Access to Crop Wild Relatives and Their Use: An Overview

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(Received: 21 August 2010; Revised: 3 August 2011; Accepted: 5 August 2011)

The Crop Wild Relatives (CWR; wild species closely related to crop taxa) have the potential to contribute beneficial traits to crop plants. They are at great risk of threats due to habitat loss, degradation and climate change and hence require immediate collection and conservation to make use of their potential value. The plant genetic resource programmes at the national, regional and global levels provide strong recommendations for conservation and use of CWR. The present account mainly deals in the Indian context and provides a wide array of information on importance, approach, access and utilization of this group of genetic resources for various users.

Key Words: Access, Crop wild relatives, Legal issues, Utilization

Introduction

Increasing recognition of the value of crop wild relatives (CWR) as a source of genetic material for crop improvement has enhanced the plant genetic resource management activities in different parts of the world. The CWR are species closely related to crop taxa which have the potential to contribute beneficial traits such as pest or disease resistance, wider adaptability/ tolerance/ resistance to disease, insect-pests, quality attribute, yield and wider adaptability to the crop. However, CWR, like any other group of wild species, are subject to increasing threats due to habitat loss, degradation and land use patterns, over-exploitation for use and climate change and hence require immediate collecting to make use for their value.

The utilization of CWR requires a multidisciplinary linkage at various levels *viz*. researchers, conservators, policy makers, partners, local communities and many other end users. The conservation programmes at the national, regional and global levels provide strong recommendations for conservation and use of CWR (Heywood *et al.*, 2008). However, activities on collection/augmentation, characterization, conservation and utilization of CWR have been given less focused as compared to crop plants. The present account mainly dealt in the Indian context and provides a wide array of information on importance, approach, access and utilization of CWR. Information on thrust, issues and concerns on legal aspects on this group of plant genetic resources included in this paper are the views of authors in light of current developments and not of National Bureau of Plant Genetic Resources.

Why Important?

In early part of the 20th century, there was a speculation that hybridization may play a major role in adaptive evolution (Stebbins, 1950). Artificial hybridization in recent times between crop plants and their wild progenitors, as well as wild relatives has led to variation in many crops. The CWR have been the donors of many useful traits such as resistance/tolerance to diseases, insect-pests and other stress (Sharma *et al*., 2003). Some of which include wild annual rice (*Oryza nivara*), the only source of resistance to rice tungro virus, wild lady's finger (*Abelmoschus tuberculatus*) for yellow vein mosaic virus and wild urd (*Vigna mungo* var. *silvestris*) for resistance to yellow vein mosaic virus (Arora and Pandey, 1996).

During 1970s, the great devastation caused by the grassy stunt virus in rice fields, from India to Indonesia, damaged the world's most important food crop. After a critical screening of over 17,000 accessions of cultivated and wild rices, a sample of *O. nivara*, collected from Gonda, Uttar Pradesh was found to contain gene for disease resistance. Presently rice containing gene for resistance to this virus is cultivated over a large part of Asia. Similarly, the muskmelon crop, threatened by a downy mildew outbreak was saved by a wild species of Indian muskmelon (*Cucumis*) which provided the gene for resistance to downy mildew (Rana, 1993).

Deliberate introduction of genes from wild progenitors is now being employed in all major crop improvement programmes (Khush and Brar, 1988). Identification of CWR of many crop plants and establishing their close

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genetic affinities with crops have made it possible to utilize them as potential source of genetic variation by the breeders (Kalloo and Bergh, 1993; Sharma *et al.*, 2003).

Introgression of genes from more distantly related species to a crop taxa is difficult due to crossability barriers, hybrid incompatibility, sterility, etc. (Newell and Hymowitz, 1982). However, successful introgression of useful genes from distantly related species to wild or cultivated species depends on cross-compatibility, production of hybrid seeds, normal development of F_1 hybrids, partial seed production (by natural or by back-crossing) and no hybrid break down in the segregating generations. The traits with biotic and abiotic stresses have made CWR a special category of plants for utilization in improvement of cultivated types (Kalloo and Chowdhary, 1992).

Some researchers observed that CWR are less vulnerable to genetic erosion, provided their environment is protected (Kalloo and Chowdhary, 1992). Their indiscriminate/over-exploitation for commercial use, large-scale deforestation, changing land use are the major causes of depletion of species from nature.

Access to CWR: How?

In the Indian context information pertaining to distribution, potential traits and crossability/hybridization potential of wild species with their crops is scattered. The knowledge on role of secondary genepool in crop evolution and potential/ desirable traits is insufficient. There is a need for evaluation/ characterization and cataloguing of CWR for desirable traits through the following steps:

a) Assessment of diversity
b) Identification (source, availability, potential traits)
c) Augmenting diversity
d) Evaluation/ characterization; multiplication/ conservation
e) Utilization

a) Assessment of Diversity

Diversity Distribution in CWR in India: The Indian gene centre, a major centre of domestication and diversity of crop plants (Zeven and de Wet, 1982; Arora, 1991) has three of the world's major hot-spots (Myers *et al.*, 2000; www.conservation.org.). It has over 47,000 plant species, including vascular plants (a dominant component) representing over 17,500 species of the angiosperms. High rate of endemism and intra-specific variation in Indian species (5,725 endemic taxa) is represented from three major phyto-geographical areas namely the Himalaya (3,471 species), the peninsular India (2,015 species) and the Andaman and Nicobar Islands (239 species) (Nayar, 1997). Amongst these the most significant component related to crop genepool is the CWR (Arora, 1991; 2000).

The Indian gene centre harbours about 166 species of native cultivated plants. The crops with primary, secondary and regional centers of diversity represent a part of native and introduced species which account for over 480 species (Nayar *et al.*, 2003). Diverse agro-climate and agricultural practices have led to rich diversity of crop species (landraces and cultivars) and the diversity in over 320 CWR (Arora, 1991; Arora and Nayar, 1984) along with wild economic species and weedy taxa that constitute a wild useful genepool (Box 1).

Crop wild relatives are component of agro-biodiversity on one side and floristic diversity occurring in biotically disturbed habitats on the other side. The CWR by and large, occur in grasslands, scrub vegetation and open degraded forest areas, disturbed habitats and farmer's fields as weedy components, within the major vegetation types. Seven botanical areas/centers have been identified in India: Western Himalaya, Eastern Himalaya, North-Eastern Region, Upper Gangetic Plains, Indus Plains, Western Peninsular Region and Deccan/ Eastern Peninsular Region (Arora and Nayar, 1984; Arora, 2000)· Maximum concentration of species is observed in the Western Ghats, North-eastern Region and the high altitude of the Western Himalaya. The taxonomic identification of CWR requires a skill on systematic botany. This is perhaps the reason why wild relatives are meagerly collected and represented in the germplasm collections of many germplasm holdings.

Box 1. Crop wild relatives (CWRs)

- ***Cultivated plants*** have been derived from the crop wild relatives through the process of selection followed by hybridization for bringing desired improvement.
- ***CWR*** have contributed significantly towards improvement of crop plants such as paddy, wheat, sugarcane, potato, brinjal and tomato.
- ***CWR*** are economically important for edible, medicinal and other uses: *Allium, Cicer, Citrus, Coix, Crotalaria, Dioscorea, Prunus, Rubus, Solanum*, etc. This class may include undomesticated wild species utilized by man.

National Inventories on CWR: During 1980s efforts for synthesis of information based on floristic data and exploratory studies brought out a scientific monograph "Wild Relatives of Crop Plants in India" (Arora and Nayar, 1984) and revisionary works in subsequent status papers (Arora, 2000; Arora and Nayar, 1984, Arora and Pandey, 1996). This monograph included information on about 320 species of CWR distributed in different phytogeographical regions of India namely, Western Himalaya (125); Eastern Himalaya (82); North-eastern region (132); Gangetic Plains (66); Indus Plains (45); Malabar/ Western Peninsular region/ Western Ghats (145), and Deccan/ Eastern Peninsular region/ Eastern Ghats (91). Of these species, 60 are endemic and rare taxa. Different crop-groups based on their agri-horticultural importance (number of species given in parenthesis) were: cereals and millets (51), legumes (31), oilseeds (12), fibres (24), vegetables (54), fruits (109), spices and condiments (27) and miscellaneous (26).

Systematic documentation using passport information generated through exploratory studies, literature, etc. will help in compiling scientific database and updated information on distribution, phenology, ecology, cytological, evolution studies for potential traits, etc., of CWR. This would provide a baseline for planning and execution of germplasm exploration and collection programmes, sorting out the priority areas/species for collection, multiplication, evaluation, utilization, *vis-à-vis* effective management and adopting suitable strategies. Updating and bringing out forthcoming publications on "Potential Value and Utilization of CWR of India" would be desirable in this context.

b) Identification (Source, Availability, Potential Traits)

The wild relatives, semi-domesticated and distantly related taxa occurring in developing countries have contributed significantly towards improvement of major crop species (Witt, 1982). Identification and utilization of a single gene of importance has played a major role in crop improvement. For example, an accession of wild and weedy tomato from Peruvian Andes in 1962 has been the source of high sugar content in modern tomato (Khoshoo, 1988). Source material (if exotic) requires channeling through specific procedures (import into India as per the provisions of the Plant Quarantine Order 2003). Collection of germplasm of an indigenous material from the source locality (protected habitat or site for endangered/threatened/rare species) requires prior permission of the Biodiversity Authorities.

c) Augmenting CWR

The germplasm of CWR is augmented through exotic and indigenous sources. The access to indigenous CWR germplasm is through collection that requires considerable skills. National Bureau of Plant Genetic Resources (NBPGR) as a national nodal organization, over the last three decades has been actively engaged in germplasm collecting and conservation of such biodiversity from exotic and indigenous sources (Arora *et al.*, 1975; Dhillon *et al.*, 2001). Realizing the importance of CWR in crop improvement, domestication and use of native diversity, these activities got further impetus with implementation of a mission-mode sub-project on "Sustainable Management of Plant Biodiversity' under the National Agricultural Technology Project (NATP)" (Pandey *et al.*, 2004; Pareek *et al.*, 2006).

During 1976-2004, collective national efforts have resulted in germplasm collecting from diverse phytogeographical regions/habitats of 23,118 accessions of wild species (including wild/weedy relatives of crop plants) belonging to 124 genera and 389 species. The diversity was augmented in genera *Piper* (18 species), *Dioscorea* and *Vigna* (16 species each), *Curcuma* (14 species), *Solanum* (12 species), *Citrus*, *Syzygium* and *Zingiber* (11 species each), *Cinnamomum* (10 species), *Allium* (9 species), *Momordica*, *Oryza* and related genera, *Trichosanthes* and *Sesamum* (6-7 species each). Major thrust in collections was made under National Agricultural Technology Project (NATP) during 1999-2004.

d) Evaluation, Multiplication, Conservation

The CWR for all their proven value and obvious potential have not been fully utilized principally due to lack of awareness about the potential of wild material, pattern of variability, reproductive biology, the knowledge and aptitude for identification, etc. The problem of taxonomic delineation is more serious for utilization of CWR. Conventional germplasm holdings are unable to represent full spectrum of variations and useful trait(s)/represented in the diversity.

Important examples of CWR with identified traits in India are *Oryza nivara*, a wild relative of cultivated *Oryza* (paddy), having resistance to grassy stunt virus from Uttar Pradesh; *O. coarctata*, a weedy relative with hardiness traits for saline/marshy habitats from Sunderban delta

region in West Bengal; *Eleusine compressa*, a wild relative of *E. coracana* (finger millet) from north western arid tracts, having traits for hardiness and drought tolerance; *Vigna mungo* var. *silvestris* and *V. radiata* var. *sublobata*, wild relatives of cultivated *V. mungo* (urd) and *V. radiata* (mung), respectively from Ghats and adjacent areas, exhibiting tolerance to yellow mosaic virus; *Cicer microphyllum*), a wild relative of *C. arietinum* (chickpea) having cold hardiness and more seeds/ pod from high altitudes of Himalayas; *Sesamum laciniatum* from coastal Andhra and Tamil Nadu, a wild relative of cultivated *S. indicum* (sesame) having resistance to leaf phyllody disease; *L. perenne*, a wild relative of cultivated *Linum usittatissimum* (linseed) with cold hardy traits from Lahaul and Spiti region and other parts of Western Himalayas; *Citrus latipes*, a wild relative of cultivated *Citrus* species (lemon and limes) with cold resistance from the Shillong plateau, Khasi hills; *Abelmoschus tuberculatus* and *A. manihot*, wild relatives of *A. esculentus* (lady's finger) tolerant/resistant to yellow vein mosaic virus and fruit borer from northern India.

The multiplication of germplasm of wild relatives in newer habitats (to which it is poorly adapted) is in itself a major cause of loss. For example wild relatives of *Vigna* collected from Western Ghats may be very poorly adapted to conditions of north India and thus are difficult to maintain and multiply under normal field conditions. Multiplication, evaluation and characterization should be done at least at 2-3 geographical locations of similar latitude/longitude for conservation and future utilization.

At the time of maintenance of CWR, seed shattering during field operations (evaluation/characterization) results in soil infestation which may lead to appearance of unwanted plants in subsequent seasons. Hot-spots and critical habitats should be used for conservation and for protection of wild species. Role models for *in situ*/ *on farm* conservation may be developed on regional basis. For this, community involvement and less dependence of local people on the natural stock (wild genetic resources) may be emphasized.

The NBPGR networks with its regional stations and 59 National Active Germplasm Sites (NAGS) representing crop-based institutes, national research centres (NRCS), State Agricultural Universities (SAUS) for multiplication, evaluation, conservation and distribution of active collections of CWR. The current holdings of wild species conserved in the national genebank are meagerly represented from Indian region. Accessions from widely distributed habitats are required to be augmented and conserved. Special collection missions are needed in areas of occurrence of diversity and conserved using *ex situ* and *in situ* approaches.

e) Utilization

Utilization of CWR involves: Identification of wild genepool of the crop; availability of sufficient material for screening and evaluation of desirable trait; and appropriate method for gene transfer. Based on genetic affinities between the crop species and CWR they can be classified into exploitable and unexploitable types. The first group includes the wild progenitors of crops, wild and weedy forms that were called the primary genepool of crops (Harlan and de Wet, 1971). This also includes the distantly but cross compatible wild related species, leading to partly fertile cross-progenies (secondary genepool). The unexploitable category of CWR includes the tertiary genepool that has little direct value. They can be used to trap valuable genes by application of gene transfer techniques.

By utilizing modern techniques such as DNA fingerprinting and molecular techniques to identify the genepool and tissue culture technique (embryo's rescue), the desired traits of wild species can be exploited. Through these approaches/applications, utilization of secondary and tertiary genepool has now become possible. However, our knowledge of CWR of most crops is still fragmentary. Basic information on species delimitation, distribution and diversity of desirable traits and genetic variation, chromosome numbers, crossability aspects, etc. in many species is either incomplete or totally lacking.

The utilization of crop wild relatives (CWR) genes to improve crop performance has been known for more than six decades. The improved interspecific hybridization techniques have led to an increase in use of secondary and tertiary genepool of many crops in the past (Hajjar and Toby, 2007). There has been steady increase in rate of release of cultivars containing genes from CWR. Introduction of genes from CWR into crops of major global food security are met with basic sources i.e. from '*in situ*', the farmers' fields and uncultivated land. Majority of new breeding materials or germplasm held in national gene bank, or organizations and the 'in trust' collections are maintained by the International Centers of the CGIAR.

Accomplishment of interspecific crosses between crops and CWR has opened new dimensions in the utilization of wild relatives in various crop improvement

programmes. The value of wild relatives was better recognized with findings of *Zea diploperennis*, a new teosinte from Mexico (Iltis, 1979) and *Oryza nivara* from India (Govindaswami *et al.*, 1966). Crossability of *Allium cepa* and *A. sativum* with *A. roylei* (a accession of Indian origin) has opened a new avenue for utilization of Indian alliums. This species has been used for transferring resistance for powdery mildew and leaf blight in the cultivated taxa (de Vries *et al.*, 1992).

The CWR resources have also been utilized as crude product in traditional medicine and traded worldwide in different regions of the globe. Over 20 per cent of these medicinal plants traded in Germany are naturalized outside their region of economic utilization and only 40 per cent are native, for example, Chinese Ginseng (*Panex ginseng*), from Afghanistan, orchids from India, etc. (Kerry Kate and Laird, 1999).

Problems Associated with CWR

While collecting the germplasm of wild relatives from natural population, problems are encountered due to asynchronized seed maturity, availability of insufficient material due to poor density of plant population and dormancy in the bud woods (trees and vegetatively propagated species). Seed germination and lack of suitable agro-climatic conditions for multiplication, often result in loss of germplasm during the process of seed multiplication. The asynchronised seed maturity and shattering habit are problematic traits associated with wild species in the natural habitats, collection sites and during evaluation and characterization. Seed dormancy problem may be overcome by breaking dormancy, using elaborate and time-consuming protocols. Using standard seed treatment protocols, which require expertise, financial inputs and manpower, this problem, may be overcome. The germplasm of wild relatives is too often represented by a few accessions available with the institutions and are considered inadequate to represent wild germplasm.

Access to CWR: Legal Issues

Enforcement of Convention on Biological Diversity CBD (1992) and provisions of Trade Related Aspects of Intellectual Property Rights (TRIPS) have led to the apprehension that exchange of germplasm would get restricted. In the post-CBD era, there was an overall decline in per cent introduction of PGR (Arjunl Lal *et al.*, 2009). Exchange of CWR in the post-CBD era is imperative as the use of exotic species is much desired for crop improvement, such as successful use of CWR of tomato, potato, etc. that have been build up through vast range of diversity and a systematic plan of addition to the diversity by collection and introduction. This activity is now restricted due to the condition for prior permit for access of germplasm (Lal *et al.*, 2009). The trend may however change after the International Treaty on Plant Genetic Resources for Food and Agriculture (IT-PGRFA), a legally binding (Kerry Kate, 1999; Gadgil *et al.*, 1996) which envisages a facilitated access to plant genetic resources for food and agriculture held by countries through multilateral system (MS) of exchange. This access under the Treaty would be only for utilization, conservation, research, breeding and training. However an access for chemical, pharmaceutical and other non-food and non-feed purpose is not covered under the Treaty. The exchange of genetic resources (Annex 1 crops of the Treaty: including 35 Food crop genera and 29 Forage Crop Species) would be under the conditions of a standard material transfer agreement (SMTA).

The mechanism of access to genetic resources from India as envisaged in the Biological Diversity Act 2002 is as follows. Section 3 of the Biological Diversity Act 2002 provides mandatory prior approval by all non-Indians (as defined in the Act) from the National Biodiversity Authority (NBA) for obtaining any biological resources occurring in India or associated knowledge for commercial or any other use. However, there are exemptions from seeking approval of NBA for exchange of genetic resources under collaborative research projects approved by the Government of India, including bilateral/MoU/multilateral agreements. Further, section 6 of the NBA grants such approvals subject to terms and conditions so as to secure equitable sharing of benefits arising out of the use of accessed biological resources, and associated knowledge. Similarly Indian industry is required to provide prior intimation to the concerned State Biodiversity Board (SBB) about the use of biological resource, and the SBB has the power to restrict any such activity which violates the objectives of conservation, sustainable use and equitable sharing of benefits. The NBA as well as the SBB is required to undertake mandatory consultation of the concerned local level Biodiversity Management Committees (BMCs) for decision making process relating to access and benefit sharing, thereby formalizing the prior informed consent by communities for access and benefit sharing. Under the Plant Varieties and Farmers' Rights Act, 2001 the rights are shared on use of any traditional varieties/landrace of a cultivar developed through selection and identification

for traits/ usefulness, and wild species or a wild relative about which the farmer possess the common knowledge, through recognition of farmers and benefit sharing of provisions from the ' Gene Fund'.

Concerns: CWR Access for Utilization

In the present international scenario, global climatic changes, unsustainability of high input agriculture, search for novel genes for biotic and abiotic stress have increased the focus on access, conservation and utilization of potential diversity in the years to come. To meet these challenges more plant species have to be tested against the threat of nature. The modern agricultural practices indirectly favour reduction of diversity by supporting crop subsidies for cultivating high yielding varieties of crops, use of herbicides to eliminate CWR, weedy relatives of crop plants. For effective implementation of biodiversity conservation programmes, involvement of local communities by providing positive incentives is desirable (Gadgil et al., 1996).

Indiscriminate harvest can be avoided by dissemination of information on sustainable harvesting tips in relation to ensuring public confidence, to maximize economic benefits and to minimize negative impacts on habitats and species diversity from use of wild genetic resources at local level. Over-exploitation of commercially important CWR as *Dioscorea, Allium, Rauvolfia* adopting precautionary measures for controlled grazing, organizing environmental education programmes and by harvesting only after maturation/ shedding of seeds, for retaining some part for perpetuation and by practicing scientific methods of storage can help to save biodiversity including CWR. Through formal and informal educational curricula, emphasis can be laid on environmental education to conserve the biodiversity. Special training courses should include issues such as diversity and management strategy, knowledge on potentials of wild relatives and promotion of biodiversity conservation.

Gaps identified on management of CWR relatives should be bridged through appropriate research and development. Communication links among relevant national/ international institutions and rapport between scientists and administrators, Non-Governmental Organizations (NGOs) and local communities can facilitate the networking in the present era.

Conclusions

The genetic erosion has increased alarmingly in all parts of the world. The national and international concern for systematic management of wild and weedy relatives of crop plants has necessitated collection and conservation for immediate and future use in breeding programmes. In response to the CBD regime, there has been a need to assess the potential of wild wealth available with us. In view of these provisions, CWR, with valuable traits and hidden potential need to be collected, conserved, characterized and documented on priority basis.

Emphasis needs to be given on target collection, conservation and sustainable management of CWR using *ex situ* and *in situ* measures especially for rare/endangered species. Collaborative/networking approaches through inter-institutional linkage can help in periodic monitoring of the status of wild genepool. For this, Botanical Surveys, Ministry of Environment and Forests, Government of India and NGOs may actively collaborate to perform the task effectively.

Keeping in view the importance of CWR in the national context, the following thrust areas have been identified:

- Assessment of gaps in collection; survey and collection of CWR through special exploration missions in priority areas/ for priority traits
- Characterization/ evaluation for desirable traits for utilization of CWR
- Establishing linkages between organizations involved in *ex situ* and *in situ* conservation
- Developing documentary information and data bases, and
- Awareness generation at various levels

The above account briefly highlights the access to CWR for utilization with special reference to the Indian gene centre. The information contained would help in understanding the basics of CWR in general and also help in assessing and evaluation/ validation of these resources with particular reference to PGRFA and rights to access and benefit sharing with global terms.

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