P. ISSN: 0971-8184 II E. ISSN: 0976-1926
DOI: 10.61949/0976-1926.2025.v38i01.02

Indian Journal of
Plant Genetic Resources

REVIEW ARTICLE

Genetic Enhancement of Local Food Systems in North-Western Himalayan Hills

Anuradha Bhartiya, Rahul Dev and Lakshmi Kant*

Abstract

A food system includes all activities in food production and consumption that impact the economy, health, and environment. The conventional system faces challenges like ensuring food security, livelihoods of the burgeoning population and sustainability under resource constraints and climate change. Furthermore, COVID-19 exposed the weaknesses of the modern food system and highlighted the need for more resilient, inclusive, and sustainable alternatives. Localized food systems (LFS) are emerging as viable alternatives. LFS, involving locally produced, small-scale food sold directly to consumers, offers social, economic, and environmental sustainability with resilience, community building, and climate adaptation but encounters economic and organizational challenges. LFS emphasizes local production, proximity and shared values like traceability and quality. Benefits include healthy food access, better farmer income, local economic growth, reduced reliance on industrialized food, eco-friendly practices, biodiversity conservation, and climate change mitigation that align with sustainable development goals (SDGs). In the Himalayan hills, LFS is crucial for food and nutritional security. Despite economic progress, food inequality, malnutrition, and micronutrient deficiencies persist. LFS, especially in smallholder agriculture, can address these challenges, offering significant health and nutritional benefits.

Keywords: Local food system, Indian Himalayas, Nutritional security, Environmental sustainability.

ICAR-Vivekananda, Parvatiya Krishi Anusandhan Sansthan, Almora 263601, Uttarakhand, India.

***Author for correspondence:**

lakshmi.kant@icar.gov.in

Received: 01/06/2024 **Revised:** 18/10/2024

Accepted: 20/11/2024

How to cite this article: Bahrtiya A, R Dev, L Kant (2025). Genetic Enhancement in Local Food Systems in North-Western Himalayan Hills. *Indian J. Plant Genet. Resour*. 38(1), 11-23. **DOI:** 10.61949/0976-1926.2025.v38i01.02

Introduction

The term "food system" encompasses the interconnected activities associated with the production and consumption of food, as well as their impacts on economic, health, and environmental outcomes. Currently, the conventional food system confronts significant challenges, including ensuring food and nutritional security of a rapidly growing population and sustaining the livelihoods of millions within the food chain in an environmentally sustainable manner amid constraints of natural resources and changing climate. Additionally, during sudden global crises such as the COVID-19 pandemic, the existing conventional supply chain experienced severe disruptions, leading to restricted food supplies worldwide. Thus, the need for a transition towards more inclusive, resilient and sustainable food systems is being felt, especially in high-income countries (Enthoven and Broeck, 2021). Presently, localized food systems are gaining worldwide attention from policymakers and planners (Diekmann *et al*., 2020). Local food systems (LFS) refer to locally or regionally produced food mostly on a small scale and selling products directly to consumers to ensure a steady food supply. Contrary to the input-intensive industrialized conventional food system, the local food system is a social, economic and environmentally sustainable alternative food network with a short supply chain of agricultural commodities produced by small farmers (Gori and Castellini, 2023). The local food systems are considered as more resilient food systems that provide multiple services such as community building, diversifying economies, civic engagement and climate resilience. Strengthening regional or local food systems has the potential to increase food consumption from local producers and enhance access to healthy and fresh food. However, the lack of economic, organizational, and physical structures of the appropriate scale are obstacles to efficiently distributing locally grown food to local consumers (Anggraeni *et al.,* 2022). The concept of "local" typically refers to products that are grown and processed near where they are sold, purchased, and consumed (Brinkley *et al*., 2021). Local food systems may generally have proximity in geography (physical locality, distance between food production and consumption), relation (close relationship between actors within the food system) and values (place of origin, traceability, freshness, quality). However, among them, geographical proximity constitutes the basis for defining the local food system, whereas the remaining dimensions represent additional features (Eriksen, 2013). Local food systems impart various benefits, which include access to safe and healthy food, enhancing farmers' benefits, boosting the local economy, reducing dependency on industry-driven foods, eco-friendly food production, local biodiversity conservation, and climate change mitigation. Thus, ultimately helps in achieving various SDGs particularly related to reducing poverty, health and well-being, sustainable cities and communities, climate change mitigation, and partnerships with different stakeholders.

Local Foods Serve as the Best Alternatives for Food, Nutritional and Health Security in the Indian Himalayan Region

Looking ahead to the future, particularly towards 2030 and beyond, the task of feeding the growing population of India will be a formidable challenge. Projections suggest that by 2030, around 600 million Indians are anticipated to reside in urban areas, necessitating a consistent supply of safe and nutritious food. However, this challenge is exacerbated by several factors, including limited natural resources and the impacts of climate change (rising temperatures and greater frequency and intensity of droughts in Western and Southern India and floods in Northern and Northeastern India) (IPCC 2018). Despite India's economic progress over the past decades, food inequality, malnutrition, overweight/obesity, and micronutrient deficiencies posed a public health challenge. Therefore, it is imperative to analyze the interplay among India's economic growth, agricultural production and nutrition using a food systems approach to address the challenges of malnutrition and public health effectively. Such an approach can facilitate a comprehensive understanding of the various factors influencing food security and nutrition outcomes across different regions of the country. Over the past decade, governments have actively promoted local food systems for their purported benefits (Jones *et al*., 2004).

Indian agriculture is dominated by small and marginal land holdings/farmers. Local food systems are uniquely tailored to the local ecological, socio-cultural, and economic context and are ideal for addressing nutritional and health security issues (Niketan *et al*., 2018). Thus, there is a need to endorse traditional food systems for health, nutritional and therapeutic benefits. A continuous decrease has been observed in the average landholding size from 2.3 hectares (1970–71) to 1.08 hectares (2015–16). About 86.2% of holdings are less than 2 hectares (ha), accounting for 47.3% of the operated area. In Uttarakhand, approximately 90.89% of holdings are marginal and small accounts of less than 2 ha (Agriculture Census Division 2015–16). Thus, under limited land resources, a strategic emphasis on promoting local food production and consumption for better food nutrition and health security of the population is required. Traditional local food systems in Indian regions are practiced mainly by smallholders, particularly women, who maintain local food habits, genetic diversity, and soil fertility of agricultural fields (Sundriyal *et al*., 2014; Maikhuri *et al*., 2015). The Himalayan local food system is low-cost, energy-efficient, local resource-dependent, and dominated by climate-smart crops, thus contributing to food production in an environmentally sustainable manner (Sundriyal *et al*., 1994; Bhartiya *et al*., 2020). Traditional foods help in addressing seasonal health issues and the diversity of recipes provides a supporting base for the nutritional security of the local communities in Uttarakhand (Mehta *et al*., 2010). Other than providing food security, the traditional food system also reduces the risk of deficiency in chronic health conditions such as obesity, high blood pressure and higher cholesterol. Improved nutrition increases mental efficiency and physical development of children. In Uttarakhand, about 86% of the area consists of hills, traditionally growing diverse range of crops including millets, cereals, pseudo-cereals, oilseeds, pulses, vegetables, numerous medicinal herbs, spices, wild edible plants, *etc.,* and most of them serve as "functional foods" to hill farming communities with nutraceutical properties and high nutritional value. The subsistence harvests and use of wild resources for food, nutrition and well-being by native communities have been other essential features of traditional hill farming. In the Himalayan region, the local food system is still prevalent and in hilly areas of Uttarakhand, about 60 to 70% of food is still produced by small-scale farmers using traditional farming methods and sold locally. Uttarakhand hills have a robust native food culture and traditions firmly rooted in their local landscapes.

Collective action by governments, local leadership, non-profit organizations, farmers and consumers can further strengthen the local food system of the region.

Need to Improve Plant Biodiversity for Strengthening Local Food Systems

North Western Himalayas (NWH) has a self-contained food system with respect to farming situations that are deeply rooted in the local traditions and culture of the region. However, the forces of globalization, vulnerabilities arising due to poverty, discrimination (of some sections) and marginalization of farming households in the hills are increasingly affecting the native food culture. Limited access to diverse food resources is affecting the nutrition and health of native communities, causing malnutrition among children and women. Over the next few decades, agricultural production practices need to change, reducing the negative impact of agriculture on the environment while continuing to increase productivity and improve sustainability. Biodiversity can play an essential role in improving local food security and sustainability through sustainable intensification, multi-functionality and the importance of appropriate policy and economic frameworks. It gives sufficient space to small-scale farmers and communities who maintain agricultural biodiversity (Galluzzi *et al*., 2011). This is an essential part of improving food security and responding to the challenge of climate change. It will require enhanced use of biodiversity for food and agriculture. Because globalized food is heavily processed and manufactured, it has more fattening and sweetening qualities than food from the local food system. This causes nutritional imbalances that have serious adverse effects on health. It is estimated that roughly 24% of total deaths worldwide in 2017 (*i.e.,* 11 million premature deaths) were attributed to unhealthy diets linked with the development of several chronic non-communicable diseases. Owing to an increasing dependence on a global food system in many countries and regions, sustainable food systems are needed for human health. Still, the sustainability of food systems depends fundamentally on preserving their biodiversity. Transforming conventional food systems to local food systems in a sustainable manner requires biodiversity conservation, adoption of sustainable production, processing and consumption practices, as well as considerations towards cultural adequacy of food practices (Bene *et al.,* 2020). Biodiversity plays an essential part in the sustainability of the local food system by contributing towards improved pest and disease control, nutrient availability, and water use, which consequently leads to increased yield levels and more nutritious food. Overall, a biodiversity-based food system can help enhance local food availability through diverse mixed-species cropping systems, generating income and improving farmers' food accessibility.

Role of Plant Biodiversity within Local Food Systems, Particularly in Regions like the Northwestern Himalayas

The Indian Himalayan region (IHR) is renowned for its abundant geological resources, diverse forests, rich flora and fauna, extensive biodiversity, pristine snow and ice formations, numerous water bodies, traditional knowledge, and mountain agriculture (Dhiman and Muthanarasimha, 2022). Local and regional agrobiodiversity (which includes both cultivated wild plants and animals) is widely acknowledged as crucial to the nutritional security and food sovereignty of numerous indigenous small-scale farming communities (Pandey *et al*., 2022). The traditional agroecosystems of IHR comprise ~273 cultivated crop species, ~898 wild relatives and related types of cultivated plants, ~744 wild edible plants and ~591 plants having industrial potential (Rana *et al*., 2012). Biodiversity is crucial for food systems, the health of our planet and human well-being. It supports the functioning of agroecosystems and the consistency of food production by maintaining soil health, fertility and the stability of the hydrological cycle. Additionally, genetic diversity in crops and animals is vital for ensuring an ample supply of nutritious food and bolstering the resilience of agroecosystems against environmental threats, including those posed by climate change (Jarzebski *et al*., 2023).

Agro-biodiversity contributes to the local food systems by offering a range of locally available nutrient-dense foods and dietary components that diversify the food basket and impart substantial health benefits, improving income, enhancing resilience and providing the genetic resources for future adaptation (Powell *et al*., 2015) and mitigating the impacts of climate change. During the COVID-19 pandemic, amid unstable conditions where issues related to the transport of food and other culinary items were raised, local food systems that comprised traditionally grown plants developed new significance as a safety net for food supply and food security (Haq *et al*., 2022). Traditional food systems are generally adapted to local environments and include a large number of wild plant species, which are beneficial as food and provide many micro-nutrients and avoid malnutrition by providing nutritionally rich meals to communities (Rana *et al*., 2012). Local food systems are deeply rooted in local resources (such as environment, expertise and heritage) and also have a significant role in supporting geographical indications and more sustainable food production by encouraging practices that promote biodiversity (Bele *et al*., 2018). The distinctive ethnic food culture and local knowledge of the Western Himalayan mountains are well known. In the NW Himalayan state of Uttarakhand, indigenous food systems are self-sustaining and depend on the cultivation of native or naturalized crops, the raising of indigenous livestock breeds, and the gathering of wild foods from nearby agroforestry and forestry areas to fulfill the specific needs of different farming situations and communities in the region (Bisht *et al*., 2018).

The predominant rainfed production system in the hills is characterized by more numbers of crops and associated biodiversity maintained through crop rotations. Mono and mixed cropping practices are the sources of valuable genes for adaptation in extreme environments. It is a matter of concern that the local food system has been facing a significant transition in recent decades due to seasonal shortfalls (Das and Mishra, 2023) and also, the number of wild and domesticated food species are sharply declining from local food systems, which endangers dietary diversity of indigenous masses (Penafiel *et al*., 2019). Despite the importance of local foods to local people in their diets, such foods have large-scale hunger eradication or, nutrition promotion, or livelihood improvement programs (Pandey *et al*., 2022).

Status of Plant Biodiversity Research, Conservation and Use in NW Himalayan Region

IHR houses a wide array of plant genetic resources (18,940) due to its diverse climatic conditions. Among these 8,500 species (40% endemics) are characterized by angiosperms. Major genera for which rich diversity exists are - *Oryza, Avena, Amaranthus, Chenopodium, Fagopyrum, Allium, Hordeum, Linum, Saccarum, Citrus, Musa, Pyrus, Prunus, Rubus, Fragaria, Sorbus, Rosa, Lilium, Vicia, Lepidium, Lathyrus, Dioscorea, Orchids, Cucumis, Solanum, Trichosanthes, Bamboos* and *Canes*. Across the wide altitude ranges, the NW Himalayan region supports tropical, sub-tropical, temperate, sub-alpine, alpine and tundra biomes/ ecosystems. The NWH bio-geographic province is essential as an estimated 20% of the species of plants in this province are endemic to the Himalayas. The notable ones are *Aconitum heterophyllum, A. falconeri*var. *latilobum, A. ferox, A. laeve, Berberispetiolaris, B. aristata, B. pseudumbellata, B. kashmiriana, B. lysium, Angelica glauca, Codonopsisaffinis, Pleurospermum densiflorum, P. candollii, Lagotiskashmiriana, Lavaterakashmiriana, Saussurea bracteata, S. graminifolia, S. simsoniana, Delphinium kashmirianum, Inula racemosa, Corylus jacquemontii, Buxus wallichiana, Arnebia benthamii, Rhododendron campanulatum, R. anthopogon, Euonymous pendulus, Allium humile, Royleacinerea, Morina longifolia, Dactylorhizahatagirea, Salvia lanata, Fritillaria roylei, Cinnamomum tamala, Lilium polyphyllum, Meconopsis acuteata, Fraxinus xanthoxyloides, Pinus gerardiana, Abiespindrow, Pittosporum eriocarpum, Rheum austral, Skimmia laureola, Ulmus wallichiana, etc*. The region also supports various critically endangered plants and a rich repository of wild plants of food value (Sharma *et al*., 1997). In the IHR, 80% of people depend on agriculture for their food and daily livelihoods. Therefore, it is known for the diversity of genetic resources of crops and their wild relatives. Although the world counts at least 50,000 species of plants suitable for human consumption and from them < 300 species enter the market (Jacques and Jacques, 2012). The Western Himalayas have a vibrant heritage of medicinal and aromatic plants. About 2,500 plant species are being utilized in different traditional medicine systems of India; > 1,750 herbal species are native to the IHR, in which the Western Himalaya has a share of about 1,000 species that are still in use (Pandey *et al*., 2006). About 47 traditional crops, including vegetables and other crops such as tea, and 38 horticultural species are known to be cultivated in the region. The genetic diversity is high in crops like rice, maize, barley, amaranth, buckwheat, small millets, beans, vegetable, fruit crops, ornamental and medicinal and aromatic plants (MAPs), probably due to ecological differentiation and intensive natural and human selection exercised by various ethnic communities over centuries and introduction of exotic genetic resources. The Himalayan agroecosystem is one of the few agroecosystems where traditional rice, wheat, maize and barley varieties are cultivated and hold a wide range of genetic diversity. The diversity at the species level is low for these crops but very high at the varietal level. Different institutions, particularly the ICAR-NBPGR, New Delhi, and various national active germplasm sites (NAGS) have collected and conserved an appreciable amount of diversity. Nearly 300 crop-specific and multi-crop exploration trips have been undertaken, and more than 30,000 germplasm accessions of various agri-horticultural crops, including some of their wild relatives, have been assembled from the Himalayan region (Rana *et al.,* 2012). The rice germplasm collected from the Western Himalayan region (from 1000–1500 m asl) (Rana *et al*., 2008) exhibited genetic variability for many traits such as plant height, number of tillers, number of panicle, grains/panicle, 100-grain weight, days to maturity, panicle shape (compact, loose, erect), awning (awnless, short to long awned), husk color, (straw, golden, golden brown, purple, black) and tolerance to shattering (highly susceptible to tolerant). Large numbers of rice landraces such as *Jattoo, Thapachini, Krishna Bhog, Govind Bhog* and *Mal Bhong* are still occupying sizable acreage because of their unique attributes like aroma, fine grains, and medicinal properties (Maikhuri *et al*., 2006). Genetic diversity in wheat is not very exciting as many landraces and old varieties have eroded after the onslaught of dwarfing wheat. Nevertheless, a few landraces still find a place in cultivation like *Kankoo* (good plant vigor, more straw, non-shattering, flour white, bread tasty and does not dry quickly); *Mundal* (awnless, bread tasty, disease resistant, non-shattering type); *Dharmauri* (awned, more straw, drought resistant, flour brown but bread tasty, more tillers, shattering type); *Bharadoo* (late maturing); *Ralieun* (easy to thresh, flour white and bread delicious); *Mundalmisri* (cold tolerant, tall, thrives best in weeds); *Kathi* (shattering resistant) and *Gazariya* (lodging resistant). Barley exhibits genetic diversity in its forms, *viz*., two- and six-rowed in hulled and hull-less types. Interestingly, bluish-black grain-type landraces having cold tolerance occur at high altitudes (above 3,300 m) in Lahaul & Spiti, Kinnaur (Nako), Pangi, Ladakh, Munsiari and Badrinath areas (Sharma *et al*. 2011). Biodiversity conservation is vital for maintaining ecological balance among different life forms of the planet and keeping natural ecosystems healthy and functional. Plant biodiversity is one the most crucial components sustaining humankind by meeting its food, fodder, fiber and fuel demands. The sustainability of the Himalayan ecosystem (nearly 18% of India) is vital for employing approximately 1.3 billion people in Asia. The value of ecosystem services provided by the Himalayan forests was estimated to be $1,150/ha annually. The IHR supports vast natural diversity, consisting of 18,440 plant species, including 1,748 and 675 species of medicinal importance and wild edibles, respectively. The highest number (701) of medicinal and aromatic plant species (MAPs) have been reported from the Uttarakhand region, followed by Himachal Pradesh (643 species) (Rana *et al.,* 2012). Nearly 26% of known MAPs are native to the Himalayan region, whereas another 6% share their nativity with Himalayan and adjoining areas (Tali *et al*., 2019). India has emerged as a vital destination in the herbal sector, with 8.13% of the global share and 22% growth, the highest globally (Virk and Witcombe, 2007). The families that signify the most significant number of medicinal plants in descending orders are Asteraceae, Fabaceae, Lamiaceae, Rubiaceae, Euphorbiaceae, Ranunculaceae, Rosaceae, Poaceae, Orchidaceae, Polygonaceae, and Gentianaceae, respectively. The medicinal plant-rich genera are *Polygonum*, *Euphorbia*, *Piper*, *Ficus*, *Aconitum* and *Swertia*, *Artemisia*, *Solanum, Berberis, Desmodium,* and *Allium,* and *Saussurea*. Biodiversity provides several facilities and services, such as food, fodder, fuel, medicine, timber, resins, oil, climate regulation, pollution control, soil and water conservation, nutrient cycling, pollination, and recreation (Rana *et al*., 2005). Humans depend upon various ecosystem services (ES) provided by forest ecosystems, which are generated because of interaction and exchange between biotic and abiotic components of an ecosystem (Rana *et al*., 2005). The biodiversity will keep declining unless scientists and practitioners effectively collaborate with stakeholders and indigenous communities for its conservation and utilization. Since local communities are essential to any conservation effort, it is crucial to balance the perspectives of scientists, conservationists, and policymakers and ensure the livelihoods of the people. Immediate efforts are needed to create awareness along with enhanced coordination involving government departments, NGOs and local institutions for conservation and sustainable use of plant genetic resources.

Local Food System for Achieving Food Resilience

Food resilience is the ability of a food system to withstand and recover from shocks and stressors while maintaining its essential functions. A local food system is a network of food production, distribution, and consumption that is designed to meet the food needs of a particular geographic area, typically within a radius of 100 miles (Grubinger, 2021). Local food systems play a crucial role in achieving food resilience. They adapt more to local conditions and respond quickly to disruptions than larger, centralized food systems. In addition, they can help reduce the carbon footprint of food production and distribution by minimizing transportation distances (Bene, 2020). They can play an essential role in building more resilient food systems, especially in times of crisis such as the COVID-19 pandemic. Some of the benefits of local food systems include reduced dependency on long and complex global supply chains that are vulnerable to disruptions and shocks, and enhanced food security and sovereignty of local communities by increasing access to fresh, nutritious, and culturally appropriate food (FAO, 2020). Additionally, the local food system can support the livelihoods and well-being of small-scale farmers and food workers, who often face marginalization and exploitation in the conventional food system and be helpful in fostering social cohesion, contributing towards environmental conservation and climate change mitigation.

Local food systems offer a viable alternative that is more responsive to the needs and aspirations of local people and the planet. These are considered more resilient than modern global industry-based food systems because they are more diverse and less dependent on external inputs (Bene *et al*., 2020). However, to achieve food resilience, there is a need to strengthen local food systems by improving the infrastructure (such as roads, markets, and storage), supporting small-scale producers and food suppliers Bene *et al*. 2020 promoting locally produced food, supporting farmers' markets and advocating for policies that support small-scale producers and food suppliers (USDA, 2019).

The local food systems in the Himalayan region promote the cultivation and consumption of indigenous crops, which are often better suited to the local environment, thus supporting sustainable agriculture without any dependency on external inputs, enhancing food security, preserving cultural heritage, protecting the environment and fostering economic and social resilience in the region. In Himalayan state, Uttarakhand a popular traditional local food system called "*Barahnaza*" is widely adopted. It includes grain crops like finger millet, amaranths, buckwheat, and maize, pulses crops (kidney bean, black gram, cowpea, black soybean, and rice bean), oilseeds (sesame, *perilla*) (Bhartiya *et al.,* 2020) and vegetable crops (cucumber, pumpkin, and bottle gourd), *etc*. This is a unique local food system practiced by small and marginal farmers of the Himalayan region for centuries that conserves agro-biodiversity (Bhartiya *et al*., 2015), meets all nutritional food requirements in addition to ensuring fodder availability, maintaining soil fertility under rainfed organic conditions. Finger millet, amaranths, buckwheat, and maize are the main sources of carbohydrates, calcium, iron, and energy, whereas black gram, cowpea, black soybean, and rice bean serve as the main sources of protein. This mixed cropping based local food system meets the requirement of food and nutritional security of communities in the region. A similar kind of local food system known as "*Naunaza*" also exists in Himachal Pradesh, which further highlights the regional importance of such diverse and sustainable cropping practices in promoting local food sovereignty.

Strategy for Nutritious Diets that Boost Immunity via the Development of Bio-fortified and Nutrition-rich Plant Varieties

Nutritious foods are the base for maintaining overall human health and boosting immunity. Unfortunately, inadequate access to sufficient and nutritious food has resulted in malnutrition and hidden hunger as a persistent global challenge prevalent in underdeveloped and developing countries. Deficiency of proteins, essential amino acids, vitamins and minerals leads to poor health and decreased immunity against various diseases by repressing immune responses and enhancing viral vulnerability (Foolchand *et al*., 2022). Further, the COVID-19 outbreak has highlighted the need to explore ways to strengthen the immune system and the role of nutrition in promoting health (Singh *et al.,* 2023).

In India, despite of impressive agricultural status (the largest producer of milk and pulses and the second-largest producer of rice, wheat, sugarcane, groundnut, vegetables, fruits and cotton globally), a disheartening reality of malnutrition and hidden hunger exists (>9.27 lakh severely acutely malnourished children of six months to six years age group and ~53.1% of women aged 15 to 49 years are anemic) (Anonymous, 2021). Plant-based foods (PBFs) constitute a significant portion of diets in developing countries (Solomons, 2000). Dietary diversity is a reliable indicator of both micronutrient sufficiency and overall diet quality. However, encouraging people to consume more nutrient-rich foods and reduce their reliance on staples can be exceptionally challenging, particularly in resource-poor communities where access, availability and affordability of nutrition-rich diet pose significant barriers (Kennedy and Moursi, 2015). Because food staples are consumed regularly in large quantities, therefore, nutrition-rich bio-fortified crops/varieties offer an efficient and cost-effective way of bringing more micronutrients to the diets, making it a relevant strategy for tackling malnutrition and hidden hunger (Ofori *et al.,* 2022). Moreover, biofortified staple cereals (nonperishable and accessible to low-income groups through the public distribution system) can have a direct impact in addressing micronutrient malnutrition in the country (Neeraja *et al.,* 2022). To mainstream nutrition in the public food distribution system and other governmental measures, India has the potential to significantly increase the breeding, release, production, and consumption of naturally nutritious crops and develop healthier food systems for future generations (Anonymous, 2021). To provide enough calories and essential nutrients 87 biofortified varieties comprising rice (8), wheat (28), maize (14), pearl millet (9), finger millet (3), small millet (1), lentil (2), groundnut (2), linseed (1), mustard (6), soybean (5), cauliflower (1), potato (2), sweet potato (2), greater yam (2) and pomegranate (1) with improved nutrients and the low anti-nutritional factors have been developed through AICRP network (Yadava *et al.,* 2022). Special efforts have also been made to popularize these biofortified varieties among the masses, which include seed production of biofortified varieties for commercial cultivation (Yadav *et al.,* 2018), ICAR-funded special programs (Nutri-sensitive Agricultural Resources and Innovations (NARI) and Poshan Vatika), Technology Incubation Centres in Agriculture (VATICA), provisions under Public Distribution System (PDS), Integrated Child Development Scheme (ICDS), mid-day meal, National Food and Nutrition Security Mission (NFSM), Rashtriya Krishi Vikas Yojna (RKVY) for up-scaling the biofortified varieties. As a result, > 5.5 mha area has been covered by biofortified varieties of different crops during 2021-22 (NAAS, 2022). The other national agencies (DBT and ICMR) and international institutions (Harvest Plus and CSIR) are also converging their research efforts for the development of biofortified staple food in India (Choudhary *et al*., 2022). The UN Food Systems Summit brought strong commitments from countries across the globe to make food systems more nutritious, equitable, environmentally sustainable, and resilient to help achieve the sustainable development goals (SDGs), particularly those relating to ending hunger and malnutrition (SDG 2) and ensuring good health and well-being (SDG 3). The development and integration of biofortified varieties in the food systems is a sustainable option for ensuring the health and well-being of the human population.

Endeavors of ICAR-VPKAS, Almora for Strengthening Local Food System

The local food system of the NWH region is deeply rooted in its geographical and cultural diversity. Uttarakhand cuisine reflects a blend of rich crop diversity nurtured under organic conditions, indigenous ingredients, traditional cultivation and culinary practices contributing to the cultural identity of the region. The institute has contributed immensely to strengthening the local food system of the region by tailoring agricultural innovations to local contexts and empowering farmers with practical skills and knowledge. Himalayan agriculture offers unique challenges and opportunities due to the diverse agro-ecological conditions in the region which necessitate the adaptation of agricultural technologies and practices to local conditions for improving productivity and profitability. Hill agriculture often relies on traditional varieties, cropping systems and cultivation practices, resulting in poor productivity levels. Thus, to deliver yield gains and profitability to farmers, demonstrations of improved production technology and awareness generation through farmer's field schools were conducted at farmers' fields. During 2022-23, demonstrations of various hill crops were conducted in ~22.68 ha acreage, and ~201 farmers of the region benefitted. Improved crop varieties of rice (26.45%), maize (56.25%), horse gram (31.62–32.22%), black soybean (38.91%) and soybean (18.90–23.17%) exhibited significant yield gains than the local cultivars and traditional cultivation practices. Frontline demonstrations promoted intra-crop diversification by introducing farmers to new varieties that are suitable for hill agriculture which is helpful in mitigating risks associated with climate variability, enhancing food security and income generation for hill communities.

Farmers were facilitated for the production of traditional crops by providing VL small tool kits (51) and for millet processing by providing Vivek Millet Thresher-cum-Pearlers (17) along with technical backstopping for improved production technologies. For scaling up the production of local crops, farmers were encouraged to produce a larger volume and facilitated for packaging, processing and value addition. To support the marketing of traditional crops-based products, the farmer's producers' organization (FPO) *Ranikhet Swayat Sahakarita Samiti* was established by NGO Lok Chetna Manch to facilitate the marketing of locally grown crops and their value-added products (Figure 1).

For linking local food system with food and nutrition security, crop and food diversity fairs (3) were conducted and local recipes (~140) of the region have also been documented to pass on the priceless knowledge and invaluable heritage to future generations and also in generating ideas for developing novel recipes from local crops for their wider adoption (Figure 2).

Figure 1: Mainstreaming traditional crops through facilitating farmers for production, processing, value addition and marketing in Uttarakhand Himalayas

Efforts for the Genetic Enhancement of the Local Food System of NW Himalayas at ICAR-VPKAS, Almora

ICAR-VPKAS, Almora, is a leading institute of ICAR working on hill agriculture. To date, the institute has developed >200 high-yielding, disease-resistant varieties of 25 hill crops, which are serving as an integral component of the local food system of the NW Himalayan region. The breeding methods being followed by the institute for the genetic enhancement of the important crops are given in Table 1.

Out of 17,500 accessions maintained at the institute's medium-term module, ~ 30 crop varieties (Table 2) have been developed by direct utilization of the local germplasm, which is an essential component of the local food system.

Future Breeding Methods for Genetic Enhancement of Local Food System

Population growth, economic growth and climate change are serious threats to food availability and making current food production systems insufficient to meet future food demand. The demand for food is increasing at a faster rate as the population growth rate is higher than the food production growth rate. Therefore, the transformation of the food system is essentially required as the prevailing food production practices are not sufficient to meet the food demand at the current rate. Therefore, a holistic approach involving different disciplines like breeding, agronomy, pathology, entomology, biochemistry *etc.,* is of utmost essential to meet the projected demand. The conventional

Figure 2: Popular traditional crop-based recipes of Uttarakhand Himalayas

Table 1: Breeding methods used for genetic enhancement of hill crops

S. No.	*Crop of LFS*	*Breeding methods*
1.	Wheat/Barley	Pedigree, Selected Bulk pedigree, Molecular Breeding-Marker Assisted Selection, Double Haploidy (Wheat/ Maize, Imperata system)
2.	Paddy	Pedigree, Bulk method, Molecular Breeding-Marker Assisted Selection, Double Haploidy (Anther Culture)
3.	Maize	Hybrid breeding, Double Haploidy (inducer-based), Molecular Breeding-Marker Assisted Selection
4.	Millets	Pedigree, Contact method, hot water treatment
5.	Amaranths	Pedigree method
6.	Horse gram	Pedigree method
7.	Black Soybean	Pedigree method
8.	Lentil	Pedigree method
9.	Garden pea	Pedigree method
10.	Onion	Hybrid, Marker Assisted Selection
11.	Garlic	Clonal selection, Bulbil
12.	Tomato	Pedigree (OP)/Hybrid
13.	Capsium	Pedigree (OP)/Hybrid/Double Haploidy

breeding methods take almost 10 to 12 years for varietal development. However, climate change, population pressure *etc*., pose fast-changing problems. Therefore, breeders should attempt to accelerate breeding in order to generate products more quickly in order to be able to respond to unpredictable changes in crop production environments. This has also put pressure on breeders to implement ways to reduce variety development and breeding cycle time with enhanced genetic gain. In recent decades, there have been many technological developments in a range of areas applicable to crop research: molecular genetics and genomics, trait physiology, phenomics, and geographical information systems. Therefore, an integrated approach involving proven conventional and new breeding methods may be an appropriate strategy. These methods can be broadly categorized into non-molecular methods and molecular methods.

Non-molecular Methods

The conventional breeding methods broadly involve crossing, generation of variability and then selection of suitable genotypes to develop breeding lines. Shortening the length of time required for the development of new breeding lines, regardless of the method used and increasing the rate of genetic gain has to be taken care of while resorting to accelerated breeding. These methods result in quicker breeding and shorter breeding cycles. These are some of the simplest and most effective ways to develop new varieties that are adapted to current climates to minimize the effects of climate change. The following methods may be applied for this.

Rapid generation advance (RGA)

These methods rely on growing all plant populations in the field, following the normal growing seasons. This includes two methods.

- *Single seed descent (SSD)*

An alternative, faster breeding method used by cereal crop breeders for a long time. This results in quick line fixation by articulating growth conditions in such a way that flowering and seed set is induced faster than under normal field conditions during a typical crop season.

- *Bulk population method*

Though there is no time savings in this method, however, resources can be saved in this breeding method.

The obvious advantages of RGA are technical simplicity, a requirement for less resources, low costs and, most importantly, speed. In addition, it shortened the variety development time and breeding cycle.

Doubled haploidy (DH)

This is one of the most potential approaches**.** Primarily it may be produced by regenerating plants through chromosome doubling of pollen grains. Other methods like chromosome elimination like wheat/maize or *imperata* system in wheat, inducer lines in maize, *etc.,* may be used. This method has several advantages. It greatly shortens the line fixation stage as completely homozygous lines may be produced immediately. However, for this, tissue culture laboratories are required and these may be applied only to those species that are amenable to tissue culture.

Shuttle breeding

This is the simplest method and was originally developed and extensively applied by Nobel Laureate Dr NE Borlaug in Mexico. In India also, this is being used in several crops like wheat, maize, rice, millet, *etc*. The biggest advantage of this is that one or two extra generations may be advanced per year by using different field locations for off-season cultivation. In addition, it improves selection under a broad range of different diseases and environmental conditions as the field locations are for a broad range of different diseases and environmental conditions.

Molecular Methods

These methods can be integrated with non-molecular methods to increase the speed as well as efficiency of crop breeding. In the last 3 decades, the use of DNA markers as an aid to selection in plant breeding has led to significant improvements in efficiency and the release of new varieties. DNA markers reduce the time required for varietal development by several years. Marker-based breeding has

Table 2: Use of local germplasm in varietal development at ICAR VPKAS

S. No.	*Crop/ Varieties*	*Pedigree*
Paddy	VL Dhan 206	Selection from *Bamani*
	VL Dhan 8	Selection from Kaoshuing22 (Good cooking quality)
Finger millet	VL Mandua 204	Selection from local from UP Hills
	VL Mandua 124	Selection from local from UP Hills
Barnyard millet	VL Madira 8	Selection from local from UP Hills
	VL Madira 29	VHC 5360-1 from *Kumaun*, UK
	VL Madira 21	Selection from local (*Gochar* selection)
	VL Madira 172	EF2/VHC 5205
Amaranthus	VL Chua 44	Selection from IC 5564
	VL Chua 110	VL *Chua* 44/GA 2
Lentil	VL Masoor 1	Selection from local germplasm from hills
	VL Masoor 4	Selection from VHC 6553 (Sera, Berinag, Pithoragarh)
	VL Masoor 103	Selection from VHC 2776-1 (Bageshwar)
	VL Masoor 125	VL Masoor 1/PL 406
	VL Masoor 126	VL Masoor 4/ PL 406
Kidney beans	VL Rajma 63	Selection from local germplasm (NWH)
Horsegram	VL Gahat 1	Selection from local germplasm (UP Hills)
	VL Gahat 8	VLG 1/ P 1648
	VL Gahat 10	VLG 1 / NIC 2659
	VL Gahat 15	VLG 1 / NIC 7321
	VL Gahat 19	Pure line selection from VH 61
Soybean	VL Soya 2	Pure line sel. from local VHC 856007
	VL Soya 21	Pure line sel. from local VHC 3055
	VL Soya 63	VLS 2 // Bragg/VHC 3022
	VL Soya 65	Selection from local Vill. Abu, Bageshwar
	VL Bhat 201	Selection from VHC 3071 Kulsari, Chamoli)
Rice bean	Him Shakti (VRB 3)	Selection from IC 538080 (Nainital)
Toria	VL Toria 3	Selection from VHC 86
Onion	VL Piaz 3	BYG 2207A/Local collections from U.P. Hills
Garlic	VL Lahsun 2	Selection from germplasm from UK Hills

been more efficient than conventional methods in terms of improved accuracy, time or cost savings. The additional benefit is that it permits screening of the segregants, which is not possible through routine phenotyping. A major advantage of using markers is that recessive alleles as well as homozygosity, can be detected very efficiently.

These can be Broadly Classified as

Marker-assisted selection

This is being routinely implemented in major crops. There are many marker-assisted varieties developed and notified in different crops.

Marker-assisted backcross breeding

Backcross breeding offers the advantage of quick correction of some deficient trait is well recognized across the world. The advantage of this method is to produce an upgraded version of the recurrent variety (with one or more characters) while retaining the original critical characteristics of the recurrent variety in the final product. The marker-assisted back cross-breeding greatly enhances the efficiency of selection.

Marker-aided pyramiding

This approach may also be used to integrate multiple genes into a single recipient variety. In both cases reduces the time required for varietal development by several years.

Genomic selection and genome editing

Genomic selection has emerged as a potential method recently. This technology may be very helpful in the coming times. The genomic selection may be used as a complementary method to MAS. Genomic selection may be very useful for the accurate selection of complex traits such as yield, to shorten the breeding cycle and to increase the rate of genetic gain. On the other hand, genome editing may be used to shorten breeding cycles and variety development times.

The ideal case would be marker-assisted selection with genomic selection and rapid generation advancement. However, some of these techniques are new, and in practice, there are many significant economic and technical obstacles to actual implementation in the public sector. Therefore, the most cost-effective and efficient way to implement genomic selection needs to be evaluated before this may be applied at an extensive scale.

Strategies to Address the Challenges of Hunger, Food Security and Malnutrition

The 2030 Agenda for Sustainable Development (with 17 sustainable development goals) was endorsed by 193 Member States during the UN General Assembly Summit in September 2015 (officially commenced on January 1, 2016). Fundamental to this global agenda for 2030 is the principle of universality: 'Leave No One Behind'. Development in all its dimensions must include all people, everywhere and should be built through the participation of everyone, especially the most vulnerable and marginalized. India has the highest (24%) population of undernourished individuals globally and in terms of India's own population, ~14% of the total population was undernourished with the largest percentage of children suffering from stunted growth (31%) and wasting (51%) compared to any other country in the world as reported by FAO, IFAD, UNICEF, WFP, and WHO in 2019 (Jose *et al*., 2019). Food insecurity has been identified as a "pressing public health concern" in India and at the household level, food security exists when all members, at all times, have access to enough food for an active, healthy life (McKay *et al*., 2023). Initiatives like *Poshan Abhiyaan* or National Nutrition Mission (NNM), *Anemia Mukt Bharat Abhiyan*, Mid-day Meal (MDM), National Food Security Act (NFSA), *Pradhan Mantri Matru Vandana Yojana* (PMMVY), Integrated Child Development Services (ICDS) Scheme have been made by Government of India to address the issues of hunger, food security and malnutrition in the country. According to the 2021 Global Nutrition Report, India is not on track to achieve five of the six global nutrition targets to address stunting, wasting, anemia, low birth weight and childhood obesity(https://www.orfonline.org/expert-speak/global-nutrition-report-2021/). The linear projections of malnutrition indicators also show that India will not be able to achieve the SDG target of eliminating all forms of malnutrition by 2030 unless more stringent and targeted actions are adopted (Jose *et al*., 2019). The factors contributing to food insecurity and malnutrition include the current policies that have encouraged modern agri-food systems, which have resulted in the higher price of healthy diets than staple cereals-based diets. As a result, low-cost foods with a high energy density and little nutritional value became more popular. Furthermore, extinction of traditional crops such as amaranth, buckwheat, minor millet, finger millet, proso millet, foxtail millet and pulses from farming systems in India. In recent years, unanticipated forces in the socio-cultural value system have changed eating habits and diets worldwide and lack of knowledge about their nutritional worth, viable local markets for produce and the rising demand for cash crops have fueled the extinction of traditional crops and consequently reduction of food diversity.

The possible strategies for addressing the challenges of hunger, food security and malnutrition could be:

- Diverting more investment in agri-food systems for improving agricultural productivity, strengthening supply chains and consumer behavior.
- Creating awareness for nutritional benefits of the local food system and promoting their marketing.
- Promoting the local food system to bridge the gaps in the nutritional composition of daily meals (through incorporating locally grown fruits, vegetables, nuts, *etc*.) is necessary to tackle the triple burden of malnutrition, nutritional disparity and food insecurity for human well-being and also for the prevention of lifestyle diseases.
- Breeding for increased yield and nutrition in a faster and more efficient way by integration of modern tools and local crop diversity for sustainable and resilient local food systems.
- Introducing future crops that are more nutritious compared to staple food crops.
- A robust data management system, improved public food distribution system and nutrition education can also be helpful in addressing the challenges of hunger, food security and malnutrition.

Future directions

- The food system comprises both farming and supply systems. It is pertinent to examine the traditional farming, supply, and related systems to understand the causes of changes in the local food system.
- Traditional foods provide a range of health benefits. However, the present generation is less exposed to the health benefits of traditional foods which need to be educated properly. Besides, the significance of traditional food crops, including millets, as their resilience to climate change and associated impacts in the present context needs to be recognized for food security and the health of the natural ecosystem and environment.
- A blend of scientific knowledge, marketing strategies, start-ups, schemes focusing on the

local food system and knowledge can help the environment and natives to go a long way in preserving biodiversity and sustainable social economy.

- The small-scale ecological farming methods are the key to ensuring resilience to climate change in Himalayan agroecologies. They are based on enhancing diversity, thereby increasing options to respond to climate instability. There is a need to support these traditional systems in order to feed local communities and, at the same time, emphasize the traditional food-based approach for benefiting community nutrition and health.
- A proactive alliance for collaboratively creating a research and advocacy agenda in support of agro-biodiversity and the revival of diverse local food systems is needed for indigenous food sovereignty.
- Developing food composition databases and continuous policy advocacy activities to educate functionaries across different sectors for formulating cross-sectoral policies with respect to food, nutrition, and health.

Acknowledgments

The authors sincerely thank Dr JP Aditya, Senior Scientist (Plant breeding), ICAR-VPKAS, Almora, for his valuable help in the preparation of the manuscript.

References

Agriculture Census Division (2015–16) Ministry of Agriculture & Farmers Welfare, GoI. http://agcensus.nic.in/document/agcen1516/T1_ac_2015_16.pdf

Anggraeni EW, Y Handayati and S Novani (2022) Improving local food systems through the coordination of agriculture supply chain actors. *Sustainability* 14(6): 3281 (1-19). DOI: 10.3390/su14063281.

Anonymous (2021) Integrating nutrient-rich crops into food systems: a tool of change. https://globalnutritionreport.org/reports/2020-global-nutrition-report/

Bele B, A Norderhaug and H Sickel (2018) Localized agri-food systems and biodiversity. *Agriculture* 8(2): 22. DOI: 10.3390/agriculture8020022

Bene C (2020) Resilience of local food systems and links to food security – a review of some important concepts in the context of COVID-19 and other shocks. *Food Secur.* 12(4): 805-822.

Bene C, SD Prager, HAE Achicanoy, PA Toro, L Lamotte, CB Cedrez and BR Mapes (2020). Global map and indicators of food system sustainability. *Sci. Data* 7(1): 1-10. https://doi.org/10.1038/s41597-020-00703-w

Bhartiya A, JP Aditya and L Kant (2015) Nutritional and remedial potential of an underutilized food legume horse gram (*Macrotyloma uniflorum*): a review. *J. Appl. Pharma. Sci.* 25(4): 908-920.

Bhartiya A, JP Aditya, D Joshi, L Kant and J Kumar (2020) Potential nutri-crops from Uttarakhand hills for diversifying food basket in a changing climate. *Indian Farmers' Dig.* 53(10): 36-39.

Bhartiya A, JP Aditya, RS Pal, N Chandra, L Kant and A Pattanayak (2020) Bhat (Black soybean): a traditional legume with high nutritional and nutraceutical properties from NW Himalayan region of India. *Indian J. Tard. Knowledge* 19(2): 307-319.

Bisht IS, PS Mehta, KS Negi, SK Verma, RK Tyagi and SC Garkoti (2018) Farmers' rights, local food systems, and sustainable household dietary diversification: a case of Uttarakhand Himalaya in north-western India. Agroecol. Sustain. *Food Syst.* 42 (1): 77-113.

Brinkley C, GM Manser and S Pesci (2021) Growing pains in local food systems: a longitudinal social network analysis on local food marketing in Baltimore County, Maryland and Chester County, Pennsylvania. *Agric. Hum. Values* 38(4): 911–927. DOI: 10.1007/s10460-021-10199-w.

Choudhary RR (2022) Biofortification in India: Present status and future prospects. Pharm. *Innov. J.* 11(1):782–786

Das S and AJ Mishra (2023) Climate change and the Western Himalayan community: exploring the local perspective through food choices. *Ambio* 52(3): 534–545. DOI: 10.1007/s13280-022-01810-3.

Dhiman MR and GP Muthanarasimha (2022) Biodiversity conservation of Western Himalayas: a pluralistic approach. DOI: 10.5772/intechopen.107075.

Diekmann LO, LC Gray and CL Thai (2020) More than food: the social benefits of localized urban food systems. Front. Sustain. *Food Syst.* 4:534219. DOI: 10.3389/fsufs.2020.534219.

Enthoven L and GV Broeck (2021) Local food systems: reviewing two decades of research. *Agric. Syst.* 193:103226. DOI: 10.1016/j.agsy.2021.103226.

EPA (2021) Local Food Systems.*www.epa.gov/sustainable-management-food/local-food-systems*.

Eriksen SN (2013) Defining local food: constructing a new taxonomy–three domains of proximity. *Acta Agric. Scand.* (Section B–Soil & Plant Science) 63: 47-55.

FAO (2020) COVID-19 and the role of local food production in building more resilient local food system. Rome. *https://doi.org/10.4060/cb1020en*

Foolchand A, T Ghazi and AA Chuturgoon (2022) Malnutrition and dietary habits alter the immune system which may consequently influence SARS-CoV-2 virulence: a review. *Int. J. Mol. Sci.* 23(5): 2654. DOI: 10.3390/ijms23052654.

Galluzzi G, CV Duijvendijk, L Collette, N Azzu, and T Hodgkin (2011) Biodiversity for food and agriculture. Contributing to food security and sustainability in a changing world. Workshop held by FAO and the Platform on Agrobiodiversity research, 14–16 April 2010, Rome, Italy.

Gori F and A Castellini (2023) Alternative food networks and short food supply chains: a systematic literature review based on a case study approach. *Sustainability* 15(10): 8140. DOI: 10.3390/su15108140.

Grubinger V (2021) Resilience and sustainability in the food system. *https://www.resilientdesign.org/resilience-and-sustainability-in-the-food-system/*

Haq SM, M Hassan, HA Jan, AAA Ghamdi, K Ahmad and AM Abbasi (2022) Traditions for future cross-national food security—Food and foraging practices among different native communities in the Western Himalayas. *Biology* 11(3):

455. DOI: 10.3390/biology11030455.

IPCC (2018) Summary for policymakers. Global warming of 1.5°C. IPCC, Geneva

Jacques PJ and JR Jacques (2012) Monocropping cultures into ruin: the loss of food varieties and cultural diversity. *Sustainability* 4(11): 2970–2997. DOI: 10.3390/su4112970

Jarzebski MP, J Su, A Abrahamyan, J Lee, J Kawasaki, B Chen, RNN Andriatsitohaina, I Ocen, GB Sioen, R Lambino, O Saito, T Elmqvist and A Gasparatos (2023) Developing biodiversity-based solutions for sustainable food systems through transdisciplinary Sustainable Development Goals Labs (SDG-Labs). Front. Sustain. *Food Syst.* 7:1144506. DOI: 10.3389/fsufs.2023.1144506.

Jones P, D Comfort and D Hillier (2004) A case study of local food and its routes to market in the UK. Br. *Food J.* 106 (4): 328–335. DOI: 10.1108/00070 700410529582

Jose S, A Gulati and K Khurana (2019) Achieving Nutritional Security in India: Vision 2030. ISBN 978-81-937769-4-0.

Kennedy G and M Moursi (2015) Dietary diversity and biofortification: closer than you think. HarvestPlus Policy Brief. Washington, D.C.: International Food Policy Research Institute (IFPRI). *http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/*

Maikhuri RK, KS Rao and KG Saxena (1996) Traditional crop diversity for sustainable development of central Himalyan agroecosystems. *Int. J. Sustain. Dev. World Ecol.* 3 (3): 8-31.

Maikhuri RK, KS Rao, and RL Semwal (2001) Changing scenario of Himalayan agroecosystems: loss of agro biodiversity, an indicator of environmental change in Central Himalaya, India. *The Environmentalist* 21(1): 23–39.

Maikhuri RK, KS Rao, KG Saxena and RL Semwal (2015) Local food systems and sustainable mountain development: a case study from Indian Himalaya. *Int. J. Sustain. Dev. World Ecol.* 22(1):61-70.

Maikhuri RK, LS Rawat, KS Negi, PC Phondani and LS Kandari (2006). Traditional crop diversity for sustainable ecological security in Indian Himalaya. *Indian J. Trad. Knowledge* 5(4): 443-458.

Mehta A, N Sharma, MS Rathore, DC Bhandari (2010) Traditional foods and beverages of Uttarakhand Himalaya. *Indian J. Trad. Knowledge* 9(2): 328-332.

NAAS (2022) Biofortification to address malnutrition in India: Present status and way forward. strategy paper, National Academy of Agricultural Sciences, New Delhi, 17: 23

Neeraja CN, F Hossain, K Hariprasanna, S Ram, CT Satyavathi, L Longvah, P Raghu, SR Voleti, and RM Sundaram (2022) Towards nutrition security of India with biofortified cereal varieties. *Curr. Sci.* 271-277.

Niketan N, G Ibrahim, R Thar, A Jain, M Abraham and S Valsangkar (2018) Exploring the potential of diversified traditional food systems to contribute to a healthy diet. Food Sovereignty Alliance India & Catholic Health Association India. *https://ruralindiaonline.org/en/library/resource*

Ofori KF, S Antoniello, MM English, and ANA Aryee (2022) Improving nutrition through biofortification–asystematic review. *Front. Nutr.* 9:1043655. DOI: 10.3389/fnut.2022.1043655.

Pandey AK, AKS Rawat and JC Ghildiyal (2006) Ethnomedicinal plants of Indian Himalaya: a review. *J. Ethnopharmacol.* 110(2):193-208.

Pandey AK, LMS Palni, A Kumar and P Joshi (2022) Local and regional agrobiodiversity: a cornerstone for nutritional security and food sovereignty of indigenous small-scale farming communities. *J. Agrobiodiv. Studies* 7(1): 45-58.

Penafiel D, W Vanhove, RL Espinel and PV Damme (2019) Food biodiversity includes both locally cultivated and wild food species in Guasaganda, Central Ecuador. *J. Ethn. Foods* 6:25. DOI: 10.1186/s42779-019-0021-7.

Powell B, SH Thilsted, A Ickowitz, C Termote, T Sunderland and A Herforth (2015) Improving diets with wild and cultivated biodiversity from across the landscape. *Food Secur.* 7: 535–554. DOI: 10.1007/s12571-015-0466-5.

Rana JC, K Pradheep, OP Chaurasia, S Sood, RM Sharma, A Singh and R Negi (2012) Genetic resources of wild edible plants and their uses among tribal communities of cold arid region of India. *Genet. Resour. Crop Evol.* 59(1):135-149.

Rana JC, KS Negi, SA Wani, S Saxena, K Pradheep, A Kak and SK Pareek (2008) Genetic resources of rice in the western Himalayan region of India: current status. *Genet. Resour. Crop. Evol.* 56: 963-973.

Rana JC, Y Sharma and A Singh (eds) (2005) Invasive alien weeds encroaching forest-an issue need to be addressed for better forest management. *Proceeding of Regional workshop on Forestry Extension Strategy Review,* December 27 2005, Himalayan Forest Research Institute (ICFR&E), Panthaghati, Shimla, pp 55-57.

Singh RK, AK Sharma and P Gupta (2023) Nutrition and immune system: exploring the role in promoting health during COVID-19 outbreak. *J. Nutr. Immunol.* 17(2): 89-104.

Sharma DC (2019) Here is how millets can make India's food basket climate-resilient. (n.d.) *https://www.downtoearth.org.in/news/agriculture/here-is-how-millets-can-make-india-s food-basket-climate-resilient-65372*

Sharma V, KD Sharma and SK Singh (2011) Assessment of genetic diversity in Indian landraces of wheat and barley using morphological traits. *Indian J. Plant Genet. Resour.* 24(2): 170-176.

Sharma VK, A Kumar, S Bhatia and M Thakur (1997) Genetic resources of crop plants and their wild relatives in the Indian Himalayan Region. *Proceedings of the International Workshop on Plant Genetic Resources,* Shimla, India, HPKVV, pp13-24.

Solomons NW (2000). Plant-based diets are traditional in developing countries: 21st century challenges for better nutrition and health. Asia Pac. *J. Clin. Nutr.* 9(Suppl 1): S41-S54.

Sundriyal RC, GCS Negi, RK Maikhuri, DS Rawat, RS Rawal, and PP Dhyani (2014) Family and smallholder farming in Himalayan communities. In: J Griffiths (ed) Deep Roots. The Food and Agriculture Organization of the United Nations (FAO), Rome, Italy 105-108 & 253

Sundriyal RC, SC Rai, E Sharma, YK Rai (1994) Hill agroforestry systems in South Sikkim, India. *Agrofor. Syst.* 26:215-235.

Tali BA, AA Khuroo, AH Ganied, IA Nawchoo (2019) Diversity, distribution and traditional uses of medicinal plants in Jammu and Kashmir (J&K) state of Indian Himalayas. *J. Herb. Med.* DOI: 10.1016/j.hermed.100280.

The Climate Group (2021) Millets: a solution to climate resilient agriculture." www.theclimategroup.org/news/millets-solution-climate-resilient-agriculture.

USDA (2019) Local Food Systems. *www.ams.usda.gov/local-food-systems*.

Virk DS and JR Witcombe (2007) Trade-offs between on-farm varietal diversity and highly client-oriented breeding - a case study of upland rice in India. *Genet. Resour. Crop Evol.* 54(4): 823-835. DOI 10.1007/s 10722-006-9158-5

Yadava DK, F Hossain and T Mohapatra (2018) Nutritional security through crop biofortification in India: status & future prospects. *Ind. J. Med. Res.* 148(5): 621–631.

Yadava DK, PR Choudhury, F Hossain, D Kumar, TR Sharma and T Mohapatra (2022) Biofortified varieties: sustainable way to alleviate malnutrition (Fourth Edition). Indian Council of Agricultural Research, New Delhi. 106 p.