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Grain Amaranth (*Amaranthus* sp.) - An Underutilized Crop Species for Nutritional Security and Climate Resilience

NIRANJANA MURTHY AND J. S. ARUN KUMAR
AICRN on Potential Crops, UAS, GKVK, Bengaluru - 560 065
E-mail : drniranjanamurthy@hotmail.com

ABSTRACT

Grain amaranth (*Amaranthus* sp.) belongs to the family Amaranthaceae and is categorized as pseudocereal in the list of underutilized crops. Sixty species of the genus *Amaranthus* are reported native to the New World and about 15 to the Old World and Australia. Grain amaranth was an ancient staple food crop for the native Aztecs of South America till Spanish invasion, when maize was introduced which replaced grain amaranth gradually. With the awareness about its nutritional qualities, especially its higher protein and lysine content, grain amaranth started gaining importance and reemerged as one of the heath care crops in many countries including India. In India, it is cultivated sporadically both in the hills as well as in plains covering states of Jammu and Kashmir in the north to Tamil Nadu in south. The Amaranth grain contains higher protein (14-16%) the common cereals like Rice, Wheat and Maize. The protein is also of higher quality due to the presence of higher lysine, an essential amino acid. In addition, Amaranth grain contains Calcium, Phosphorus, Iron and Beta-carotene, 6 to 10 per cent oil which is predominantly unsaturated (76%) and is high in linoleic acid. Amaranth oil was found to have 7 per cent squalene, a high priced material which is used in cosmetics. Being a C_4 crop species, grain amaranth can produce higher biomass and is suited to survive and thrive in an environment affected by climate change. The potentiality of this underutilized crop for higher nutrition qualities and climate resilience is yet to be utilized to fuller extent.

BY the year 2050, agriculture will have to meet the food and nutrition requirements of about 9 billion people. Moreover, to maintain that level of productivity indefinitely it must do so using environmentally sustainable production systems (Kahane *et al.,* 2013). Modern agricultural systems that promote cultivation of a very limited number of crop species have relegated indigenous crops to the status of 'neglected and underutilized crop species' (NUS). From a total of 352,000 known plant species, approximately 7,000 have been used for human food since the origin of agriculture. Out of these, only three crops *viz.,* Rice, Wheat and Maize provide nearly 50-60 per cent of the world's plant-derived calories.This narrow level of food crop cultivation and consumption may be a disaster in terms of climate resilience, food and nutritional security in the future. According to an FAO report, 925 million people were undernourished in 2010 (FAO, 2010). Around 162 million children under the age of five in developing countries exhibit stunted growth due to chronic under-nutrition and 148 million children are under weight. Micronutrient malnutrition is indeed affecting around 2 billion people (over 30 per cent of the world population) with serious public health consequences. At the same time, overweight and obesity is becoming a recognized problem, even in low income countries. Around 43 million children under five years of age are overweight and more than a billion adults, almost equal to the number of people suffering from undernourishment worldwide, are overweight, of which 300 million are obese. Therefore, there is a need to enlarge our food basket with alternative food crops with high nutritive value and to diversify our agricultural system with lesser known, under-exploited species which are also adapted to stressed environments and provide food and nutritional security to the ever growing population which is of global concern. In this context, grain amaranth a traditional underutilized crop species can play a crucial role to achieve food and nutritional security, sustainable income generation and food culture of the rural poor.

What are these Underutilized crop species?

Underutilized is commonly applied to refer to the species that have not been fully exploited. Plant biodiversity represents the primary source for food, feed, shelter, medicines and many other products and means that make life on earth possible and enjoyable

(WCMC, 1992 ; UNEP, 1995). The term 'underutilized species' has been defined in a number of ways. The Global Facilitation Unit (GFU) for Underutilized Species defined UU species as those crop species with a potential, not fully exploited, to contribute to food security and poverty alleviation and that tend to have common features like a strong link to cultural heritage, poorly documented and researched, adapted to specific agro-ecological niches, weak or non-existent seed supply systems, traditional uses and produced with little or no external inputs. This variation in definitions suggests that the perception of utility of underutilized species is not uniform. A species that is not fully exploited today may be highly useful later, some time in the future. Underutilized species are probably best understood when they are considered within a specific locality and over a specific period of time. Hence, it is difficult to define just what qualifies as an 'underutilized species'. The terms such as 'underutilized', 'neglected', 'orphan', 'minor', 'promising', 'niche' and 'traditional' are often used interchangeably to characterize the range of plant species with under-exploited potential for contributing to food security, health (nutritional / medicinal), income generation and environmental services. A more diverse farming system can facilitate more climate resilience, overcoming the loss due to biotic and abiotic stresses and to improve food and nutrition security.

Agriculture production must be increased to respond to the demands of a growing world population and the challenges posed by climate change. Higher temperatures, unpredictable rainfall and weather patterns, changes in growing seasons, increased occurrences of drought and extreme weather events will exert a greater strain on agriculture. Emerging evidence suggests that climate change will cause shifts in food production and yield loss due to more unpredictable and hostile weather patterns. A key strategy to adapt to a changing climate is the development and promotion of underutilized crop species.

Research network for underutilized crop species in India

About 70 species of underutilized, neglected and minor crops have been identified which may hold promise in the Asia - Pacific region (Arora, 2002). Amongst these, only a few have been prioritized for scientific exploitation in a phased manner in India for which an All India Coordinated Research Project (AICRP) on Underutilized and Underexploited Plants, now rechristened as All India Coordinated Research Network (AICRN) on Potential Crops, was initiated in 1982 under ICAR umbrella with the main objective of generating improved technology in selected crops of minor economic importance for food, fodder and industrial use. The Network Coordinating Unit is located at the National Bureau of Plant Genetic Resources, New Delhi. At present, the network is conducting research on 17 crops of food, fodder and industrial value through 13 main, 5 cooperating and 5 voluntary centers located in diverse agro-climatic zones of the country. The listed crops have been categorized in six groups which are 1) Pseudocereals (Grain Amaranth (*Amaranthus* spp.), Buckwheat (*Fagopyrum esculentum*) and Grain Chenopods / Quinoa (*Fagopyrum esculentum*); 2) Minor Cereal (Job's Tears (*Coix lacryma-jobi*); 3) Food Legumes (Rice Bean (*Vigna umbellate*), Faba Bean (*Vicia faba*), Adzuki Bean (*Vigna angularis*) and Winged Bean (*Psophocarpus tetragonolobus*);4) Vegetables (Kankoda (*Momordia dioca*) and Kalingada; 5) Oil Seed Crops Perilla (*Perilla frutescens*), Simarouba (*Simarouba glauca*), Tumba (*Leucas* spp.), Jatropha (*Jatropha curcas*) and Ojoba (*Simmondsia chinensis*) and 6) Industrial Crop (Rubber (*Hevea* sp.).

The University of Agricultural Sciences, Bengaluru Center was started in 1986 to work on three underutilized crops *viz.,* Grain Amaranth, Rice Bean and Winged Bean. Quinoa was added to the list from last two years. Though, these crops have high nutritional potentiality, still they are not grown by the farmers of Karnataka to a desired extent. The research on these crops is very limited. Apart from these, research work on biofuel crops like, Jatropha and Simarouba is carried out through externally funded projects both in UAS, Bengaluru and UAS, Dharwad. The accomplishments made with regard to these four underutilized crops *viz*, Grain amaranth, rice bean, winged bean and Quinoa under AICRN on Potential crops scheme are presented and the potential and importance grain amaranth as an underutilized crop for nutritional security is discussed in detail.

For the last three decades, the University has developed two varieties in Grain Amaranth *viz.,* 'Suvarna' and 'KBGA-1'of which 'Suvarna' is very potential high yielding variety which is used as national check in All India Coordinated Varietal Trials. In Rice Bean, one variety 'KBR-1' has been developed and is due for release. As a minor pulse, Rice Bean has multiple utility which can go very well in rice fallows and is an ideal crop for fodder and green manure purpose. In Winged Bean, variety 'KBWB-1' has been developed. Though, Winged Bean has got high nutritive value and all parts of the plant can be used, more efforts are required to popularize this nutritive underutilized species.

Grain Amaranth

Grain Amaranth (*Amaranthus* spp.) belongs to the family Amaranthaceae and is categorized as psuedocereal in the list of underutilized crops. Amaranths are widely distributed throughout the old and new world. In India, these are cultivated both in hills as well as plains covering states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Assam, Meghalaya, Arunachal Pradesh, Nagaland, Tripura, Jharkhand, Chattisgarh, Maharashtra, Gujarat, Orissa, Karnataka, Kerala and Tamil Nadu.The exact information about the statistics on area and production in India is lacking. However, as a grain crop it is estimated to be grown in about 30 - 40 thousand hectares. Amaranth has great potential to combat climate change and malnutrition. It is receiving attention now-a-days because of its high nutritional value, rapid growth, adaptability to a wide range of climatic and soil conditions (Chitra *et al.,* 2016). Though, Grain Amaranth is grown in many states in India with varied proportions, the area under this crop in Gujarat is increasing, particularly in Banaskantha district where this crop competes with wheat and potato on account of water scarcity. In Karnataka, the crop is grown as Akkadi crop with other cereals sporadically in limited areas of Tumkur, Kolar, Chitradurga districts and in Tribal hilly areas of Biligiriranagana Hills, Male Mahadeshwara Hills of Chamarajanagar district of southern Karnataka (Niranjana Murthy, 2013; Niranjana Murthy *et al.,* 2011). In northern Karnataka, it is grown as mixed crop with other cereals in few pockets of Belgaum, Bagalkote, Bijapur and Bidar districts.

Rebirth of Grain Amaranth as a Health Care Crop

The word "amaranth" in Greek means "everlasting" and in fact, the crop has endured. The distinctly beautiful appearance of amaranth has helped to prevent the crop from slipping into obscurity. The enchanting beauty of the vividly coloured leaves, stems and seed heads in an amaranth field is a sight which evokes emotions that other crops cannot stir (Kauffman and Weber, 1990). Though, grain amaranth was an ancient staple food crop for the native Aztecs of South America, its cultivation vanished after Spanish invasion who introduced maize crop which replaced grain amaranth gradually. However, after knowing the biochemistry in the middle of the 20th century, the nutritional qualities, especially the higher protein and lysine content of Grain Amaranth was known and the crop started gaining importance and re-emerged as one of the heath care crops in many countries including India.

Grain Amaranth as nutritionally potential crop

Amaranth has very high nutritional value (Saunders and Becker, 1983 ; Joshi and Paroda, 1991) due to its protein quality and other nutrients. The nutritional composition of Grain Amaranth in comparison with other cereals is presented in the Table I. It is also an excellent source of iron and beta carotene and thus can help in circumventing iron and vitamin A deficiency. Presence of higher amount of folic acid also helps in increasing the blood hemoglobin level. Amaranth can be an ideal crop with C_4 metabolism suited to survive and thrive in an environment affected by climate change. The protein in amaranth seeds being of high quality, AMA-1' gene has been isolated from this crop and efforts were made to introduce this AMA-1 gene into other important food crops like rice and potato.

Amaranth has multiple uses. Its tender leaves are used as vegetable. The grains are used in various culinary preparations. Popped grains are used in the form of puddings or mixed with sugar syrup to make sweet balls (laddu), with honey to make flat round bread and with milk and sugar to make porridge. Its

TABLE I
Nutritional composition (per 100 gram) of grain amaranth in comparison with other cereals

Food grain	Protein (g)	Carbohydrates (g)	Lipid (g)	Crude fibre (g)	Mineral matter (g)	Ca (mg)	P (mg)	Fe (mg)
Grain Amaranth	16.0	62.0	8.0	2.43	3.0	490	600	17.5
Buckwheat	13.0	72.9	7.4	10.5	2.1	120	280	15.5
Chenopodium	14.0	65.0	7.0	7.0	3.0	47	457	4.5
Job's tear	11.4	73.5	3.5	-	0.8	-	-	-
Foxtail millet	12.3	60.9	4.3	8.0	3.3	31	290	5.0
Maize	11.0	66.0	3.5	-	1.1	10	-	-
Barley	11.0	69.0	1.3	-	1.9	-	-	-
Wheat	12.0	69.0	1.7	1.2	2.7	41	306	5.3
Rice	6.7	78.0	0.3	0.2	0.3	45	160	3.5

(Source : Joshi and Paroda, 1991)

TABLE II
Essential amino acid composition (g/100g protein) in grain amaranth in comparison to other cereals and milk

Food grain	Lysine	Methionine	Cystine	Isoleucine	Leucine
Grain Amaranth	5.0	4.0	4.0	3.0	4.7
Buckwheat	6.2	1.6	1.6	3.7	6.2
Foxtail millet	2.2	2.8	1.6	7.6	16.7
Proso millet	3.0	2.6	1.0	8.1	12.2
Wheat	2.8	1.5	2.2	3.3	6.7
Rice	3.8	2.3	1.4	3.8	3.2
Maize	2.9	3.4	3.4	4.1	13.0
Barley	3.0	3.2	3.7	4.0	7.5
Milk	5.8	3.7	2.1	5.0	7.3

(Source : Bhagmal, 1994)

flour can be used for making chapattis when mixed with maize and finger millet flour. Amaranth oil, containing 'squalene' a cosmetic ingredient and skin penetrant, is also used as lubricant for computer discs.

The food value of grain amaranth was recognized by people from Mexico to Peru to Nepal long before any, nutritional analyses had been conducted. Because it is easy to digest, amaranth is traditionally given to those who are recovering from an illness or a fasting period. In Mexico, grain amaranth is popped and mixed with a sugar solution to make a confection called alegria (happiness). A traditional Mexican drink called atole is made from milled and roasted amaranth seed. In India, *A. hypochondriacus* L. is known as *rajgeera* (the King's grain) and is often popped to be used in confections called *laddu*, which are very similar to Mexican *alegria.* In Nepal, amaranth seeds are eaten as a gruel called *sattoo* or milled into a flour to make chapattis (Singhal and Kulkarni, 1988).

During the last three decades, number of overviews have been published which provide a wide range of information on the nutritional components, digestibility and potential problems that will be encountered by those who intend to use grain amaranth as a food product (Becker *et al.,* 1981; Teutonics and Knorr, 1985; Bressani *et al.*, 1987a; Saunders and Becker, 1984 and Pedersen *et al.*, 1987). The most studied nutritional aspect concerning the food value of grain amaranth is the identification of the limiting amino acids of the protein component. The crude protein content of selected light-seeded grain amaranths has been reported to range from 12.5 to 17.6 (Teutonico and Knorr, 1985, Becker *et al.,* 1981, Lorenz and Gross, 1984, Sanchez Marroquin *et al.,* 1986, Pedersen *et al.,* 1987, Correa *et al.,* 1986). Amaranth grain is reported to have high levels of lysine, a nutritionally critical amino acid, ranging from 0.73 to 0.84 per cent of the total protein content (Bressani 1987a). The limiting amino acid is usually reported to be leucine (Singhal and Kulkarni, 1988). Underutilized crops (also known as understudied, neglected, orphan, lost or disadvantaged crops) play an important role in food security, nutrition, and income generation of many resource-poor farmers and consumers especially in the developing world (Massawe *et al.,* 2015).

The potential complimentary nature of amaranth protein has been studied by combining amaranth with wheat (Pant, 1985), sorghum (Pedersen, 1987) and maize (Tovar and Carpenter 1982 ; Sanchez Marroquin and Maya, 1985). Ordinary maize meal supplemented with as little as 12.7 per cent (by weight) of toasted amaranth flour provides a nutritionally superior source of protein that can satisfy a good portion of the protein requirement of young children, and provide approximately 70 per cent of diet energy (Morales *et al.*, 1988). A combination of rice and amaranth in a 1:1 ratio has been reported to approach the FAO / WHO protein specifications (Singhal and Kulkarni, 1988).

The starch component of amaranth is distinctive. The starch granules are polygonal, measure 1 to 3 mm in diameter, and have a high swelling power(Stone and Lorenz, 1984). There is a distinctive gel characteristic to the starch (Yanez *et al.,* 1986). Waxy and non-waxy starch granules have been identified (Konishi *et al.,* 1985). Interest has been expressed in specialized food and industrial applications for amaranth starch as a result of its distinctive characteristics.

Amaranth grain contains 6 to 10 per cent oil, which is found mostly within the germ (Betschart *et al.,* 1981; Lorenz and Hwang, 1985 and Garcia *et al.,* 1987a). It is predominantly unsaturated oil (76%) and is high in linoleic acid, which is necessary for human nutrition. In analyses conducted at the USDA Western Regional Research Center, amaranth oil was found to have 7 per cent squalene, which is much higher than the amounts found in other common vegetable oils. Squalene, a high priced material, is usually extracted from shark livers and used in cosmetics (Lyon and Becker, 1987).

Due to the fact that grain amaranth has high protein, as well as a high fat content, there is the potential to use it as an energy food. Using milled and toasted amaranth products, digestion and absorption was found to be high in human feeding studies (Morales *et al.*, 1988). The balance of carbohydrates, fats, and protein, allow amaranth the opportunity to achieve a balanced nutrient uptake with lower amounts of consumption than with other cereals. It has been noted (Morales *et al.,* 1988) that high protein rice is the only other cereal which has been cited to satisfy protein and energy needs.

Animal feeding studies (Betschart *et al.,* 1981; Saunders and Becker, 1984) indicate relatively high protein qualities. However, in some studies, weight gains were much lower than would have been expected (Cheeke and Bronson,1980; Afolabi and Oke, 1981) for reasons that are not clear.

The digestibility and protein efficiency ratio are improved if the grain is heat processed (Bressani *et al.,* 1987b; Garcia *et al.,* 1987b; Mendoza and Bressani, 1987; Pant 1985 and Sanchez-Marroquin *et al.,* 1985). The removal of lectins by heat processing has been reported to improve the protein efficiency ratio of the amaranth flour (Singhal and Kulkarni, 1988). There are a number of viable methods for processing, including popping, flours milled from toasted grain, heat-rolled flakes, extrusion, and wet cooking as a gruel. Excessive thermal processing has been shown to reduce the quality of amaranth grain (Bressani and Elias, 1986). The potential for reducing nutritional quality is most evident when amaranth grain is processed using hot dry heat (as in toasting or popping). An interesting application for amaranth is to use it as a food for people with allergies to other grains. The seed of grain amaranth is not a grain from a cereal plant, but is rather a pseudocereal from a dicotyledonous plant. It is unrelated to any other food crops that are commonly consumed, which makes it less likely to cause problems to people who have built up allergies due to repeated consumption of the same foods. Grain-free recipes which include amaranth flour have been published (Jones, 1984). In the USA, many amaranth products are being produced by specially companies which cater to the health-conscious market. Amaranth has been successfully processed in combination with other grains to produce cold, breakfast cereals. It is also being used for mixes that are used to prepare hot breakfast cereals and pancakes. In addition, there are breads, crackers and pastes on the market. Popped amaranth grain continues to attract considerable attention. The popped grain provides opportunities for processors to develop innovative products.

Grain amaranth is a new crop that is in its adolescence. The cultivation and utilization of grain amaranth will continue to increase as more information is developed to exploit the market niches for high quality protein foods.

Amaranth as a crop for sustainable development of agriculture

The search for new crops, which produce both food and energy, together with the development of appropriate technology, is becoming a matter of paramount importance. Amaranth could be characterized as a high-energy multipurpose C_4 plant, fits the bill as a true 4F crop (Food, Feed, Fuel and Fiber) as well as being a short cycle, drought and salinity tolerant crop. The amaranth agro-environmental system is a key link in the sustainable production of agriculture. It will play an important role in healthy food as well as environmental protection in the next century. Amaranth is one of few plants, which becomes a model plant and of great interest for many researchers around the world. Crop husbandry methods for amaranth have been researched in many countries, where its several species have been cultivated from many centuries. Amaranth which produces a large amount of biomass in a short period of time, can be used as a forage crop for domesticated animals. In China, amaranth has been cultivated expressly for use as forage for cattle. There are several cuttings made per growing season. Little is known about actual water requirements of grain amaranth. Observations in many test plots and farmers' fields suggest that grain amaranth is drought tolerant at later stages of growth. Residual soil moisture is needed to assure that emergence occurs. Researchers in China have reported that the water requirement for growing grain amaranth is 42 - 47 per cent that of wheat, 51 - 62 per cent that of maize and 79 per cent that of cotton. Kenyan farmers in regions with marginal rainfall plant amaranth rather than maize because they believe there is less risk of a crop failure (Gupta, 1986) Observations indicate that amaranth in the coastal desert of Peru requires half the irrigation required by corn (Sumar, 1986).

Modern prospects for Grain Amaranth

The cultivation of grain amaranth is now in the process of expanding in a number of countries. Over the past 25 years, there have been some well-executed projects in which researchers, farmers and food processors have invested imagination, time and money on this crop in China (Sun and Hongliang, 1987). There has been increasing interest in grain amaranth in the international community. A number of conferences for the promotion of the crop have been held in 1977, 1979. Conferences were hosted in Mexico in 1984 and 1986, with presentation of papers from individuals representing 19 different Mexican institutions. In 1987, an annual amaranth conference was initiated in the People's Republic of China to bring together researchers in over 22 provinces (Sun, 1987). Also in 1987, The University of La Pampa in Argentina hosted a national conference on amaranth, with papers presented by 17 researchers (Actas de las Primerasjornadas Nacionales Sobre Amarantos, 1987).

The American Amaranth Institute (AAI), which has been organized to help promote research and development, is working closely with many of the research institutions. The AAI is also working with Crop Improvement Associations to develop standards for amaranth seed certification. The synergism of the completed and on-going projects at RRC, the domestic and international institutions, and the AAI has provided a wealth of information and experiences for modern farmers to draw on as they initiate commercial production. Farmers are developing innovative techniques to find ways to produce grain amaranth economically. As a result of their ingenuity, the supply of commercially available amaranth has increased to the point where several food companies are producing amaranth products which can be purchased in many stores in the USA. The cultivation of grain amaranth is now in the process of expanding in a number of countries. In USA, it is considered as one of the Health Care Crops. The drought tolerant characteristics of amaranth make it a prospective dryland crop for farmers in semi-arid areas. The rising demand for amaranth food products will require a substantial increase in amaranth production during the coming years.

Research issues to be addressed in grain amaranth

Neglected and underutilized crops are essential to the livelihoods of millions of poor farmers throughout the globe. They are part of the biological assets of the rural poor. In identifying research and development issues, it is essential to approach the problem from this perspective. Strengthened community involvement in the management of underutilized crops and a deliberate attention to resourcing their needs for new materials and securing access to existing ones will provide a basis for some more work on key production issues. The first of these is obviously that of the development of improved materials. Participatory plant breeding approaches may not only be an important element of the work on these crops; it may be the only feasible approach to obtain improved materials. Similarly, participatory approaches may be essential to resolve other production and marketing constraints. Ultimately, we have to recognize that underutilized crops present their own range of problems and opportunities. New technologies like molecular genetics and GIS will certainly play their part in the process of developing conservation and use strategies. There is also much work to be done on the development of sustainable linkages between organizations, farmers and consumers.

In grain amaranth, harvest and postharvest handling is very difficult because of small sized seeds. There is high degree of seed shattering and lodging occurs at maturity. This makes the crop less productive. Hence, there is need to develop genotypes with bold sized seeds, non-shattering, dwarf and non-lodging types. There is a major problem in grinding amaranth grains in normal grinders and non-availability of popping machine restrict full utilization of grain amaranth as food and value added products. There is need to address these issues to popularize the use of grain amaranth.

Strategies to promote underutilized crop species including grain amaranth

The work on underutilized species is perhaps the most challenging endeavour in the history of plant genetic resources since the early 1970s, a period that witnessed a world race to rescue of landraces of major crops. Such a chain of actors, which is needed at local, regional, national and international level, will allow covering research aspects but also marketing and policy issues usually dealt with in isolated fashion. The Networking concept for plant genetic resources based on more efficient partnership and participatory approaches is needed. At local level, the first and foremost task is to create awareness with consumers on the nutritional potential of UU Crops to promote the regular consumption in different value added forms. Though, the cultivation of UU crops is simple the crops need to be made more remunerative. It is necessary to work out the stability of UU crops in different cropping systems. The key strategic element for large scale promotion of UU crops is linking cultivation and use, in order to secure the resource base of these crops. For this, linkages are to be established among producers, traders, processors, consumers and other formal and informal sectors. The food processing industries, Millers and Bakers should come forward to promote the blend the products of UU Crops so that market link can be established. From the point of crop improvement, the UU crops need better attention from the researchers and funding agencies.There are many underutilized food and non-food plant species, having good potential to contribute to the income of farmers (Hegde, 2007). There are many underutilized crops that have potential to consider for promoting and popularizing in India. There are 30 minor fruit crop species of which the important ones such as custard apple, Indian gooseberry, jamoon, pomello, wood apple, rose apple, carambola and canthium which need research and development initiation / intensification to harness the untapped nutritional, medicinal and industrial value of these crops. These underutilized crops may be considered as potential future crops to achieve multifacet objectives of agriculture and food diversification, nutritional requirement and for climate resilience agriculture.

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