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Crop Wild Relatives in India: Inventorization, Prioritization and Conservation#

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Identified as a critical component for food and nutritional security and environmental sustainability in the current century, crop wild relatives (CWR) warrant species-level prioritization and meaningful germplasm conservation. A rough-and-ready approach placing all other species of a crop genus as CWR is unacceptable, as it would lead to the listing of many unrelated species, also conversely, in some crops, the search has gone beyond the crop genera. Initially, based on overall closeness with the crop as well as their potential for use, a total of 861 Indian CWR taxa (769 species) were prioritized for 171 ICAR-mandated crops falling under 14 crop groups. Further prioritization was made on shortlisted taxa, based on the economic importance of crops *per se*, level of closeness to crops (cytogenetically/morphologically/molecularly), possessing traits of breeders' interest, or already under wide-hybridization programme, and the extent of distribution/threat. This resulted in the identification of 292 taxa (257 species) belonging to 85 crops. These high-priority taxa were further analyzed for conservation gaps, if any. Of 292 taxa, only 167 were conserved in the National Genebank. While 28 taxa were represented with only one accession and 81 with <10 accessions, only 40 were with a fair number of accessions (≥50); however, they too lacked representative samples from across a geographical and ecological range. This communication highlights the constraints involved in the process including insufficient information on threat status, gap areas for future collection, and thrust areas.

Key Words: Gap analysis, Genebank, Germplasm collection, Threat status assessment, Wild species

Introduction

India is endowed with a rich diversity in crops and it is one of the 12 centres of crop diversity in the world (Zeven and de Wet, 1982). About 166 crop taxa have originated and/or developed diversity in India (Arora, 1991). Indian Gene Centre has particularly contributed to the origin and evolution of 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, etc. Recently, a few more crops, *viz*., horse gram, sesame, okra, and muskmelon were added to this list. The rich occurrence of close relatives of these native crops in this country forms important evidence in this regard. In addition, Indian agriculture has been consistently enriched by the introduction of new crops since antiquity, and many species are in the process of domestication. Nayar *et al.* (2003) inventoried 480 crop species in this country.

As long as the breeders' needs are incessant, the available germplasm base in most crops is proven to be insufficient, especially for the stress-related traits such as tolerance to biotic pests (insects, nematodes, pathogens, and weeds) and abiotic factors (salinity, drought, cold, and heat). In this context, wild species related to crops, which are surviving in harsh environmental conditions, marginal lands, and field boundaries, would play a crucial role in offering these much-needed traits. Also, some wild relatives can contribute to yield and quality traits as well. Often, they serve as rootstock to impart resistance/tolerance to abiotic and biotic stresses, increase crop productivity, and help to induce flowering. Though, there has been a steady increase in the rate of release of cultivars containing genes from CWR, most of the CWR are not only in peril in natural habitats in the wake of man-made disasters but are highly under-represented in the *ex situ* genebanks.

This work has been presented at the Second International Agrobiodiversity Congress held online in Nov. 2021, and largely excerpted from the book entitled "Crop Wild Relatives in India: Prioritisation, Collection, and Conservation" authored by Pradheep *et al.* (2021), and published by ICAR-NBPGR

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According to Maxted *et al.* (2006), CWR can be defined as "a wild plant taxon that has an indirect use derived from its close genetic relationship to a crop". The closer the species is related to crops, the more the possibility/practicality to get their traits incorporated. Wild forms (i.e., wild but distinct morphotypes belonging to the same taxon in which crop is grouped) or wild populations (i.e., wild plants morphologically indistinguishable from cultivated partners) of crops, wild progenitors, and wild taxa closely related to crop plants, all constitute CWR. Maxted *et al.* (2006) were of the view that closer wild relatives could be found within genepool GP_{1B} (based on crossability) or Taxon Group 1 & 2 (based on infrageneric classification; *genus-tribe-section-series*).

It is to be noted that the common approach of considering all the species of the same crop genus as CWR is not justifiable, especially for large genera encompassing diverse kinds of plants (e.g., *Crotalaria*, *Dioscorea*, *Ficus*, *Ipomoea*, *Panicum*) and in well-researched crops (e.g., barley, wheat, maize, sugarcane); here species of related genera often utilised). Therefore, their prioritization is crucial for meaningful conservation. From the crop improvement angle, the genepool concept needs to be given priority, nevertheless, complete information on crossability is hardly available for most crops. The existence of natural hybrids and successful experimental wide hybridizations indicates that they are closely related. Different species (within the genus) exhibiting the same chromosome number and homology would be rather related. An integrated approach involving morphology, cytogenetics, and molecular systematics, supplemented with allied evidence (graft compatibility, palynology, chemotaxonomy, micromorphology) would help establish the level of relatedness of wild species with the crop.

Earlier, on the basis of evidence from morphology, cytology, crossability, and utility, Arora and Nayar (1984) reported the occurrence of 326 wild relatives in India, which needs a revisit due to a lot of dynamics in species distribution, species concept, threat status, discovery of new taxa since then, and the growing importance of unattended crop-groups such as forages, ornamentals, medicinal and aromatic plants. Latter works (Singh *et al*., 2013; Pradheep *et al*., 2014; Singh, 2017), focused more on the distribution and usefulness of the wild species related to crops. The development of checklists and inventories is vital in any national strategy for the conservation and use of plant diversity (Brehm *et al*., 2008). Analysing the gap existing between available CWR (in nature) *vis à vis* how many and to how much extent they are conserved (Seed /Cryo/*In Vitro*/Field Genebank) would help in formulating future exploration plans rationally, including revisiting. Keeping this in view, the research questions set out to answer are as follows:

- How many meaningful CWR occur in India?
- How many of them are conserved *ex situ* and to what extent?
- What issues and constraints are associated with the prioritization and conservation of CWR in India?

Materials and Methods

The information available on wild species related to crops (Arora and Nayar, 1984; Pradheep *et al*., 2014; Singh, 2017) and new literature (published till February 2021) formed the base for this work. Based on the overall closeness of wild taxon with the ICAR-mandated crops and their usefulness in crop breeding, initial prioritization was made. Those prioritized taxa were further subjected to criteria – economic importance of crops *per se*, level of closeness to crops (cytogenetically/ morphologically/ molecularly), possessing traits of breeders' interest, or already under the wide-hybridization programme, and the extent of distribution/threat. Wherever feasible, feedback from crop experts was utilized in the prioritization process. The scoring technique adopted for prioritization of CWR taxa (Pradheep *et al*., 2016) was not followed in this analysis as only incomplete information is available on the criteria such as the extent of distribution/threat (as comprehensive flora of India is yet to be published, and only one-fifth of prioritized taxa were subjected to threat status assessment), and level of closeness. Therefore, only subjective assessments have been made to pinpoint the high-priority CWR taxa. Gap areas for future collection of high-priority taxa were identified as per the steps mentioned in Fig. 1.

Results and Discussion

Initial prioritization of CWR resulted in a total of 861 CWR taxa (769 species) in 171 ICAR-mandated crops (Table 1; for the entire list, see Pradheep *et al*., 2021), which accounts for about 4% of flowering plants in India. There are 150 crop taxa having wild/weedy forms or populations occurring in India (Table 1), which means these crops have either originated from here or developed

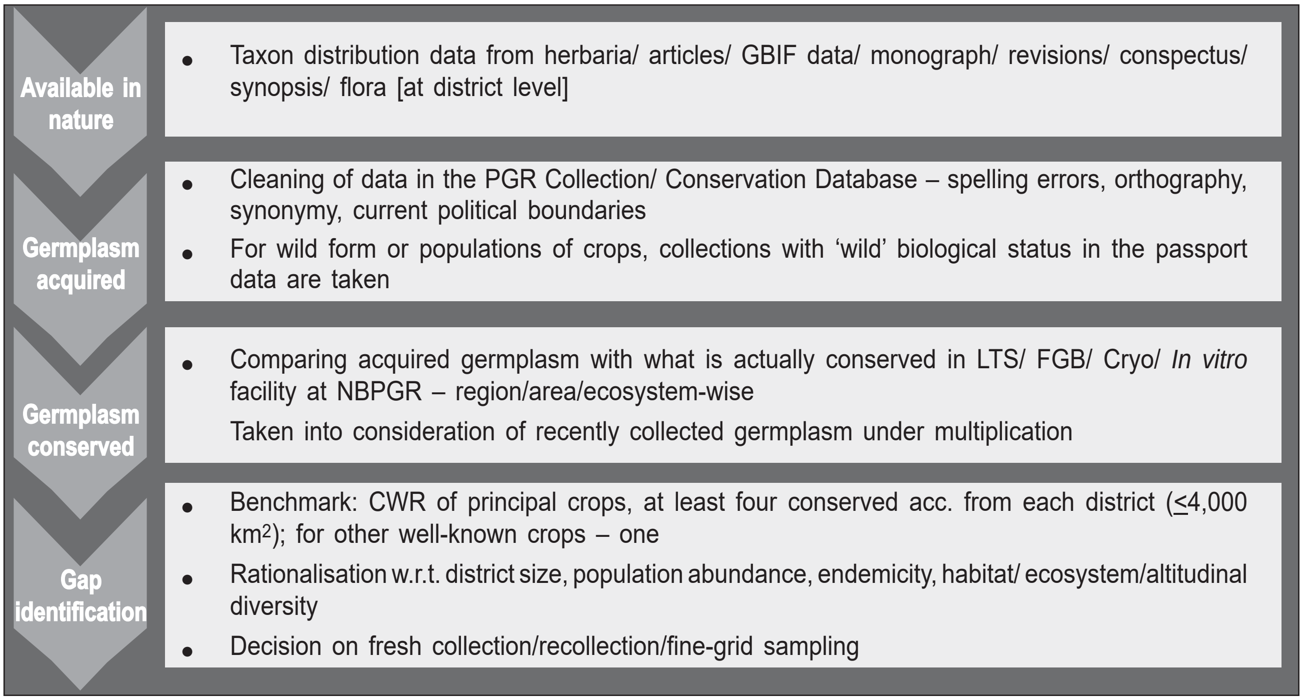

Fig. 1. Gap identification strategy for germplasm collection in high-priority CWR

Table 1. Summary of crop-group wise prioritized crops and their wild relatives for India

S. No.	Crop-group*	No. of crops		CWR species		CWR taxa	
		Initially prioritized	Further prioritized	Initially prioritized**	Further prioritized	Initially prioritized	Further prioritized
1.	Cereals	5	3	52 (2)	46	58	50
2.	Millets	8	5	23 (1)	8	27	9
3.	Pseudocereals	3	1	14 (1)	1	14	1
4.	Grain legumes	10	9	51 (4)	27	59	30
5.	Oilseeds	5	4	13 (1)	10	14	10
6.	Fibres	5	4	19 (3)	9	21	9
7.	Forages	16	4	58 (14)	4	63	5
8.	Fruits and nuts	36	14	130 (17)	55	148	65
9.	Vegetables	26	21	87 (13)	46	102	54
10.	Spices and condiments	12	7	58 (8)	22	62	24
11.	Ornamental plants	13	2	141 (59)	5	153	8
12.	Medicinal & aromatic plants	20	7	74 (19)	8	85	11
13.	Plantation crops	3	1	12 (0)	1	14	1
14.	Others	9	3	37 (8)	15	41	15
Total		171	85	769 (150)	257	861	292

*One crop may involve more than one species **Figures in parenthesis are crop taxa having wild/weedy form(s) or wild populations occurring in India, which are also included for counting as CWR. Source: Pradheep *et al.* (2021)

a secondary centre of diversity. Crop groups like fruits and nuts, vegetables and medicinal and aromatic plants exhibited ≥20 priority crops, while a higher number of meaningful CWR taxa were found in ornamental plants (141), followed by fruits and nuts (130), vegetables (87) and medicinal and aromatic plants (74), owing to the involvement of higher numbers of crops as well as closely related taxa to these crops.

Further prioritization based on four criteria resulted in the identification of 292 high-priority taxa (257 species) belonging to 85 crops (Table 1; for the list, see Pradheep *et al*., 2021). Here, crop representatives from groups such as forages, ornamental plants, and fruit and nuts were kept minimum, keeping in view the meagre attention currently given to utilizing wild species in the improvement of crops under these groups. Nevertheless, in forage grasses, a separate exercise was made, resulting in prioritizing 44 wild taxa for 15 crops. In general, biodiversity hotspot regions such as Western Ghats, North Eastern India, Himalayas, Andaman & Nicobar Islands tend to have a greater number of CWR.

Out of high-priority 292 taxa, only 167 are conserved in the National Gene Bank (NGB) of ICAR-NBPGR (including collections at Regional Stations), indicating the need for augmenting other wild relatives, with correct taxonomic identity (Fig. 2). Of yet-to-be collected 125 taxa, a minimum of 30 are endemic, niche-specific, rare and threatened taxa, and some are highlighted in the Box 1. Further, collected species are largely underrepresented, as almost half the conserved species are with <10 accessions on hold. While 28 taxa were represented with only one accession and 15 with just two accessions, only 40 were with a fair number of accessions (between 50 and 559) which includes species like *Abelmoschus tetraphyllus*, *Oryza nivara*, *O. rufipogon*, *Saccharum spontaneum*, *Sesamum indicum* subsp. *malabaricum*, *Solanum insanum*, *Trifolium repens*, *Vigna sublobata* and *Withania somnifera*. However, the latter taxa too lacked representative samples from across a geographical and ecological range. Similar is the scenario in the world as well, and according to Castaneda-Alvarez *et al*. (2016), over 70% of CWR species in the world need collection and conservation in the genebank, and over 95% are insufficiently represented indicating the need for systematic representation from the full geographic and ecological range of species. In the Indian context, huge collection gaps exist even in crucial crop groups (e.g., cereals and pulses), in protected areas (PA) and in fragile ecosystems such as coastal and cold-arid regions.

Box 1. Some rare and endemic CWR yet-to-be represented in NGB

1. *Agropyron thomsonii*
2. *Allium farctum*
3. *Cajanus sericeus*
4. *Cajanus trinervius*
5. *Corchorus urticifolius*
6. *Elymus gangotrianus*
7. *Fagopyrum tataricum* subsp. *potaninii*
8. *Gossypium stocksii*
9. *Hordeum × lagunculciforme*
10. *Hordeum spontaneum*
11. *Macrotyloma uniflorum* var. *stenocarpum*
12. *Mangifera sylvatica*
13. *Medicago sativa* notho subsp. *varia*
14. *Musa acuminata* subsp. *manipurensis*
15. *Musa balbisiana* var. *sepa-athiya*
16. *Oryza malampuzhaensis*
17. *Solanum multiflorum*
18. *Sorghum propinquum*
19. *Trichosanthes cucumerina* subsp. *villosula*
20. *Vigna nepalensis*

Some Observations on Various Crop-groups

A perusal of Fig. 2 indicates that even the easy-to-conserve crop groups like cereals, legumes, and vegetables, see huge gaps in species representation. For example, out of 50 prioritised taxa for cereal crops, only 18 were represented. This difference arises mainly due to a vast number of wild Triticeae members (*Aegilops*, *Agropyron*, *Elymus*, *Eremopogon*, *Hordeum*, *Leymus*) occurring in the Western Himalayas, however, only a few had so far been represented in NGB. When coming to the total wild accessions collected (Fig. 3), vegetables and cereals dominated the collections, as are easily bankable through seeds. Fruits and nuts, ornamental plants, and medicinal and aromatic plants are difficult-to-conserve groups and often require maintenance in FGB. The collection to conservation gap is particularly higher in vegetatively propagated germplasm.

In rice, GP_2 and GP_3 species such as *Oryza meyeriana*, *O. officinalis*, and *O. coarctata* need thorough representation in NGB. In millets, barring *Setaria viridis* (a progenitor of foxtail millet), there is a need to assemble at least the primary genepool of crops, though sizeable numbers of unidentified wild germplasm do exist in *Panicum* and *Pennisetum* genera. There is a need to systematically collect the secondary and tertiary genepools of pigeonpea, apart from its endemic progenitor, *Cajanus cajanifolius*. Only two collections are on hold for the latter species, however, need to have a meaningful collection of at least 25 accessions. *Sesamum prostratum*, a coastal strand vegetation species,

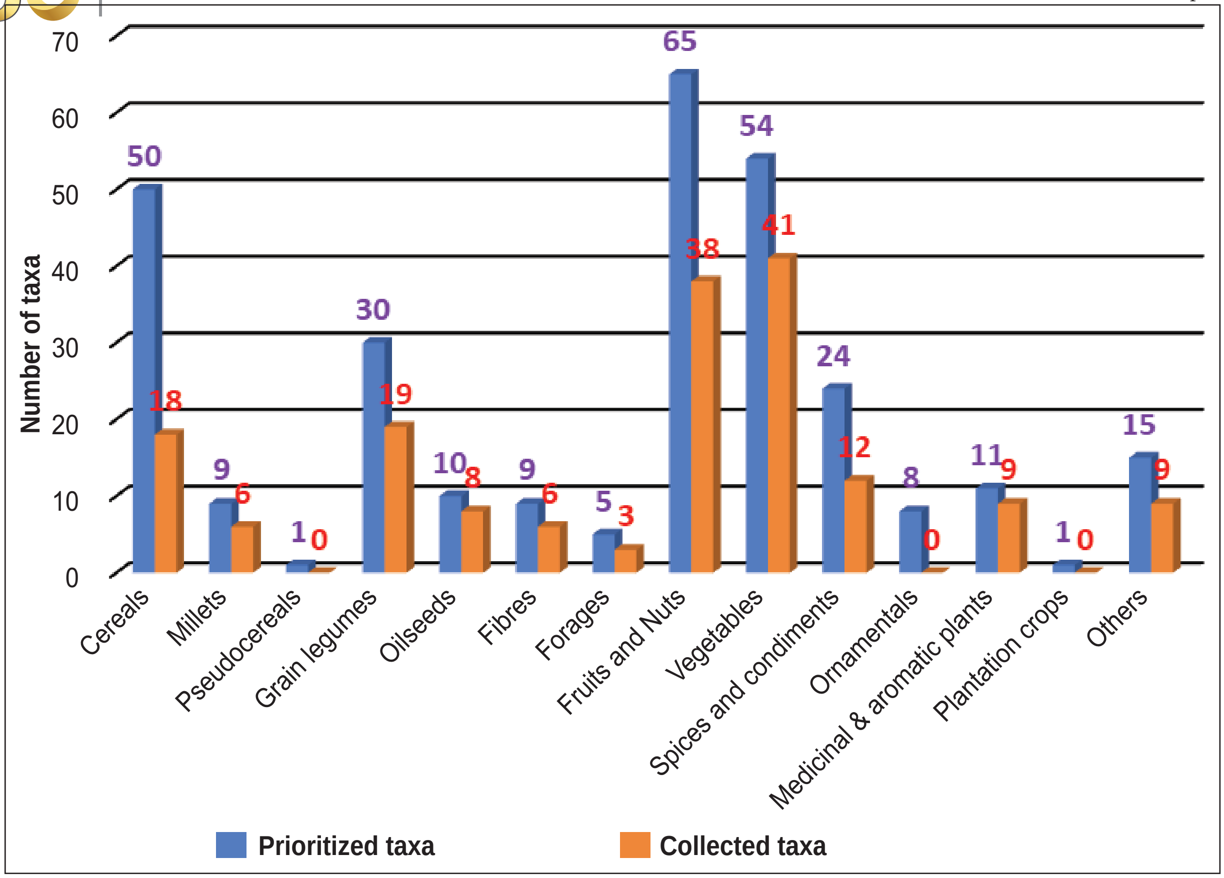

Fig. 2. A crop-group-wise comparison of highly-prioritised vs collected CWR taxa

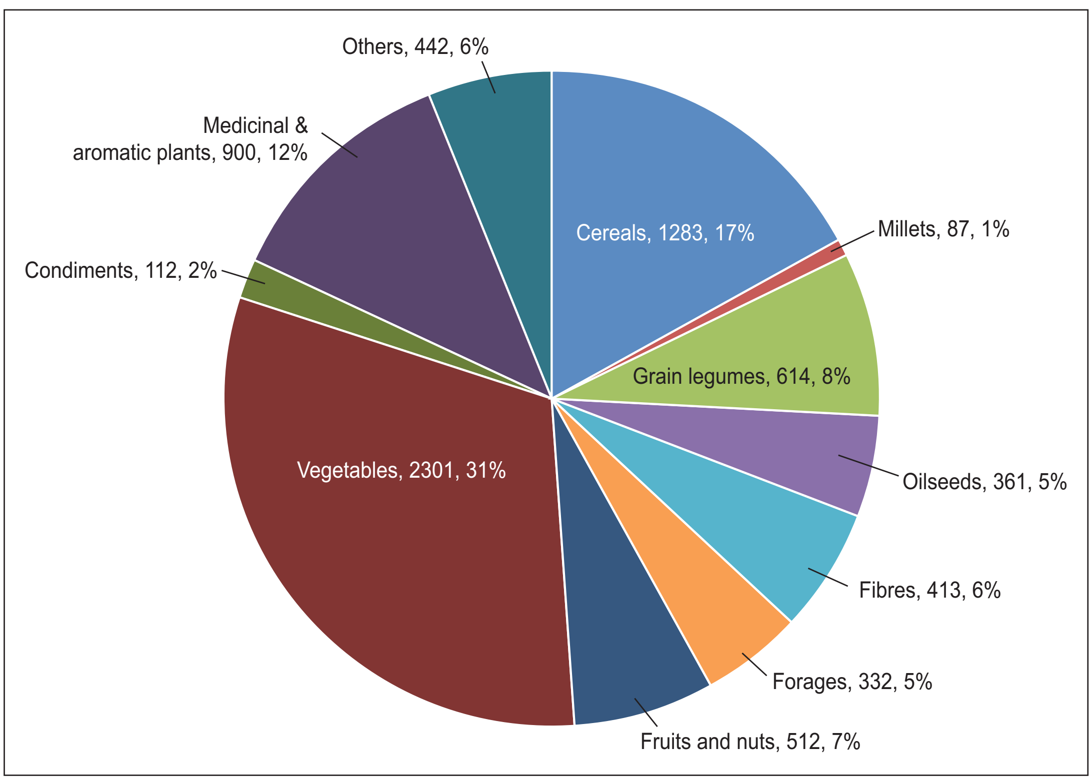

Fig. 3. A break-up of crop-group-wise collected CWR accessions

endemic to the East Coast of southern Andhra Pradesh and northern Tamil Nadu and of Sri Lanka, needs fine grid collecting. In fibre crops, >95% germplasm belongs to wild relatives of jute. A relative of Levant cotton, *Gossypium stocksii* was reported to grow in the Kachchh and Dwarka areas of Gujarat, needing extensive herbaria studies coupled with field surveys to locate and collect.

There exists a huge conservation gap in the case of CWR of horticultural crops (barring vegetables and spices) and forages, as in these cases, even systematic collecting of crop germplasm *per se* needs to be achieved. Often, crops of these groups rarely underwent the domestication process, therefore cultivated forms are hardly distinguishable from the wild ones and are often destructively harvested in the wild (esp. medicinal plants and orchids). In fruit crops, thanks to the systematic explorations undertaken for augmenting *Citrus* genepool, at the same time, nearly 25 *Musa* taxa are yet to find a place in NGB. In the case of brinjal genepool, confusion in taxonomic identity of otherwise distinct taxa – *Solanum violaceum* (with *S. anguivi*), *S. lasiocarpum* (with *S. ferox*), *S. insanum* (with *S. incanum*), is often reflected in the collections, besides reports on germplasm utilisation. Systematic studies at Bureau in the crop genera – *Momordica*, *Abelmoschus*, *Cucumis*, *Trichosanthes*, *Allium*, *Luffa* and leafy amaranths had advanced the knowledge of CWR and their relationship with cultivated species.

Important Target Areas for CWR Collection

Taxa-wise collection gaps (292 taxa) were worked out at the district level, and a total of 75 exploration trips were suggested across the country for the next five years (Pradheep *et al*., 2021). This includes fragile ecosystems such as the cold-arid Himalayas, coastal areas, A&N islands, and Thar deserts, besides some diversity-rich gap areas (see Box 2). Based on geographical significance/ uniqueness and richness of wild relatives, 15 PA were also identified for exploration and collection. Apart from representative samples, focused collection through fine-grid sampling shall be undertaken from hotspot areas (for biotic stress tolerance); cold arid Himalayas (cold), Thar desert (heat and drought), and coastal areas (salinity). Keeping in view the nature of wild species (habit/ versatility) and the remoteness of collection locality, the choice shall be made between revisit or seed regeneration in case of germplasm with insufficient seeds aimed for NGB conservation.

Box 2. Some CWR diversity-rich gap areas

- Coastal tracts, esp. East Coast, Gujarat coast
- Himalaya and NEH Region
- A&N, especially unexplored islands
- Western Ghats, esp. central & northern tracts
- Eastern Ghats, especially of Odisha, Karnataka and Tamil Nadu
- Desert areas, esp. Thar desert
- Semi-arid areas (northern and central Karnataka, adjoining Deccan Plateau, semi-arid Tamil Nadu)
- Bundelkhand region
- Duars & terai belt
- Bastar-Vizag-Malkangiri-Koraput-ranges
- Vindhya-Satpura Ranges in central India
- Chotanagpur belt of Jharkhand

Important Issues and Thrust Areas

- Shortage of trained manpower in basic disciplines such as taxonomy and cytogenetics resulting in taxonomic misidentification, and paucity of chromosomal data and crossability, respectively. Taxonomic studies/revisions and the development of illustrated keys for field identification of various wild species are worth-considering.
- Incomplete knowledge of the level of closeness of CWR, their distribution, threat status and usefulness. Crossability studies would aid in the realization of the genepool concept in crops, helpful in knowing the closest relatives. IUCN Red List has data of just 19.5% of prioritized taxa, therefore threat status assessment needs to be geared up for remaining wild species.
- Wild forms of crops need a clear entry in passport data (either in the 'biological status' field of passport data or distinguished as different infraspecific taxon). New information emanated from the studies needs to be incorporated then and there, particularly the taxonomic identity corrections including new species if any described from using existing germplasm holdings.
- Often, not all the collected/studied germplasm go for long-term conservation due to multifarious reasons.

Pradheep *et al*. (2015) identified bottlenecks leading to low seed turnout during CWR collecting and suggested means to minimise the same. Rigorous monitoring/interaction between the stakeholders during seed regeneration/ initial field establishment (in the case of vegetative propagules) would be helpful in its realisation.

Other areas which need strengthening include knowledge of the population structure of wild species, studies on conservation/storage behaviour, protocol standardization for *in vitro* (RET spp.) and pollen cryopreservation (helpful in wide hybridization). Getting blanket permission for PA entry and effective use of GIS tools would aid in representative sampling across diverse habitats. The development of an integrated database of germplasm holdings inclusive of the SAUs and allied stakeholders would aid in comprehensive gap analysis.

Conclusion

In the context of the requirement of novel genes for crop improvement, sophisticated biotechnological tools amenable to transfer useful traits to crops, increasing anthropogenic pressure and negative impact of climate change on wild species, and meagre *ex situ* germplasm collections, any effort to inventorize, prioritize, collect and conserve CWR is of paramount significance in agricultural research works. This paper identifies 861 priority taxa (769 spp.) of CWR value for 171 Indian crops and further narrowed 292 high-priority taxa for 85 important crops. About 43% of high-priority taxa were yet to be represented while 15% were represented by 1-2 acc., and 28% with <10 acc. in genebank indicating the lack of adequate representative collections in most of the taxa. Huge collection gaps were identified even in cereals and pulses, in PA and in fragile ecosystems, and accordingly, exploration trips were proposed. Working on the thrust areas identified herewith would be of help in the proper management of CWR germplasm in the country.

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