Alternative Crops for Augmenting Farmers' Income in Abiotic Stress Regions

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Citation

Pradhan A, Rane J and Pathak H (2021) Alternative crops for augmenting farmers' income in abiotic stress regions. Technical Bulletin No. 29. ICAR-National Institute of Abiotic Stress Management, Baramati, Pune, Maharashtra, pp 26.

Printed: February, 2021

ISBN No.: 978-81-949091-6-3

Published by

Director, ICAR-National Institute of Abiotic Stress Management, Baramati, Pune, Maharashtra

Design & Art

Mr. Pravin More, Senior Technical Assistant (Computer)

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Preface

Alternative crops, also known as orphan-, indigenous-, lost-, minor-, underutilized-crops, play an important role in food and nutritional security as well as the livelihood of resource poor farmers. They offer new opportunities to address socioeconomic and environmental challenges in the advent of climate change as most of them are nutritious, resilient to abiotic stresses, suitable for marginal and low-input environments and represent a broad pool of genetic resources for future crop improvement. Inclusion of such alternative crops in the existing cropping systems could contribute to sustainable, nutritious, healthy and diverse food systems in marginalized agro-ecological conditions. However, there is need to increase our knowledge and promote the crops that have the potential for increased production under adverse climatic conditions.

In this bulletin, alternative crops from different crop types along with their scope and opportunities are represented. Several global and national institutions or platforms dedicated to research on alternative crops, the activities and progresses including ICAR-NIASM initiatives, are reported. Some of the critical constraints to their widespread cultivation and consumption as well as strategies are also highlighted.

We sincerely acknowledge the invaluable contributions rendered by all the eminent speakers of the national webinar on "underutilized crops for augmenting farmers income in abiotic stress regions" for sharing their research insights on various aspects of underutilized crops. Acknowledgements are also due to Indian Council of Agricultural Research, New Delhi for their continuous support and encouragement.

We hope that the information contained in this bulletin will be useful for researchers, farmers, students and other stakeholders.

February, 2021 **Authors**

Content

1. Introduction

Agricultural productivity must be increased sustainably in order to eradicate hunger and malnutrition as committed to in the 2030 Agenda for Sustainable Development (SDGs) and meet the projected 50% increase in demand for nutritious food between 2012 and 2050. The over 800 million people who are chronically hungry and the two billion who suffer micronutrient deficiencies worldwide underline the need to act. This situation is exacerbated by the ever more frequent erratic extreme weather events. About 90% of global agricultural land faces the distress of various abiotic stresses viz., moisture stress, heat stress, nutrient stress, pollution/heavy metal stress, salt stress, mechanical stress *etc.*, limiting crop production up to 70%. These climate-induced challenges are intensifying, causing socio-economic insecurities as well as nutrition and health challenges, particularly in marginalized communities. Furthermore, climate-change impacts have put an additional pressure on already stressed natural resource base, reducing the resilience of agro-ecosystems that are, in part, providing food and nutritional security in rural communities. There are 400,000 plant species identified on the planet out of which 30,000 are known to be edible with only 6000 being used as food. Further only 150 crops are cultivated on significant scale worldwide, dominated by only three crops *viz.*, maize, wheat and rice that supply nearly 60% of our daily protein and carbohydrate (FAO Commission on Genetic Resources for Food and Agriculture, 2019). The last 60 years of research investments over few resources intensive crops—the so-called ‘Green Revolution’ have led to higher yields and important contributions to reduce hunger in the world. However, this huge achievement has been accompanied by a major downside: the heavy erosion of our plant-based diets and the loss of the biological foundation on which our farming practices are based. A staggering 75% of crop diversity has been lost in the course of last century (an estimated 300,000 varieties). Just twelve crops together with five animal species provide 75% of the world’s food, and of the 137 most important crops in the world, 20 are cultivated over 80% of the global agricultural area and the remaining 117 on a mere 20%. These trends are worsening every year. The lack of genetic diversity within the gene pools of these few crops leaves our agricultural systems vulnerable to pests and diseases, and to abiotic stress. In addition, commercial advantages of mono cropping and the high yield of many improved hybrid crops, masked the local crop diversity along with the wealth of traditional knowledge about their cultivation and uses. Also, from the perspective of sustainable food security, relying on such a narrow food base makes our food supply extremely vulnerable.

Basing our diet on a very small number of major crops has dire implications for both food security and nutrition. There is increasing evidence that the diets around the world have become more similar further indicating the change in the relative importance of different crop plants in national food supplies worldwide (CIAT, 2017). Clearly, the world needs a new green revolution to tackle the daunting problems of hunger and malnutrition, which cannot succeed without agro-biodiversity. Food based solutions that diversify what we grow and what we eat provide enduring benefits to local communities and the environment by addressing these problems at their base. Research efforts to secure the production of staple crops to feed the world should continue, but that must be complemented by parallel investments on alternative crops that are nutritious and stress resilient. Diversifying the production systems with those alternative crops will buffer food systems against socio-economic shocks, climate risks and at the same time strengthen the health of agro-ecosystems, support smallholder agriculture, safeguard food cultures and associated economies that revolve around local crops and traditions.

2. Alternative Crops: Definition, Opportunities and Research Status

2.1. Definition

Alternative crops, also called orphan, abandoned, neglected, lost, underutilized, local, minor, traditional, niche, or underdeveloped crops, are part of a large portfolio of useful species which are marginalized, if not entirely ignored, by researchers, breeders and policy makers. They are non-commodity crops and belong to a large, biodiverse group of thousands of domesticated, semi-domesticated or wild species having great potential: hardy and highly nutritious, these cereals, pseudo cereals, millets, fruits and nuts, vegetables, pulses, roots and tubers, oil seeds, latex/rubber/gums, fibres, starch/sugar, and dye form a universe of tastes and flavours that have been shaping traditional systems everywhere (Appendix I). They may be a well-established major crop in one country and a neglected minor crop in another. However, alternative crops differ from major staple crops in fundamental ways such as traditional method of cultivation, use of informal seed sources and involvement of strong gender element. Their processing can be laborious, grading and packaging primitive and the products marketed locally with limited involvement of large enterprises. Having long been neglected by mainstream agriculture for a variety of agronomic, genetic, economic, social and cultural reasons, today these crops are receiving increasing recognition because of their potential role in mitigating abiotic and biotic stresses and other associated risks in agricultural production systems (Fig. 1). Over the last ten years or so, an increasing number of projects have directed their attention to the significance of alternative crops in improving nutrition, generating income, maintaining ecosystem health and empowering the poor and marginalized, as well as in promoting cultural diversity.

Reasons of negligence of alternative crops	Reasons for mainstreaming alternative crops
• Supply constraints	• Adapt to harsh environment
• Consumption constraints	• Multiple utility
• Poor shelf life	• High/balanced nutritional quality
• Unrecognized nutritional value	• Low input requiring (eco-friendly)
• Poor consumer awareness	• High risk bearing (resilient)
• Reputational problems	• Suitable for marginal & problem soil
• Genetic erosion	• Compatible with local culture
	• Soil enrichment capacity
	• Pool of genetic resources
	• Scope for value added products
	• Sustainable
	• Export potential

Fig. 1. An overview of reasons of negligence and mainstreaming of alternative crops

2.2. Opportunities for Mainstreaming Alternative Crops

Alternative crops offer tremendous opportunities– regardless of their development status; to improve people's diets and to strengthen the potential for income generation not only for farmers, but also for all the other stakeholders engaged in the associated value chains. Their use also empowers indigenous communities (women in particular), reaffirms people's identity by placing a value on traditional food and the associated culture, and makes agricultural production systems more resilient in the face of climate change where biodiversity has important role to play.

2.2.1. Food Security and Climate Resilience

Alternative crops have the potential to contribute to food security at local and regional levels. At the national level, they can strengthen a country's food and buffer economic and social shocks that might hit the population as a result of concentrating on limited no. of crops. Often known as 'famine food', farmers have returned to and relied on alternative crops throughout history whenever major staple crops have failed. They can also provide a safety net during periods of stress and following disasters and other emergencies. Although many alternative crops characteristically have lower yields than the main staple crops, they often compensate for this by being more resistant to biotic and abiotic challenges and providing dependable harvests in unfavourable climatic conditions or on difficult soils. This adaptive capacity is one of the key traits of many alternative crops. They are often grown in poor areas where difficult agro-ecological conditions predominate, and where smallholder farmers do not have the means to adopt the high-input agricultural practices geared to major staple crops. Further, farmers maintain high levels of traditional varietal diversity. This provides insurance since traditional varieties are often best adapted to marginal ecosystems and heterogeneous environments, and the most resistant to local pests and diseases. Enhancing diversity by growing alternative food and forage crops will not only diversify agro-ecosystems but will also improve their adaptability to extreme climatic conditions and provide resilience to biotic and abiotic stresses.

2.2.2. Nutrition Security

In the Green Revolution and the decades that followed, the focus of agricultural research was on increasing crop yields to ensure adequate calories for people who would otherwise have gone hungry. However, less attention was given to nutritional quality – providing a sufficient quantity of food trumped providing nutritious food. As a result, diets deficient in essential vitamins and micro-nutrients still persist in many parts of the world. Globally, 800 million people are food insecure, 2 billion suffer from micronutrient deficiencies and 2.1 billion are overweight or obese. In this scenario, alternative crops comprising of cereals, millets, pulses, vegetables, and fruits provide essential micro-nutrients and thus complement staple foods (Appendix II). Additionally, they provide flavoring in local cuisine, strengthen local gastronomic traditions and provide income opportunities for both the rural and urban poor. Many alternative crops are high in carotenoids and minerals and therefore could play a role in helping to improve the micro-nutrient content in the diets of millions of people around the world. Strategies based on diverse local food crops can provide a valuable and sustainable complement to other means of tackling malnutrition. It is widely accepted that increased consumption of locally available indigenous or traditional fruits, vegetables, grains, roots and tubers can improve nutrition and increase human productivity.

2.2.3. Income and Livelihood of Small and Marginal Farmers

Higher incomes for small-scale farmers and entrepreneurs are often quoted as one of the benefits of improving the production and quality of alternative crops, especially high-value crops, such as local fruits and vegetables. Strategic interventions to that end will involve making those crops more commercially competitive by developing improved ‘modern’ varieties. Poor competitiveness also stems from lack of capacity in poor rural areas to negotiate with the private sector to access the new technologies and markets which would increase the potential demand for these local crops. Internationally, there is a rising interest in new foods and other products which can contribute in novel ways to human health and nutrition. Local, national and global markets will be effective in supporting diversity only if consumers are educated about diversity and are willing to pay for products that support diversity. Higher-value niche markets can be developed through strategic placements of alternative crops in large commercial outlets, such as supermarkets catering to urban populations and the developing middle-classes. Training stakeholders in value chain development is important, as is increasing the availability of credit to small producers and micro-processors. Training will need to be broad and cover areas such as processing, packaging, bookkeeping, economies of scale, accessing market information (e.g. through channels such as text messaging on mobile phones), negotiating with different actors and learning how to respond to market changes.

2.2.4. Cultural Identity

Increasingly it is being recognized that traditional food systems are intertwined with the cultural identity of indigenous peoples. Their knowledge of local ecosystems and food sources has evolved over generations. It is becoming clear that conserving traditional food systems is a powerful way to contribute toward saving local ecosystems and food sources as well. While modern agriculture has succeeded in increasing the yields of staple crops to feed a burgeoning world population, at the same time there have been some unintended consequences with regard to the food systems of traditional, indigenous farming systems in many regions of the world. Because of the benefits traditional food systems offer in terms of physical health and the continuity of cultures, many indigenous groups are actively finding ways to combat the loss of their food heritage and their sense of ‘connection to the land’. These efforts include stemming the loss of the agricultural biodiversity on which food systems are based and conserving the local ecosystems on which generations of people have based their patterns of living and their traditional cultures. Also of critical importance are the many on-going attempts to document, before it is lost, the indigenous knowledge of local plant foods, including their growth requirements, storage and other post-harvest needs and methods of food preparation. Support to seed systems for traditional crops is also a priority for many programmes initiated by international aid and scientific organizations. Many activities focus on the women in the communities, as women often play key roles in cultivating, gathering, preparing and storing foods as well as in managing the family diet. The conservation of traditional food systems is important among the migrant groups that characterize modern societies. Many migrants are from traditional rural communities where off farm labour is an important component of livelihoods and causes individuals to leave their home villages and regions in search of work. When transferred to urban areas, having access to traditional foods and methods of preparation is important in maintaining a connection with the migrants’ cultural roots and in fostering cohesion among fellow migrants.

2.2.5. Pool of Genetic Resources

Alternative crops represent a valuable pool of genetic resources, which can support the SDGs related to food, health and poverty. The genetic diversity of this resource base has important value as the basis for breeding programmes, which rely on variability as the basis from which beneficial traits can be identified and nurtured. While the long-term reduction in genetic diversity in major crops has become a key issue in their breeding and development, alternative crops retain huge genetic diversity within and among different provenances of landraces.

2.3. Research Status

2.3.1. Global Research Status

The importance of alternative crops is widely recognized by the global scientific community as depicted by number of species of different alternative crops that are currently under research across globe (Fig. 2 & Appendix II). This section provides an overview of major global endeavors and research networks working in the area.

i) The **Second Global Plan of Action for Plant Genetic Resources for Food and Agriculture** is the globally agreed framework for the conservation and sustainable use of plant genetic resources for food and agriculture. It addresses the new challenges and opportunities through 18 Priority Activities (PA) covering four thematic areas: *In situ* conservation and management, *Ex Situ* conservation, sustainable use, and building sustainable institutional and human capacities. Its PA 9 gives greater emphasis and visibility to plant breeding, supporting plant breeding, genetic enhancement and base-broadening efforts whereas PA 10 and 11 are dedicated to "promoting diversification of crop production and broadening crop diversity for sustainable agriculture" ,"promoting development and commercialization of all varieties, primarily farmers' varieties/landraces and underutilized species", respectively. The adoption of the Second Global Plan of Action reflects an international consensus, and testifies the political will to identify and carry out agreed priorities.

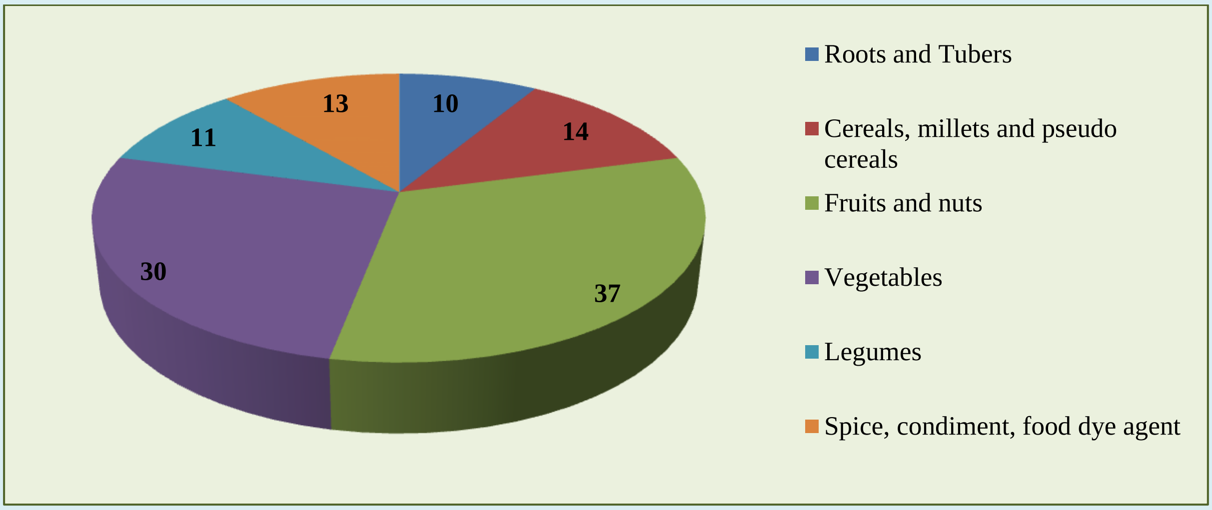


Fig. 2. No. of species in alternative food groups that are currently under research across globe

ii) The alliance of **Bioversity International** and **International Center for Tropical Agriculture** (CIAT), a CGIAR center, based at Rome, Italy is working with local, national, and multinational partners across globe, and with the public and private sectors and civil society to provide food system solutions at the nexus of agriculture, environment, and nutrition. Bioversity International also manages a web portal called **The Neglected and Underutilized Species (NUS) Community**, (www.nuscommunity.org), dedicated to providing support tools for research on, and promotion of, the use of neglected and underutilized crops. It serves as a repository for research results and varied information, news and literature and policy advice on the use and conservation of these species (www.alliancebioversityciat.org).

Globally, a total 4200 minor fruits and nuts species (3000 in tropical and 1200 in temperate regions) has been recorded including 261 species reported in Asia pacific region, 84 species in India (Arora, 1985 and Pareek et al., 1998). As a part of the programme, Bioversity International, Bengaluru has a genetic diversity park, which comprises collections of 35 families, 67 genera, 126 species and 265 varieties of minor fruits and nuts as of 31st Dec 2019 (Appendix III). However, based on the criteria for mainstreaming these minor fruit crops *viz*., a) nutrient dense; b) climate resilient; c) economically viable and d) locally available and adaptable, few fruit crops are considered as potential underutilized fruits for mainstreaming in the food systems of India such as *Artocarpus sp*., *Annoana sp*., *Ziziphus sp*., *Syzygium sp*., drumstick and Tamarind (Table 1 & Appendix IV).

Table 1. Potential fruit crops for mainstreaming in Indian food production system.

Crops	Species	Varieties
Jackfruit (*Artocarpus sp)*	06	52
Custard apple (*Annona sp)*	07	24
Ber (*Ziziphus sp)*	04	08
Jewish Plum (*Syzygium sp)*	14	29
Drumstick (*Moringa oleifera)*	01	04
Tamarind (*Tamarindus indica)*	01	04

Source: S. B. Dandin (2020), Liaison officer, Bioversity International, Bengaluru

iii) Food and Agriculture Organization (FAO) launched the **Future Smart Food** (FSF) Initiative inter alia, to promote the widespread cultivation and consumption of alternative crops as means to improved nutrition and enhanced productivity and resilience of agricultural and food systems. The FSF Initiative – with 30 national and international organizations collaborating – is being implemented under the auspices of FAO's Regional Initiative on Zero Hunger Challenge for the Asia and Pacific Region (RI-ZHC). As part of the RI-ZHC, Cambodia, Lao PDR, Myanmar, Bangladesh, Bhutan, Vietnam, India and Nepal are being assisted with the mainstreaming of alternative crops in their National Food Security and Nutrition Strategy through the Regional Technical Cooperation Project (TCP) "Creating Enabling Environments for Nutrition-sensitive Food and Agriculture to Address Malnutrition" (www.fao.org).

iv) **Crops For the Future (CFF)**, an AIRCA (Association of International Research and Development Centers for Agriculture) center, located in Seminyeh, Malaysia is a research company focused on the improvement of underutilised crops, so that they might be grown and consumed more widely with benefits to human food and nutritional security. CFF has adopted a food system approach in Bambara groundnut (*Vigna subterranea*) with emphasis on the short-day photoperiod requirement for pod-filling and the hard-to-cook trait. Selective breeding has allowed the development of lines that are less susceptible to photoperiod but also provided a range of tools and approaches that are now being exploited in other crops such as winged bean (*Psophocarpus tetragonolobus*), amaranth (*Amaranthus* spp.), moringa (*Moringa oleifera*) and proso (*Panicum miliaceum*) and foxtail (*Setaria italica*) millets. It has also developed and tested new food products and demonstrated that several crops can be used as feed for black soldier fly which can, in turn, be used to feed fish thereby reducing the need for fishmeal. CFF has also launched the Forgotten Foods Network (FFN) in 2017, as a global repository on recipes, uses and nutritional values of ingredients and products from NUS (www.cffresearch.org).

v) **The African Orphan Crops Consortium** (AOCC) aims to reduce stunting and malnutrition by providing nutritional security through improving locally adapted nutritious, but neglected, under-researched or orphan African food crops. Through stakeholder consultations supported by the African Union, 101 African orphan and under-researched crop species were prioritized to mainstream into African agri-food systems. The AOCC, through a network of international–regional–public–private partnerships and collaborations, is generating genomic resources of three types, i.e., reference genome sequence, transcriptome sequence, and re-sequencing 100 accessions/species, using next-generation sequencing (NGS) technology. Furthermore, the University of California Davis African Plant Breeding Academy under the AOCC banner is training 150 lead African scientists to breed high yielding, nutritious, and climate-resilient (biotic and abiotic stress tolerant) crop varieties that meet African farmer and consumer needs. To date, one or more forms of sequence data have been produced for 60 crops. Reference genome sequences for eight species have already been published, four are almost near completion, and 26 are in progress (www.africanorphancrops.org).

vi) **The consultative group for international agricultural research (CGIAR)** plays a vital role among international institutions involved in germplasm collection and conservation. From the 15 CGIAR centers, those with the mandate on alternative crops are: Africa Rice on rice; International Center for Agricultural Research in the dry areas (ICARDA) on lentil and chickpea; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) on sorghum, finger millet, ground nut, chickpea, pigeon pea, and pearl millet; International Institute of Tropical Agriculture (IITA) on banana, plantain, cassava, cowpea and yam; International Centre for Tropical Agriculture (CIAT) on beans and cassava; International Potato Centre (CIP) on sweet potato and Bioversity International on banana. The total number of crop accessions including major and orphan crops deposited at CGIAR centres are estimated to be around 760,000.These centres have been providing substantial technical and financial support to the national institutions in the developing world (www.cgiar.org).

vii) **International Centre for Bio-saline Agriculture (ICBA)**, Dubai is engaged in research for improving food security and nutrition, enhancing water security and environmental sustainability, and creating jobs and livelihoods in marginal and abiotic stressed environments. It has Crop improvement and sustainable production as one of the major research theme which focuses on crop diversification using underutilized, stress-tolerant crops for food, feed and biofuel and salinity as well as plant breeding, genomics, genetics, seed production and post-harvest technologies, agricultural value chains (www.biosaline.org).

2.3.2. National Research Status

i) **Indian Council of Agricultural Research (ICAR)- National Bureau of Plant Genetic Resource (NBPGR), New Delhi** has a dedicated research programme called 'All India Coordinated Research Network (AICRN) on Potential crops' which envisages identification, augmentation and improvement of plant species with potential for commercialization as crops for climate resilient and sustainable food system. Currently the institute is coordinating and conducting research on 17 crops of food, fodder and industrial value (Table 2) through 14 co-ordinated, 9 cooperating and 15 voluntary centres located in diverse agro-climatic zones of the country. The varieties released for different potential crops, collection of indigenous diversity and status of germplasm collected under the programme are depicted in Table 3, 4 and Fig. 3, respectively. As of 31st March 2020, 2,75,045 accessions have been collected and 4,45,927 germplasms are conserved (Appendix V) under the programme (**www.nbpgr.ernet.in**).

Table 2. Crops prioritized for research (* in bold) under AICRN potential crops.

S No.	Crop Group	Crops
1	Pseudocereals	**Grain amaranth (*Amaranthus* sp.), Buckwheat (*Fagopyrum* sp. Chenopodium (*Chenopodium* sp.)**
2	Minor cereal	**Job's tear (*Coix lacryma*-jobi)**
3	Food legumes	**Rice bean (*Vigna umbellata*), Adzuki bean (*Vigna angularis*) Faba bean (*Vicia faba*), Winged bean (*Psophocarpus tetragonolobus*)**
4	Oil seeds	**Perilla (*Perilla frutescens*), Paradise tree (*Simarouba glauca*)**
5	Vegetables	**Kankoda (*Momordica dioica*), Kalingada (*Citrullus lanatus*)** Moringa (*Moringa oleifera*)
6	Fodder	Pillipsera (*Vigna trilobata*),*Vigna glabrescens*, Eupatorium, Salt bush (Atriplex sp.), Forage groundnut, *Leucaena leucocephala Colophospermum mopane*, *Cassia sturtii*, *Sesbania sp.*, *Indigofera sp.*
7	Crops of problem soils	**Tumba (*Citrullus colocynthus*),** *Vigna marina*
8	Industrial plants	**Jojoba (*Simmondsia chinensis*),** Guayule (*Parthenium argentatum*), **Jatropha (*Jatropha curcas*),** Bitter apple (*Citrullus colosymthis*), Euphorbia sp., Lana (*Haloxylon salicornicum*)
9	Minor fruits	Ker (*Capparis decidua*)

Source: ICAR-NBPGR, 2020

Table 3. Details of the varieties released in underutilized grain crops under AICRN potential crops.

S No.	Crop	Varieties
1	Grain Amaranth	Annapurna, PRA-1, PRA-2, PRA-3, Durga, VL Chua 44, GA-1, Suvarna, GA-2, Kapilasa, GA-3, RMA-4, RMA-7, KBGA-1
2	Buckwheat	Himpriya, VL Ugal 7, PRB 1, Himgiri, Sangala B-1
3	Chenopodium	Him Bathua
4	Moth bean	RMO-257, CAZRI Moth-3, RMO-423, GMO-2, CAZRI Moth-2 and RMO-435
5	Horse gram	AK 21, AK 42, CRIDA-18R, VLG-15, BJPL-1, Chhattisgarh kulthi-3, Phule Sakas, CRHG-22, AK-53, VL Gahat 19, Indira Kulthi 1, VL Gahat 15, CRIDA-1-18R, VL Gahat 8, VL Gahat 10
6	Rice bean	RBL-1, PRR-1, PRR-2, RBL-6, RBL 35, RBL 50, BRS 1, VRB-3, Palam Rajmung-1
4	Faba bean	VH 82-1, HFB-1
5	Winged bean	AKWB-1, Indira winged bean-1, Chhattisgarh Chaudhari Sem

Source: ICAR-NBPGR, 2020

Table 4. Indigenous diversity collected in underutilized crops.

S No.	Crop	Total collection
1	Amaranth	2272
2	Buckwheat	1162
3	Chenopodium	215
4	Job's tear	274
5	Rice bean	1275
6	Adzuki bean	73
7	Faba bean	401
8	Winged bean	232
9	Perilla	355
10	Jatropha	903
11	Tumba	172
12	Spine gourd	522
	Total	**7856**

Source: ICAR-NBPGR, 2020

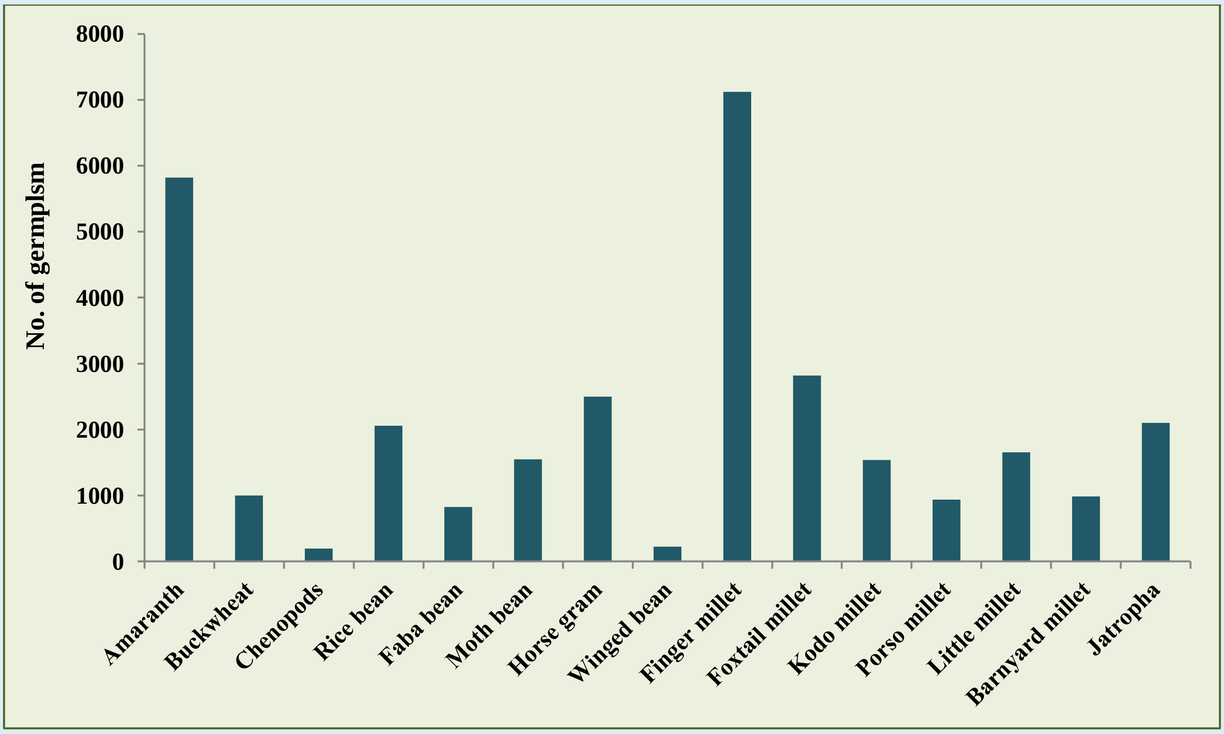


Fig. 3. Status of potential crops germplasm at ICAR-NBPGR
Source: ICAR-NBPGR, 2020

Types of inflorescence colours found in Quinoa (*Source*: ICAR, NIASM)

Winged bean
(*Psophocarpus tetragonolobus*)

Perilla
(Perilla frutescens)

Kalingada
(*Citrullus lanatus*)

Kankoda
(*Momordica dioica*)

Paradise tree
(*Simarouba glauca*)

Faba bean
(*Vicia faba*)

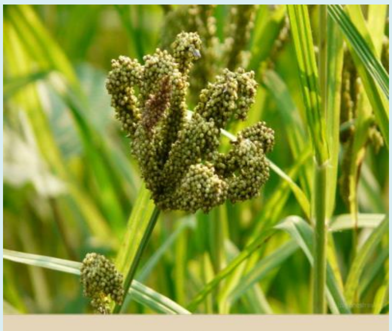
Adzuki bean
(*Vigna angularis*)

CROPS CURRENTLY UNDER RESEARCH IN AICRN POTENTIAL CROPS PROGRAMME, ICAR-NBPGR
Source: ICAR-NBPGR, 2020

ii) **ICAR- Indian Institute of Millets Research (IIMR)**, **Hyderabad** coordinates and facilitates millets research at national level through All India Coordinated Research Projects on sorghum, pearl millet and small millets and provides linkages with various national and international agencies with research focuses *viz.*, genetic resource management; crop improvement for increased productivity; genetic enhancement for high biomass per unit time; mitigating adverse effects of climate change; development of crop production technologies for increased input efficiency; biotic and abiotic stress management; seed science and technology; value addition for commercialization; functional foods and basic studies (www.millets.res.in).

Pearl millet/bajra
(*Pennisetum americanum*)

Great millet/sorghum/jowar
(*Sorghum bicolor*)



Finger millet/ragi
(*Elusine coracana*)

Little millet/kutki
(*Panicum sumatrense*)

Kodo millet
(*Paspalum scorbiculatum*)

Proso millet/cheena
(*Panicum miliaceum*)

Foxtail millet/kangni
(*Setaria italica*)

Barnyard millet/sanwa
(*Echinocloa frumentacea*)

Browntop millet
(*Brachiaria ramose*)

Seekiya
(*Digitaria sangunalis*)

Teff
(*Eragrostis teff*)

Fonio
(*Digitaria exilis*)

DIFFERENT TYPES OF MILLETS UNDER RESEARCH AT ICAR- IIMR
Source: ICAR-IIMR, 2020

iii) **Council of Scientific & Industrial Research (CSIR)-Central Food Technology Research Institute, Mysore** has been working on underutilized crops for almost a decade. Their research is largely focused on nutritional qualities of underutilized crops including quinoa, chia and less known fruits. They are also developing technologies for value addition through optimised processing technologies for these crops and propagating the technology among the farmers. CFTRI labs are now focusing on unexplored commercially valued minor/exotic fruits such as Cape Goose berry, Rose apple, Java apple etc. for products development: These studies are aiming at development of suitable processed products which are nutritionally valued from human health and nutrition point of view. Some of the innovative technologies developed by CFTRI include Zerumbone projected as a nutraceutical possessing physiological health benefits. The process for the preparation of pure Zerumbone crystals now finds application in Food & Pharma sectors. *Zingiber Zerumbet Smith* is Southeast Asian ginger family plant, which grows tall upright up to 3m tall and has long, narrow leaves. Now this crop has been widely cultivated in tropical and sub-tropical area around the world. Zerumbone is a sesquiterpene phytochemical from *Zingiber Zerumbet* and has been subjected for biochemical studies because of its high medicinal values. CSIR-CFTRI developed a facile process for the preparation of pure Zerumbone crystals, which results in the pharmaceutical benefits such as anti-tumour, anti-inflammatory, anti-pyretic, analgesic etc. In addition, CFTRI has made extensive efforts in popularizing alternative crops such as quinoa and chia in India for their nutritive value and attractive remuneration (www.cftri.res.in).

2.3.3. Research Efforts and Initiatives at ICAR- NIASM

ICAR-National Institute of Abiotic Stress Management (NIASM), established in 2009 at Malegaon, Baramati, Maharashtra, India aims at exploring the avenues for management of abiotic stresses affecting the very sustainability of national food production systems. It specifically addresses the aberration induced stresses due to atmospheric, water and edaphic factors, which are estimated to cause 50% losses in crop productivity. Since these stresses are predicted to amplify due to climate change and land degradation, the primary task for the institute is to evolve alleviation techniques through advances in frontier science research viz., defining of target environments, adaptive techniques, mitigation strategies, policy support in addition to exploitation of synergies through networking. Among several research programs of the institute, one project specifically focuses on mainstreaming alternative crops for sustainable food systems in semi-arid regions of India. The project, which builds on preliminary investigations on quinoa at the institute, has now become one of the flagship projects being executed by School of Water Stress Management with multidisciplinary approaches (Fig. 4). At present the crops which are being focused are quinoa, chia, dragon fruit, cactus in close collaboration with national institutes like NBPGR, New Delhi; IIMR, Hyderabad; CFTRI, Mysore and international institutes such as Bioversity International, India; CFF, Malaysia; ICRISAT, India and CIAT, Colombia.

Objectives:

- To evaluate Genotype x Environment interactions to optimise combinations of agro-ecology and alternative crops.
- To facilitate genetic improvement of productivity and quality of alternative crops.
- To optimise agronomy for alternative crops.
- To explore value addition through post-harvest technology.
- To identify stress tolerance genes and microbial associations for improvement of drought tolerance in other crops.
- To demonstrate the alternative crop in farmers field.

Expected Outputs

Output 1	*Alternative crops that can enhance income individually or in cropping system* • By its own nutritive value as food or fodder • By additional values as neutraceuticals • Use as industrial raw material • Between two consecutive crop season • Weed suppressant for consecutive crop • Soil health contributors • Alternate use –extracts, associate microbes
Output 2	*Genetically Improved Cultivar/Genetic Stock* • Adapted to target area • High productivity • Less anti-nutritional factors • Resilience to abiotic and biotic factors prevailing in the region
Output 3	*Package of practices* • Agronomy, irrigation schedule, microbe
Output 4	*Processing technology* • Reduction in saponin in quinoa, antinutritional factors in other crops
Output 5	*Scientific Insights* • Tolerance traits and mechanisms • Anti-nutritional factors metabolism • Processing technology • Useful microbes

Alternative Crops Research Framework

Target environment insights	**Productivity enhancement**		**Value addition**	
Suitability assessment	*Genetic improvement*	*Resource management*	*Post-harvest process*	*Alternate uses*
Assessing scope and target environments	Genetic improvement Physiological traits Stress responsive genes Genomics Phenomics	Agronomy Cropping system Water use efficiency	Bioregulators Antioxidants	Useful microbes Weed suppressants Livestock feed Fish feed

Fig. 4. ICAR-NIASM flagship project research framework on alternative crops

Dragon fruit (*Hylocerus undatus*)

Quinoa (*Chenopodium quinoa*)

Chia (*Salvia hispanica*)

Cactus (*Opuntia sp.*)

Initiatives for improvement of Quinoa and Chia

ALTERNATIVE CROPS AT ICAR-NIASM

3. Challenges and Research Gaps

Alternative crops have great untapped potential to support smallholder farmers and rural communities by improving their incomes and food and nutritional security while also sustaining the genetic resources needed to address present and future environmental challenges. However, there are ample evidences on the challenges that exist across a spectrum of areas, from social to economic and environmental (Table 6). Major research gaps found in mainstreaming alternative crops are discussed below.

- **Land use classification:** There is need for a paradigm shift in the current approaches that are used for land use classification, which continue to exclude alternative crops. Therefore, there is need on crop suitability mapping and fitting these crops into specific agro-ecologies. A current gap to this would be the need to develop crop specific factors for alternative crops that can be used to describe them as part of crop suitability mapping.
- **Agronomy:** Whilst there have been strides in describing the agronomy of various alternative crops, there are still major gaps with regards to issues such as optimum planting densities, pest and disease management and fertiliser management, among other things. This lack of knowledge makes it challenging to promote alternative crops as there are often no production guidelines describing the best management practices for them.
- **Ecophysiology:** There are reports of several alternative crops possessing tolerance to key abiotic stresses such as drought and heat stress. However, much of this information remains anecdotal and patchy. There is therefore a need to generate more empirical information on the ecophysiology of alternative crops. This should be linked to agro-ecologies in order to support the crop suitability mapping/land use classification.
- **Post-harvest handling and storage:** For most alternative crops, there is a total lack of documented appropriate post-harvest handling and storage practices. This means, even when farmers are able to produce these crops, there may be significant post-harvest losses. Developing appropriate post-harvest handling and storage practices would also contribute towards developing best management practices for these crops.
- **Nutritional value:** Similar to agronomic aspects of alternative crops, there is lack of comparable information on the nutritional value of these crops. Addressing this knowledge gap will go some way in highlighting the nutritional benefits often associated with use of alternative crops and their promotion as healthy options.
- **Product development:** Currently, there are few products developed using alternative crops. Research on product development would also create new uses and markets for these crops and add to the new paradigm on their greater value and inclusion.
- **Marketing:** Access to markets remains an obstacle for alternative crops. Existing markets have been developed to support the major crops based on the existing paradigm that supports a few major food crops. There is need for research on market analyses to ascertain opportunities for mainstreaming or disrupting existing markets to allow for alternative crops' inclusion. Such research should also consider possibilities the feasibility of developing new niche markets specifically for these crops.

Table 6. Challenges in mainstreaming alternative crops.

Environmental	Agronomic	Social	Economic	Political
• Effect of climate change • Loss of genetic diversity and knowledge • Ecosystem degradation • Environmental pollution	• Lack of seed supply system • Insufficient propagation materials and seeds • Overuse of pesticides, fertilizers and other agrochemicals • Crop production technology not optimized	• Lack of inclination towards new and improved high yielding varieties • Change in diet through increased awareness • Building strategies based on indigenous knowledge of traditional crops • Lack of awareness on nutritional value and other uses • Migration of farm labour to urban areas • Overexploitation of wild resources • Perceived low status of some local and traditional foods	• Changes in land use • Lack of competitiveness with other major crops • Lack of market infrastructure • Lack of market niche • Lack of incentives for farmers	• Lack of policy to make conservation and use • Lack of funds and facilities for ex situ conservation • Absence of legal framework, policies, projects, national programmes and strategies • Lack of integration bewteen conservation and use programmes • Limited support for scientific research & access to international gemrmplasm

4. Strategies for Promoting and Mainstreaming Alternative Crops

- **Proper Documentation** revealing the potentials of alternative crops, their distribution, social values and local use coupled with effective **dissemination** is needed to protect and conserve traditional knowledge about these crops for future generations.
- **Participatory research** is fundamental towards effective conservation, characterization, collection, crop improvement, production and management programs, nutritional aspects, adaptive traits and commercialization of alternative crops.
- **Development of new markets** in order to reach as wide user community as possible including –but not exclusively- traditional growing areas- is another strategic domain that would create new sources of revenues to the local people.
- **Capacity building** such as training farmers, particularly women along value chains for crop management, producing good quality seed, selecting varieties, intercropping systems, managing soil health, post-harvest management and marketing. Broadening agricultural curricula to include the conservation and use of alternative crops along with the staple crops will encourage young scientists to take food and nutritional approaches for entrepreneurship developments in agriculture
- **Partnerships** that facilitate strategic synergies among national, regional and international networks, and collaborative platforms, need to be encouraged and supported.
- **Enabling policies** and **alignment with government schemes** for resource use efficiency, environmental friendly farming systems Major activities that need to be performed under each of the mentioned strategies are summarized in Table 8.

Table 8. Strategies including major activities to be performed for promoting alternative crops.

Strategies	Major activities
Documentation and dissemination	• Development of eco-geographic databases on target species; • Development of use-oriented and nutritional database to asses social impact of these species over the territory; • Dissemination to users of information on improved varieties and agronomic requirements for enhancing productivity; • Development of tools (newsletters, internet web pages, training programmes, workshops) for disseminating relevant information to stakeholders. • Change perceptions • Raise public awareness • Provide policymakers with evidence • Set up global on-farm alternative crop species conservation programmes
Participatory research	• Target area delineation and matching the crops with agro-ecologies for less competition among farmers but high benefits for alternative crops • Analyses of constraints and development of strategic work plans for enhancing seed/germplasm selection and supply, production, processing, commercialization, marketing • Characterization and evaluation work using descriptor lists and farmers' criteria • Development / strengthening the seed supply systems • Participatory plant breeding and selection activities • Study on adaptive traits in alternative crops landraces • Strengthen methodology in alternative crops research • Link scientific and indigenous knowledge • Share knowledge and lessons learned
Marketing	• Develop market oriented strategies • Improve value chains • Direct links between producer and consumer to reduce cost of marketing and demand driven production
Capacity building	• Upgrade capacity in value chains • Fostering synergism at national, regional and international level • Boost infrastructure and institutions • Develop capacity in researching, teaching, policymaking, trading and farming alternative crops
Partnerships	• Encourage collaboration in research, promotion, conservation and sustainable use of alternative crops • Collaborate with local communities • Engage farmer and women organizations • Encourage local production and dissemination of seed • Cooperation across levels • Create multi-stakeholder platforms

Strategies	Major activities
Policy	• Streamlining best package of practice, processing and value addition • Provide incentives under crop diversification for sustainable agriculture, subsidizing marketing • Extend schemes such as crop insurance to alternative crops • Inclusion in school and anganwadi feeding programs • Incentives for conservation of agrobiodiversity

5. Summary and Way Forward

A significant increase in cultivation and consumption of alternative crops, will contribute to the efforts to eliminate hunger, malnutrition and poverty as committed in the sustainable developmental goals. It will also enable countries to increase resilience and better adapt their agricultural production systems to changing climate. The fact that most of these crops are abiotic stress tolerant and nutrient dense makes them an important resource for addressing key challenges of improving food and nutrition security. Besides these crops have great potential in sustaining the genetic resources needed to make future crops and crop production climate smart. In addition, agricultural production focused on agro-biodiversity can contribute to harnessing and safeguarding centuries-old traditions and is a powerful instrument for keeping alive the cultural identity of farmers and indigenous communities. However, to promote alternative crops, there is a need to overcome major obstacles, which occur along entire value chains. This can be addressed through R&D and suitable policy frameworks. Hence, there is a need of intensive efforts to develop appropriate national strategies and policies to promote diversification of cropping systems based on the R&D outputs. This calls for a paradigm shift with regards to how research is currently prioritized and funded, a system that has favored the major crops that are aligned to industrial agriculture. This shift should also include introduction of an agro-ecology based land use classification system, which would allow for the inclusion of alternative crops in the crop choice and food networks. This should be matched with identifying and prioritizing a few alternative crops that have the greatest potential for success with respect to addressing food security and sovereignty, climate change adaptation and improving rural livelihoods. Through concerted action at international, national as well as at local levels, these valuable genetic resources can be transmitted on to future generations and thus can significantly contribute to humankind's wellbeing.

6. Acknowledgement

The authors are thankful to all the speakers of the National webinar on “Underutilized crops for augmenting farmers income in abiotic stress regions” Dr N Krishna Kumar, Ex DDG (Horticulture), ICAR, Ex South Asia Representative, Biodiversity International; Dr S Dandin, Ex Vice Chancellor, University of Horticultural Sciences, Bagalkot; Dr RK Singh, Principal Scientist & Program Leader, International Center for Biosaline Agriculture, Dubai, United Arab Emirates; Dr Kuldeep Singh, Director, ICAR- National Bureau of Plant Genetic Resources, New Delhi; Dr Vilas Tonapy, Director, ICAR-Indian Institute of Millet Research, Hyderabad; Mr Luis Salazar Licea, Nottingham University, United Kingdom for sharing their research insights on various aspects of underutilized crops.

7. References

CIAT. 2017. https://ciat.cgiar.org/the-changing-global-diet.

Food and Agriculture Organization of the UN (FAO). 2019. The second global plan of action for plant genetic resources for food and agriculture. Rome: Commission on Genetic Resources for Food and Agriculture, FAO.

Francis, C.A., Jensen, E.S., Lieblein, G., Breland, T.A. 2017. Agroecologist education for sustainable development of farming and food systems. Agron J 109:23–32.

Gaisberger, H., Deletre, M., Gaiji, S., Bordoni, P., Padulosi, S., Hermann, M., Arnaud, E. 2016. Diversity of neglected and underutilized plant species (NUS) in perspective. Bioversity International - CGIAR, Rome, Italy.

Gillespie, S., van den Bold, M. 2017. Agriculture, food systems, and nutrition: meeting the challenge. Glob Challenges 1:1600002. https://doi.org/10.1002/gch2.201600002.

Kour, S., Bakshi, P., Sharma, A., Wali, V.K., Jasrotia, A., Kumari, S. 2018. Strategies on conservation, improvement and utilization of underutilized fruit crops. Int J Curr Microbiol App Sci 7:638–650.

Lonhvah, T., Ananthan, R., Bhaskarachary, K., Venkaiah, K. 2017. *Indian food composition tables*. Hyderabad: National Institute of Nutrition, Indian council of Medical Research.

Mabhaudhi, T., Chibarabada, T., Chimonyo, V., Murugan,i V., Pereira, L., Sobratee, N., Govender, L., Slotow, R., Modi, A. 2019. Mainstreaming underutilized indigenous and traditional crops into food systems: a South African perspective. Sustainability 11:172.

Mabhaudhi, T., Chimonyo, V.G.P., Chibarabada, T.P., Modi, A.T. 2017. Developing a roadmap for improving neglected and underutilized crops: a case study of South Africa. Front Plant Sci 8:8.

Massawe, F., Mayes, S., Cheng, A. 2016. Crop diversity: an unexploited treasure trove for food security. Trends Plant Sci 21:365–368.

Mayes, S., Massawe, F.J., Alderson, P.G., Roberts, J.A., Azam-Ali, S.N., Hermann, M. 2011. The potential for underutilized crops to improve security of food production. Journal of Experimental Botany 63(3): 1075-1079.

Nyadanu, D., Aboagye, L.M., Akromah, R., Dansi, A. 2015. Agro-biodiversity and challenges of on-farm conservation: the case of plant genetic resources of neglected and underutilized crop species in Ghana. Genet. Resour Crop Evol. https://doi.org/10.1007/s1072 2-015-0327-2.

Padulosi, S., Bala Ravi, S., Rojas, W., Valdivia, R., Jager, M., Polar, V., Gotor, E., Bhag Mal. 2013. Experiences and lessons learned in the framework of a global effort in support of neglected and underutilized species. Acta Horticulturae 979: 517-531 pp. International Society for Horticultural Science. Leuven, Belgium.

Padulosi, S., Heywood, V., Hunter, D., Jarvis, A. 2011. Underutilized species and climate change: current status and outlook. Crop Adaptation to Climate Change. Wiley-Blackwell, Oxford, UK, pp 507–521.

Padulosi, S., Thompson, J., Rudebjer, P. 2013. Fighting poverty, hunger and malnutrition with neglected and underutilized species (NUS): needs, challenges and the way forward. Bioversity International, Rome.

Tadele, Z. 2017. Raising crop productivity in Africa through intensification. Agronomy 7:22.

Tadele, Z. 2018 African orphan crops under abiotic stresses: challenges and opportunities. Sci (Cairo) 2018:1–19. https://doi. org/10.1155/2018/1451894.

Will, M. 2008. Promoting value chains of neglected and underutilized species for pro-poor growth and biodiversity conservation. Rome: Global Facilitation Unit for Underutilized Species (GFU), Bioversity International.

Williams, J.T., Haq, N. 2000. Global research on underutilised crops; an assessment of current activities and proposals for enhanced cooperation. Southampton, UK: International Centre for Underutilised Crops.

Appendix I. Examples of Alternative Crops Used as Food from Around the World

Food group	Scientific name	Food groups	Scientific name
Cereals, millets and pseudo-cereals		Locust bean	*Parkia biglobosa*
Einkorn	*Triticum monococcum*	Winged bean	*Psophocarpus tetragonolobus*
Emmer	*T. dicoccon*	Chayote	*Sechium edule*
Spelt	*T. spelta*	Chrysanthemum	*Chrysanthemum coronarium*
Tef	*Eragrostis tef*	Bitter gourd	*Momordica charantia*
Fonio	*Digitaria exilis*	Angle gourd	*Luffa acutangula*
Quinoa	*Chenopodium Spp.*	Snake gourd	*Thrichosantes cucumerina var. anguina*
Finger millet	*Eleusine coracana*	Ceylon spinach	*Basella rubra*
Kodo millet	*Paspalum scrobiculatum*	Spider plant	*Cleome gynandra*
Foxtail millet	*Setaria italic*	Jute	*Corchorus olitorius*
Little millet	*Panicum sumatrense*	Black nightshade	*Solanum nigrum*
Proso millet	*Panicum miliaceum*	Ivy gourd	*Coccinia grandis*
Amaranth	*Amaranthus caudatus*	Gourd	*Lagenaria siceraria*
Buckwheat	*Fagopyrum spp.*	Celosia	*Celosia argentea*
Job's tears	*Coix lacryma-jobi*	Dika	*Irvingia spp.*
Chia	*Salvia hispanica*	Egusi	*Citrullus lanatus*
Roots and Tubers		Marama	*Tylosema esculentum*
Yams	*Dioscorea spp.*	Shea butter	*Vitellaria paradoxa*
Yacon	*Smallanthus sonchifolius*	Giant swamp taro	*Cyrtosperma merkusii*
Ulluco	*Ullucus tuberosus*	Akoub	*Gundelia tournefortii*
Taro	*Colocasia esculenta*	Crambe	*Crambe spp.*
Arracacha	*Arracacia xanthorriza*	Cardoon	*Cynara cardunculus*
American yam bean	*Pachyrhizus spp.*	Eru	*Gnetum africanum*
Maca	*Lepidium meyenii*	Purslane	*Portulaca oleracea*
Oca	*Oxalis tuberosa*	Golden thistle	*Scolymus hispanicus*
Parsnip	*Pastinaca sativa*	Bitter leaf	*Vernonia amygdalina*
Cocoyam	*Xanthosoma sagittifolium*	**Fruits and nuts**	
Legumes		Dragon fruit	*Hylocereus spp.*
Mungbean	*Vigna radiata*	Maya nut	*Brosimum alicastrum*
Adzuki bean	*V. angularis*	Breadfruit	*Artocarpus altilis*
Ricebean	*V. umbellata*	Jackfruit	*Artocarpus heterophyllus*

Food group	Scientific name	Food groups	Scientific name
Lupin	*Lupinus mutabilis*	Baobab	*Adansonia digitata*
Bambara groundnut	*Vigna subterranea*	Jujube	*Ziziphus mauritiana*
Jack bean	*Canavalia ensiformis*	Cherimoya	*Annona cherimola*
Grasspea	*Lathyrus sativus*	Cape gooseberry	*Pysalis peruviana*
Lablab	*Lablab purpureus*	Naranjilla	*Solanum quitoense*
Pigeon pea	*Cajanus cajan*	Pomegranate	*Punica granatum*
African yam bean	*Sphenostylis stenocarpa*	Noni	*Morinda citrifolia*
Kersting's groundnut	*Macrotyloma geocarpum*	Marula	*Sclerocarya birrea*
Spice, condiment, food dye agent		Tamarind	*Tamarindus indica*
Makoni	*Fadogia ancylantha*	Annona	*Annona spp.*
Annatto	*Bixa orellana*	Safou	*Dacryodes edulis*
Mustard seed	*Brassica juncea*	Mangosteen	*Garcinia mangostana*
Fenugreek	*Trigonella foenumgraecum*	Monkey orange	*Strychnos cocculoides*
Pandan	*Pandanus amaryllifolius*	Salak	*Salacca spp.*
Polygonum	*Poligonum odoratum*	Nipa palm	*Nypa fruticans*
Antidesma	*Antidesma venosum*	Duku	*Lansium domesticum*
Uer	*Lippia carviodora*	Boscia	*Boscia spp.*
Rocket	*Diplotaxis spp.*	Carissa	*Carissa edulis*
Caper	*Capparis spinosa*	Coccinia	*Coccinia trilobata*
Monkey cola	*Cola lateritia*	Acacia	*Acacia toritilis*
Sea buckthorn	*Hippophae rhamnoides*	Kei apple	*Dovyalis caffra*
Nigella	*Nigella sativa*	Tree grapes	*Lamnea spp.*
Vegetables		Medlars	*Vanguera spp.*
Moringa	*Moringa oleifera*	Pitanga	*Eugenia uniflora*
African eggplant	*Solanum aethiopicum*	Malabar chestnut	*Pachira aquatica*
Leaf amaranth	*Amaranthus spp.*	Camu camu	*Myrciaria dubia*
Brazil nut	*Bertholletia excels*	Miracle fruit	*Synsepalum dulcificum*
Egg nut	*Couepia longipendula*	Araza	*Eugenia stipitata*
Quince	*Cydonia oblonga*	Lúcuma	*Lucuma obovata*
Yara yara	*Duguetia lepidota*		

Source: Author's own compilation

Appendix II. Nutritional Status of Some Alternative Crops vs. Major Crops (per 100 g edible portion)

Crop group	Protein (g)	Carbohydrate (g)	Lipid (g)	Dietary fibre (g)	Mineral matter (g)	Ca (mg)	P (mg)	Fe (mg)
Amaranth	14.59	59.98	5.74	5.76	3.0	181	374	9.33
Quinoa	13.11	53.65	5.50	14.66	2.65	198	212	7.51
Buck wheat	13.0	72.9	7.4	10.5	2.1	120.0	280	15.5
Pearl millet	10.9	61.8	5.43	11.5	2.3	27.4	289	6.4
Finger millet	7.2	66.8	1.92	11.2	2.7	364.0	210.0	4.6
Sorghum	9.9	67.7	1.73	10.2	1.6	27.6	274	3.9
Barnyard millet	6.2	65.5	2.2	-	4.7	20.0	280	5.0
Little millet	10.1	65.5	3.89	7.7	1.70	16.1	130	1.2
Proso millet	12.50	70.4	1.10	-	1.90	14.0	206	0.8
Foxtail millet	12.30	60.1	4.30	-	3.30	31.0	188	2.8
Kodo millet	8.90	66.2	2.55	6.4	2.60	15.3	101	2.3
Ricebean	19.97	51.26	0.74	13.37	3.54	200	270	4.76
Moth bean	19.75	52.09	1.76	15.12	3.14	154	362	7.90
Horse gram	21.73	57.24	0.62	7.88	3.24	269	298	8.76
Rice	**7.90**	**78.2**	**0.52**	**2.8**	**0.60**	**7.50**	**96**	**0.6**
Wheat	**10.60**	**64.7**	**1.47**	**11.2**	**1.50**	**39.4**	**315**	**2.8**
Maize	**8.80**	**64.77**	**3.77**	**12.24**	**1.500**	**8.91**	**279**	**2.49**

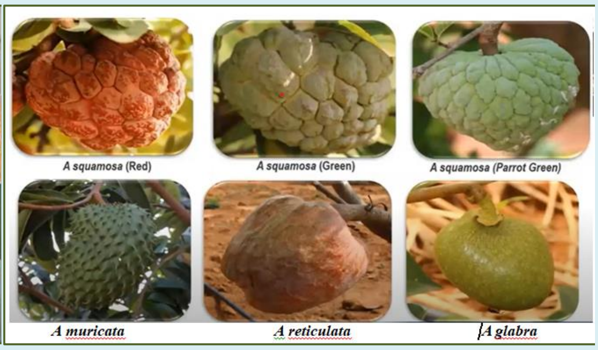
Source: Indian Food Composition Tables, NIN (Longvah et al., 2017)

Appendix III. Minor Fruit Species Maintained in *Ex situ* Genetic Diversity Park, Bengaluru

Source: S.B. Dandin, (2020). Liaison officer, Bioversity International, Bengaluru

Appendix IV. Potential Fruit Crops for Mainstreaming in Indian Food Production System

Genetic variability in Jackfruit bulbs (colour, shape & size)



Variability maintained in Custard apple *(Annona sp.)*

Variability maintained in Myrtaceae

Variability maintained in rose apple (*Syzygium malaccense)*

Variability maintained *in Ziziphus sp.*

Fruits of *Gracinia sp.*

Source: S. B. Dandin, (2020), Liaison officer, Bioversity International, Bengaluru

Appendix V. Germplasm Status at National Gene bank (March 31, 2020)

Crop/crop group	Total species	Present status of total accessions conserved
Cereals	136	165966
Millets	28	59434
Forages	200	7261
Pseudo-cereals	55	7791
Legumes	109	74992
Oilseeds	84	60386
Fibre crops	77	15877
Vegetables	212	27082
Fruits & nuts	68	289
Medicinal & aromatic plants & narcotics	681	268
Ornamental	122	668
Spices & condiments	28	3254
Agroforestry	191	1653
Duplicate safety samples (lentil, pigeon pea)	-	10235
Trial material (wheat, barley)	-	10771
Total	**1991**	**4,45,927**

Source: ICAR-NBPGR, 2020

List of Technical Bulletins Published by ICAR-NIASM

1. Maurya UK (2010) Geology of the NIAM Site, Malegaon, Baramati.
2. Maurya UK (2011) Identification of Abiotic Edaphic Stressors of Deccan Trap at NIASM Site, Malegaon (A Geotechnical and Geological Study).
3. Maurya UK (2011) Formation of Zeolite in Development of Edaphic Stressors on Vertic Toposeqence.
4. Maurya UK (2012) Groundwater Exploration, Development and Management in NIASM watershed, Malegaon.
5. Bal SK (2015) Hailstorm: Causes, Damages and Post hail Management in Agriculture.
6. Saha SS (2015) Trend in Climate Features and Greenhouse Gas exchange of Crops in Scarcity Zone (Baramati) of western Maharashtra.
7. Kamble AL (2015) Towards Sustainable Livelihood of tribal Farmers: Achievements under TSP by NIASM, Baramati.
8. Minhas PS (2015) Turing Basaltic Terrain into Model Research Farm: Chronicle Description
9. Jagadish R, Kumar M, Kumar P, Raina SK, Govindasamy V, Singh AK and Singh NP (2016) NIASM-Plant Phenomics.
10. Krishnani KK, Kurade NP, Patel DP, Kamble AK, Meena RL, Kumar N, Nirmale AV, Minhas PS and Singh NP (2017) A Step towards improving livelihood of tribal farmers trough integrated farming.
11. Kumar N, Krishnani KK, Singh NP, Kurade NP, Patel DP, Kamble AK, Meena RL and Nirmale AV (2017) समन्वित मत्स्य पालन.
12. Kumar N, Krishnani KK, Singh NP, Kurade NP, Patel DP, Kamble AK, Meena RL and Nirmale AV (2017) एकात्मिक मत्स्य पालन.
13. Kumar N, Krishnani KK and Singh NP (2017) मत्स्य पालन.
14. Kumar N, Krishnani KK and Singh NP (2017) कार्प संवर्धन.
15. Rajagopal V, Chaudhary RL, Kumar N, Krishnani KK, Singh Y and Bal SK (2018) Soil Health Status of NIASM Southern Farm Land.
16. Gaikwad BB, Singh Y, More NS and Nebu V (2018) Characterization of abiotic stress responses in field and horticultural crops through hyper spectral remote sensing.
17. Chaudhary RL, Singh AK, Wakchaure GC, Minhas PS, Krishnani KK and Singh NP (2018) SORF: Multi-purpose Machine for Ratoon Sugarcane.
18. Kumar N, Kumar P and Singh NP (2019) Elemental profiling of Biological and non-biological samples.
19. Singh Y, Potekar S and Singh NP (2019) Variation in climate features at Baramati: Decade Study.
20. Harisha CB and Singh NP (2019) Hand Book of Dry Land Medicinal Plants.
21. Jagadish R, Pradhan A, Aher L, Gubbala M, Singh NP (2019) Quinoa: an alternative food crop for water scarcity zones of India.
22. Jagadish R, Singh NP and Gubbala M (2019) Doubling Farmers Income by 2022 Strategy Document for Maharashtra.

23. Singh Y, Kumar PS, Nangare DD, Kumar M, Taware PB, Bal SK, Rane J and NP Singh (2019) Dragon Fruit: Wonder crop for rocky barren lands and water scarce areas.
24. Bhendarkar MP and Brahmane MP (2019) मत्स्य प्रशिक्षण पुस्तिका.
25. Singh RN, Potekar S, Chaudhary A, Das DK and Rane J (2020) Climate trends in Western Maharashtra, India.
26. Nangare DD, Taware PB, Singh Y, Kumar PS, Bal SK, Ali S and Pathak H (2020) Dragon Fruit: A Potential crop for abiotic stressed areas.
27. Wakchaure GC, Kumar S, Meena KK, Rane J and H Pathak (2020) Dragon Fruit Cultivation in India: Scope, Marketing, Constraints and Policy Issues.
28. Chavan S, Kakade V and Nangare DD (2021) वनशेती शाश्वत उत्पन्नाचा स्त्रोत.
29. Pradhan A, Rane J and Pathak H (2021) Alternative crops for augmenting farmers' income in abiotic stress regions.