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## Improving resource conservation, productivity and profitability of neglected and underutilized crops in the breadbasket of India: A review

**M Sharath Chandra, RK Naresh, OVS Thenua, Rajat Singh and D Geethanjali**

### Abstract

Underutilized and neglected crops species are ancient indigenous crop species which are still used at some level within the local, national or even international communities, but have the potential to contribute to food security, nutrition, dietary and culinary diversification, health and income generation. The neglected and underutilized crops included such as cereals and pseudo cereals, legumes, vegetables, oilseeds, roots and tubers, aromatic and medicinal plants, fruits and nuts etc. Neglected and Underutilized crops are lesser-known plant species in terms of marketing and research, but well adapted to marginal biotic and abiotic stress conditions. Where these crops have been traditionally under cultivation and intrinsically linked with food security, livelihood and cultural identity of local rural communities in the breadbasket of India. These crops by virtue of their extremely high resilience to the harsh agro-climatic conditions, particularly in marginal soils, hilly terrain and under aberrant rainfall, are well adapted to offer a dependable level of food security to the poor. They are also valued for their better nutritious profile of the grains and high quality straw. The grains have high bio-available minerals, particularly calcium and iron, vitamins, dietary fibre, and other phyto-chemicals. Their unique physico-chemical composition renders them slow digestible and with low glycemic index, which is a valued nutraceutical property in food grains. The long shelf life of these grains is also an attribute preferred by the communities living in regions characterized by poor communication. The potential of neglected and underutilised crops with respect to how they can contribute to tropical challenges, such as food and nutrition security, human health and well-being, climate change adaptation, the environment, and employment creation in poor rural communities in India. This review paper collected literature has been an overview for improving resource conservation to address one aspect of the challenge that faces us if we want to diversify crops and increase the contribution of productivity and profitability that neglected and underutilized crops towards food security.

**Keywords:** Neglected and underutilized crops (NUCS), resource conservation, productivity, profitability

### 1. Introduction

Adaptation of agriculture to changing climatic conditions including utilization and promotion of suitable crops. Adaptation (underutilized and neglected crops, etc.) will be one of the central tasks of future agricultural activities. It will be especially important in view of the need for securing the food basis and providing balanced nutrition for the rural population in the breadbasket of India. There are calls for a paradigm shift in agriculture to explore non-conventional pathways such as neglected and underutilized crops (NUCS) as possible future crops (Massawe *et al.*, 2015) [38]. Important components of agro-biodiversity are neglected and underutilized plants that have a lot of traits and properties important for our future nutrition base. These species are often traditionally used, or are wild species that contribute to nutrition and a balanced diet for poor and underprivileged folks. In addition, these plants may have a variety of additional properties, such as potential for future adaptation to climate change (heat or salt tolerance), medicinal properties, as well as resistance genes against pests and diseases, thus helping us to reduce use of pesticides (Chibarabada *et al.*, 2017; Hadebe *et al.*, 2017; Mabhaudhi *et al.*, 2017) [8, 25, 34]. In addition, most NUS are nutrient dense and could be useful in diversifying diets (Mayes *et al.*, 2012) [40] and addressing micronutrient deficiencies in poor rural communities (Chibarabada *et al.*, 2017; Govender *et al.*, 2017) [8, 20]. Thus, their promotion in marginal agricultural production areas could improve availability and access to nutritious food by rural people (Williams and Haq, 2000) [63]. Their promotion in rural areas could also create opportunities for rural economic development through the development of

new value chains (Mabhaudhi *et al.*, 2017) [34]. Importantly, NUS, which include crop wild relatives (CWR), are an important germplasm resource for future crop improvements for beneficial traits such as nutritional value and abiotic and biotic stress tolerances (Castaneda-Alvarez *et al.*, 2016) [6]. However, much of this reported potential is currently premised on anecdotal evidence with limited robust, empirical, and comparable information (Mabhaudhi *et al.*, 2016b) [35]. Thus, there is a need to promote evidence-based approaches that can assist in developing policy and increased research funding to support NUS (Mabhaudhi and Modi, 2013) [33].

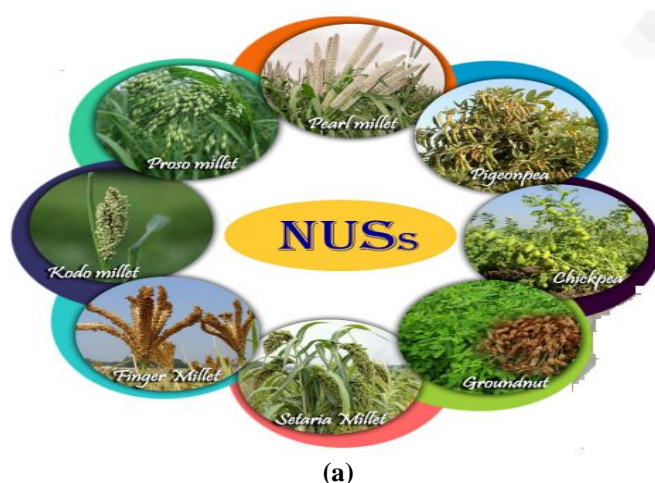
As a result, diets deficient in essential vitamins and micro-nutrients still persist in many parts of the world. Of the world's estimated 7,000 million people, 500 million still suffer from protein-energy malnutrition, but over 1,600 million suffer from iron deficiency, over 200 million from vitamin A insufficiency (WHO 2008, 2009) and it has been estimated that over 400,000 children die each year from effects directly related to zinc deficiency (Harvest Plus, 2011). Underutilized crops provide essential micro-nutrients and thus complement staple foods. Additionally, NUS provide flavouring in local cuisine, strengthen local gastronomic traditions and provide income opportunities for both the rural and urban poor. Strategies based on diverse local food crops can provide a valuable and sustainable complement to other means of tackling malnutrition.

*“Neglected crops” are those grown primarily in their centres of origin by traditional farmers, where they are still important for the subsistence of local communities. Some species may be widely distributed around the world but tend to occupy special niches in the local ecology and in local production and consumption systems. While these crops continue to be maintained by socio-cultural preferences and the ways they are used, they remain inadequately documented and neglected by formal research and conservation. “Underutilized crops” were once grown more widely or intensively but are falling into disuse for a variety of agronomic, genetic, economic and cultural reasons. Farmers and consumers are using these crops less because they are in some way not competitive with other species in the same agricultural environment. The decline of these crops may erode the genetic base and prevent distinctive and valuable traits being used in crop adaptation and improvement (IPGRI, 2002) [27].*

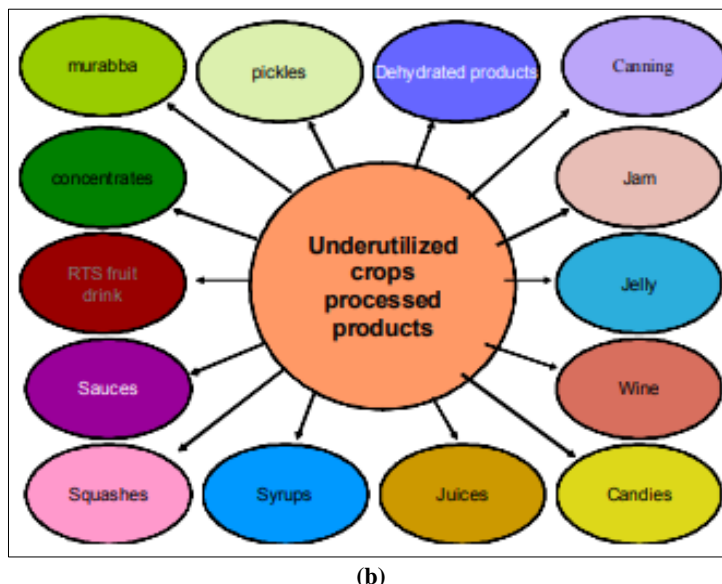
*“Underutilized crops” are plant species that are used traditionally for their food, fibre, fodder, oil or medicinal properties, but have yet to be adopted by large scale agriculturalists. Underutilized plants, in general, constitute those plant species that occur as life support species in extreme environmental conditions and threatened habitats, having genetic tolerance to survive under harsh conditions and possess qualities of nutritional and/or industrial importance for a variety of purposes (Thakur, 2014) [58]. Kunkel (1984) [32] discussed that once underutilized food crops are properly utilized, they may help to contribute in food security, nutrition, health, income generation and environmental services when properly utilized. The underutilized foods can be defined as “the foods which are less available, less utilized or rarely used or region specific” (William and Haq, 2002) [63].*

Neglected and underutilized plants are those that could be - and, in many cases, historically have been - used for food and other uses on a larger scale. Global Facilitation Unit (GFU) for Underutilized species also defines UUC's as, “those plant species with under-exploited potential for contributing to food security, health (nutritional/medicinal), income generation and environmental services”. These underutilized crop species have also been described as “minor”, “orphan”, “promising” and “little-used” (Thakur, 2014) [58].

NUS are mostly wild or semi-domesticated species adapted to local environments. These traditional foods were in use for centuries but increasingly became forgotten when more productive (or profitable, or prestigious, or easier to process) crops replaced them in the farming systems. NUS can be named as Future Smart Food when they are nutritionally dense, climate resilient, economically viable, and locally available or adaptable (FAO, 2018). Neglected and Underutilized Plant Species (NUS) offer tremendous opportunities for fighting poverty, hunger and malnutrition. Historically, underutilized plants have often been used for food and other uses on a large scale and in some countries are still very common especially among small or marginal farmers in the rural areas. They have multiple values: their nutritional value is high, and they are often an essential source of vitamins, micronutrients and protein and thus help to attain nutritional security (San *et al.*, 2019) [51]. NUSs are Smart Foods: Highly nutritious, environmentally friendly, Climate smart – resilient under extreme weather conditions, Significant yield gap, Good opportunities to diversify both diets and on-farm, Untapped demand and uses (Wani *et al.* 2015) [61]. Many underutilized food crops in India and majority are not well known or well documented (Solomon, 1998) [56]. Singh *et al.*, 2012 studied the diversity of underutilized vegetable crops species in North-East India. Bal (2003) [3] studies the underutilized fruits for Punjab subtropics. The ethno botanical data for all the underutilized species is still to be explored for such species. Some of the neglected and underutilized plant species crops are in fig 1a & table 1 and various processed food products from underutilized fruits (Fig.1b).



**Fig 1a:** Neglected and underutilized crops [Source: Wani *et al.* 2015] [61]



**Fig 1b:** Various processed food products from underutilized fruits [Source: Thakur, 2014] [58]

**Table 1:** Some underutilized fruit crops of India [Source: Gajanana *et al.*, 2010; Kour *et al.*, 2018] [17, 30]

Crop	Scientific Name	Family
Jamun	<i>Syzygium cumini</i>	Myrtaceae
Anola	<i>Emblica officianalis</i>	Euphorbiaceae
Ber	<i>Ziziphus mauritiana</i>	Rhamnaceae
Bael	<i>Aegle marmelos</i>	Rutaceae
Jackfruit	<i>Artocarpus heterophyllus</i>	Moraceae
Karonda	<i>Carissa carandus</i>	Apocynaceae
Carambola	<i>Averrhoa carambola</i>	Oxalidaceae
Fig	<i>Ficus carica</i>	Moraceae
Phalsa	<i>Grewia subinaequalis</i>	Tiliaceae
Custard apple	<i>Annona squamosa</i>	Annonaceae
Loquat	<i>Eriobotrya japonica</i>	Rosaceae
Tamarind	<i>Tamarindus indica</i>	Leguminosae
Rambutan	<i>Nephelium lappaceum</i>	Sapindaceae

Kaundal *et al.* (2019) [29] reported that horse gram or Kulthi bean has been an underutilized legume crop with immense medicinal importance/potential. It is considered as a rich source of protein, vitamins, and minerals. It is characteristically known for its biotic and abiotic resistance, e.g., resistant to drought, salt, and insects.

Thakur (2014) [58] and Mohmoud El sohl (2016) reported that the neglected and underutilized food crop, a plant species must have the following features:

- Crop must have a scientific or ethno botanical proof of food value,
- Adaptation to specific agro-ecological niches and marginal land,
- Crop must have been cultivated, either in the past, or only being cultivated in a specific geographical area,
- It must be currently cultivated less than other conventional crops,
- Crop must have weak or no formal seed supply system,
- Crops are recognized to have indigenous uses in localized areas,
- Received little attention from research, extension services, farmers, policy and decision makers, technology providers and consumers,
- Scarcely represented in ex situ collection;
- May be highly nutritious and/or have therapeutic medicinal or therapeutic properties or other multiple uses.

**Diversification for food security: the role of neglected and underutilized crops**

The world depends for its basic diet of carbohydrates, fats, and proteins on a very limited number of crop species. For carbohydrates, three related species (wheat, rice, and maize) dominate human consumption (Collins and Hawtin, 1999) [10]. Any short-term improvement in food security will need to include modification (either transgenic or through conventional breeding) of these and other staple crops. However, a focus purely on the productivity of current major crops, often selected and developed under high intensity agriculture, cannot meet the challenge of food insecurity and potentially makes agriculture even more vulnerable to future biotic and abiotic stresses (Mayes *et al.*, 2012) [40].

Accordingly, FAO has stressed the importance of neglected and underutilized species which would play a crucial role in the fight against hunger, and called for increased research on underutilized food resources especially those produced on poor and underutilized lands (wetlands, swamps, saline soil, etc.) by the poor. Many neglected and underutilized species are adapted to low-input agriculture and contains high vitamins and minerals which are crucial for solving child under nutrition. The use of these species – whether wild, managed or cultivated, can have immediate consequences on the food security and well-being of the poor. Neglected and underutilized species play crucial role in the fight against hunger and are a key resource for agriculture and rural

development. He called for increasing research on underutilized crops for the benefit of smallholder farmers. In addition, many neglected and underutilized species play a role in keeping cultural diversity alive. They occupy important niches, conserving traditional landscape, adapted to the risky and fragile conditions of rural communities (Tyagi *et al.*, 2018)<sup>[60]</sup>.

Salvi (2016)<sup>[50]</sup> opined that the use of plants has long been an intimate part of local cultures and traditions. Many neglected and underutilized species play a role in keeping alive cultural diversity associated with food habits, health practices, religious rituals and social exchanges. A successful and sustainable use of underutilized species relies on both the provision of diversity for current uses and its maintenance for future deployment. In view of the local specificity of underutilized species such two-fold objective requires however a conservation and development approach rather distinctive from that applied to other crops (Kour *et al.*, 2018)<sup>[30]</sup>.

Neglected or underutilized crops have the potential to play a number of roles in the improvement of food security in India that include being:

- part of a focused effort to help the poor for subsistence and income,
- a way to reduce the risk of over-dependency on very limited numbers of major staple food crops,
- a way to increase sustainability of agriculture through a reduction in inputs,
- increase the food quality;
- a way to preserve and celebrate cultural and dietary diversity,
- a way to use marginal and wastelands for agricultural purposes to meet the ever increasing food demand (Mayes *et al.*, 2011; Kour *et al.*, 2018)<sup>[41, 30]</sup>.

Padulosi *et al.* (2015)<sup>[45]</sup> argue that directing greater research attention to nutritious cereals like millets would be a highly strategic and viable choice. It can offer great benefits in terms of lower input requirements, adaptation to climate change, and cultivation of marginal soils, along with social gains in

terms of enhanced self-reliance of local populations and more resilient food systems. Enhancing the use of minor millets represents an important proposition to contribute to food security and dietary diversity. It also represents an opportunity to increase productivity, especially in lower-performing areas. Reducing yields gaps in such parts of the world has been estimated to provide the basic caloric requirements for more than 800 million people (West *et al.*, 2014)<sup>[62]</sup>. However, the challenges to promoting widespread cultivation of finger millet are immense. The crop needs to be an economically viable solution for farmers in order to play a decisive role in contributing to climate resilience, food security and nutrition.

Boosting crop diversification with minor millets requires an integrated strategy to overcome a range of obstacles. There is an apparent lack of awareness regarding its nutritional qualities among consumers. Furthermore, inadequate support by decision-makers has resulted in limited investment into research and development, as well as extension services (Fischer *et al.*, 2016; Pallante *et al.*, 2016)<sup>[16, 46]</sup>.

Hegde, (2002), suggested that staple crops face major challenges in the near future and a diversification away from over-dependency on staple crops will be important as part of the progress towards the goal of achieving security of food production. In India, there are large areas of marginal and wasteland, which are not suitable for cultivation of staple crops, either due to poor quality soil or lack of water resources. Most of UUC species are tolerant to harsh agro-climatic conditions; they have excellent potential for establishment on marginal and wasteland throughout the tropics (Kour *et al.*, 2018)<sup>[30]</sup>.

Rai *et al.* (2005)<sup>[48]</sup> reported that the North-East India is rich in fruit diversity and contains more than one-third of the country's total diversity. Based on the areas and crops and their distribution, underutilized fruit crops of the region are given in Table 2. A wide range of vegetable crops are grown in this region, which includes solanaceous vegetables, cucurbitaceous, okra, various kinds of beans, tubers & roots crops, spices, cole crops as well as some species of leafy vegetables (Table 3).

**Table 2:** Diversities of underutilized fruit crops in North-East India [Source: Rai *et al.* 2005]<sup>[48]</sup>

Botanical Name	Distribution
<i>Pyrus pashia</i>	Khasi & Jaintia hills (Meghalaya)
<i>Prunus nepaulensis</i>	Khasi hill (Meghalaya)
<i>Myrica fraquhariana</i>	Sibsagar (Dikho valley Assam), Naga hills, Khasi & Jaintia hill (Meghalaya)
<i>Passiflora edulis</i>	Meghalaya, Mizoram, Manipur, Nagaland and Sikkim
<i>Averrhoa carambola</i>	Assam, Meghalaya and Tripura
<i>Dillenia indica</i>	Meghalaya and Assam
<i>Garcinia cowa</i>	Mizoram
<i>Phyllanthus acidus</i>	Assam, Meghalaya, Mizoram, Manipur and Nagaland
<i>Elaegnis spp.</i>	North east frontier tracts, lower Assam and Meghalaya
<i>Docynia indica</i>	Khasi hill (Meghalaya) and Sikkim

**Table 3:** Diversities of underutilized vegetable crops in North-East India [Source: Rai *et al.* 2005]<sup>[48]</sup>

Species	Distribution
<i>Cyphomandra betacca</i>	Meghalaya and Sikkim
<i>C. minimum Syn. C. fastigiatum</i>	Whole North eastern region
<i>Sechium edule</i>	High hills of Meghalaya, Manipur, Mizoram, Nagaland, Sikkim and Darjeeling hills of West Bengal
<i>Momordica cochinchinensis</i>	Assam, Meghalaya and Manipur
<i>Momordica dioca</i>	Garro Hills of Meghalaya and Tripura
<i>Conavalia ensiformis</i>	Meghalaya, Manipur and Nagaland
<i>Vicia faba</i>	Manipur and Nagaland
<i>Psophocarpus tetragonolobus</i>	Tripura and Manipur

<i>Parkia roxburghii</i>	Meghalaya, Manipur and Nagaland
<i>Trichosanthus dioca</i>	Tropical areas of Assam and Tripura
<i>Coccinia grandis</i>	Assam
<i>Allium sativum</i>	Meghalaya and Tripura
<i>Flemingia vestita</i> syn <i>Maughania vestita</i>	Meghalaya
<i>Amorphophallus</i> spp.	Meghalaya and Tripura

#### Advantages of Neglected and underutilised crops (NUCs):

The benefits of these underutilized plant species are many fold:

- They have potential to contribute to poverty elimination through employment opportunities and income generation and also through improved efficiency and profitability of farm household labour use in both rural and urban environments.
- With the use of underutilized crops, there is a way to reduce the risk of over-reliance on very limited number of major crops.
- They can contribute to sustainable livelihoods through household food security as they can widen the food edibility options.
- They add nutrients to the diet and are sometimes convenience food for low income urban people. They are adapted to fragile environments and can contribute to the stability of agro ecosystems, particularly in the arid, semi-arid lands, mountains, steppes and tropical forests.
- They provide a broad spectrum of crops to improve productivity and global food security and to meet new market demands.

- They assist development of rural community through small-scale investment.
- They have a strong cultural and sacred identify and are associated with traditional customs and beliefs. Therefore, a best way to preserve and celebrate cultural and dietary diversity.
- They provide a opportunity of a broad spectrum of crops to improve productivity and global food security and to meet new market demands. (Thakur, 2014; Bhatt *et al.*, 2019)<sup>[58, 4]</sup>.

Adhikari *et al.* (2017)<sup>[1]</sup> reported that Neglected and underutilized food crops (NUFCs) are comparable to advanced cereals in terms of dietary energy and protein content, but are also rich in micronutrients (Table 4). For instance, pearl millet has a higher content of micronutrients (such as calcium, iron, zinc, riboflavin and folic acid) than rice or maize. Pearl millet *also* has a higher content of micronutrients (excluding calcium) than wheat. This implies that, in the past, food consumption was much more diverse and nutritionally rich.

**Table 4:** Nutritional value of neglected and underutilized food crops: some examples [Source: Gopalan *et al.*, 1989; Adhikari *et al.* 2017]<sup>[19, 1]</sup>.

Nutrient	Some Examples of Traditional Food Crops (Content/100 g)							Advanced Cereals (Content/100 g)		
	Pearl Millet	Sorghum	Finger Millet	Foxtail Millet	Proso Millet	Barnyard Millet	Kodo Millet	Rice (Milled)	Maize	Wheat Flour
Energy (kcal)	361	349	328	331	341	397	309	345	342	346
Protein (g)	11.6	10.4	7.3	12.3	7.7	6.2	8.3	6.8	11.1	12.1
Fat (g)	5.0	1.9	1.3	4.3	4.7	2.2	1.4	0.4	3.6	1.7
Calcium (mg)	42.0	25.0	344	31.0	17.0	20.0	27.0	10.0	10.0	48.0
Iron (mg)	8.0	4.1	3.9	2.8	9.3	5.0	0.5	3.2	2.3	4.9
Zinc (mg)	3.1	1.6	2.3	2.4	3.7	3.0	0.7	1.4	2.8	2.2
Thiamine (mg)	0.33	0.37	0.42	0.59	0.21	0.33	0.33	0.06	0.42	0.49
Riboflavin (mg)	0.25	0.13	0.19	0.11	0.01	0.10	0.09	0.06	0.10	0.17
Folic acid (mg)	45.5	20	18.3	15.0	9.0	-	23.1	8.0	20	36.6
Fiber (g)	1.2	1.6	3.6	8.0	7.6	9.8	9.0	0.2	2.7	1.2

#### Improving Resource Conservation of Neglected and Underutilized Crops

In India and its neighbouring countries, various native fruits, such as aonla, bael fruit (*Aegle marmelos*), jackfruit, jamun (*Syzygium cuminii*), karonda (*Carissa congesta*), Kokum (*Garcinia indica*) and phalsa (*Grewia subinaequalis*) are underutilized. Some of these might be important in the near or far future, because of their therapeutic/medicinal and nutritive value as well as their excellent flavour and very attractive appearance. Consumers today are becoming increasingly conscious of the health and nutritional aspects of their food. Underutilized fruits could play an important role in satisfying demand for nutritious, pleasantly flavoured and attractive natural food of high therapeutic value (Kour *et al.*, 2018)<sup>[30]</sup>. Underutilized fruit crops can be defined as fruit crops which are have value but not widely grown, rarely found in the market and not cultivated commercially (Agent, 1994)<sup>[2]</sup>.

Resource conservation is very important, because many species are becoming extinct and many others are threatened and endangered. The diversity of some fruits is well collected,

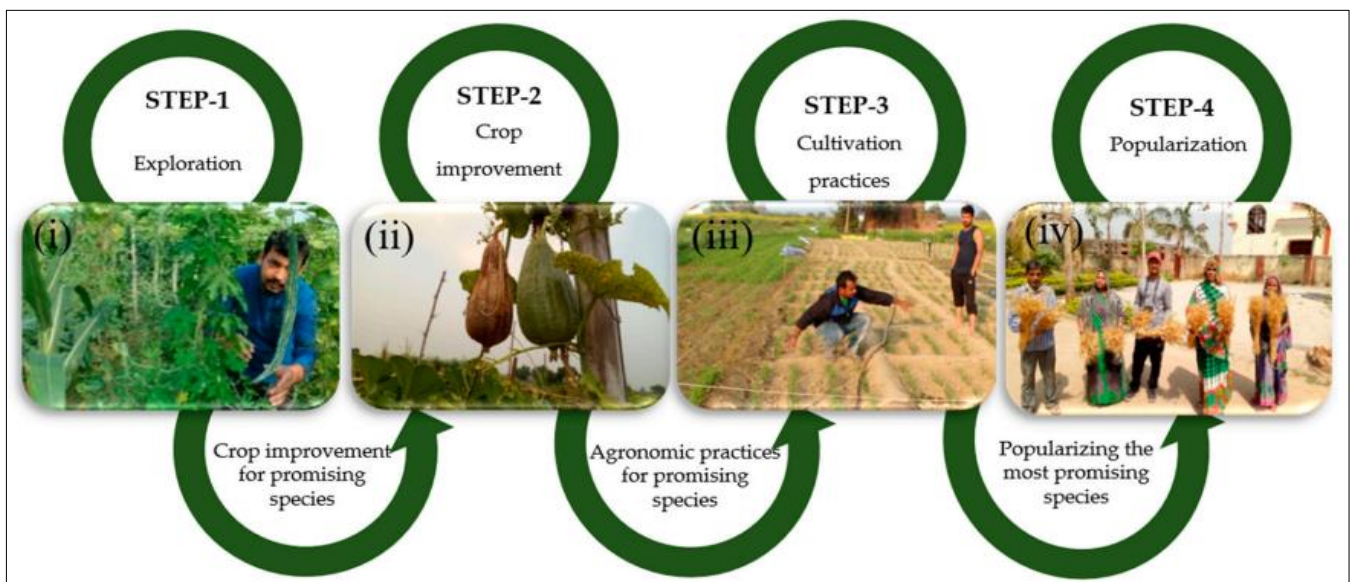
while for other fruits relatively little has been done yet (Arora, 1994). The resource conservation of these underutilized fruit crops include some of the main components are; Identification and collecting live samples of neglected and underutilized crop species establishment of plant arboretum for neglected and underutilized vegetables, fruits and other crop species and promote studies, research and multiplication for the benefit of future generation, conducting awareness creation and educational workshops on the medicinal and nutritional values of identified underutilized species, conducting field research and studies to identify the most suitable techniques for the growing of these plant species and introduction of identified underutilized vegetables and other crop species to the rural home gardens and facilitate the community contribution for conservation of such crop species (Dahanayake, 2015)<sup>[11]</sup>. Underutilized fruit crops can be used for sustainable land use since they do not require external inputs, such as irrigation or fertilization. Undomesticated landraces have adapted to a variety of ecosystems and can sometimes survive conditions which highbred cultivars

cannot. The low external input requirements have also given rise to suggestions that underutilized crops production can go hand in hand with organic certification, thus opening niche market options to the producers (Hellin, 2009)<sup>[26]</sup>.

Increasingly, global food movements such as 'Slow Food' are promoting this holistic approach to food (Slow Food, 2016). A related development in the evolution of food systems is the growing potential of indigenous food systems and neglected crops to contribute to the diversification of diets away from the narrow food base of maize, rice, wheat, barley and soybean (FAO, 2017)<sup>[15]</sup>. Increased reliance on major food crops has been accompanied by a shrinking of the food basket in India which humankind has been relying upon for generations. However, the shrinking of agricultural biodiversity has reduced both the intra and inter specific diversity of crops, increasing the level of vulnerability among users, particularly the poorer sections, for whom diversity in crops is a necessity for survival rather than a choice. Vitamins and other micronutrients are for instance being searched in crops and plant species with greater emphasis than in the past in recognition of their role in combating diet imbalances. Although 'hidden hunger' affects mainly developing countries, particularly children and older people (FAO, 1997), it is increasingly being recorded also among the more vulnerable social groups in developed nations. These underutilized crops (referred to also by other terms such as minor, orphan, neglected, underutilized, underexploited, underdeveloped, lost, new, novel, promising, alternative, local, traditional, niche crops) have been included in worldwide plans of action after having successfully raised and other highly nutritious plant resources (Bhunja *et al.*, 2009)<sup>[5]</sup>.

Many underutilized crop species have similar or higher nutritional values than global crops, which is especially

relevant for those produced under challenging growing conditions. For example, indigenous fruits and vegetables are being explored for their role in providing nutrient dense foods under low irrigation (Chivenge *et al.*, 2015)<sup>[9]</sup>. Moreover, the quality and availability of two other inputs vital for agricultural production, i.e., water and land, are already in a thinning state (Dubey *et al.*, 2016; Tripathi *et al.*, 2017)<sup>[12, 59]</sup>. The changing climatic condition is another impediment for food production as it negatively affects the quality and availability of the critical resources as well as the quality and quantity of the agricultural production itself (Parodi *et al.*, 2018)<sup>[47]</sup>. Since we have to enhance the food production by 70% for meeting the demand of the growing population in 2050, the cultivation of resilient, nutritionally rich, and low-resource intensive crops are of paramount importance for human wellbeing and environmental sustainability (Nair *et al.*, 2019)<sup>[14, 42]</sup>. In this context, (Ewel *et al.*, 2018; Singh *et al.*, 2018)<sup>[14, 52]</sup> the domestication of undomesticated, wild and neglected crops and exploiting their natural traits to efficiently use critical natural resources such as N, P, water, and land offers huge promise in attaining future food security as they are bestowed with high nutritional value (Gruber *et al.*, 2017; Singh *et al.*, 2019)<sup>[53]</sup> and adaptive traits. Importantly, they need only minimal input and care so they can be easily cultivated in marginal and other nutrient-poor soil and even under changing climatic conditions (Singh *et al.*, 2019)<sup>[53]</sup>. Four important steps, i.e., (i) exploring the unexplored, (ii) refining the unrefined traits, (iii) cultivating the uncultivated, and (iv) popularizing the unpopular for the large-scale exploitation of such important but still underutilized and neglected crops for global food and nutritional security (Fig. 2).



**Fig 2:** A casual loop diagram showing various steps involved in the sustainable utilization of wild and neglected crops for global food and nutritional security. (i) Step-1: exploration of various kind of wild and neglected crops; (ii) Step-2: improving the desirable traits in promising species by conventional as well as modern biotechnological approaches; (iii) Step-3: standardization and optimization of various agronomic practices for their large-scale exploitation and (iv) Step-4: the popularization of unpopular crops among farmers, policy makers, and other stakeholders. [Source: Singh *et al.*, 2019]<sup>[53]</sup>.

Massawe *et al.* (2016)<sup>[39]</sup> opined that the neglected and underutilized wild species are a treasure trove for food security. However, majority of such lesser known species are undomesticated, and therefore, farmers are not aware of their cultivation and propagation methods. Therefore, standardizing

the agronomic practices (Fig. 3a) for such uncultivated edible crops is another major step for optimizing their resource use and also for improving the yield and nutritional quality (Ewel *et al.*, 2018)<sup>[14]</sup>, whereas the exploitation of modern techniques for germplasm storage is also essential for

maintaining such vital resources for the future use (Singh and Abhilash, 2018; Singh *et al.*, 2019) <sup>[53, 54]</sup>. Creating community gene banks at farmer's fields is an excellent

strategy for the long-term conservation of such underutilized species (Fig. 3b).



**Fig 3a:** Optimization of agronomic practices and mass multiplication strategies are essential for the large-scale exploitation of underutilized crops. Picture shows the various stages of the mass propagation and cultivation of Indian spinach (*Basella alba* and *Basella rubra*)

**Fig 3b:** Field gene bank for conservation of neglected and underutilized crops. Maintaining germplasm of promising species at farmer's field itself is a promising strategy for conservation. [Source: Singh *et al.*, 2019] <sup>[53]</sup>

### Production Potential of Neglected and Underutilized Crops

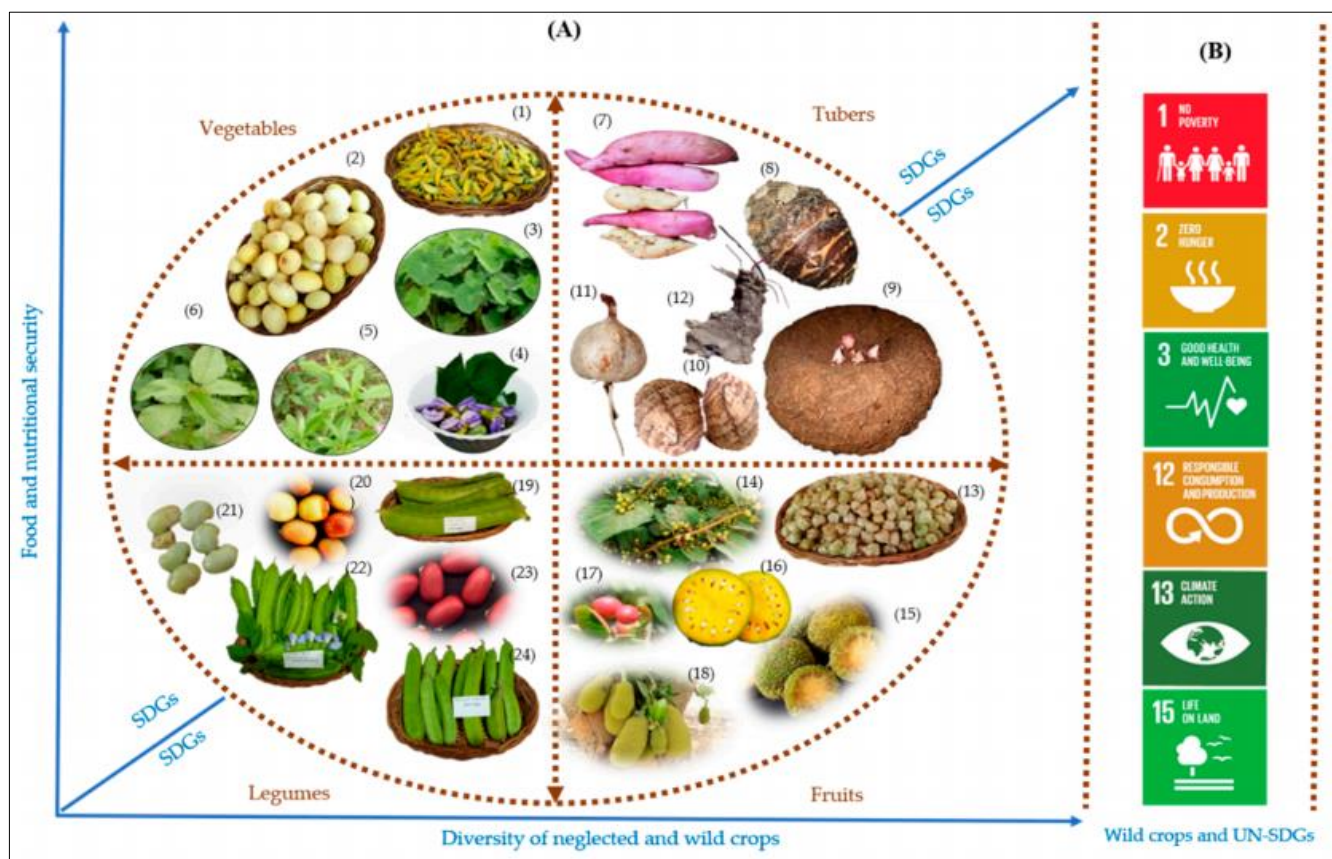
Many neglected and underutilized vegetables are nutritionally rich and are adapted to low-input agriculture. The erosion of these species, whether wild, managed or cultivated, can have immediate consequences on the food security and well-being of the poor. Their enhanced use can bring about better nutrition. For example, many underutilized vegetables contain more vitamin C and pro-vitamin A than widely available commercial species and varieties. Focusing attention on neglected and underutilized vegetables is an effective way to help maintain a diverse and healthy diet and to combat micronutrient deficiencies, the so-called 'hidden hunger', and other dietary deficiencies particularly among the rural poor and the more vulnerable social groups in developing countries (Jena *et al.*, 2018). Neglected and underutilized plant species have a distinctive past, current, or potential use value, but their use is currently limited relative to their economic potential (Gruere *et al.*, 2007) <sup>[24]</sup>.

Minor millets are particularly neglected in terms of research and development. Their potential for climate smart agriculture and enhanced nutrition is also underexploited. Accounting for less than 1% of grains produced globally, they are nevertheless essential for food security in their respective agro-ecosystems, which are often marginal areas [Mal *et al.*, 2010] <sup>[37]</sup>. Minor millets are adapted to a range of growing conditions, mature quickly and are better able to withstand climatic extremes. High in micronutrients, including calcium, iron and dietary fibre, they also offer a greater variety of vitamins, contain more antioxidants and have more usable protein than wheat, rice or maize [Fischer *et al.*, 2016; Taylor *et al.*, 2006; Ravi *et al.*, 2010; Padulosi *et al.*, 2015] <sup>[16, 57, 49]</sup>.

<sup>45]</sup>. Grovermann *et al.* (2018) <sup>[21]</sup> reported that the potential for improved growing practices to achieve better yields, but also education levels and technical support emerge as crucial factors for boosting finger millet productivity.

Kaundal *et al.* (2019) <sup>[29]</sup> reported that Horse gram an underutilized legume crop is a sturdy, nutritive as well as medicinal food crop which has been under cynical abhorrence for ages. Its present consumption status cannot belittle its numerous beneficial bioactivities. Our intransigent neglect of not categorizing it as major food crop needs to be allayed by projecting it as major pulse.

Greater use of moringa has good potential in the fight against hunger and malnutrition in the developing world by improving nutrition and health of the rural and urban poor, increasing incomes of smallholder farmers, and enhancing environmental services by controlling soil and wind erosion, and providing shade and clean water. Given its multiple uses and wide range of adaptability, moringa is an ideal crop for sustainable food production that would thrive as the climate changes (Ebert. 2016) <sup>[13]</sup>. Singh *et al.* (2019) <sup>[53]</sup> revealed that there are many potential future smart foods (FSF) such as finger millet, kodo millet, little millet (cereals/pseudo-cereals), air potato, turnip, kohlrabi, kudzu (roots and tubers), winged bean, sword bean, pigeon pea, chick pea (pulses), spine gourd, clove bean, phalsa, custard apple, kadamba, chenopodium, brown mustard, water spinach, jujube, ground cherry (fruits and vegetables) etc. to be included in the regional list and thereby encouraged to be exploited them for future food security (for more such species are shown in Fig. 4A). The cultivation of such species are not only important for global food security but also for attaining many other UN-SDGs (Fig. 4B).



**Fig 4:** Schematic representation of the inter-relationship between diversity of wild and neglected crops, food and nutritional security and UN-SDGs. (A) food and nutritional security increases with the large-scale exploitation of neglected and wild crops. (B) Sustainable utilization of wild and neglected crops is essential for attaining UN-SDGs. [Source: Singh *et al.*, 2019] <sup>[53]</sup>.

In India, Underutilized fruit crops are those of local or regional importance, but generally lacks national recognition, all though they are rich source of anti oxidants and minerals. Lack of interest on underutilized crops may be due to astringency, acidic nature of fruits like aonla, bael and karonda etc. Value addition of these fruits can help to meet the nutritional requirement of the people and economic sustainability (Kumar, 2016) <sup>[31]</sup>.

Nandal and Bhardwaj (2014) <sup>[43]</sup> reported that the underutilized horticultural crops, which are neither grown commercially on large scale nor traded widely, they cultivated, traded, and consumed locally. These crops have many advantages like easier to grow and hardy in nature, producing a crop even under adverse soil and climatic conditions and these crops become a solution to the social problem of health and nutrition insecurity, poverty, and unemployment. The consumption of underutilized fruit crops can provide nutrition to the poor and needy tribals by meeting the nutrient requirements of vulnerable groups. As underutilized fruits, nuts, and vegetables are a rich of source of carbohydrates, fats, proteins, energy, vitamins-A, B1, B2, B3, B6, B9, B12, C, folic acid, and minerals-Ca, P, Fe, and dietary fiber. Thus, they have the nutritional capacity to prevent and cure various diseases like kwashiorkor, marasmus, night blindness, anemia, diabetes, cancer, hypertension, and hidden hunger. It is the fact that seasonal, locally available, and cheap fruits and vegetables can also keep the population healthy and nutritionally secure rather than costly off-season ones. Also, the underutilized crops have the potential to give economic security to tribals by giving employment and by fetching good returns from their sale in raw form as well as value-added products.

### Marketing strategies for utilization of Neglected and Underutilized Crops

Most of the minor fruits are enriched with nutritional and medicinal value and can be grown even in wastelands without much care. Therefore, it is worthwhile to look into the organized cultivation and improvement of minor group of crops like aonla, pumpkin, wood apple, bael etc. so that their utilization can be maximized. There is always demand from consumers for new, delicious, nutritious and attractive food products. To satisfy this demand, there is a constant effort to develop products from diverse sources. The nutrient rich fruits, economically cheaper fruits must have a good treatment to make innovations to treat malnutrition in the country (Chandra *et al.*, 2017) <sup>[17]</sup>. Many of these traditional crops grown for food, fiber, fodder, oil and as sources of traditional medicine play a major role in the subsistence of local communities and frequently are of special social, cultural and medicinal value. With good adaptation to often marginal lands, they constitute an important part of the local diet of communities providing valuable nutritional components, which are often lacking in staple crops (Jain and Gupta, 2013) <sup>[28]</sup>.

Gruere *et al.* (2006) <sup>[23]</sup> reported the market equilibrium; First, the apparent lack of demand may be due to incomplete or asymmetric information, where Consumers may be willing to buy the product, but not in places where it is sold; consumers may have access to the product, but its quality at the point of purchase may be inadequate. The demand may be restricted to local community users, rural areas, aged consumers (if products of the underutilized plant species lost its appeal), low income consumers, or members of a community who use underutilized plant species products in a traditional fashion



that is not known to the outside world. In some cases, introduced species and products are cheaper or more convenient to buy although the native underutilized plant species have greater nutritional value. For example, in Bolivia, rice and maize are consumed locally instead of quinoa because they are sold at lower prices on local markets. Quinoa is mainly produced for the export market. Secondly, even if there is a strong demand for products derived from an underutilized plant species, there may be inefficiencies that reduce available supply or quality. In developing economies, the lack of credit and physical infrastructure impede the ability of chain actors to improve marketing approaches. Furthermore, the marketing channel may be inefficient or incomplete, adding transaction costs. In particular, an unorganized marketing channel, simple (collection and distribution) or more complex (wholesale, processing and retailing), can by itself create inefficiencies that are sufficient to limit significantly the market for underutilized plant species. An example is the market for caper buds in Syria. There is a high mark-up at the end of the supply chain, a lack of transparency, and mistrust among actors, negatively affecting the income share earned by poor collectors in rural areas (Guiliani 2006) [18]. Finally, the species may not have been improved through basic selection, resulting in

germplasm with both lower productivity potential and lower value at least for commercially-oriented producers.

Gruere *et al.* (2006) [23] Classified underutilized plant species according to four economic criteria (Table 5):

1. Observed and potential value characterization: private versus public value; observed value (collected versus cultivated, crop competition), gap of scientific knowledge (production, uses, properties), distribution of knowledge among local users (even versus asymmetric in favour of who); temporal characterization (past, recent or pre-existing knowledge); spatial characterization (local versus regional),
2. Output market: missing or not, due to exogenous or endogenous constraints; particular to species or not.
3. Market imperfections: Demand side (asymmetric information, market access). Supply side: primary producers (incomplete markets for labour, information, risk, credit, or other factors); insufficient quality of inputs or output; marketing channel inefficiencies (organization, information, market power, infrastructure, credit).
4. Market failures: Specific sources of production externality (environmental, health etc), type of public good provision (local, regional, global).

**Table 5:** Classification of selected underutilized plant species according to economic criteria [Source: Gruere *et al.*, 2006] [23]

Example	Characterization of the underutilised plant species					Economic constraints				Market failures
	Economic Value					Output market		Market imperfections		
	Region	Observed value <sup>a</sup>	Knowledge Gap <sup>b</sup>	Vector type <sup>c</sup>	Temporal Evolution <sup>d</sup>	Presence	Constraints	Demand	Supply	
Quinoa	Andean region	Cultivated (rice, maize)	Small in & large out	E	I and II	Yes/No	Endogenous exogenous	Information	Organization, low productivity	Diet quality
	United states	Cultivated (niche market)	Large out	B	II	Yes	None	Information		Diet quality
	Syria	Collected	Small in & out	C	II	No	exogenous	Information	Organization, Processing, No cultivation	Health
Capers	Morocco	Collected Cultivated	Small in & out	C	II	Yes	exogenous	Information	Over supply	Health
	Italy	Cultivated (niche market)	Large in & small out	B	II	Yes	None	None	Labour availability	Health
Laurel	Syria	Collected Managed	Large in & small out	C	II	Yes	Endogenous	Information intermediaries	Quality standards	Health
Rice - bean	Vietnam	Cultivated	Small in & out	A,D	III	No	exogenous	Information	low productivity	Ecological services
Mallow	Syria	Collected Cultivated	Small in & out		I	Yes/ No	Endogenous	Insufficient	Handling organization	Diet quality
Baobab	African dry areas	Collected Managed	Small in & out	E	II	Yes	Endogenous	Information	Quality standards, Processing, Organization	Health
Purslane	Syria	Collected Cultivated	Small in & out	C	III	Yes	Endogenous	Information	Handling	Diet quality
Jujube	Syria	Collected Managed	Small in & out	C	III	No	exogenous	Insufficient	Quality standards, Organization	Diet quality

Gajanana *et al.* (2010) [17] reported a small scale processing units were established at the community village level in the state of Karnataka, Maharashtra and Gujarat in India for processing of underutilized fruits like aonla, tamarind and jackfruit into different products. Later, a survey was undertaken to ascertain the processing and market potential of underutilized fruit products. The market survey in the Hassan district of Karanataka has indicated the presence of underutilized fruit products like citron pickles, tamarind paste and jackfruit chips, which are sold by the retailers in small quantities. The market survey of underutilized fruit products in Pune (Maharashtra) has indicated the trading of

underutilized fruit products like aonla pickle, aonla squash, aonla supari and tamarind products like concentrate, pani puri masala in the market, though in small quantities. The market survey in the Dharmapur and Valsad markets, Gujarat has indicated the presence of underutilized fruit products like pachan aonla (digestive aonla), ber powder, salted ber and tamarind under different brand names like Oswal, Khelkar, Frootlet, etc. The share of the underutilized fruit products is small but these products have made their presence felt in the market. By and large, consumers have accepted the quality and price of the products of the small scale community processing unit. However, label needs improvement and is to

be made more attractive. Thus, market research has helped in identifying the potential markets for the underutilized fruit products of the community level processing units. Some of

the Underutilized fruits and their products for market research (Table 6)

**Table 6:** Underutilized fruits and their products for market research [Source: Gajanana *et al.*, 2010; Kour *et al.*, 2018] <sup>[17, 30]</sup>.

S. No.	Underutilized fruit	Fruit product
1.	Aonla	Pickle, Candy, Squash, Murabba, Dry aonla (supari) and Mouth freshener or Pachan aonla (digestive aonla)
2.	Tamarind	Tokku (chutney), Pickle, Paste or Concentrate, Panipuri masala, Dry tamarind (powder), Candy
3.	Ber	Ber powder, Salted ber
4.	Jack fruit	Chips, Papad
5.	Karronda	Pickle
6.	Citron	Pickle

Thakur. (2014) <sup>[58]</sup> reported that there are very many difficulties in popularizing underutilised crops (UUC's) at market and consumer level because of a variety of reasons. Hence, there has been uttermost need to give guidance and knowledge to consumers about the use of UUC's. Major fruit and vegetable distributors, failed to market UUC's and their products in the most desired and tempting way by displaying the quality, price and information results in ignorance about the fruit texture, colour, flavour, and optimum maturity before consumption by consumers. Basically most of the consumers are unaware about these plant products, their mode of usage, expectation of sensory qualities, and mode of storage and ripening. Finally, there is a lack of sustained and informative research on the same field. A spectacular wide strategy has to be developed for underutilized crops for the benefit of mankind. But for the same protocol for increasing use of underutilized crops for food security involves overcoming many constraints and obstacles, from genetic through management, cultural acceptability, and marketing, to policy and decision-makers in government (Padulosi *et al.*, 2002) <sup>[44]</sup>. There are very good examples for the development of an indigenous crop within its local community where it provides direct benefits to that community through food and often income security, providing the local community with purchasing power (Mayes *et al.*, 2011) <sup>[41]</sup>.

### Conclusions

Neglected and Underutilized crops (NUCs) have great potential to alleviate hunger directly, through increasing food production in challenging environments where major crops are severely limited, through nutritional enhancement to diets focused on staples, and through providing the poor with purchasing power, helping them buy the food that is available. Many underutilized crops were once more widely grown but are today falling into disuse for a variety of agronomic, genetic, economic and cultural factors. NUS are healthier foods which could enrich diets. Only if these crops, particularly those locally available and culturally acceptable, would adequately researched, marketed, and utilized, it could help in curbing food insecurity and nutrient deficiency through improving diets with too much refined carbohydrates and fats. The general decline of these crops may erode the genetic base and prevent the use of distinctive useful traits in crop adaptation and improvement. Production, post harvest handling and processing of neglected and underutilized crops practiced today perpetuate heavy losses, inadequate infrastructure facilities cripple marketing prospects, low production of neglected and underutilized crops results in lesser yield of processed products, thereby increasing the production cost during processing. To overcome these problems, the development of technologies is required

urgently to minimize the losses during post harvest handling and also technologies suitable for specific processing purposes, products development and storage of fresh and processed products. Underutilized crops are the options for scaling-up neglected crops for large-scale agriculture appear to be increasingly exhausted and were adopted socially and environmentally in local conditions, survived for centuries under changing climate conditions, and contributed to poor rural communities, many species have the potential to contribute to food security, nutrition, dietary and culinary diversification, combating vitamin and micronutrient deficiencies, health and income generation particularly in rural communities dependent on agriculture. It would require a strong advocacy, policy support, research and development effort, and resource allocation. Neglected and underutilized crops, being more resilient and better adapted to grow in marginal environments than current staple crops, offer cost-effective and viable solutions for food production. NUCs will continue to be important to increase income particularly in rural areas thus their improvement will improve livelihoods to traditional communities and rural areas.

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