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Exploration and Collection of Plant Genetic Resources in India: Status and Priorities

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Plant exploration and germplasm collection is the foremost activity in PGR management system aimed at augmenting genetic resources for *ex-situ* conservation and utilization by end users. Organized PGR collecting was initiated in India way back in 1946, and so far, 2.82 lakhs accessions representative of nearly 1,695 crops/species have been collected through 2,838 explorations undertaken across the country mainly in collaboration with ICAR crop-based institutes and SAUs. Till two decades back, the focus has been shifted mainly on the collection of cultivated variability which has resulted in fair representative collections for important crops from across India. Now, increasing importance has been entrusted to crop wild relatives, minor fruits and wild edibles species, which has resulted in a phenomenal share of wild germplasm (18%) in the total collection. This communication highlights the collection trends, salient achievements made, emerging issues, and the priority areas which need adequate addressing for meaningful germplasm collections.

Key Words: Crop landraces, Diversity-rich areas, Gap analysis, Germplasm augmentation, Trait-specific germplasm

Introduction

The Indian subcontinent represents four mega biodiversity hotspots, one among 12 megacentres of crop plant diversity in the world, and about 166 crop taxa have originated and/or developed diversity here (Zeven and de Wet, 1982). There are 861 taxa of crop wild relatives documented in India, which includes wild/weedy forms or wild populations of 150 crop taxa in this country (Pradheep *et al*., 2021). Crops such as rice, sugarcane, green gram, black gram, jute, mango, citrus, banana, cucumber, snake gourd, yam, taro, turmeric, ginger, cardamom, black pepper, jack fruit, horse gram, sesame, okra, and muskmelon, etc. have originated and evolved here. In addition, since antiquity, several new crops were also introduced in Indian agriculture at various times, resulting in constant enrichment of cultivated species, besides many semi-domesticates. A total of 480 crop species of food and agricultural importance and >1000 wild edible plants were documented in this country (Arora and Pandey, 1996; Nayar *et al*., 2003).

Plant genetic resources (PGR) are one of the most important components of present and future crop breeding programmes. The pattern of crop diversity depends on interactions between plants' genetic makeup and environmental factors including biotic and human factors. Augmentation of germplasm is the first and foremost activity in the PGR management system. Germplasm collectors rationally apply scientific principles during collection to arrive at an optimum number of samples from a particular site, which is manageable by curators/breeders. More the scientifically-collected diversity is conserved and made available for future use, better the chances of fulfilling future demands. For a successful germplasm collection programme, considerable knowledge of diverse disciplines such as phytogeography, agro-ecology, plant taxonomy and ethnobotany, the biology of crops, and the allied fields is of paramount significance. The threat to loss of diversity, particularly in the wake of anthropogenic pressures and emerging vagaries of climate change, necessitates collecting representative diversity for conservation lest it is lost forever. Besides, germplasm collecting is also aimed for use in breeding programmes, immediate use (e.g., wild edibles), and filling the gaps in existing *ex situ* collections. The germplasm may represent any of the following kinds, namely, wild form, weedy race, landrace/primitive cultivar, obsolete and advanced cultivars, ecotype, botanical form/variety, subspecies, wild progenitor, crossable wild relatives, etc.; this indicates that an explorer generally aims to collect genepool samples. In recent years, increasing interest

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was shown in germplasm collection of wild species of current and potential use.

There were reports of sporadic collections of indigenous crop germplasm during the earlier part of the 20th century. However, systematic plant exploration and collection work was initiated in India with the establishment of a nucleus Plant Exploration and Collection Unit in 1946 in the then Division of Botany, Imperial Agricultural Research Institute, New Delhi under the leadership of Dr Harbhajan Singh, who is also known as 'Indian Vavilov', and had significantly contributed to the field of PGR collection. The period between 1946 and 1976, has also witnessed several national and international collaborative explorations in the country, fetching a sizeable collection of over 31,225 acc. comprising cereals, millets, legumes, oilseeds, vegetables, fibre yielding and other economic plants.

The exploration activities have been more systematized with the creation of NBPGR in 1976. The Bureau with its 10 Regional Stations coordinates/ undertakes exploration with crop-based institutes of ICAR, AICRPs and SAUs. The majority of exploration missions during the initial years were of multi-crop/ region-specific surveys and collection; however, during the 1980s, collaborative explorations with crop-based institutes received a greater impetus. Priorities were set at both crop/ species level as well as phytogeography/ habitat level. After the implementation of the Convention on Biological Diversity in 1993, germplasm was considered sovereign property of the nation. This demanded the urgent need for survey, inventorisation, collection, conservation and documentation of native PGR. Collection activity has gained momentum through the World Bank-aided National Agricultural Technology Project (NATP) on Sustainable Management of Plant Biodiversity, operational at ICAR-NBPGR from September 1999 to 2005 (as reflected in Fig. 1). During the past two decades, the number of annual explorations remains almost unchanged (30-40 in number), but priority has shifted towards collecting trait-specific germplasm and wild germplasm including CWR and minor fruits, which resulted in a significant increase of wild germplasm (18%) and 890 wild species are collected. At the same time, accessions collected per exploration trip was more than 100 per trip till 1992, becoming less than 100 subsequently (see Fig. 1) indicating focused collecting.

Collection Status

Since the inception of NBPGR, a significant amount of diversity in the majority of crops and their wild relatives have been assembled from all the phytogeographic/ agroecological regions of the country. So far, a total of 2,81,759 accessions comprising cultivated (2,11,574) and wild species (38,950) have been assembled through 2,838 explorations conducted in collaboration with ICAR crop-based institutes, SAUs, KVKs and other stakeholders (Fig. 1). Crop group-wise holdings indicate that the majority of collections have been made in the cereals (61,496) followed by vegetables (55,353) and pulses (42,162). Collections in other crop groups include 22,879 in millets, 7,447 in pseudocereals, 25,659 in oilseeds, 5,707 in fibres, 14,525 in fruits, 2,046 in fodder species, 28,317 in spices, condiments and M&AP, 2,107 in agroforestry species and 1,235 in sugarcane. The germplasm collections for major crops are given in Table 1.

Details of areas/regions from where germplasm collections made (phytogeography/ crop/ crop-group/ wise), gap areas (geographic region/crop/crop-group-wise), and targeted priority traits, if any, were documented then and there in the past works (Arora, 1988; Malik and Srivastava, 2004; Ahlawat *et al.*, 2015). The Western Ghats, Western Himalayas, arid and semi-arid regions and Andaman & Nicobar Islands were reasonably well explored for crops, while remote and tribal areas of the NEH region, central and eastern India, Eastern Ghats, and Jammu & Kashmir, as well as distinct ecosystems like coastal areas and cold-arid tracts, exhibited some collection deficits, which are being addressed in a phased manner. Collected germplasm represents distinctly named landraces/local cultivars (e.g., rice-14,491; maize-316; pigeonpea-97). In general, more emphasis was given to augmenting orthodox seed-bearing field crops (including vegetables, and seed spices) as they can be bankable in the NGB. However, the functioning of the cryobank facility and the development of adequate protocols have led to the collection of recalcitrant species like citrus, and minor or under-utilized fruits as well. For collection and conservation of perennial horticultural crops (like fruit, plantation, and other tree crops) whose conservation is mainly made through field gene bank, the Bureau is maintaining a strong linkage with the respective NAGS. Salient collection achievements are given in Box 1.

Table 1. Germplasm collection status of major crops

S. No.	Crop-group	Crops (accessions)*
1.	Cereals	Rice (103,538), wheat (21,107), maize (14,221), barley (7,889), oats (619)
2.	Millets	Sorghum (13,742), pearlmillet (9,074), finger millet (12,918), foxtail millet (6,142), kodo millet (2,744), barnyard millet (2,510), proso millet (1,854), little millet (765)
3.	Pseudocereals	Grain amaranth (6,817), buckwheat (1,909), chenopod (379), job's tears (344)
4.	Grain legumes	Chickpea (16,300), pigeonpea (14,436), greengram (7,534), blackgram (5919), French bean (7,295), horsegram-(3,614), lentil (5,028), mothbean (2,672), adzuki bean (162), cowpea (8,807)
5.	Oilseeds	Groundnut (12,014), sesame (10,275), rapeseed & mustard (8,089), soybean (4,185), linseed (3.077), niger (2,857), perilla (583)
6.	Vegetables	Chilli (8,069), okra (4,462), lablab bean (4,115), tomato (1,549), brinjal (6,251), onion (2,931), garlic (1,952), *Colocasia* (2,739), bittergourd (*Momordica* spp., 2,360), ridge-gourd (1,593), sponge gourd (1,385), bottle gourd (2,011), pointed gourd (163), watermelon (804), cucumber (1,746), snapmelon (356), pea (5,245), winged bean (305), drumstick (234), yam (81), *Dioscorea* spp (1,750), pumpkin (1,898), ivy gourd (310)
7.	Fibre	Cotton (14,202), jute (2,948), sunnhemp (419), *roselle* (1,291)
8.	Fruits and nuts	Bael (127), custard apple (378), chironji (140), *Capparis* (68), *Cordia* (130), aonla (183), phalsa (187), karonda (29), khirni (103), *Salvadora* (147), pomegranate (360), ber (112), sapota (57), peach (115), walnut (764), apple (110), citrus (847), jackfruit (581), water nut (764), papaya (189), apricot (664), pear (102)
9.	Fodder spp.	Sain grass (264), lucerne (352), Sorghum (13,742)
10.	Spices and condiments	Dill (99), celery (129), caraway (45), black caraway (16), coriander (1,778), cumin (560), fennel (181), Nigella (51), anise (19), fenugreek (558), turmeric (2,822), ginger (2,525)
11	M&AP	Aloe (454), ashwagandha (97), giloe (317), *Ocimum* (633), kalmegh (222), bhang (27)
12.	Agroforestry spp.	*Acacia nilotica* (134), *Casuarina equisetifolia* (4), Eucalyptus (5), *Leucaena leucocephala* (13)

*This collection figure includes collections from all stakeholders processed for IC numbers

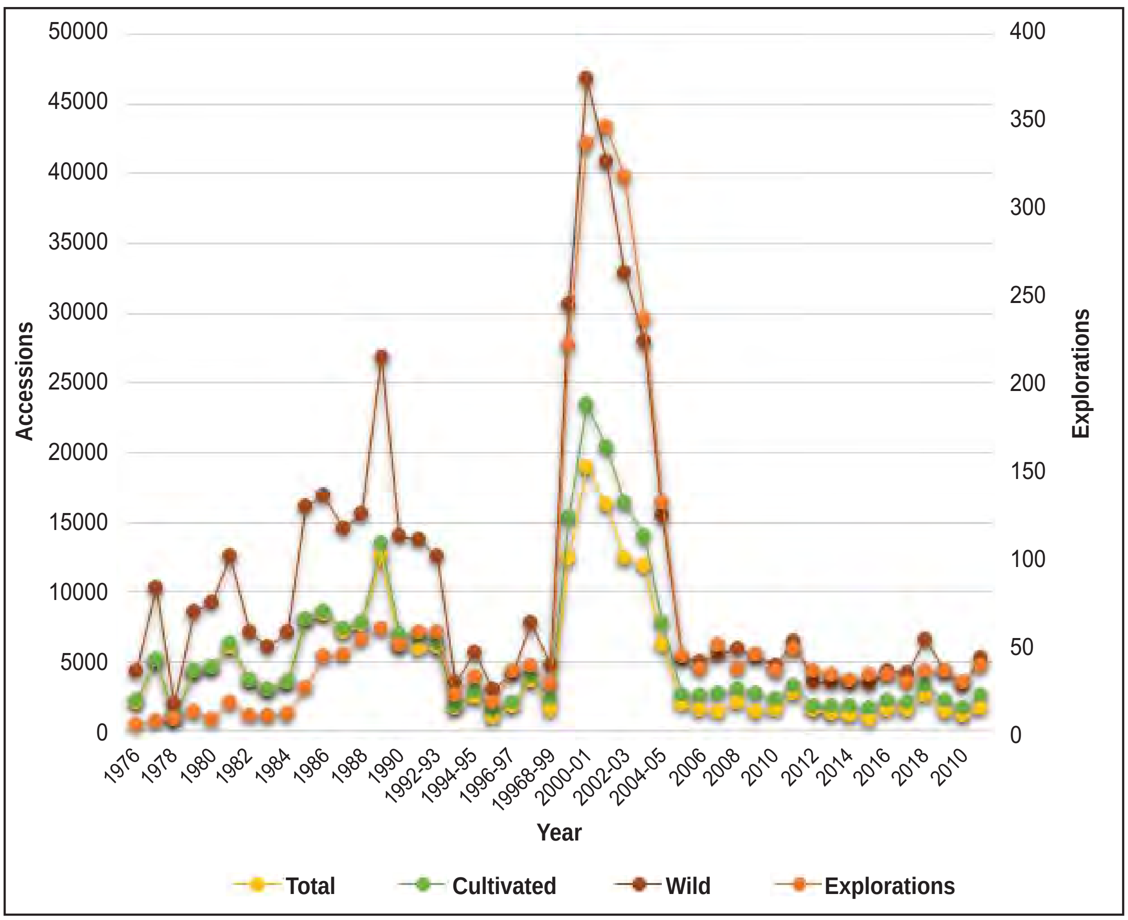

Fig. 1. Trends in germplasm collection since the inception of NBPGR

Box 1. Significant Achievements at a Glance

- From 1966 to prior to the adoption of CBD, joint explorations in collaboration with other countries and CGIAR centres were undertaken under PL-480 scheme, Indo-Australian mission, Indo-Canadian mission, Indo-Japanese mission, INDO-USAID, USIF, G-15, IPGRI, IRRI, ICRISAT, etc. A total of 50,205 samples were collected within India (37,580) and from foreign countries (12,625).
- ***Implementation of NATP-Plant Biodiversity***: a unique effort at the national level, wherein more than 130 organizations representing all crop-based Institutes, SAUs, NGOs, etc. collaborated for the national cause of collecting and conserving agro-biodiversity in mission mode approach. A total of 1,733 explorations were undertaken and 1,05,949 acc. were augmented.
- ***Trait-specific collections*****:** Exclusive explorations for biotic and abiotic stress in tolerant germplasm are conducted for rice, wheat, maize, brassica, oilseeds, etc. crops. Some examples include drought/terminal heat tolerant wheat landraces (Kharchia, Lal gehun, Wazia, Khattia) from areas adjoining the southern Thar Desert; grey mildew immune cotton from Tamil Nadu; orange-fleshed cucumber from Manipur and Mizoram; spineless bael from Jaunpur; deep water rice landraces from Assam; salt-tolerant rice landraces from West Bengal. The germplasm for quality traits are collected generally based on the information from farmers.
- ***Diversity-rich areas explored/Special Exploration Missions executed***: 16 special missions have been undertaken in different inaccessible areas like A&N islands, Brahmaputra River island (Assam), Sunderbans delta (West Bengal), Valley of Flowers (Uttarakhand), Zanskar valley, Western Ghats (Maharashtra and Karnataka) etc.
- ***Rescue missions***: cyclone-hit areas (1999-2000) and flood-affected areas (2008) in Odisha; Tehri dam catchment areas (2000) and natural calamity-affected areas (2013) in Uttarakhand; Earthquake-hit areas of Kachchh (Gujarat, 2001); Sardar Sarovar catchment areas (Gujarat, MP and Maharashtra, 2001-2003).
- ***Difficult/disturbed areas explored***: Long duration (45 days) exploration in Nicobar; Nyoma and Zanskar (>3500m) in Ladakh; Gurez and Kistwar in J&K; Malkangiri hills (Odisha); Gadchiroli district (Maharashtra); Bastar, Sukma and Konta (Chhattisgarh).
- ***Use of GIS in gap analysis*****:** Geo-referencing and mapping of diversity vis-à-vis germplasm collected and conserved has been completed in 21 major crops (rice, wheat, maize, chickpea, pigeonpea, *Sesamum*, pearl millet, sorghum, fox-tail milllet, finger milllet, proso milllet, little milllet, kodo millet, black gram, mothbean, green gram, cowpea, ricebean, tomato, brinjal, *Allium*) and accordingly gap areas were identified up to district/taluk level. This activity also facilitates the identification of duplicates and updating of passport data. Trait-specific germplasm and potential sites are being identified through grid mapping.
- ***PGR Map***: The PGR Map is a web-based and mobile application that provides three uses: "*What's around me*" helps to obtain the accessions collected and conserved in the genebank from a particular location in India from where the user is accessing; "*Search the map*" helps to list the accessions collected and conserved in the genebank; "*Search for species*" helps to map the collection sites of a species.
- ***National Herbarium of Cultivated Plants-*****:** This Index-Herbariorum accredited herbarium has 25,283 herbarium specimens representative of 267 families, 1,547 genera and 4,380 species of important taxa of PGR relevance including over 500 crop taxa and 550 CWRs. Sixteen new taxa, not represented earlier were added in 2022. Additionally, 3,181 seed samples and 756 economic products/ carpological samples provide representative/referral collections as supplementary holdings. Twenty-five type specimens of 18 taxa (belonging to 7 genera and 5 families) are represented. *Digital images of herbariums* (10,441) were added to the virtual digital database of NHCP at website of NBPGR (*http://www.nbpgr.ernet.in:8080/nhcp/*) and available for reference and studies.
- ***Taxonomic/Biosytematic studies*****:** Studies on the germplasm assembled through various explorations have advanced the knowledge of CWR and their relationship with cultivated species, helped in correcting misidentifications, updating their nomenclature. This has resulted in 24 new plant discoveries and 10 new distribution records in the country, besides 45 records on new distribution in various Indian states. Also, 10 new records of cultivation of economically important species (e.g., *Plukenetia corniculata*, *Inula racemosa*, *Allium fasciculatum*) were made. Illustrated guides for species identification in *Vigna*, *Abelmoschus*, *Cucumis*, *Allium* and *Sesamum* were prepared.
- ***Ethnobotanical information compiled*****:** Ethnobotanical observations and new uses of plants, especially those collected from tribal-dominated tracts, are recorded and published.

Analysis of gaps in the collection in a scientific manner (keeping in view actual variability/ diversity present in habitats, the conserved material, material under regeneration, and best utilization of GIS tools) and pinpointing the pattern of infraspecific diversity through a mission-mode approach is on the way. So far, gap analysis work has been completed for 21 crops and the reports are available online (http://www.nbpgr.ernet.in/Publications.aspx) gap areas identified through this procedure are being explored/re-explored through Annual Exploration Plans in a phased manner. Pradheep *et al.* (2021) have identified gap areas for 292 high priority-wild taxa (related to 85 crops) at the district level; of them, more than 100 taxa are yet to be augmented from natural habitats.

In situ Conservation of PGR

Locating and declaration of Citrus Gene Sanctuary in Garo hills of Meghalaya was the first attempt of NBPGR on documentation of diversity rich site for *in-situ* conservation during 1980s (Singh, 1981). Subsequently, there was a long gap on this activity, however, PPV&FRA has recognized custodian farmers and awarded them by Genome Saviour Awards. In last three years, the NBPGR has identified high density population sites of wild rice (*Orzya rufipogon*) in Assam, wild pigeonpea (*Cajanus cajanifolius*) in Bailadila range of Chhattisgarh and for guava in Uttarakhand.

The ICAR-NBPGR has located an ideal habitat having good population of wild rice- *Oryza rufipogon* between Borjuli Bagan and Misamari in Sonitpur district of Assam, for its perpetuation and long-term conservation in nature through protection under "The

Biological Diversity Act 2002" involving all stakeholders like State Forest Department, Assam State Biodiversity Board (SBB) and National Biodiversity Authority (NBA), Biodiversity Management Committee, Village Panchayat/ local body. The Government of Assam has declared (on 7th May, 2022) it as "Biodiversity Heritage Site of wild rice". Probably this may be first initiative of the ICAR on *in-situ* conservation of CWR through BHS.

During an on-farm survey in Pithoragarh district of Uttarakhand, the natural stands of guava in forests and farmer's fields spreading along the East Ramganga River valley between Muwani to Nachani was located during 2019. Occurrence of guava stands in forests, beyond its cultivation areas in hills was unusual observation. Elderly persons of area could not guess history of its introduction in that area. Detailed survey conducted in 2020 and 2021, revealed naturalised distribution in large area in cultivated and abandoned fields, hill tops and along river bank of Saryu and Kali river valleys, surrounding about 50 villages at 780 m to 1350 m amsl. A large variability in fruit shape, fruit size/fruit weight (100-300g), fruit colour, pulp colour (pink/reddish and

Habitat of naturalised guava population in Pithoragarh district (Left) and fruit variability (Right)

normal) and taste etc. was recorded. A large quantity of fruits is transported by villagers to Pithoragarh, Lohaghat, Champawat and local markets of surrounding areas for sale. The possibility of its *in-situ* conservation and diversity enhancement by introducing other species of *Psidium* is being explored involving all the stakeholders.

Emerging Issues

In recent years, collection activities are being suffered due to the following issues, which may be circumvented at the earliest in the interest of this noble cause of conservation for posterity.

- As farmers are increasingly aware of the registration scope of elite germplasm/unique landraces under the PPVFRA regime, convincing and acquiring germplasm is often a challenge. Also, in some states, vigilant members of the State Biodiversity Boards directing explorers to get permission from their end. Also, the hassles imposed by the forest department to survey and collect PGR from Protected Areas.
- Lack of trained human resources in this field calls for an emphasis on developing skilled manpower and the use of modern tools. Cases on re-demanding the IC numbers to germplasm conserved in FGBs on account of no records, are being received particularly from young or incumbent scientists.
- Sometimes, 'fancy' names are assigned to the landraces for gaining popularity, and marketability (apart from different names for the same landrace and vice versa). This necessitates thorough verification through various sources which often consumes time.
- Visible sensitiveness of phenology of wild species due to changes in climate, therefore, making it difficult to strategize the collection activities.
- Losing importance of infraspecific classification in crops (and non-recognizing of infraspecific taxa by taxonomists) resulting in loss of valuable information, which has a huge role in the collection, categorization, characterization, and maintenance of a larger number of samples.
- Lack of interest in multiplication of cross-pollinated crops particularly in vegetables, large fruit with low seeds is a deterrent in germplasm collection of such crops, though criteria of OP vegetable crops have been relaxed from 4000 to 1000 seeds for submitting in NGB.

Priorities and Thrust Areas

- Reducing the collection-to-conservation gaps (Operational gap) through proper coordination, active monitoring and reporting systems, and strengthening the regeneration facilities at the multiplication site, especially for cross-pollinated crops. It is strongly advised to gather an adequate sample size in the field itself, wherever possible.
- Studies on improving storage conditions (including packing) of vegetative propagules and live plants during transport are the need of the hour, as more recalcitrant species, fruit crops and tree species are on the priority list for collection.
- As the importance of collecting wild species including CWR is gaining momentum, it is imperative to develop illustrative field identification keys using leaf, fruit and seed characters.
- Enhancing the effectiveness of collecting trait-specific germplasm through the adoption of FIGS in identifying sites for exploration, encouraging the use of portable equipments/kits (TSS meter, P^H meter, lysimeter, chlorophyll fluorescence meter, NIR food analyser, seed driers, etc.) and the thorough knowledge of habitat/ecological/micro-climate conditions, (pest) hotspot areas, and morphological traits associated with the trait of interest.
- Augmenting representative diversity of relatively less-attended crop groups such as M&AP, forages, ornamentals and green manure, agro-forestry species and also plants belonging to RET species, nutraceutical and industrial value, after required prioritization.
- Similar to the Botanical Survey of India involved in the preparation of flora, development of the PGR Inventory/ checklist for states and country, involving inputs from all possible sources and stakeholders. This would enable identifying meaningful gaps in collections, changes in diversity distribution over time, and aid during collecting. Also, the valuable data lying in the form of field notebooks, reports of collecting missions and collectors' notes need to be brought out to the benefit of the user.
- Need for a unified collection database involving details of collections by all the stakeholders (ICAR institutes, SAUs and other govt. organizations,

including collections made under different international centres); this only will ensure a better understanding of the germplasm collections on hold, besides meaningful gap analysis.

Other priorities include strengthening expertise in techniques of *in vitro* germplasm collection (which has the advantage of safe movement of germplasm), and the use of species distribution models (like Maximum Entropy, MaxEnt, BioClim, and EcoCrop) for possible localities of populations of rare CWR and RET species. It is also desired to undertake collaborative explorations in foreign countries having primary and secondary centres of diversity of priority crops, for which low diversity exists in national genebanks.

Conclusion

In the current scenario, germplasm collection for utilization is the prevailing trend, and breeders are interested in a few but selected materials showing desirable traits. Hence, it is required to adopt the recent but feasible technologies to maximize the coverage and efficiency of germplasm collection. Though time-consuming, detailed documentation in the field itself during collection is preferred for the fullest utilization of germplasm, besides protecting them legally. Germplasm collections should also need to address specific common problems, which arise then and there (e.g., search for immunity boosting plants/accessions during COVID). Collection priorities need to be reassessed at regular intervals; accordingly, the exploration plan shall be formulated after meaningful gap analysis. A mature decision needs to be taken between recollection and regeneration of accessions with inadequate sample size; and between germplasm collecting from farmers' fields or natural habitats or keeping it *in situ*/on-farm, keeping in view the pros and cons. Educating citizens through PGR awareness campaign, and partnership approach with grassroot level workers (like those in KVK, and NGO) would help in acquiring desired germplasm in remote and inaccessible areas.

References

Ahlawat SP, KC Bhatt and K Pradheep (2015). Plant exploration and germplasm collection at ICAR-NBPGR, New Delhi: Status and priorities. *In:* Pradheep K, A Pandey, KC Bhatt, SP Ahlawat, DP Semwal and KC Bansal (Eds). *Training Manual: Crop Wild Relatives: Identification, Collecting and Utilization*. ICAR-National Bureau of Plant Genetic Resources, New Delhi. pp 1-17.

Arora RK and Pandey A (1996) *Wild Edible Plants of India: Diversity, Conservation and Use*. National Bureau of Plant Genetic Resources, New Delhi, India.

Arora, RK (1988) The Indian gene centre-Priorities and prospects for collection. In: RS Paroda, RK Arora and KPS Chandel (eds). *Plant Genetic Resources: Indian Perspective*, NBPGR, New Delhi, pp. 66-75.

Malik SS and U Srivastava (2004) Germplasm collection, achievements, gaps and opportunities. In: Dhillon BS, RK Tyagi, A Lal and S Saxena (eds) *Plant Genetic Resource Management*. Narosa Publishing House, New Delhi, pp 153–171.

Nayar ER, A Pandey, K Venkateswaran, R Gupta and BS Dhillon (2003) *Crop Plants of India: A Checklist of Scientific Names*. ICAR-National Bureau of Plant Genetic Resources, New Delhi, India, 48 p.

Pradheep K, SP Ahlawat, S Nivedhitha, Veena Gupta and Kuldeep Singh (2021) *Crop Wild Relatives in India: Prioritisation, Collection and Conservation*. ICAR-National Bureau of Plant Genetic Resources, New Delhi, 181 p.

Singh B (1981) Establishment of First Gene sanctuary for Citrus in Garo Hills. Concept Publ. Co., New Delhi, p. 182.

Zeven, AC and JMJ de Wet (1982) *The Dictionary of Cultivated Plants and their Region of Diversity*. PUDOC. Wageningen.