P. ISSN: 0971-8184 II E. ISSN: 0976-1926
DOI: 10.61949/0976-1926.2025.v38i02.03

Indian Journal of
Plant Genetic Resources

REVIEW ARTICLE

Use of Plant Genetic Resources in Crop Improvement under the Indian Himalayan Perspective

Pradeep Kumar Thakur, Manisha Kumari, Raghav Sood and Mohar Singh*

Abstract

The Indian Himalayas, a treasure of biological diversity, harbor a wealth of plant genetic resources (PGR). This mountainous region's varied climate and terrain have fostered a unique ecosystem teeming with plant life, from ancient, locally adapted crop varieties to wild species. These invaluable genetic resources are essential for enhancing crop resilience and productivity, making their sustainable use pivotal for the future of Himalayan agriculture. These resources, encompassing cereals, pseudo-cereals, pulses, fruits and vegetables, offer boundless potential for enhancing agricultural productivity, resilience and sustainability. For instance, cereals like rice, maize, barley, and millets exhibit unique diversity adapted to local conditions, while pseudo cereals such as buckwheat and amaranth thrive in high altitudes, providing essential nutrients. Pulses, including beans, peas and lentils, show remarkable variability contributing significantly to the Himalayan diets. However, fruits and vegetables are equally diverse, with the region producing a wide range of temperate and subtropical fruits, as well as indigenous vegetables adapted to specific ecological niches. The utilization of PGRs involves traditional breeding techniques and advanced biotechnological approaches to develop high-yielding and resilient cultivars. Further, the region faces challenges like biodiversity loss due to the replacement of conventional cultivars and landraces with high-yielding varieties and the impact of biotic and abiotic stresses. Conservation and systematic utilization of PGRs are essential to prevent genetic degradation and address global issues such as climate change and food insecurity. Organized efforts in exploring, collecting and preserving PGRs are imperative for maintaining genetic diversity and securing the agricultural heritage of the Himalayan region for future generations. This review article aims to provide a comprehensive overview of the status and utilization of PGR in crop improvement and future perspective within the Himalayan region.

Keywords: Plant Genetic Resources, Indian Himalayas, Crop Improvement, PGR Utilization.

ICAR-National Bureau of Plant Genetic Resource Regional Station, Shimla-171 004, Himachal Pradesh, India.

***Author for correspondence:**

Mohar.Singh2@icar.gov.in

Received: 22/08/2024 **Revised:** 04/12/2024

Accepted: 05/01/2025

How to cite this article: Thakur PK, Kumari M, Sood R and Singh M. (2025). Use of Plant Genetic Resources in Crop Improvement under the Indian Himalayan Perspective. Indian J. Plant Genetic Resources. 155-160.
DOI: 10.61949/0976-1926.2025.v38i02.03

Introduction

The Indian Himalayan region is a biodiversity hotspot, with a broad range of plant species uniquely adapted to its challenging climatic and geographical conditions. Nestled amidst the majestic peaks of the Himalayas, this region has incredible ecological diversity, ranging from lush subtropical plains to rocky alpine territory. Within this mosaic of landscapes lie invaluable genetic reservoirs that hold the key to addressing the agricultural challenges and harnessing the opportunities unique to this region (Salgotra and Chauhan, 2023). The Himalayas possess a distinctive ecosystem and a rich legacy of traditional wisdom and an active indigenous culture. It has been provided with a great diversity of plant genetic resources (PGRs) of numerous crop species and their wild relatives because of its diverse climatic situations (Sharma *et al*. 2022). The sustainable development of agriculture in the Himalayas depends on the effective utilization of its rich plant genetic resources. These resources include a wide range of wild and domesticated plant species, all with distinct characteristics developed over millennia of adaptation to the various agro-climatic conditions. From traditional landraces cultivated by indigenous communities to wild relatives harboring novel traits of interest for crop improvement, offers great potential for enhancing agricultural productivity, resilience, and sustainability.

Plant genetic resources (PGRs) are defined as basic raw material of a crop species, comprising all of alleles of different genes required to meet current and future needs of crop improvement. PGRs in the Himalayas comprise newly developed varieties, landraces, modern cultivars, obsolete cultivars, breeding stocks, wild forms, wild species of cultivated crops and genetic stocks such as current breeder's lines, other elite lines and mutants (Ulukan, 2011). These serve as the fundamental components for enhancing the genetic makeup of commercial and agricultural crops (Hasan and Abdullah, 2015). Farmers in the region have used these landraces for generations to secure their livelihoods. The majority of the agricultural processing and industry sectors also depend on genetic resources. Therefore, these are the pillars of crop improvement programs, particularly in the varietal developmental programs and the level of genetic diversity found in PGRs determines global food security (Ogwu *et al*., 2014). These resources are also employed in systematic investigations, including pathologic, molecular studies, phylogenetic, evolutionary, cytogenetic, biochemical, and physiological studies. These always have wider versatility with desirable quality attributes, drought tolerance, pest resistance and other characteristics, regardless of production potential. Through the hybridization and selection process, these landraces were enhanced for developing high-yielding cultivars. These varieties have replaced conventional cultivars and landraces in the Himalayan agroecosystem, resulting in biodiversity loss (Hyten *et al*., 2009). The situation is made worse by the biotic and abiotic stresses that reoccur frequently, which causes a significant loss of invaluable genetic resources. To prevent such a terrible catastrophe, it is necessary to conserve these valuable resources from genetic degradation and use them judiciously. To meet the current and future global issues, PGRs need to be explored, collected, preserved and used cautiously. Furthermore, it is imperative for every nation to conduct an organized survey, exploration, collecting, protection and sustainable use of genetic resources. The efficient use of PGRs has significant consequences for the socio-economic development, environmental conservation, and food security of the Himalayan region, where agriculture provides the primary means of livelihood for millions of people (Singh *et al.,* 2020). In recent years, the importance of PGRs in crop improvement has gained due recognition, driven by the pressing need to address challenges such as climate change, food insecurity and resource depletion. As we embark on this exploration of plant genetic resources and their role in crop improvement, it is evident that the conservation and utilization of genetic diversity represent not only a scientific endeavor but also a moral responsibility to safeguard the agricultural heritage and secure the future of generations to come in the Himalayan region.

Status of PGR under Indian Himalayan Region

The Himalayan region is one of the rare agro-ecosystems that cultivate conventional varieties of rice, maize, and pseudo cereals and have a wide range of genetic diversity in these crop plants. Although species diversity is low in these crops, it is quite high at the varietal level, particularly in rice and maize. Out of the 22 species of rice, the Eastern and North-eastern Himalayas is native to five wild species comprising of *Oryza granulala, O. officinalis, O. rufipogan, O. meyeriana,* and *O. nivara* (Hore and Sharma, 1993; Rana *et al.,* 2008). In comparison to other regions of the nation, the Northeastern area is considered to be one of the world's hotspots for rice genetic resources and a promising area for rice cultivation with incredibly varied growth conditions. The North-East region, known as the rice secondary center of origin, is rich in genetic resources that demonstrate the distinctness for useful characteristics (Yumnam *et al*., 2011). In the eastern and North-eastern regions, the collected germplasm diversity ranges from 6000 to 8000 (Hore and Sharma, 1993), while in the Western Himalayan region, it ranges from 1000-1500 (Rana *et al*., 2008). Several rice landraces, including *Begumi, Ramjwain, Mehwan, Thapachini, Jattoo, Gnoba, Batlong, Kalijhini, Chuhartu Qudirbeigh, Tongla, Maiku Tsuk Buidhan, Mirikrak, Ryllobed, Phulpattas, Allangamo, Pyapi, Mushkbudji, Tilkakchandan, Koliajiri, malbhong, Krishma Bhog, Ainoari* and *Rarreamoare* still growing on large acreage due to its unique qualities, such as aroma, fine grains and therapeutic qualities (Hore, 2005; Rana *et al*., 2008). Many landraces are sold at premium prices these days compared to common (*parmal*) types because of their high demand and limited supply. Maize in the region possesses an equally high genetic diversity, notably the presence of Sikkim primitives, which are recognized for their profusion and primitiveness. There are eighteen distinctive races and three sub-races, most of which are found in the northeastern (Singh, 1977). In Himachal Pradesh, certain landraces, such as *Bhambla, Gadda, Sathoo, Temta, Bhakadu, Chitkanoo, Rohdu, Misirimakai, Sweti, Poorvi Botapa, Bhogadchalli*, and *Khasi Riewhadem*, are recognized for their exceptional qualities. Particularly, *chitkanoo* is grown in Chamba because of its extraordinary popping quality, and *Murli* maize in the Ramaganga valley in the Kumaon Himalayas of Uttarakhand is a prominent bearer with excellent flavor. Since many landraces and older kinds of wheat have disappeared due to the advent of dwarfing wheat. A few landraces are still under cultivation in the region, nevertheless, like *Kankoo*, which has good plant vigor, more straw, non-shattering, produces white flour, and does not dry out rapidly; *Mundal* - awnless, sweet bread that resists sickness, and non-shattering;

Bharadoo - late maturing; *Dharmauri* - awned, more straw, drought resistant, flour brown yet bread excellent, more tillers; *Ralieun*: effortless to thresh, with white flour and delicious bread; *Mundalmisri* is cold tolerant, *Kathi* is shatter resistant, *Gazariya* is lodging resistant, *Rigaliya* is tall and grows best under heavy weed infestation conditions.

Pseudocereals like buckwheat and amaranth, though lesser known, are integral part of the Himalayan diet, especially in higher altitudes where cereal cultivation is challenging (Rana *et al*., 2012). The major crops in pseudocereals are buckwheat, grain amaranth and chenopods. Three species in the genus Amaranthus - A. *hypochondriacus, A. caudatus* and *A. cruentus* are cultivated for grain purposes, while *A. dubius, A. blitoides, A. hybridus, A. lividus, A. retroflexus, A. spinosus, A. tricolor* and A. *viridis* occur in the wild form and are also utilized as leafy vegetables. There are 15 recognized species in the genus *Fagopyrum*, two of which are cultivated *viz*., *F. esculentum and F. tataricum*. *F. tataricum* ssp. *himalianum* and *F. esculentum ssp. emerginatum*, found in the cold, arid region of the Western Himalayas (Rana, 2004), while *F. tataricum* spp. *annum* also found in the Eastern Himalayas (Ohnishi, 1998). Among chenopods, *Chenopodium amranticolor*, *C. ambrosioides, C. botrys, C. foliosum, C. glaucum, C. hybridum, C. murale* and *C. opulifolium* are wild species, while *C. album* and *C. quinoa* are cultivated (Chowdhery and Wadhwa, 1984). Pseudo cereals are mainly grown in specific geographic areas and are highly valued in the traditional Himalayan agro-ecosystems because of their high nutritional and industrial value, ability to thrive in infertile agro-ecosystems, longer storage life and resistance to grain quality deterioration.

Pulses, including beans, peas and lentils, are essential components of the Himalayan food system, providing protein and other essential nutrients. Their diversity is remarkable, with numerous landraces exhibiting variations in color, size and maturity period. This region possesses a wide range of genetic variation across genera such as *Phaseolus, Pisum, Lens, Vicia* and *Vigna* species. Common beans grown at higher altitudes exhibit a notably larger genetic variation in terms of seed size, seed color and flavor. Its long, capsule-shaped, red-seeded ecological types are cultivated in the Chamba, Kinnaur districts of Himachal Pradesh and Rajouri and Bhaderwah districts of Jammu & Kashmir are well-known for their flavor and culinary quality. The imported pulse adzuki bean (*Vigna angularis*) performed incredibly well and is proven to be an excellent replacement for *V. mungo*, especially in the sub-Himalayan regions where leaf spot occurrences are quite high. The cultivation of rice bean (*V. umbellata*), is more prevalent in the north-eastern region and less prominent in the western region. It has a very high yield, is nearly disease-free, can withstand heavy rains, and exhibits variability in terms of different seed sizes and colours. *Cicer microphyllum*, *Lathyrus aphaca*, *Trigonella emodi*, *Moghani avestita*, *Mucuna bracteata*, *Mucuna capitata*, *Vigna capensis*, *V. pilosa*, *V. vexillata* and *V. radiata* var. *sublobata* are important wild relatives of Indian Himalayan region (Sharma and Rana, 2005; Arora *et al.* 2006).

Fruits and vegetables are equally diverse, with the region offering a wide range of options. However, apples, pears, plums, and apricots are cultivated in higher altitudes, while citrus fruits thrive in lower regions. In India, the cultivation of temperate fruits stretches from Jammu & Kashmir in the North to the sub-tropical plains in the north and Arunachal Pradesh in the East (Gupta, 2011). Further, the majority of the region is in the North-West, where commercially grown apples, pears, peaches, plums, apricots, cherries, almonds and walnuts are grown, but the north-east region is rich in genetic variety for citrus, mango, and banana (Dhillon and Rana, 2004). In addition to major fruit species, there are various smaller fruits growing naturally and have a significant impact on the hill economy (Parmar and Kaushal, 1982). A few examples are: *Prunus mira*, which thrives in extremely cold climates and is widely used as a rootstock for several stone fruits, and is also used for the production of brew. Fruits that are edible are harvested by farmers and used to make brew; stones are sowed to raise rootstocks for almond and peach trees. In the dry environment, there is also a large prevalence of apricots, especially the drier varieties. In Kinnaur and Leh, two of its varieties—red-fruited and white-fruited—are grown extensively (Sharma, 1999). Because of its sweet flavor, its kernel is utilized as an adulterant in almond kernels. Important nuts with varietal variation in the area are hazelnut (*Corylus colurna*), walnut (*Juglans regia*), and almond (*Prunus dulcis*). The sub-Himalayan region is home to *Myrica nagi* (*Kaphal*), a plant that varies in fruit color, sweetness, and size of the stone and fruit. There is a possibility for the domestication of certain large-fruited varieties found in the north-eastern region. Pine nuts, also known as Chilgoja (*Pinus gerardiana*), are found growing in the Gilgit region of Leh & Ladakh and Garhwal region of Uttarakhand, and Pangi and Kinnaur districts of Himachal Pradesh. However, because of the overharvesting of these highly valuable nuts, there are issues with regeneration seeds in these areas. *Rubus* is the most variable and complex genus, widely and predominantly distributed in temperate and warm temperate regions of the North-western and Western Himalayan region which contain 32 species and four varieties (Sharma and Chandel, 1996). Fruits that were introduced, such as pecan nuts, Japanese persimmons and kiwi fruit have adapted extremely well to the area and have made significant contributions to the farm economies.

The Himalayas are home to a vast genetic diversity of vegetable crops, which are grown during both the regular season and the "off-season," greatly boosting agricultural revenues. Vegetables such as garden peas, cabbage, cauliflower, broccoli, green capsicum, tomato and cucumber are key off-season crops. Numerous species of *Solanum*, including *S. macrocarpon, S. xanthcarpum, S. indicum, S. mammosum, S. khasianum, S. torvum, S. berbisetum, S. ferox, S. spirale, S. sisymbrifolium, S. kurzii* and *S. gilo*, are used for culinary and medicinal purposes (Rana et.al 2012) and can be found in different parts of the Himalayan region. In the Himalayas, particularly in the North-East, *Capsicum annum* var. *avicular* (bird pepper wild type, thought to be the ancestor of bell pepper), *Capsicum annum* var. *grossum*, *C. annum* var. *longum*, *C.chinense*, *C.frutescens*, *C. eximium* and *C. minimum* (bird-eye chili) are grown. *Cucurbita*, *Momordica*, *Luffa* and *Trichosanthes* are common cucurbitaceous vegetable varieties. A significant group of plants, the genus *Allium*, has roughly thirty species in the Indian subcontinent (Babu, 1977), all of which are found in the Himalayan region in the wild forms. Additionally, there is genetic variation in the root and tuber crops *Dioscorea*, *Colocasia* and *Amorphophallus*. Furthermore, the region is home to approximately 367 different edible plant species, of which 65 are commonly used edible vegetables that can be found at somewhat better prices in local and city markets. The naturally occurring fungus *Morchella esculenta*, known as *guchchhi*, is a highly valuable genetic resource. *Dioscorea* species with white and red skin were found in the Northeast Region. These species include *D. alata, D. bulbifera, D. brevipetiolata, D. esculenta, D. hamiltonii, D. hispida, D. kamaonensis, D. nummularia, D. pentaphylla, D. puber* and *D. quinata*. The tribal people of Tripura cultivate *Vigna vexillata*, one of the intriguing species of *Vigna*, which varies in terms of both pods and tubers (Arora and Pandey, 1996). While winged beans are only grown in humid subtropical regions of the Northeastern states of India, sword beans are also grown there on a small scale (Sarma, 2001). Among the multipurpose tree species found in various regions of the Indian Himalayan Region (IHR) are the tree bean (*Parkia roxburghii*) and the sajina (*Moringa oleifera*) (Kumar *et al*., 2002). In Meghalaya and other parts of IHR, the tree tomato (*Cyphomandra betacca*) is produced as a backyard enterprise crop. It is a perennial shrub that yields red tomato-like fruits that are utilized as such (Thakur *et al*., 1988). Assam, the Shivalik hills, and the Garo hills of Meghalaya are home to large populations of *kartoli* (*Momordica dioica*) and *kakrol* (*Momordica cochinchinesis*) (Ram *et al*., 2002).

Utilization of PGR from the Himalayas

Landraces had greater diversity than modern varieties. Because modern cultivars are bred for specific features such as high yield, disease resistance, insect pest resistance, stress tolerance, and nutritional enhancement. To create new crop varieties, plant breeders engaged in a crossing program to choose parents from PGRs (Duvick, 1986; Wilkes, 1991). PGRs can be utilized in breeding programs in four different ways: (i) pre-breeding material development for use in practical plant breeding (ii) the creation of genetic stock as a source of quality traits and resilience to different biotic and abiotic challenges, (iii) PGRs characterization and identification for male sterility in order to create hybrids, and (iv) transfer of desired gene from other genetic resources to widely used crop varieties, leading to the creation of modern cultivars. Additionally, PGRs are utilized to create hybrids, also known as composites or synthetics, and to introduce genes to eliminate variety bottlenecks. These activities promote genetic variation in the breeding population. In the Indian Himalayan region, there are several noteworthy examples showing the effective use of PGRs for the production of high-yielding cultivars either through hybridization or selection.

Cereals

One of the first instances of utilizing wild germplasm in rice resistance breeding is the use of genes from an *Oryza nivara* species from the North-West Himalayas to provide sustainable resistance to the grassy stunt virus (Khush, 1997). *Oryza rufipogon*, an annual wild rice species found in several regions of the North-West Himalayas, is highly resistant to blast disease in rice (Rathour *et al*., 2005). A number of rice varieties have also been developed in the entire region as a result of selection from the available germplasm. Further, *Ranbir Basmati* and *Saanwal Basmati* were produced by Sher-e-Kashmir University of Agricultural Sciences and Technology Jammu (SKUAST) through selection from *Basmati 370*, and they were made available for cultivation in 2005 and 2007, respectively. Later, in 2014, high-yielding *Basmati 564* had been developed from *Basmati 370* by selection. From *Basmati 370*, which has a high production potential, it developed *Jammu Basmati 118, 123,* and *138*. In the year 2020, these varieties were released for cultivation by the State Variety Release Committee (SVRC). The genetic improvement and homogeneity of the three most widely consumed rice varieties *viz*. *Mushk Budji, Kamad*, and Red Rice of the Kashmir Valley were additionally enhanced by pure line selection. Red rice cultivated in the region has recently received widespread attention due to its distinct red pericarp color and great nutritional content. In 2005, ICAR- Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora Uttarakhand developed the maize variety VL Baby Corn 1 utilizing the native landrace *Murali Makkai*, primitive Sikkim maize has prolific seed-producing ability including high popping capacity. *Palam Lal Dhaan -I* (HPR 2720) and *Him Palam Lal Dhan-2* (HPR 2795) developed from red rice by Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya (CSKHPKV), Palampur, Himachal Pradesh.

Pseudocereals

In pseudocereals, many varieties have been released through selection from the collections made from the Himalayan region. High-yielding cultivars, *Annapurna* was released in 1984 through direct selection from a local line and *Durga* in 2006 developed from accession IC35407 by the ICAR-NBPGR

Regional Station, Shimla are two noteworthy examples of the successful use of indigenous amaranth germplasm. The buckwheat variety *Himpriya* was also produced by the ICAR-NBPGR Regional Station, Shimla. It was a pure line selection from accession IC13374, and *Shimla B1* from IC341671, which was notified by the Central Variety Release Committee in 1991. Himphaphra, a buckwheat variety regarded for its high protein content (13.10%), was produced by the station from accession IC341589 (Sharma *et al.,* 2022). Furthermore, very recently the variety *Him Gauri* of amaranth developed from accession IC037156 through selection and dedication to the nation by the Hon'ble Prime Minister of India.

Pulses

In pulses CSKHPKV, Palampur, developed three well-known rajmash varieties, namely; *Baspa* (KRC-8) was released for cultivation in Himachal Pradesh after being derived from collection from Kinnaur. This cultivar is still being grown in many parts of the state due to its alluring seed color and resistance against bean anthracnose. The variety *Triloki* developed from a rajmash landrace found in the Lahaul Valley, while *Kailash* (SRC-74) has been selected from local germplasm collected from the Sangla Valley and allowed for cultivation in the dry temperate zone of Himachal Pradesh. The *Bhaderwah* Rajmash variety (BR-104) was developed by SKUAST, Jammu, using local germplasm through selection, and it was released by the SVRC in 2020. Also, using local germplasm collections, the CSKHPKV, Palampur developed the horse gram *Baiju* (HPK-4) variety. In 2011, ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora crossed *VL Masoor 501* × *VL Masoor 103* to develop lentil *VL Masoor 514*, resistant to rust and wilt. *VL Masoor 103* is a selection from the native collection of Uttarakhand Himalayas. In adzukibean, the variety Him Jawala developed from accession IC341939 through selection and released at the national level by ICAR- NBPGR Regional Station, Shimla.

Fruits and Vegetables

Fruit species that grow wild in abundance in the Himalayas have been used as rootstock for crops of cultivated temperate and sub-temperate fruits. These include kainth for pear, crab apple for apple, wild apricot or *chulli* for apricot and many more are among them. However, the high-yielding walnut and pecan nut types, *Bhusan* and SJPP-25, were recently produced by SKUAST, Jammu. These were developed by the selection of native germplasm that was augmented from the Kishtwar district of Jammu & Kashmir and released for cultivation in the state. Similarly, a native landrace produced the popular drying apricot variety known as *Halmen*, which is grown in Kargil, Leh, and Spiti regions. *Lakadong* - grown in the Jowai district of Meghalaya, is a local variety of turmeric. Similarly, *Racharpo*, the world's sweetest apricot variety and used for table purposes, was chosen from a landrace in Kargil (Sharma *et al*., 2022).

Future Perspective and Action Plan

- The challenges posed by climate change and globalization threaten these invaluable resources, emphasizing the urgent need for conservation and sustainable utilization. The conservation and utilization of genetic diversity are not only scientific endeavors but also moral responsibilities to safeguard the agricultural heritage and secure the future of generations to come.
- To maximize genetic diversity in PGRs, an integrated approach combining traditional breeding methods and modern genomic tools is necessary. This method is critical for increasing crop resilience, productivity, and sustainability while also ensuring that agricultural systems can adjust to future needs and environmental changes.
- Empowering farmers through training programs and promoting the cultivation of traditional landraces will help to preserve indigenous crop diversity.
- Using biotechnological innovations like next-generation sequencing (NGS) and high-throughput phenotyping to develop varieties of crops that can adapt to climate change and sustain food security.
- The Himalayas' unique genetic diversity is an important resource for national and global food and nutritional security, and its appropriate use holds the key to a sustainable future for mountain agriculture.
- PGR conservation requires focusing on genetically rich areas, such as tribal belts, as well as strengthening and expanding the germplasm conservation network by involving all stakeholders, including communities.
- Pre-breeding is required to incorporate target traits, which increase productivity and stability of performance, and give outstanding qualities for food and feed products.
- Value addition of products of local crop landraces is the utmost important aspect; this would encourage farmers to cultivate traditional diversity/landraces to enhance their income.

References

Arora RK and A Pandey (1996) Wild edible plants of India-diversity, conservation and use. ICAR, NBPGR, New Delhi, 294 p.

Arora RK, R Nayarand, APandey (2006) Indian Centre of Floristic and Economic Plant Diversity: A Review'. In: Singh K, K Srinivasan, S Saxena and BS Dhillon (eds) Hundred Years of Plant Genetic Resources Management in India. NBPGR (ICAR), Pusa Campus, New Delhi, India.

Babu CR (1977) Herbaceous Flora of Dehradun. Publication and Information Department, Council of Scientific and Industrial Research, New Delhi, India, 721p.

Chaudhary HK, GS Sethi, S Singh, A Pratap and S Sharma (2005) Efficient haploid induction in wheat by using pollen of *Imperata cylindrica*. *Plant Breed.* 124(1):96–98.

Chowdhery HJ and BM Wadhwa (1984).Flora of Himachal Pradesh. I-III Volumes.Howrah, Botanical Survey of India, India, 860 p.

Dhillon BS and JC Rana (2004) Temperate fruits genetic resources management in India - issues and strategies. *Acta Hort*. 662:139-146.

Duvick DN (1986) Plant breeding: Past achievements and expectations for the future. *Econ. Bot.* 40:289–297.

Gupta S (2011) Management of temperate fruit genetic resources in India. *Acta Horticulturae Abstracts*, p 918.

Hasan M and HM Abdullah (2015) Plant genetic resources and traditional knowledge: emerging needs for conservation. Plant Genetic Resources and Traditional Knowledge for Food Security, *Springer Singapore* 105-120.

Hetta G, Babal B, Sharma G D, Kumar R and Rana SS (2022) Organic by default: Hill state making way for a fast comeback of red rice. *Just Agriculture* 2(8):1-6.

Hore DK (2005) Rice diversity collection, conservation and management in northeastern India. *Genet. Resour. Crop. Evol*. 52:1129-1140.

Hore DK and BD Sharma (1993) Wild rice genetic resources of North-east India. *Indian J. Plant Genet. Resour*. 6:27-32.

Hyten DL, JR Smith, RD Frederick, ML Tucker, Q Song and PB Cregan (2009) Bulked segregant analysis using the Golden Gate assay to locate the Rpp3 locus that confers resistance to soybean rust in soybean. *Crop Sci.* 49:265–327.

Khush GS (1997) Origin, dispersal, cultivation and variation of rice. *Plant Mol. Biol*. 35:25-34.

Kumar SK, VR Suresh, SV Nagachen and TR Singh (2002) Tree bean: a potential multipurpose tree. *Indian Hort, 47*(3):10-11.

Ogwu MC, ME Osawaru and CM Ahana (2014) Challenges in conserving and utilizing plant genetic resources (PGR). *Int. J. Genet. Mol. Biol*. 6:16–22.

Ohnishi O (1998) Search for the wild ancestor of buckwheat. I. Description of new *Fagopyrum* (Polygonaceae) species and their distribution in China and the Himalayan hills. *Fagopyrum* 15:18-28.

Parmar C and MK Kaushal (1982) Wild Fruits of the Sub-Himalayan Region. Kalyani Publishers, New Delhi, India, 136 p.

Ram D, G Kalloo and MK Banerjee (2002) Popularizing *kakrol* and *kartoli*: the indigenous nutritious vegetables. *Indian Hort.*, *47*(3):6-9.

Rana JC (2004) Buckwheat genetic resources management in India. In: Faberova I (Ed) Advances in Buckwheat Research: Proceedings of the 9th International Symposium on Buckwheat, August 18-22, Research Institute of Crop Production, Prague, Czech Republic, pp 271-282

Rana JC, KS Negi, SA Wani, S Saxena, K Pradheep, AK and SK Pareek (2008) Genetic resources of rice in the western Himalayan region of India – current status. *Genet. Resour. Crop.Evol*. 65:963-973. Rana JC, M Dutta and RS Rathi (2012) Plant genetic resources of the Indian Himalayan region–an overview. *Indian J. Genet. Plant Breed.*72 (02):115-29.

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

Rathour R, V Gaur, RP Kaushik and RS Chauhan (2005) *Oryza rufipogon* – a possible source of novel resistance specificities against rice blast (*Magnaporthe grisea*). *Curr Sci.* 89(3): 443-447.

Salgotra RK and BS Chauhan (2023) Genetic diversity, conservation, and utilization of plant genetic resources. *Genes* 14:174.

Sarma B. K. 2001. Underutilized crops for hills and mountain ecosystems. Summer school on agriculture for hills and mountain ecosystem, ICAR. pp. 308-314.

Sharma BD and DK Hore (1990) Rice germplasm collection in Tripura state. *Indian J. Plant Genet.Resour.*3:71-74.

Sharma BD and KPS Chandel (1996) Occurrence, distribution and diversity of soft fruits in N-W and W-Himalayas and prospects of their conservation and utilization. *Indian J. Plant Genet. Resour.*9: 237-246.

Sharma BD and Rana JC (2005) Plant Genetic Resources of Western Himalaya – Status and Prospects. Bishen Singh Mahendra Pal Singh, Dehradun, India, 467p.

Sharma JK (1999) Three wild apricots of the Himalaya. *Fruit Var. J.* 53:146-147.

Sharma SK, N Malhotra and M Singh (2022) Plant genetic resources for crop improvement: the North-western Himalayan perspective. *Indian J. Plant Genet. Resour.* 35(3):151–153.

Singh B (1977) Races of maize in India. Indian Council of Agricultural Research (ICAR), New Delhi, 62p.

Singh K, K Gupta,V Tyagi, S Rajkumar (2020) Plant genetic resources in India: management and utilization. *Vavilov J. Genet. Breed.* 24:306-314.

Thakur A K, Himangini and Kumari N. 2020. Red Rice in Himachal Pradesh: History, Tradition and Uses. *Int. J. Economic Plants* 7(2):60-65.

Thakur ANS, YP Sharma and RN Barwal (1988) Tree tomato cultivation in Meghalaya, *Indian Farming* 37(11): **3**.

Ulukan H (2011) Plant genetic resources and breeding: Current scenario and future prospects. *Int. J. Agric. Biol*. 13:447–454.

Wilkes G (1991) *In situ* conservation of agricultural systems. In: Oldfield, ML, Alcorn JB (eds); *Biodiversity: Culture, Conservations, and Eco-Development*. Westview Press: Boulder, CO, USA, pp 86–101.

Yumnam JY, SI Bhuyan, ML Khan and OP Tripathi (2011) Agro-diversity of East Siang-Arunachal Pradesh, Eastern Himalaya. *Asian J. Agril. Sci*. 3:317-326.