivation. So far less breeding work has been done and lack of information on genetics and breeding behaviour of this crop.

Grain Amaranth Cultivation

- Amaranth is cultivated both in hills as well as plains encompassing the state of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Assam, Meghalaya, Nagaland, Arunachal Pradesh, Tripura, Jharkhand, Chhattisgarh, Maharashtra, Gujarat, Orissa, Karnataka, Kerala and Tamilnadu. It is cultivated both as pure as well as mixed crop during *rabi* and *kharif* seasons.
- The exact information on grain amaranth area, production and productivity at national level is lacking. In Gujarat it is grown in districts of North Gujarat and Middle Gujarat as a sole crop, or taken as a mixed crop during *rabi* Season. In Gujarat state this crop mainly cultivated in villages of Banas kantha and Kheda districts.
- In Uttarakhand it is mainly grown in Chamoli and Uttarkashi as a sole crop, or taken as a mixed crop and on the borders of the field of other crops during *kharif* Season.

The evaluation of indigenous and exotic germplasm collections of grain amaranths over several years led to characterization of genetic resources as well as identification of trait specific genotypes. As a result of intensive collection and evaluation of more than 500

accessions in grain amaranths, two varieties have been identified and released for cultivation. These varieties are Gujarat Amaranth-1 and Gujarat Amaranth-2. Important features of this varieties are given below.

Gujarat Amaranth-1 (GA-1)

- Released in the year 1989-90
- Growth habit: Tall
- Leaf sheath: Light green
- Foliage colour: Dark green
- Av. days to heading: 60 days
- Av. Days to maturity: 110-115 days
- Av. Plant height: 200-210 cm
- Ear colour: Light green to yellow
- Ear shape: Semi compact
- Length of Inflorescence: 120-125 cm
- 1000-seed weight: 0.8 g
- Av. Grain yield (Q/ha): 22.82

Fig 1. GA-1

Gujarat Amaranth-2 (GA-2)

- Released in the year 1998-99
- Growth habit: Tall
- Leaf sheath: Pink red
- Foliage colour: Light red
- Av. days to heading: 50 days
- Av. Days to maturity: 98-102 days
- Av. Plant height: 180-190 cm
- Ear colour: Red
- Ear shape: Compact
- Length of Inflorescence:85-100 cm
- 1000 seed weight: 0.8 g
- Av. Grain yield (Q/ha): 23.72

Fig 2. GA-2

Besides genetic improvement, the mandate of the centre is also to develop production technology of underutilized crops. To meet this target, a number of field experiments on various aspects *viz.*, time of sowing, nutrient requirement, weed management and cropping system research have been conducted. Based on the recently obtained number of recommendations on production technologies have been mate for the farmers.

Sowing Time and Spacing Requirement

The farmers growing sole grain amaranth in the light textured soils are advised to sow GA-1 during first to third week of November following broad casting or line sowing (30, 45 and 60 cm between row) method for getting maximum yield and net realization.

Fertilizer Management

To grow sole grain amaranth in the light textured soils are advised to applied 60:40 kg NP/ha. Marginal farmers are advised to applied 60:40 kg NP/ha. 50% N and whole dose of Phosphorus should be applied as basal dose, while remaining dose of N should be applied at 30 and 50 DAS.

Irrigation and Fertilizer Management

The farmers growing sole grain amaranth in the light textured soils are advised to grow GA-1 crop with six irrigations scheduled at 0.6 IW/CPE ratios with 60 kg Nitrogen/ha. Marginal farmers can apply 40 kg Nitrogen/ha. They should apply first irrigation at the time of sowing. Second light irrigation after 5 to 6 days and remaining four irrigations.

Integrated Fertilizer Management

GA-2 of grain Amaranth and should be fertilized with 5 tonnes FYM/ha + 100 % RDF (60:40:00 kg N:P:K/ha) for achieving maximum net returns.

Integrated Nutrient Management

The farmers growing grain amaranth GA-2 in the light textured soils are advised apply 75 % N (45 kg N /ha) through recommended dose of fertilizer (60 kg N/ha) in combination with 25 % N (15 kg N /ha) through castor cake or FYM and 40 kg P_2O_5 for securing higher grain yield (1765 kg/ha) with maximum net return and cost benefit ratio (3.21).

Table 1. Comparative nutritional value of pseudo-cereal and cereals

Crop	Protein (%)	Iron (%)	Lipids (%)	Minerals (%)
Amaranth	**16**	**18%**	**8**	**3**
Wheat	12	10%	1.7	2.7
Rice	6.7	3%	0.3	0.3
Maize	11	3%	3.5	1.1

Value Addition and Product Development

- The flour of grain amaranth can be used through value addition to the commonly used flours in the preparation of Chapati, roti, dosa, halva and other product.
- In addition, there are bakery products bread, cakes, biscuits, cookies, noodles and pastes on the market.
- Popped amaranth grain can be used for preparation of laddu and chikki. The popped grain provides opportunities for processors to develop innovative products.

Fig. 3. Traditional and other value-added product of Amaranth

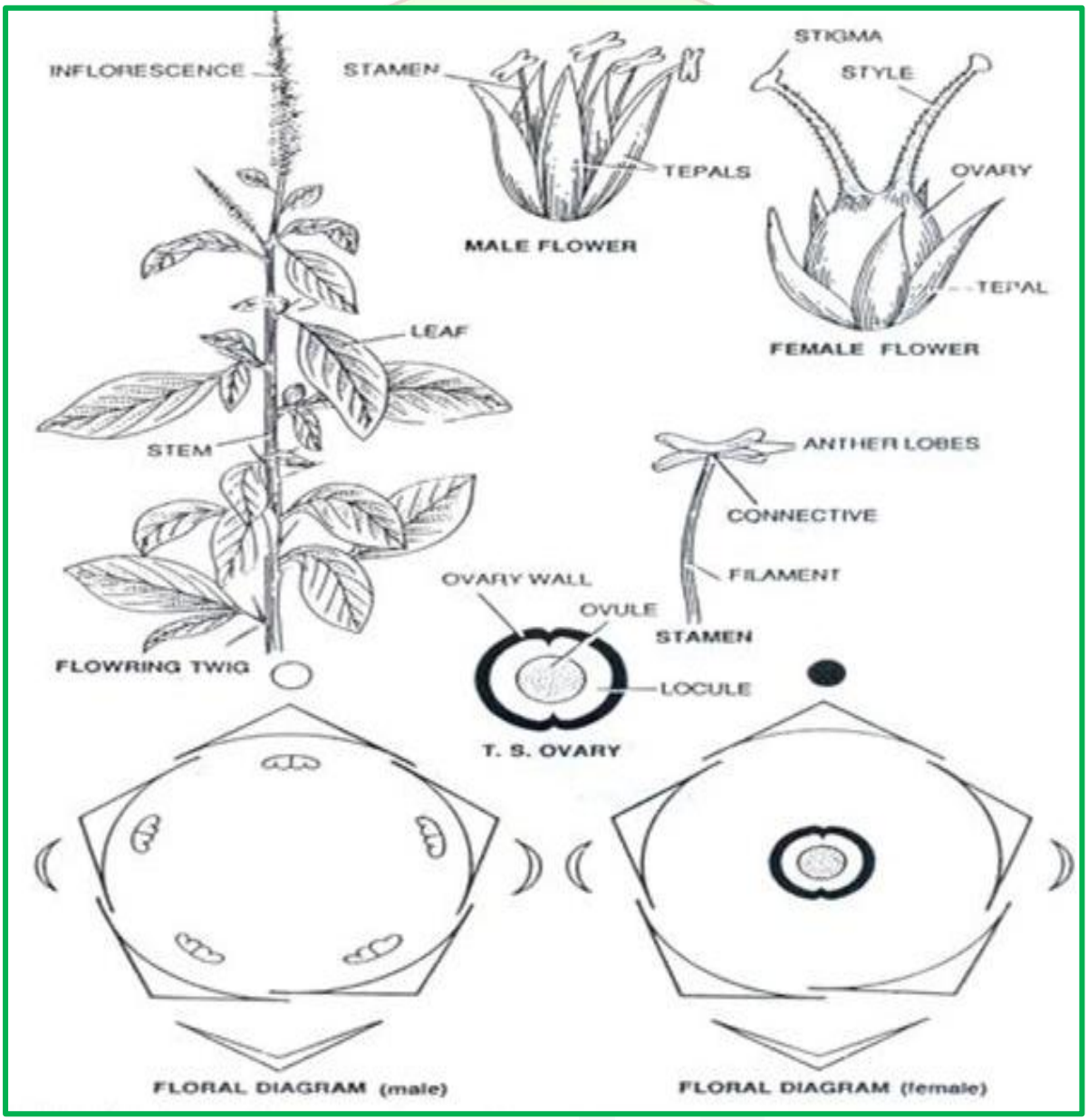
Breeding Objectives

- Increasing grain yield
- Early maturity
- Low seed shattering
- Lodging resistant
- Bold seeded variety
- Improving quality parameter

Table 2. Varieties of Amaranth identified/released under AICRN on Potential Crops in India

Sr. No.	Name of the Varieties	Name of Centre/ Institution
1	(1) Chhattisgarh Rajagara-1	Ambikapur, Chhattisgarh
2	(1) Suvarna (2) KBGA 1 (3) KBGA 4	Bangalore, Karnataka
3	(1) BGA-2 (2) Suvarna	Bhubaneshwar, Odisha
4	(1) GA-1 (2) GA-2 (3) GA-3	SDAU, S K Nagar, Gujarat
5	(1) RMA-4 (2) RMA 7	Mandor, Rajasthan
6	(1) PRA -1 (2) PRA -2 (3) PRA -3	Ranichauri, Uttarakhand
7	(1) VL Chua 44	Almora, Uttarakhand
8	(1) Annapurna (2) Durga	Shimla, Himachal Pradesh

Floral Biology



Flower Formula: Br. ⊕ ♂P_5A_5 $\underline{G}$(2)

			
GA- 2	GA - 3	GA-4-9	BGA-7
			
BGA-9	BGA-10	BGA-14	BGA-20
			
RMA-63	RGA-13	RGA-14	RGA-16
			
RGA-17	RGA-18	RGAG-12-22	RGAG-14-3

			
RHGA-13-3	MGA-502	SUVARNA	SKNA-1510
			
SKGPA-61	SKGPA- 74	SKGPA-150	SKGPA-155
			
SKNA-401	SKNA-403	SKNA-808	SKNA-813
			
SKNA-903	SKNA-908	SKNA-1201	SKNA- 1207

			
SKNA- 1305	SKNA-1313	SKNA-1403	SKNA-1406
			
SKNA-1407	SKNA-1414	SKNA-1501	SKNA-1502
			
SKNA-1503	SKNA-1508		

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