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Plant genetic resources of the Indian Himalayan region – an overview

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Abstract

The Indian Himalayan region houses wide array of plant genetic resources due to its diverse climatic conditions. India's recognition as a 'mega-biodiversity' country derives partly from the Himalayas wherein out of 6000 endemic plant species, 2532 species occur. 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,* and *Trichosanthes, Bamboos* and *Canes*. These plant species and varieties have contributed significantly to food and environment security of the hill people. It also provides stability to the food production systems by minimising crop losses due to diseases, insect pests and weather odds. Besides, there are several wild relatives possess genes for various purposes and has lot of breeding value. Despite that, the most distressing situation is that many of these valuable genetic resources are eroding at very high rate. The crops, folk varieties and landraces of local importance adapted to specific micro-climatic niches are being replaced by a few high yielding varieties and cash crops. Nonetheless, appreciable amount of diversity has been collected and being conserved *ex situ* by different institutions particularly the NBPGR and NAGS. Nearly, 300 crop-specific and multi-crops exploration trips have been undertaken and more than 30,000 germplasm accessions of various agri-horticultural crops including some of their wild relative have been assembled from Himalayan region while around 6000 have been introduced from exotic sources.

Key words : Genetic resources, Himalayan region, land races, conservation

Introduction

The Indian Himalayan Region (IHR) has four major divisions from west to east i.e. north-west Himalaya comprising Jammu & Kashmir, Himachal Pradesh and Uttarakhand while eastern and north-eastern include Sikkim, Arunachal Pradesh and Darjeeling extension of the eastern flank encompassing states of Meghalaya, Assam, Tripura, Manipur, Nagaland and Mizoram. The Himalayan agro-ecosystem is the planet's highest and home to the world's unique crop biodiversity. India's recognition as a 'mega-biodiversity' country derives partly from the Himalaya distinguished as a global biodiversity 'hotspot' wherein out of 6,000 endemic plant species, 2,532 species occur [1]. The plant biodiversity of this land are composed of European temperate plants, Chinese, Burmese (Myanmar), Saharan, African elements of plant vegetation [2-4]. The total endemic genera of India constituted 6.5% of the total 2,252 genera found in this country. Out of 21 agro-ecosystems identified, five agro-ecosystems fall in the Himalaya [5]. This illustrates the diversity in agro-ecological zones or agro-ecosystems that occurs in the length and breadth of the Himalaya. Rainfed production system, which is predominant in the mountains, is characterized by more numbers of crops and associated biodiversity as compared to the irrigated (6). IHR house diversity of traditional agro-ecosystems, human ethnic races and other wild forms of flora represented by about 273 cultivated crops species, 898 wild relatives and related types of cultivated plant, 744 wild edible plants and 591 plants having industrial potential [7]. Farmers here maintain high levels of crops diversity by rotation of crops in time and space together with adoption of both mono and mixed cropping practices [8-10]. This is something we need to recognize and promote as they contain genes, which are adapted to extreme environments. Thus, provide stability to the food production systems by minimizing crop losses due to diseases, insect-pests and weather odds, conserves soil fertility, protects soil from erosion and increases productivity per unit area due to maximum utilisation of production resources [11]. Implicit in this, the proper choice of crop species to develop suitable cropping

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patterns and provides scope for on-farm conservation of traditional crops and landraces [12]. PGR management, therefore, in the context of food security vis-à-vis environment security is a worldwide concern and needs to be looked holistically and sustainably to appropriately address the emerging challenges. Here, we have given an overview of the PGR and their role in food security and also as gene sources for breeding crops to new environments, genetic erosion, conservation and potential they possess to address today's most pertinent issue, the climate change.

PGR status and utilization patterns

In the IHR 80% of people depends on agriculture for their food and daily livelihoods, therefore known for diversity of genetic resources of crop plants, their wild relatives and has a rich repository of wild plants of food values (Table 1) [7, 13]. The rich inter-specific diversity exists for genera like *Oryza, Avena, Amaranthus, Chenopodium, Fagopyrum, Allium, Hordeum, Linum, Saccarum, Citrus, Musa, Pyrus, Prunus, Rubus, Fragaria, Sorbus, Rosa,Lilium, Vicia,Vigna, Lepidium, Lathyrus, Dioscorea, Orchids, Colocasia, Cucumis, Solanum, Trichosanthes, Bamboos* and *Canes* contributing significantly in the sustenance of the traditional Himalayan agro-ecosystems [14, 15]. The genetic diversity at varietal level is distinctly high in crops like rice, maize, barley, amaranth, buckwheat, small millets, beans, vegetable, fruit crops, ornamental and Medicinal & Aromatic Plants (M&AP) crops.This has been due to ecological differentiation and intensive natural and human selection exercised by various ethnic communities over centuries with time to time introduction of exotics. The crops group wise status of PGR and their role in the food security and farm prosperity is discussed below.

Cereals

Himalayan agro-ecosystem is one of the few agro-ecosystems where traditional varieties of rice, wheat, maize and barley are cultivated and hold wide range of genetic diversity. The diversity at species level is although low for these crops but very high at varietal level (Table 2) especially in rice and maize. It is however, attributed to the occurrence of large number agriculturally marginal environments in the hills and modern varieties have not been sufficiently attractive option for farmers to replace landraces in such environments (16).In rice, out of 22 species, 5wild species *Oryza granulala, O. officinalis, O. rufipogan, O. meyeriana* and *O. nivara* along with different forms occur in the eastern and north-eastern Himalaya [17-19]. The north-eastern region is considered to be one of the hot pockets of rice genetic resources in the world and a potential rice-growing region with extremely diverse rice growing conditions as compared to other parts of the country. Being the secondary centre of origin of rice, the NE region is rich in diverse germplasm that shows the distinctness amongst the germplasm [20]. The germplasm diversity that has been collected varies from 6000 to 8000 in the eastern and north eastern region [21] and from 1000-1500 in Western Himalayan region [19]. Genetic variability recorded for large number of traits such as plant height, no. of tillers, no. 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) andtolerance to shattering (highly susceptible to tolerant).Large numbers of rice landraces such as *Jattoo, Begumi, Ramjwain, Kalijhini, Chuhartu Qudirbeigh, Mushkbudji, Mehwan, Thapachini, Tilkakchandan, Bakulia, Mirikrak, Gnoba, Batlong, Ryllobed, Tongla,Maiku Tsuk Buidhan, Lama, Krishma Bhog, Phulpattas, Allang amo,Pyapi, Aino ari,*

Table 1. Species of cultivated crops in the IHR in comparison to the country status

Crop group	Western	Central	North-Eastern	Total India
Cereals, Millets & Pseudocereals	19	16	19	51
Legumes	20	17	10	31
Vegetables	30	28	65	103
Oilseeds	11	9	11	12
Fibre plants	5	7	6	24
Spices & condiments	16	15	11	27
Fruits	34	27	45	109
Total species	135 (38%)	119 (33%)	167 (47%)	357

Table 2. Important landraces and varieties of cereals especially rice in the IHR

State	Crop	Landraces
Himachal Pradesh	Rice	Madholu, Roda, Phulpatash, Cheenu, Ramjawain, Kaladhan, Kali jhini, Bohana, Katheri, Tapta, Sukura, Rangri, Jaldhara, Jattoo, Sukhdwas, Jhinjhini, Jaulia, Chuaratu, Peelu, Debal, Matali, Jiri, Begumi, Nakanda, Achhain, Hansraj
	Wheat	Dharmori, Kankoo, Shruin, Misri, Gazariya, Ralienu, Trimundi, Brad Kanak, Kathi, Rigaliya.
	Maize	Chitknoo, Salhu, Bhogad, Temta, Gadda, Rohdu
Jammu & Kahsmir	Rice (Kashmir)	Aziz beoul, Baber, Balaanzul, Begum, Gul zag, Kalabrear, Kalaphool, Larbeoul, Mahwam , Meer Zag, Mehvan, Mushkandi, Mushkbudgi , Muspeeri, Niver zag, Nonbeoul, Qadir beigh, Qadir ganaie, Rehman batti, Safed brez, Shahie, Siga, Tilla zag, Zagad, Zagibaber
	Rice (Jammu)	Kala Dhan, Sugdass, Varderur, Shahi, Kalini, Bansaal, Banji, Bhutini, Munji
	Wheat	Ghoon, Kankoo.
	Maize	Chiti Makka, Lal Makka, Sathi.
Uttarakhand	Rice	Anandi, Anchan, Bakua, Barpasso, Bunpasa, Chamaraya, Chamyad, Ghesu, Indrasan, Jangai, Jawari, Jumaria, Kalthuni, Katyoor, Kauhati, Madguri, Patari, Razuli, Rwathati, Safed khoyla, Sawa, Sela, Semolal, Suknandi, Taknoi, Thapacheeni, Uskar, Tilakchandan,
	Wheat	Syat gyun/ Safed gehun, Mundiya/Mundri/Munar, Dudhi, Jhusia / Jhuswal Dawat dakhnai, Chanausi, Naphal
	Maize	Pilli makki, Murali makka,Timasia, Gorakha makka, Anguli ghogha, Safed makka
Sikkim and North Bengal Hills	Rice	Sannodhan, Lambadhan, Sunidhan, Sunodhan, Motodhan, Jharodhan, Sundari, Galodhan, Paukhidhan, Laxmidhan, Koetodhan, Palidhan, Dosaradhan, Setino, Khanato, Putodhan, Manglidhan, Nampokdhan, Mehadhan, Galaidhan, Mangthan, Sundoriodhan, Pakidhan, Latodhan, Bhayodhan, Bihundhan, Didhan, Dukadhan,Ahodhan, Parodhan, Rajodhan, Batodhan, Samidhan, Pedhonilo, Pithodhan, Sikkadhan, Sunntadhan, Sekiteli, Lahudhan, Addy, Thapachini, Nardikalma, Chirakey, Kalakalas, Ramlakni, Dutkalani, Laskansal, Bhasamanik, Jhapaka
	Maize	Kukkuri, Sweti, Sweti-Chapti.
Arunachal Pradesh	Rice	Ashy, Panola, Choking, Susannah, Pangram, Bade, Jaiyango, Latung, Oiti, Deko, Keieng, Lhamang, Mipun, Ahusdhan, Satya, Channadhan, Mahen, Charimpok,Tagin, Katimahiya, Lahi, homang, Lengman, Halodhor, Akhodimio, Ningmaibasa, Nunmum, Phomgman, Khodmio, Lambadhan, Mamkinkeng, Kharangchang, Chhalayaang, Khopsang, Chihachock, Biharichameli, Samkungchameli, Lamachameli, Chameli, Chamtong, Khichang, Kudumoni, Chakechungcham, Chakhicham, Sasaing, Chamtongli Betkhuit, Parong, Sakhi, Taisa, Simoi, Chaliin, Sanyak, Chadown- Betguti, Yaling, Deku, Pankajichha, Chha, Chhai, Simoichha, Tinmahinadhan, Joyadhan, Chachan, Basmotoi, Koduchechamali, Kodomungchameli. Chakhichameli, Khutarachameli, Betguti, Chameli, Boradhan, Kanchalmang, Emo Empo, Khawji, Payo, Namyi, Sangkhaw, Chamic, Frow, Manpa. Amdang, Ahu, Kerpu, Punghng, Chuksingpa, Amiong, Maidang-ahu, Champhal, Arnte-boro, Oiky, Keling, Chanka, Dajum, Bang-napdai, Nemo, Nipun, Pangra-balongba, Pyat pyani, Miyo, Yayo, Khawnowjoma, Amo, Khaw-makhew, Seti, Impo-Elang, Ke-boro, Maibung, Johala, Khownamtoek, Jingmik, Chomju, Bali, Yabor, Pyapon, Kamplungmang, Moping, Mahjang, Penin, K, Khopsan, Amyong, Gyapung, Dazum, Kyummang, Immo-Eukhe, Pyare, Poppy, Anker, Asiamkel, Daro, Impare,Ningkriahu, Khatu, Khamang, Kerpu, Jarti, Impohath, Immo Elang, PyatKogya, Ji Pyat, Pyping, Pyakhe, Pyping, Tababum, Pyping, Pyaphu, Daro, Tulu Amte Kimin, Khaw, Makhew, Soiki, Moping, Palman, Neuly, Tyng, Makhomali, Pungngahu.

	Maize	Oghum, Oyusum, Fengtang, Ashum, Top puli, Tapio, Tami, Puiritchi, Topp.
Meghalaya	Rice	Kbalum, Manipur, Bhoiwag, Manisang, Longsong, Laispah, Shroi, Frow, Ryllowhite, Abor red Ryllo Red, Meghalaya, Batlong, Mawkher, Leihkhyriemkho, Laispahaba, Leihkhyriem, Sohem, Tharoh, Leiukho, Lespahnoh, Leihpasyi, Sohemiao, Kpapnah, Kpalum, Nangjugu Lyngsi, Tongla, Maikutsuk, Abor A, Tura, Darjeeling, Umsning, Assam, Malaria, Sohkurleh, Dullo, Thernru, Lyngsi, Kab asawrit, Rachhangtu, Hillock, Mirikrak, Nonglwai, Ryllo white, Khonorullo, Kba Thugmaw, Kuki, Mynri
	Maize	Poorvi Botapa, Khasi Riewhadem, Tsungrhu.
Assam	Rice	Rongali, Bondhubora, Gumini borodhan, Amrujoha, Kolajoha, Dhaliboro, Boro 1, Seetabhog, Tulsibhog, Begonbishi, Hatibandha, Ikaraguti, Pokikola, Balam, Gomiri, Kolabora, Panimuri Tarabali, Hatidatia, Suagmoni, Rangadoria, Kalajoha, Pokhanibora, Dumai, Koi Muruli, alem, Nilagi, Bardhan, Badal Sali, Betguti Sali, Kola Sali, Halodhar, Lawdubi Sali, Ekhara Sali, Bogi Sali, Kula Sali, Ronga Sali, Jiton Sali, Bomi Sali, Badshabhog, Solpona, Kalomdani, Muga Sali, Madari Sali, Japok Sali, Dholamuta, Monohar Sali, Bonjoha, Chakoa, Bangal Sali, Kansi Sali,Kolijoha, Saheb Sali, Konjoha, Keteki joha, Moina Sali, Ampakhi, Manikimadhuri, Gandhi Bora, Ghew Bora, Chakoa Bora, Nol Bora, KolongiBao, Basikolom, Maimansingiabao, Kakoa Bao, Negheri Bao, Bira bhonga, Kati Boro,Ketura, Komoldhan, Moinagiri, Horusali, hamtisali, Silsali, Toraboli, Hatimulsali, Bonjoha
Manipur	Rice	Keisangba, Tondonba, Chingmorangphou, Tompuing, Bhousak, Khangola, Charongphou, Hemant, Desa, Khongjaiphou, Morangphou, Koraiphou, Makhomubi, Jouchou, Changman, Sulamphou, Taothalbi, Chakhao (black), Chakhao (white), Manipuri, Langmabi, Maophou, Manipuri (small), Makhemeil, Manipuri yellow, Lethati, Chakou, Miakrilha, Changkohpal, Mazha, Changhosam, Napdai, Changat, Phaichang, Eyroya, Hate, Nhpgai, Kohheng, Bang-Napdai Changpalman, Charhor, Changngatpal, Langmanbi, Chana, Chao' Djiikero, Buh Bam Kohn, Changhasan, Kolchang, Langmei, Assam Tan, Bangmai, Khhangman, Taingod, Napdai Hangme, Makhom, Meill Changman, Maonap, Magulong, Kahinghih, Farmba, Hnapdai,Saitralbu, Tangna, Nahpgei, Longhha.
Mizoram	Rice	Tangate, Zichum, Batetype, Ugemap,Taisanghar, Thlanchhuab, Matani, Kangpui, Idaw, America, Mizo, Buhtial, Taiklawngh, Farate, Mizo (big), Maibasa, Maibring, Rungteinn, Buhtui, Bahbite, Releng, Buhskhi, Ringteii, Bangbow, Taikouwn, Nagatai, Taikawnpui, Veipheitai Taifarete, Lengpui, Kawinglawntawi, Thawkmawh, Relengwi, Rungfei, Maibasapui, Mawbuh, Farel, Maotai, Tai, Rungtai, Birichuk, Kawnlong Taikarlang, Lawngtlai, Lawngtalawai, Chinairi, Horipui, Baitarisno, Pawnbuh, Sihletma, Ngarempaoo, Mang, Champhai, Tui, Rangoon, Manbuh, Bu, Fazaitai, Trai, Traivuban,Buhchi, Idaw, Boban, Buhbantharam, Buhpui, Puthalama, Mangbuh, Zorambuh, Fangsang, Fangsin, Zotawuh, Buhbawn, Tialte, Zerusalem, Ngokawi, Rengkoi, Americabuh, Nonglwai, Majhera, Bapnah, Lakang, Lumum, Heijong, Midokru, Mantai, Chinairi, Manusal, Leiletbuh, Maibiring, Thalnchhuah, Buhte, Kangpui, Taisanghar, Farete, Pumphir, Phulbuh, Taibialbuh, Maibiring
Nagaland	Rice	Nagaland Sinsatsu, Henigido, Akatan, Kemehyasopa, Kemenhya, Ngoba, Mikotchuwakelu,Mikudep, Sarang, Sarengma, Misarengma, Khulong, Misokmil, Mitonging, Yaribatsuk, Moyatsuk, Maikutsuk, Pangnakla, Geartsuk, Mamen, Yirnontsuk, Makuktanakla, Meserong, Kiyirtsuk, Maikumapuk, Nagaland special
Tripura	Rice	Mepbaw, Bungpet, Rangagellong, Chunglei, Nobdumli, Leitan, Sahoksan, Noining, Changman, Dulakmorong, Anning, Billrong, Ningsi, Maicassak, Biralbinni, Khawai, Bagonbejon, Bamkoilua, Paijong, Kalisatiya, Chanmouri, Rangoonbuh, Binni, Sonamukhi, Meli, Jhummalati, Bethi, Sarendyama, Maidani, Charui, Karnram, Billrong, Dulakanrong, Garomaloti

GovindBhog, Kolakhara, Sadakhara, Koliajiri, malbhong, Chakoa, bora, Amo hasso and Rarre amo, Phorel are still occupying sizable acreage because of their special attributes like aroma, fine grains and medicinal properties [6, 18, 19]. Nowadays, high in demand and shot in supply many of these landraces are sold at premium price as compared to common (*parmal*) varieties.

Maize in the region has equally rich genetic diversity including the occurrence of Sikkim primitives, which are known for their prolificacy and primitiveness. There are 18 distinct races and three sub races and majority of these are occurring in north-eastern [22]. Some named landraces like *Bhambla, Chitkanoo, Gadda, Sathoo, Rohdu, Temta,Bhakadu, Misiri makai*, *Bhogad challi, Sweti, Poorvi Botapa, Khasi Riewhadem*are known for their quality attributes, for example *chitkanoo* isgrown in Chamba for its excellent popping quality; Murli maize in Ramaganga valley is prolific bearer and has excellent taste. In wheat, the genetic diversity is not much exciting as many landraces and old varieties have eroded after the onslaught of dwarfing wheat. Nevertheless, few landraces still find place in cultivation are: *Kankoo* - good plant vigour, 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 tasty; *Mundalmisri* - cold tolerant, *Rigaliya* (tall, thrives best in weeds), *Kathi* (shattering resistant) and *Gazariya* (lodging resistant). Barley exhibit 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 altitude (above 3300 m) in Lahaul & Spiti, Kinnaur (Nako), Pangi, Ladakh, Munsiari and Badrinath areas [23]. Both two and six rowed types are preponderant in *H. vulgare* and occasional occurrence of wild *H. spontaneum* types (with black brittle own types) and *H. bulbocastanum* can be encountered in the natural populations.

Small millets and pseudocereals

The important crops comprise this group are finger millet, proso-millet, fox-tail millet and barnyard millet among small millets and amaranth, buckwheat, and chenopod among pseudocereals. It also exhibits diversity in specific minor millet species like *Coix-lacryna jobi* (soft shelled forms), *Digitaria cruciata* var. *esculenta*, *D. sanguinalis*, *Echinochloa colonum*, *Eleusine coracana*, *Panicum sumatrense* and *Paspalum scrobiculatum.* The genus *Amaranthus* has three cultivated species for grain purpose viz. *A. hyphochondriacus, A. caudatus*, and *A. cruentus* while of *A. dubius, A. blitoides, A. hybridus, A. lividus, A. retroflexus*, *A. spinosus, A. tricolor,* and *A. v*iridisoccur wild and also used as leafy vegetable [24]. The genus *Fagopyrum* has 15 known speciesof which two *F. esculentum*, and *F. tataricum*are cultivated types. Others like *F. tataricum*ssp. *annum*occurs in the Eastern Himalayas, *F. tataricum*ssp. *potanini*in Tibet, Kashmir Himalayas and northern Pakistan [25], while *F. tataricum* ssp. *himalianum*, and *F. esculentum* ssp. *emerginatum* are occurring in the cold arid region of Western Himalaya [26]. Among chenopods, *Chenopodium album* is the cultivated species while *C. amranticolor, C. ambrosioides, C. botrys, C. foliosum, C.glaucum, C. hybridum, C. murale* and *C. opulifolium* are occurring wild [27]. The cultivation of small millets and pseudocereals is restricted to specialised geographical pockets and has high degree of acceptability in the traditional Himalayan agro-ecosystems particularly due to their ability to perform in poorly fertile mountain agro-ecosystems coupled with very high nutritional and industrial importance and longer storability without any pests attack and deterioration in grain quality. Landraces like Nangchuni, Chhapariya, Timasia, Lal/Rata madua, Putkiya/Mutkiya of finger millet are very popular among farmers of Uttarakhand, and HP. Additionally these crop species are considered to be most resilient to climate change.

Grain legumes and oil seeds

The IHR holds rich genetic diversity in genus like *Phaseolus*, *Pisum, Lens, Vicia*, and *Vigna* species. Kidney bean (*Phasoleus vulgaris*) cultivated at higher elevations have distinctly high genetic diversity for seed colour, seed size and taste. Its red colored small seeded and long capsule shaped ecotypes grown in Chamba, Kinnaur, Rajouri, Bhaderwah, areas are popular for their taste and cooking quality. Black gram (mah) grown in these areas is slightly greenish in colour and has good quality i.e. taste and cooked without using pressure cooker. Horse gram is adapted to rainfed poorly fertile lands in the mountains. It is also used as medicine to treat calculus afflictions, corpulence, hiccups, and worms [28]. Traditional varieties of these legumes fetch

premium price in the market and it is almost twice than the released one comes from plains. Thus, these genetic resources are needed to be exploited to harness the benefits of climate specificity and increasing farm incomes. Adzuki bean (*Vigna angularis*) an introduced pulse has performed very well and proving a good substitute for *V. mungo* particularly in the sub-Himalayan areas where incidences of leaf spot are very high. Rice bean (*V. umbellata*) is extensively grown in north-eastern region while sporadically in western region. It is very high yielding, almost disease free and tolerant to high rainfall and posses variability for various seed colours and size. *Cicer microphyllum*, *Lathyrus aphaca*, *Moghania vestita*, *M. bracteata, Mucuna capitata*, *Trigonella emodi*, *Vigna capensis*, *V. radiata* var. *sublobata*, *V. pilosa,* and *V. vexillata* are important wild relatives [7, 29].

In oilseed, *Brassica s*pecies namely *Brassica campestris* var. brown sarson, *B. campestris* var. toria, *B. nigra,* and *B. juncea* occupy large areas. Besides, cultivated crops there are some tree oils which are extensively used by hill people. The wild apricot (*Prunus armeniaca)* or '*chuli'* growing abundantly in trans-Himalayan region has bitter kernels and used for the extraction of oil, yellow in colour and with a typical apricot odour. It is used for cooking, religious, cosmetic and medicinal purposes (body massage of the people suffering from and arthritis) and sold at premium price [30]. Similarly, walnut is another important crop of the region which is used both for edible purposes (medium to thin shell) and for oil extraction (hard shelled). Its oil is not used as extensively as other oils in food preparation due to its high cost. It is rich in omega-3 essential fatty acids, light-coloured and delicate in flavour and scent, with a nutty quality. The seeds of *Aesandra butyracea* (*Chiuri, Chevera*) produce fatty acid oil that is mainly used as vegetable butter in Pithoragarh region of UK [31]. Wild relatives such as *Linum perenne* in the cold arid region and *Carthamus lanatus, Lepidium capitatum*, *L. draba*, *L. latifolium*, *L. ruderale* in WH and *Brassica tilocularis* in eastern Himalaya are common.

Fruits and vegetables

Temperate fruit cultivation in India extends from North (J&K) to subtropical plains in the North, and also to Arunachal Pradesh in the East [32]. The main region is, however, falls in the north-western region where apple, pear, peach, plum, apricot, cherry, almond and walnut are commercially grown, while north eastern region is rich in genetic diversity for mango, banana and Citrus [33]. The north eastern region has rich genetic diversity of *Citrus* species where 17 species, 52 cultivars and a few natural hybrids have been described [34]. In lemon alone, as many as 32 strains are available. The species *Citrus limon, C. medica, C. jambhiri, C. ichangensis, C. latipes, C. macroptera, C. assamensis, C. indica, C. macroptera* and *C. aurantium* are considered indigenous to this region [35]. This region is also has large diversity of wild *Musa* species and out of the 42 species, 14 species especially *Musa velutina, M. balbisiana, M. velutina, M. manni*i occur here [36]. Maximum genetic variability of *Musa acuminata* and *M. balbisiana* occurs in NE India. *M. flaviflora* is localized to Manipur and Meghalaya. There are other species found in Sikkim and Khasi Hills, which need systematic collection and conservation. Some native *Mangifera spp*. are found in Tripura, Manipur, Mizoram and South Assam. Wild form of *M. indica* and its allied species *M. sylvetica* occur in Arunachal Pradesh, *M. khasiana* and *M. pentandra* in Meghalaya and Assam. The genus *Malus* has 30 species world-wide and only two *Malus baccata* (popularly known as crab apple) and *M. sikkimensis* occur wild in India. Two varieties of *Malus baccata* has also been identified as *M. baccata* var. *himalaica* in north western region and Meghalaya and *M. baccata* var. *dirangensis* in Arunachal Pradesh. *Pyrus* and *Prunus* have 14 and 22 species, respectively, also constitute an important component of the temperate fruit diversity.

Apart from cultivated fruit, there large number of minor fruit occurring naturally and contributing greatly to hill economy [37-39]. They are highly adapted to specific microclimatic niches thus narrowly distributed. Few examples are - *Prunus mira* grows in extremely cold areas and used extensively for making brew and as rootstock for different stone fruits. Farmers collect fruits which are edible, and also used for making brew and stones are sown for raising rootstocks for peach and almond. The preponderance particularly of the drier types of apricot (*Prunus armeniaca*) is also high in the arid region. Two of its variants viz. red-fruited and white-fruited are widely grown in Kinnaur and Leh [40]. Its kernel is sweet in taste hence used as adulterant in almond kernels. Walnut (*Juglans regia*), almond (*Prunus dulcis*) and hazel nut (*Corylus colurna*) are important nuts for which varietal diversity is occurring in the region. Genetic variability in walnut is considerable for shell

thickness, nut size, nut-kernel ratio and almost all the trees growing here with more preponderance in Chamba, Kullu, Kinnaur, Kashmir, Uttrakashi, Arunachal and Sikkim are chance seedlings [39]. Hazelnut, popularly known as *bhotia badam* or *thangee* produce good quality nuts and endemic to Pangi, upper Shimla, Kinnaur, Kargil, Drass, Munshari.

Wild pomegranate locally called 'daru' is famous for *anardana* and grows wild in entire mid Western Himalayan ranges and had wide range of variability for fruit and other traits including biotic and abiotic stresses. Sea buckthorn (*Hippophae rhamnoides*) grows in cold dry regions, has high economic potential due to its nutritional value and other multifarious uses and being exploited greatly for making juice and cosmetics by the companies. We have collected more than 10 morphotypes from Ladkah and Spiti region. *Myrica nagi* (kaphal) grows wild throughout the sub Himalayan tract and has variability for fruit colour, sweetness, fruit and stone size. Some large fruited types are occurring in north-eastern region have domestication potential. Pine nut or Chilgoja (*Pinus gerardiana*) found growing in between Gilgit and Garhwal region including Pangi and Kinnaur, however, facing regeneration problems due to over harvesting of nuts which have high market value.

In soft fruits *Rubus* is the most variable genus widely distributed and out of 57 species of *Rubus* that are occurring in India; 33 species and four taxonomic varieties are found in IHR[41]. The two species *R. ellipticus* and *R. niveus* have wide range of variability for foliar and fruit characters and great industrial potential. Plantation crops like tea (*Camellia sinensis*) grown in the Kangra valley is famous for aroma and being exported from the valley. Introduced fruit like kiwi fruit, Japanese persimmon and pecan nut have adapted very well in the region and contributing largely in the farm economies. The Shillong plateau of Khasi hills in Meghalaya has many Prunus species such as *P. napalensis*, *P. undulata* and *P. cerasoides*. Wild kiwi (*Actinidia callosa*) is found growing in the natural forests of Arunachal Pradesh and Sikkim. Two species of *Elaegnus*, *viz*., *E. latifolia* and *E. pyriformis* have large fruits are grown in north-east region [42]. It is quite common in Sibsagar (Dikho valley), Naga hills, Khasi and Jaintia hills. The fruits of *Docynia indica* and *D. hookeriana* acidic, greenish with red tinged are eaten fresh and in pickles as well as in jelly preparation.

Vegetable crops have rich genetic diversity in the Himalaya and grown both as normal season and also as 'offseason', contributing significantly for increasing farm incomes. The important vegetable crops growing as offseason are garden pea, cabbage, cauliflower, broccoli, green capsicum, tomato and cucumber. There is wide range of *Solanum* species such as *Solanum macrocarpon, S. xanthcarpum, S. indicum, S. mammosum, S. khasianum, S. torvum, S. berbisetum, S. ferox, S. spirale, S. sisymbrifolium, S. kurzii, S. gilo* are found in the various parts of IHR and used for edible and medicinal purposes. Chillies of the IHR are world-wide famous for its high capsaicin content. *Capsicum annum* var. *avicular* (bird pepper Wild type, said to be progenitor of bell pepper), *C. annum* var. *grossum, C. annum* var. *longum, C. chinense, C. frutescens*, *C. eximium, C. minimum* (bird-eye-chili) are cultivated all across IHR especially the NE region. Among cucurbitaceous vegetables Cucurbita, *Momordica*, *Luffa* and *Trichosanthes* are of common occurrence. It includes *Cucurbita maxima, C. moschata, C. ficifolia*, *C. pepo, Coccinia grandis, Cucumis sativus. Cucumis callosus, Luffa acutangula, L. cylindrica Momordica charantia, Trichosanthus anguina, Benincasa hispida, Lagenaria siceraria.* Genus *Allium* represents a major group and about 30 species are found in Indian region [43], of which all wild species are occurring in the Himalayan region. Allium species such as *Allium cepa* var. *cepa*, *A. cepa* var. *aggregatum*, *A. cepa* var. *viviparum, A. sativum, A. ampeloprasum* var. *Porrum* are cultivated both at large scale and in the kitchen gardens. Genetic diversity also exists in root and tuber crops, namely, *Amorphophallus, Dioscorea,* and *Colocasia*. Besides, there are about 367 edible plant species occurring in the region, of which 65 plant species such as *Amarnathus dubius* (chaulai), *Chenopodium album* (bathua), *Fagopyrum esculentum* (breahsa), *Malva verticillata* (sonchal), *Portulaca oleracea* (kulfa), *Bauhinia verigata* (kachnar), *Ficus palmate* (bahrunee), *Cordia dichotoma* (lasora), *Phytolaca acinosa* (jalga) and *Diplazium esculentum* (ligroo), etc. are widely used edible vegetables and also find place in the local and city markets at reasonably better prices. Kasmiri hawks and lotus stems (kamal kakdi) have great market in Kashmir valley. The coloured varieties (yellow and red) of capsicum and cherry tomato are being grown under protected cultivation in the shivalik region. *Morchella esculenta* (guchi) a naturally occurring mushroom is a highly speciality genetic resources and has very high market value.

An impressive diversity of 23 *Dioscorea* species and many cultivated types occur in the region. A number of *Dioscorea* species *alata, bulbifera, brevipetiolata, esculenta, hamiltonii, hispida, kamaonensis,*

nummularia, pentaphylla, puber and *quinata* were recorded in the NE Region and have white skinned and the red skinned variety. One of the interesting species of *Vigna* namely *V. vexillata* is grown by the tribal people of Tripura has variation both for tubers and pods [44]. Sword bean (*Canavalia ensiformis*) is also cultivated on limited scale while winged bean is confined to humid sub tropical parts of north-eastern region [45]. Tree bean (*Parkia roxburghii*)and sajina (*Moringa oleifera*) are some of the multipurpose tree species in different parts of IHR [46]. Tree tomato (*Cyphomandra betacca*) is grown as backyard venture crop in Meghalaya and other parts of IHR as a perennial shrub produce red tomato like fruits and used as such [47]. Cho-Cho (*Sechium edule*), a native of tropical America, is a very popular vegetable in the region commonly called squash and grows abundantly without much care and attention. *Flemingia vestita* known as Sohphlong, is consumed raw. It is a weak climbing/trailing type, underground tubers, distributed the humid to sub tropical regions up to 1500m [45]. Kakrol (*Momordica cochinchinesis*) and kartoli (*M. dioica*) are widely spread in Assam, the Garo hills of Meghalaya and Shivalik hills [48]. A wide range of variability has been found in *Gingiber*, *Curcuma*, *Colocasia* and *Alocasia*. Lakadong - a local variety of turmeric is grown in Jowai area of Meghalaya. Landraces of *Colocasia* such as Garokatch, Tha'h have high yield, early maturity, good cooking, low acridity) and Wangpanaii is non acrid and eaten like salad. Poona and Thinglaidon and Nadiavarieties of green ginger have performed better in most of the NE region indicating suitability for large scale cultivation. Another type of ginger having rhizomes with bluish black tinge inside called black ginger is grown in Mizoram. Wild relatives of large cardamom (*Amomum subulatum*) and cinnamon are available in the forests of this region. Among wild relatives *Abelmoschus manihot* (*tetraphyllus* forms), *Cucumis hardwickii*, *C. trigonus*, *Luffa echinata*, *L. graveolens*, *Solanum incanum*, *S. indicum*, *Trichosanthes multiloba*, *T. himalensis, T. lobata, T. bracteata, Neoluffa sikkimensis* are common.

Medicinal, aromatic and spices

The IHR support a rich trove of genetic wealth of many high valued medicinal plants. These include*Aconitum* species*, Nardostachys grandiflora, Dactylorhiza hatagirea*, *Picrorhiza kurrooa*, *Rheum australe*, *Swertia chirayita*, *Ephedra gerardiana*, *Hyoscyamus niger*, *Atropa acuminata*, *Podophyllum hexandrum*, *Saussurea costus*, *Gentiana kurroo, Rhododendron arboreum*, *Swertia chirayita, Taxus baccata, Viola biflora, Rauvolfia serpentina*, *Solanum khasianum*, *Dioscorea proceri*, *Coptis teeta, Valeriana wallichii*etc.Also,the cultivation of few species like *Aconitum heterophyllum* (atees), *Picrorhiza kurrooa* (kadu), *Dactylorhiza hatagirea* (salam panja), *Swertia chirayita* (chiryta), *Saussurea costus* (kuth) and *Valeriana wallichii* (musakbala) have brought under cultivation in the high hill region and *Asparagus racemosus* (satvar), C*hlorophytum borivilianum* (safed musli), *Withania somnifera* (asvagandha), and *Setevia rubidiana*in the Shivalik region, have been taken up recently.

Aromatic plants like *Pelargonium graveolense* (geranium), *Lavendula angustifolia* (lavender) and *Rosmarinus officinalis* (rosemary) are also cultivated at large scale. This region has the credit for having all the important eight constituent plants of *Chyvanprash* viz. *Lilium polyphyllum* (Ksheera-kakoli), *Roscea purpurea* (kakoli) *Malaxis acuminata* (Jeevak), *M. muscifera* (Rishbhak), *Polygonatum cirrhifolium* (Meda), *P. verticillatum* (Maha-meda), *Habenaria intermedia* (Viridhi), *H. edgeworthii* (Ridhi). The genetic resources of spices and condiments include *Alpinia speciosa, Angelica glauca, Amomum aromaticum, Curcuma* spp., *Zingiber officinale, Piper longum, Carum carvi, Onosoma echioides,Bunium persicum, Carum roxburghianum, Murraya koenigii, Foeniculum vulgare, Cinnamonum tamla,Ocimum basilicum* etc. Among these *Bunium persicum* (kala zeera), *Onosoma echioides* (ratanjot), *Angelica glauca* (chaura), *Allium tuberosum* (zimu). *Crocus sativus* (saffron) are high valued crops contributing towards farm prosperity.

Ornamentals

This region has diversity of ornamental plants both under cultivation and occurring naturally. Major ornamental species include gladiolus, carnation, rose, chrysanthemum, anthurium, alstromeria, tulip, lilies are cultivated in the region particularly under protected cultivation. Besides, there are many naturally occurring potential ornamentals that are endemic to the region include *Rosa moschata*, *Lilium bulbiferum*, *L. longiflorum, Eremurus himalaicus*, *Primula denticulata, P. rosea, Nelumbo nucifera*, *Tulipa stellata* and *T. aitchisonii*. Some of the species of *Lilium viz*., *L. nepalense, L. polyphyllum,* and *L. wallichianum* have originated in Himalayas. About 134 naturally occurring

plants of ornamental value have been described from here [49]. Indian orchids also form a major group of ornamental crops and many with proven floricultural and/ or herbal traits such as *Arachnis, Ascocentrum, Calanthe, Cymbidium, Dendrobium, Habenaria, Paphiopedilum, Phalaenopsis, Phaius, Renanthera, Rhynchostylis, Spathoglottis, Vanilla,* and *Vanda* are occurring here. Among 1300 species of orchids that are found in India, the Himalayan region particularly the north-eastern India has about 700 species [36]. Of these, 545 species belonging to 122 genera are restricted to Arunachal Pradesh [50] and 12 species are endangered, 16 vulnerable, and 31 are nearly threatened [51].

Grasses

The major temperate grasses and legumes which offer significant diversity include *Agrostis, Agropyron, Dactylis, Elymus, Festuca, Lolium, Phalaris, Phleum* and *Stipa* among grasses while legumes are *Astragalus, Lespodeza, Lotus, Medicago, Melilotus* and *Trifolium* [52, 43, 53]. In case of forage legumes the diversity is extensive and the same is being expanded by natural hybridization. The extent of diversity found in natural populations of *Medicago sativa* and *M. falcata* in Ladakh is a classical example of natural variations. It is believed that the traders who used to traverse through Ladakh along the old Silk Route noticed better forage yield of *M. sativa* in Yarkand (Uzbekistan) and introduced this in Ladakh. Now both *M. falcata* and *M. sativa* have hybridized to such an extent that at least five undifferentiated forms are found [54, 55].

PGR as sources of genes

Plant genetic resources in general and crop wild relatives in particular, provide researchers with genes useful for developing biotic and abiotic resistance [56] and have contributed in crops such as rice, strawberry, cucumber, sugarcane, tomatoes, tobacco etc. [57]. Unlike their cultivated allies, wild species do not receive management interventions which help them adapt to changing conditions and, thus adaptation is limited to their biological capacity to deal with change. The crops wild relatives form a very valuable component of agro-biodiversity which is being targeted desperately by biotechnologists and organised business sectors because of the genes of resistance to diseases and pests and adaptation to stress environments [58].Therefore, PGR apart from ameliorating farm incomes, also play great role in the crop improvement. However, utilization of wild species for crop improvement has been enjoyed a great success only in few crops, while disappointing for numerous others. Some of the wild relatives of indigenous crops that have been successfully used for transferring genes are *Solanum incanum, S. viarum, S. melongena* var. *insanum* for *Fusarium* wilt, bacterial wilt resistance and frost tolerance; *S. torvum S. sisymbrifolium* for *Verticillium* wilt and *Meloidogyne incognita* nematode; *S. gilo, S. integrifolium* for *M. incognita* race 1 and 2and *S. khasianum* for shoot and fruit borer resistance in brinjal. Another species *S. torvum* is extensively used in Ayurvedic medicine system. *Solanum pimpinellifolium* is also good source of resistance to late blight and tomato leaf curl virus [59]. In chilli, a collections from Tezpur (Assam) has been found to have the highest capsaicin content recorded so far anywhere in the world. The wild species of okra *Abelmoschus crinitus* occurring in the Shivalik hills with a marked dry season, and *A. angulosus* grows at high altitudes, being cold tolerant and have shown complete resistance to Yellow Mosaic Virus. *Cucumis hardwickii* and *C. callosus* for downy mildew and fruit fly, *Cucumis melo* var. *chito* for *Fusarium* wilt resistance in cucumber; *Allium ampeloprasum* for downy mildew, *Allium roylei* and *A. fistulosum* to anthracnose, downy mildew, leaf blight in onion and *Momordica dioica* for drought tolerance in bitter gourd. *Vigna vexillata* has high protein and resistance to cowpea pod sucking bug and buchids and is crossable with *V. unguiculata* and *V. radaita*; *Cicer microphyllum* growing in harsh climate of Ladakh and Spiti have genes for cold and drought tolerance, longer pod length and large number of seeds/pod while *Pisumsativum* var. *arvense* and *Linum perenne* grown in the same region have useful variability for powdery mildew resistance for pea and cold and drought tolerance for both. *Cajanus platycarpa* occurring in Shivaik region is closely related to *C. cajan* and is photo-insensitive, highly resistant to *Phytophthora* bight and reniform nematode and pod borer. *Macrotyloma sar-garhwalensis* have crude protein of 38.0% which is about two times higher than the cultivated horse gram.

Malus baccata, *M. Sikkimensis* in apple; *Pyrus pashia* and *P. pyrifolia* in pear; *Prunus cerasoides, P. napalensis*, and *P. undulata* in cherry and *P. mira* in peach are used as rootstocks with multiple disease and insect resistance and drought tolerance. *Malus baccata* has shown resistance to collar rot, root rot and woolly aphis and tolerance to drought in apple while *Pyrus pyrifolia* and *P. pashia* showed resistance to powdery mildew and root rot in pear. In Citrus, *Citrus jambhiri, C. limonia* and *C. karna* are used as rootstocks for cultivated species and are tolerant to citrus tristeza virus

and most promising rootstocks for mandarin, orange and Kinnow in the lower hills. *Vitis parviflora* showed multiple disease resistance; *Vitis himalayana* is late ripener, hence escape fruit cracking in rainy season, also cold hardy and drought tolerant in grapes; Eleven species of rose found growing wild are *Rosa brunnoni, R. foetida, R. gigantea, R. Involucrate, R. longicuspis, R. macrophylla, R. moschata, R. rubiginosa, R. sericea*, *R. webbiana,* and *R. wichuriana* and four of the 11 have contributed to the development of modern garden roses.The *w*ild relatives of *Allium* such as *A. schoenoprasum*, *A. carolinianum, A. tuberosum, A. chinensis, A. consanguineum, A. humile, A. przewalskianum, A. stolczkii, A. stracheyi, A. victorialis* and A. *wallichii* have great breeding potential. Wild kiwi (*Actinidia callosa*) is found growing in the natural forests of Arunachal Pradesh and may be used in breeding non-hairy varieties.

Threats to PGR

The extremely dangerous human ego of winning over or improving nature, propelled most likely by stupendous scientific achievements during the last quarter of the century, which had admittedly been mind boggling, has caused us to commit mistakes, often in the grab of unfounded scientific reasoning and also in the false plea of guarding human interests for the so called "Development". Obviously in doing so the all important quality of life and the cobweb of lifeline on the earth has been simply overlooked and has resulted in living a poor quality of life, though we might have achieved the tantalizing and debatable easy life style in the name of "Development in civilization". However, due to the global natural resource crunch, it has become crystal clear that we have no option but to conserve whatever genetic resources are left with us. Traditionally hundreds of varieties of cereals, millets, pseudocereals, pulses, oil seeds, fruits, vegetables, tubers, bulbs, and spices had been cultivated in these hills have either vanished from farmer's fields or area under traditional diversity has declined substantially due to large number of factors including onslaught cash crops like hops, green pea, tomato, capsicum, cabbage, apple, kiwi, potato, rajmash, saffron etc and of course wide spread of modern varieties. Wild progenitor and other related species depict the same story. Massive developmental activities causing climate change havealtered the species composition. Many temperate species reported a century back as common are not traceable in their original habitats, rather found either in their upper limit or occur at higher elevation than the original and/or with shrunken distribution.

The crops species like fox tail millet, proso-millet, barnyard millet, buckwheat, chenopod, horse gram, sesame have disappeared from many areas particularly from the intensive agriculture areas[14 , 60] Cotton was once grown in Kashmir valley is now not even grown in kitchen gardens. Three varieties of rapeseed oil namely, *tilgoglu, taruz* or *sarshaf* and *sandiji* once very popular in Kashmir are extinct now.The case study conducted in Himachal showed that the number of landraces of rice have come down to 18 in 2000-2005 from 57 in 1970-1975 in and around Karsogarea[19]. The percent loss of landraces of rice and wheat varied from 30-80% in different parts of WH [7, 8, 61].A study conducted by Nautiyal et al[62]in UK showed that a prominent scented paddy landrace *Mukhmar* has become extinct from many areas.In the Himalayan Gazettes of 1882, Atkinson listed 48 varieties of rice and stated that there were thousands of other nondescript varieties[63]. Today, only seven or eight of these varieties are cultivated, with only *Ramjawan, Thapchini, Lamati* and *Rikhva* on irrigated land and *Chiyasu* in rainfed areas of UK [64, 65]. In Kashmir, many highly quality landraces of rice had been lost and one of the best landraces called *Mushqbudji* has become rare [19]. The north eastern region estimated to be growing more than 30,000 rice cultivars in the past but have lost major chunk by now e.g. in Tripura, landraces have reduced to 32 in 2004 from 105 in 1975 [18]. Other parts of the world depict same story e.g. in Pokhara valley of Nepal 43 landraces [66] and 140 in 9 districts of the Western Development Region of Nepal [67] has disappeared over the past 25 years. The area under landraces in Balochistan Province of Pakistan had reduced to 8% in 1996–1997 from 40% in 1972–1973 [68].In Down to Earth, May 2002, it has been reported that of the 7098 apple varieties documented as having been in use between 1804 and 1904 about 86% have been lost. Similarly 95% of cabbage, 91% of maize, 60% of wheat, 40% of rice, 94% of pea and 81% of tomato varieties no longer exist now. In Himachal Pradesh, English settlers way back in 1870 planted some 90 varieties of apple in Mashobra and further in 1920 Mr. SN Stokes introduced Starking delicious, Red delicious and Richard Delicious from the US in Kotgarh. The three varieties since then have occupied major acreage (>80%) under apple. Recently, out of 154 landraces that were recorded in N-W Himalyan region as many as 80-90 have reached at the verge of extinction and may disappear from farmer's field in the next 5-10 years and even faster, if the present trend continues[19].

Although, it is hard to say to what extent the genetic base has already been eroded, but the intensive agriculture or commercial agriculture certainly have encouraged replacement of traditional crops and varieties. It is estimated that 15-37% of wild species falls in the danger of extinction based on a cross section of about 1100 plant species [69], while 16-22% species of wild relatives with direct value to agriculture are in the danger of extinction and the process will go on, if no corrective measures are undertaken to minimize the adverse effect of climate change [70].

Invasion of alien weedy plant species has encroached not only the barren lands and community grasslands but cultivated fields also. In the past about 20 years, invasion through species like *Lantana camara, Ageratum conyzoides, Eupatorium adenophorum, Eupatorium odoratum, Bidense pilosa, Partheneum hysterophorus, Polygonum molli*, *Cystissus scipasrius*has caused enormous loss to biodiversity [24,71]. These species are so competitive that they have eliminated many poor competitor economic species, wild relatives, grasses, ornamental and herbs from their natural habitats.The rate of genetic erosion through various factors is so rapid and widespread that 25 years from now natural habitats may have little to offer to plant breeders searching for genetic variability. Breeders would rely on the world's gene banks with the hope that enough material was saved, and in a good condition to provide them the genes they need.

Conservation of PGR

Keeping in view the facts discussed above it is utmost important to conserve the genetic resources before they go extinct, both *in situ*and *ex situ*. [72, 73]. Fortunately, remote areas still cut off with the road communication, largely depend on the traditional varieties and crops albeit on a small scale. However, is it suffices to conserve them in the National Gene Bank? And forget! The reply of this cannot be affirmative since for the long term agricultural sustainability; these resources must be allowed to grow in the traditional agro-ecosystems [74]. The value and use of many resources are known to mankind but there are lot more exists for which we don't have much knowledge. Nevertheless, future research findings will bring forth new facts about them. The crop diversity in agro-ecosystems be it mountain or plains, is a basis to bring stability in the food production as it minimises crop losses and maximum utilisation of production resources. The well known traditional farming system which has been conserving the genetic diversity on-farm need to re-looked now. For instance, *Jhum* or shifting cultivation a way of life for the tribals of northeast India has been taking care all essential crops such as rice (*Oryza saliva*), maize (*Zea mays*), cassava (*Manihot esculenta*), aroids (*Colocasia* sps.) sweet potato (*Ipomea batatas*), ginger (*Zingiber officinale*), finger millet (*Eleusine coracana*), Cotton (*Gossypium* sps.), tobacco (*Nicotiana tabacum*), cucurbits etc. in the same field as mixed land use system resembling latest cafeteria system of cultivation. The large number of crop species (sometimes up to 40) over both space and time are effectively managed due to the sequential harvesting during the year. Similarly, other systems like *Apatanis* of Arunchal, *Zabo* of Nagalnad and *Baranaja* of Western Himalaya have played significant role in conservation of agro-biodiversity. The maintenance and conservation of traditional agro-ecosystems in their entirety is the only sensible way to preserve *in situ*on farm repositories of crop germplasm [74-77]. The issue of on-farm conservation has recently attracted the attention of many conservationists but the question –how to promote it, still remains obscure. The mechanisms of suitably compensating the traditional growers for losses accruing on not adoption of modern agricultural techniques are still a debatable issue. Presently, whatever crops and varieties are being conserved on-farm is only due to remoteness of the areas or due to high price value of some resources such as red grained rice landraces, pine nut, black cumin etc. Unlike *ex situ* conservation, a systematic approach and plan of action is lacking and thus need to be taken on priority.

Nonetheless, on the *ex situ* front, appreciable efforts have been made and large amount of genetic diversity has been collected and being conserved in the National Gene Bank at NBPGR and other crops based institutes designated as NAGS. Nearly 300 crop-specific and multi-crops exploration trips have been undertaken and more than 30,000 germplasm accessions of various agri-horticultural crops including about 500 wild relatives have been assembled by various institutes from IHR. Gaps in the indigenous genetic diversity have been filled by introducing more than 6000 germplasm accessions of various agri-horticultural crops including some new crops like *Actinidia deliciosa*, *Diospyros kaki,Carya illinoensis*, *Feijoa sellowiana*, *Ziziphus jujuba*, *Vigna angularis* and *Chenopodium quinoa*and large number of varieties and accessions of various crops grown in the region.

Scope and potential

Increasing or even maintaining food production to meet expected demand will require greater use of genetic resources. We need to incorporate a broader range of crops and exploitation of naturally occurring and/or under-utilized crop species and related wild taxa to make better use of marginal lands and changing environments for the self-reliance of agro-ecosystems. Unfortunately, the speciality high value crop plant species which is a monopoly of the Himalayan region have still not been exploited to their full potential. These include saffron, kala zeera, wild *Allium* species, chilgoza, sea buckthorn, walnuts, hazelnuts, dry apricots, local maize, naked barley, purple and green kernel rice, multi-spiklet rice, medicinal rice, high cucurmin turmeric, variety of chow-chow, non-acrid *Colocasia* are to name a few. These resources including many others occurring naturally need to be bio-prospect in order to make them an economic resource for earning livelihoods. To promote and utilize the concept of eco-tourism, the indigenous communities must exploit the local plant genetic resources for earning economic gains. This is possible by way of serving local food dishes with modern refinement, developing scented herbal cold and hot drinks, a score of handicrafts and using wild edibles. Unless these vast biodiversity resources are utilized more and more, they cannot be saved.

The use of off–season cultivation must involve an array of crops or varieties in order to keep intact the concept of sustainability through diversity. Thus, inclusion of local resources in the existing cropping patterns will be highly desirable. However, this requires a well established multi-disciplinary research backup. Enhanced competitiveness, documentation, information, public awareness, value added research, better policies and legislations, and farmers oriented marketing network are some of the areas that needs to be addressed to harness the full potential of locally available plant genetic resources for enhancing farm incomes of hill farmers. Further as climate change continues to change the geography of agriculture, we have to mimic natural systems ourselves and use a diversity of approaches to ensure that farmers and breeders have the ability to get hold of and make use of as much diversity as possible and in that way, we might stand a chance of creating secure food systems.

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