Indian J. Plant Genet. Resour. 35(3): 131–135 (2022)
DOI 10.5958/0976-1926.2022.00055.9

Plant Taxonomy and Biosystematics in PGR Collecting and Conservation

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A sound understanding of the principles and practices of plant taxonomy is essential for plant genetic resources (PGR) conservation. Identification of new crop wild relatives (CWR) taxa, designating appropriate taxon status for discontinuous variants representing a geographical area, developing descriptors for new crops, and recruiting wild economic plants and semi-domesticates into cultivation, all require a good taxonomic base. The taxonomy of cultivated plants is essentially governed by a different set of guidelines under International Code of Nomenclature for Cultivated Plants (ICNCP). Biosystematic analysis helps to elucidate the genepool relationship of wild relatives with the crop, thereby promoting its utilization in crop improvement.

Key Words: Crop wild relatives, Genepool, Germplasm, ICNCP, Plant identification

Introduction

Plant taxonomy is the practice and science of identification, naming and classification based on well-laid-out principles. Correct botanical identity of a taxon is a prelude to its utilisation in research programmes as the wrong taxonomic identity of a plant specimen may lead to spurious results and utter confusion. With the current emphasis to include more and more wild economic plants into the domain of agriculture and forestry, correct botanical identity becomes more important for research information pertaining to the taxon, and their efficient utilisation. The Indian subcontinent with four mega biodiversity hotspots (https://www.cepf.net) has 861 taxa of crop wild relatives recorded at present (Pradheep *et. al*., 2021). Ensuring the correct botanical identity of the specimen and ensuring universality in the nomenclature of newly collected material is important in the utilisation of this treasure for agricultural improvement. The wrong botanical identity of genebank samples could have far-reaching consequences as the 'original error' is repeated at many levels by varied users over a long period of time. In order to avoid such problems and in the light of the rapidly decreasing number of expert taxonomists, and in the present era of access to digital records of historic herbarium specimens and literature, a germplasm collector needs to develop plant identification skills and have an understanding of nomenclatural rules, to ensure accuracy of passport data and other initial records.

Taxonomic issues for a plant genetics resource (PGR) worker with agricultural science background are many. The foremost is designating unique morphological variants of CWR taxa into appropriate taxonomic entities and determining their taxonomic status as distinct species or infraspecific taxa. Ignoring discontinuous variants is dangerous in genebank conservation as precious variants may get unrepresented in core collections as a result of generalisation. Frequent nomenclatural changes on the basis of molecular study and phylogenetic analysis are another taxonomic issue daunting the non-classical taxonomists dealing with CWR taxa. Many are not aware of these nomenclatural changes in economically important species (e.g., tomato, pearl millet, Chinese potato, etc.). More important, the substantiating evidence for merging taxa, needs to be thoroughly checked by the PGR scientist (discussed below), especially in the case of genera with very high species diversity, rare species which are poorly represented in herbaria, taxa with minute floral parts (e.g., Poaceae), species complexes (e.g., *Oryza rufipogon- nivara-* f. *spontanea*), cryptic species and the like.

Understanding patterns of variation in crop plants and PGR, in general, was dependent on the collection and study of cultivated plants superimposed by that of wild and weedy forms (de Candolle, 1883), domestication traits, and use of wild taxa and progenitors leading to defining centres of diversity of crop taxa (Vavilov, 1922); thus, a nearly 150-year long knowledge of PGR diversity in relation to geography forms the basis of collection and

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exchange of germplasm, its use in breeding programmes and bringing into cultivation a wide range of locally used taxa in 12 mega-centres of agro- diversity all over the world (Zeven and Zhukovsky, 1975). Phylogenetic study and biogeographic analysis based strongly on newer evidence provide further clues to understanding the cultivation and domestication processes over space and time. Genepools of crop plants as defined by Harlan and de Wet (1971), though having an experimental basis related to a relative degree of crossability among crop and wild species of seed-producing predominantly annual crops, provided a concept that used morphological, cytological, phytochemical and molecular evidences to determine the wild relatives belonging to a wide range of crop genepools.

Vavilov's Law of Homologous Series (Vavilov, 1922), determined regularities in the expression in respect of the morphological and physiological characters, which distinguish varieties and races (Nanjundiah *et al*., 2022) as well as parallel variations seen in species of the same genus; he demonstrated its predictive value for variation across related genera, *viz*., wheat, barley and rye, a trend observed later in the systematic study of other taxa, *viz*., *Phaseolus* and *Vigna* (Smartt, 1990).

Precise taxonomic data helps to estimate the ecogeographic representativeness of crop genepool captured in a genebank (Dempewolf *et al*., 2014), thereby helpful in devising future collection strategies, as CWR are, in general, under-represented in genebanks across the globe (Castañeda-Álvarez *et al*., 2016). Updated taxonomic knowledge helps in the prioritization of taxa, sorting out spelling errors, orthography, mismatches in common vs scientific names, synonymy, wrong identity, misapplied names in passport data and collection, and conservation databases, including the PGR portal. Taxonomy has a clear role in preparing species inventories, red lists, identification of protected areas, gene sanctuaries, and biodiversity heritage sites. At the same time, taxonomic data is critical as well, for example, IUCN Red List or CITES has earlier named a species under their list, but because of synonymy, if this species has been merged with the related species, funding (if any) to protect its population would be in question.

Taxonomy and PGR Management

A sound understanding of plant taxonomic principles is essential in PGR management, right from exploration and collection of germplasm to conservation/documentation. Plant identification in their natural habitats needs good observation skills, field knowledge, and regular practice. Explorers perceive a wide range of taxa while on survey and collection. They need to distinguish, on the spot, target species from umpteen number of other species at the collection site. In this regard, key or spot characters in combination with habitat information available in past collection records (*viz.* in floras, monographs and treatises) are an aid to the collector. For example, if an explorer intended to collect germplasm of wild species of *Trichosanthes*, he could look for medium-sized climbers with fringed white flowers and red cricket ball-sized fruits, which are very unique and discernible traits even at a distance, and sitting in a fast-moving vehicle.

Expertise in field identification, even in the absence of flowers or fruiting specimens, rather based on available plant parts is often required for CWR collection as in many cases, by the time the seed matures, flowering might have stopped or the plant may have started to wilt and dry. The study of herbarium specimens and spirit collections/ carpological specimens are essential for the plant exploration of a specific CWR group. Publication of handy field aids like seed atlas, fruit atlas, and illustrated field guides with keys will be useful for CWR explorers (Pandey *et. al*., 2011). Habitat information including associated species is very important, especially when collecting niche-specific taxa/wild species necessitating the need for the taxonomic expertise of a collector.

Recircumscription of taxa as a result of revisionary and systematic studies is a common feature in taxonomy. PGR scientist has to make a decision based on their taxonomic knowledge and as Charles Darwin rightly suggests that "in determining whether a form should be ranked as a species or variety, the opinion of naturalists having sound judgement and wide experience seems the only guide to follow".

Morphological variations are the basis of taxonomic classification. In fact, characterization is essentially describing an accession based on a set of morphological characters called descriptors and descriptor states. The development of descriptors for crop species needs a sound understanding of morphology, which is essentially a taxonomic element. A sound understanding and application of taxonomic /morphological knowledge will help to take out unique variants and non-matching entities during the process of characterization.

Field-level practices like identification and removal of weedy or off-type plants/rogues, mechanical admixtures, rootstock vs scions, and pollinizers, all require taxonomic knowledge. Undesirable genetic contamination due to crossability with progenitors/ close CWRs (especially transgenic crops) can be conveniently sorted out using taxonomic expertise. Traditional taxonomy is still the forerunner, though the latest developments in molecular techniques (such as DNA barcoding and molecular systematics) provide substantiating and supporting evidence, and in cases such as introgression, disjunct variants within a taxon help to resolve confusion as well as determine the probable evolutionary trend. Selecting *in situ* conservation sites, demarcating genetic reserves within protected sites, and environmental impact analysis, all require adequate knowledge of the region's flora.

Taxonomic knowledge on invasive and quarantine weeds in terms of their accurate identification is a must to enable the blacklisting of species for entry to the country. Adequate awareness is essential of the changes in nomenclature, and familiarity with common synonyms used worldwide for a particular species. Here, the updated seed atlas of weeds of quarantine significance and mimicry weeds is helpful.

Updated and precise taxonomic identification and labelling of accessions form the foundation for various genebank management activities such as organizing germplasm collections and retrieving the accessions. Taxonomic units such as genus, and species, are part of the documentation systems of genebanks and information retrieval. Wherever taxonomic information up to the infraspecific level is available, documentation systems should be in a position to accommodate the same. Similarly, it is always a good practice to include author citation as a part of documentation systems including journals/ reports as there are cases with the same name proposed by different authors. There needs a mechanism to swiftly correct the taxonomic identity of germplasm if later proved to be misidentified or there is a need to redesignate with the new taxon name (in the case kept under a 'broad' species name). Correct spelling (including avoiding orthographic errors, and correct terminal ending of epithet) is a must for database entry (for that IPNI offers the best), otherwise, more than one entry will be there for the same species. Knowledge of synonyms and adequate awareness of changes in nomenclature is a must for the proper documentation of germplasm collections. Guzzon and Ardenghi (2018) suggested a taxonomic and nomenclatural peer-review process to ensure taxonomic authenticity before making each new accession accessible to different stakeholders.

ICAR-NBPGR has been instrumental in pursuing taxonomic work on CWR taxa for the past four decades which led to 24 new plant discoveries and 10 new distribution records in the country, besides numerous records on new distribution in various Indian states (Box 1; Table 1). The enormous number of diverse species represented in two major facilities at the Bureau, *viz*., National Genebank (2,000 species; 0.5 million germplasm accessions) and National Herbarium of Cultivated Plants (4,300 species; 25,000 herbarium specimens) further signifies the role of taxonomists in PGR management works.

Table 1. First report by NBPGR of PGR taxa in India based on their natural occurrence

S.No.	Taxon	Remarks
1.	*Corchorus pseudo-olitorius* Islam & Zaid	Described from Pakistan; now from Delhi and Tamil Nadu; a CWR of jute
2.	*Cucumis muriculatus* Chakrav.	Described from Myanmar, now reported from Mizoram; a CWR of cucumber
3.	*Dioscorea piscatorum* Prain & Burkill	Lesser Sunda Islands native species was reported from Nicobar; wild edible tuber used by Nicobaris
4.	*Fagopyrum gracilipes* (Hemsl.) Dammer ex Diels	Chinese native species reported from Arunachal Pradesh; weed in buckwheat fields
5.	*Momordica subangulata* Blume subsp. *subangulata*	Indo-Chinese taxon was located in Arunachal Pradesh and Nagaland; a CWR of teasel gourd
6.	*Rubus praecox* Bertol.	European species reported from Jammu & Kashmir; a minor fruit related to blackberry
7.	*Trichosanthes dunniana* H.Lév.	Indo-Chinese species documented from Manipur, Mizoram, Nagaland
8.	*Trichosanthes tricuspidata* Lour.	Indo-Chinese species reported from A&N islands; *T. bracteata* was earlier misidentified in Indian literature
9.	*Trichosanthes wallichiana* subsp. *subrosea* (CY Cheng & CH Yueh) K Pradheep & KJ John	Indo-Chinese taxon reported from NE India. New nomenclatural combination made
10.	*Ziziphus subquinquenervia* Miq.	Indonesian species was reported from Great Nicobar; minor fruit

Box 1. New Taxa Described by NBPGR

1. *Abelmoschus angulosus* Wight & Arn. var. *mahendragiriensis* RC Misra
2. *Abelmoschus enbeepeegearensis* K.J. John, Scariah, Nissar, KV Bhat & SRYadav
3. *Abelmoschus palianus* Sutar, KV Bhat & SR Yadav
4. *Abelmoschus pungens* var. *mizoramensis* KJ John, Krishnaraj & K Pradheep
5. *Allium negianum* A.Pandey *et al*.
6. *Begonia bachulkarii* Aitawade, Kattuk & SR Yadav
7. *Cucumis melo* subsp. *melo* var. *alwarensis* A Pandey & S Rajkumar
8. *Curcuma amada* var. *glabra* Velay, Unnikr, Asha & Maya
9. *Curcuma karnatakensis* Amalraj, Velay & Mural
10. *Curcuma kshonapatra* Velay
11. *Curcuma kudagensis* Velay, VS Pillai & Amalraj
12. *Curcuma longa* var. *vanaharidra* Velay, Pandrav, JK George & Varap
13. *Curcuma malabarica* Velay, Amalraj & Mural
14. *Curcuma nilamburensis* Velay, Mural, Amalraj, PL Gautam & S Mandal
15. *Curcuma thalakaveriensis* Velay, Amalraj & Mural
16. *Curcuma vellanikkarensis* Velay, Mural, Amalraj, PL Gautam & S Mandal
17. *Herpetospermum operculatum* K Pradheep, A Pandey, KC Bhatt & ER Nayar
18. *Momordica cochinchinensis* (Lour.) Spreng. subsp. *andamanensis* Kattu, Roy & Krishnaraj
19. *Momordica sahyadrica* KJ John & VT Antony
20. *Momordica sahyadrica* subsp. *anamalayana* KJ John, K Pradheep & Krishnaraj
21. *Piper pseudonigrum* Velay & Amalraj
22. *Trichosanthes dunniana* H Lév. subsp. *clarkei* K Pradheep
23. *Vigna konkanensis* Latha, KV Bhat, IS Bisht, Scariah, KJ John & Krishnaraj
24. *Vigna sahyadriana* Aitawade, KV Bhat & SR Yadav

Cultivated Plant Taxonomy

Taxonomy and nomenclature of cultivated plants especially within the crop taxon is an entirely different proposition from that of wild plants. While up to species level cultivated plant nomenclature is governed by ICN guidelines like any other plants, designating infraspecific categories like 'cultivars' man-made hybrids, chimaeras etc. are governed by an entirely different set of rules under the ICNCP. With private sector breeding initiatives progressing at a faster pace, many new cultivars/varieties in perennial horticultural plants and vegetatively propagated crops like tuber crops, banana, potato, sugarcane, fruit trees and ornamentals are bound to be developed and along with that IPR related legal issues, which demand proper naming of new cultivars.

Capacity Building

A strong plant taxonomic base was felt and stressed by expert committees like RAC & QRT of ICAR-NBPGR. Considering these suggestions, recently ICAR-NBPGR has signed an MoU with Botanical Survey of India (BSI) for fostering mutual cooperation in various aspects of plant taxonomic research related to PGR. Further, in order to enhance the taxonomic knowledge base of PGR scientists, especially plant identification skills, the ICAR-NBPGR conducted a one-week online training programme on Plant Taxonomy for the benefit of entry-level scientists of the national agricultural system.

Suggestions for Furthering Taxonomic Studies in PGR

1. An attachment training on taxonomy and morphology for all newly recruited PGR workers commissioned to work in the PGR discipline. About three months of attachment in premier institutes/labs (such as BSI, CSIR-NBRI, FRI, Shivaji University, Kolhapur, and other centres of excellence in plant taxonomy) is desirable. A collaborative programme between scientific societies such as ISPGR and the Indian Association of Angiosperm Taxonomy (IAAT) may be resorted to bridge the knowledge gap in applied taxonomy.
2. Currently working PGR scientists need hands-on taxonomy training (2-3 weeks) at regular intervals (in 5 years) in key deficit areas such as plant identification skills including short-cut keys for discerning different families and genera, spot characters for identification of CWR taxa in the field, botanical nomenclature, and cultivated plant taxonomy. International taxonomy training needs to be encouraged for a few senior-level scientists of the bureau. NBPGR authorities need to groom strong expertise in the taxonomy of CWR/cultivated plants and their infraspecific classification, and an MoU with appropriate institutes (such as CSIR-NBRI, IPK-Gatersleben) may be contemplated. A designated taxonomist at the national level positioned at NHCP-NBPGR/PPVFRA is a dire need to address taxonomic issues in cultivated plants as well as

promote research in this comparatively neglected branch.

3. In collaboration with the expert institutes, it is dire need of the hour to bring out authentic checklists, interactive keys and illustrated plant identification guides (with the inclusion of fruit, seed, and vegetative characters) for different plant/ crop groups/ economically important genera to faster realization of correctly-identified wild germplasm for using in PGR and crop improvement works. It includes redesignating existing germplasm collections with correct taxonomic identity and accepted names. Also, focus on identification using seeds, seedlings and vegetative characters for use in genebank management may be given attention.
4. Revamping PG syllabus for PGR course, especiallly incorporating more credit hours for enhancing plant identification skills as a sizeable percentage of fresh ARS recruits for the discipline of Economic Botany and PGR are from agricultural science background.
5. Undertaking comparatively basic taxonomic studies (especially systematic studies for delineating CWR taxa) in unattended crop groups such as medicinal and aromatic plants, ornamentals and forages, after adequate prioritization as part of dissertation work of M.Sc. (PGR). Voucher herbarium specimen of experimental study material needs to be safeguarded to ascertain their taxonomic identity in future.
6. Digital databases, *viz*., World Checklist of Vascular Plants (WCVP), Plants of the World Online (POWO) and Global Biodiversity Information Network (GBIF) are currently being used as a 'ready reckoner' for accepted plant names. There is a need to recognise that these, in contrast to a data collator such as International Plant Names Index (IPNI), are compilations of historical data on plant nomenclature, and as such should be used as a source of information, rather than authentic and verified taxon names. PGR workers should be trained to make use of these sources to check the latest nomenclature.

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