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Plant Genetic Resources and Traditional Knowledge: Emerging Needs for Conservation

Mehfuz Hasan and Hasan M. Abdullah

Abstract

Plant genetic resources and traditional knowledge comprise an inimitable universal heritage, and their conservation and utilization are of instantaneous concern. As it is the basic source of all types of agricultural activity, the conservation and protection of these precious materials are of immense potential. Plant genetic resources conserved by the farmers constitute our invaluable assets to meet the growing demands to increase crop production and productivity. The Convention on Biological Diversity is engaged with the genetic erosion and waning use of agrobiodiversity in modern-day agriculture. This is perhaps the most comprehensive intergovernmental agreement concerning for conservation, proper utilization of genetic resources, and giving out the benefits arising out of exploitation in an equitable way. Concern about the looming accessibility of agricultural production, food security, and environmental stability has encouraged the conservation of plant genetic resources and indigenous knowledge to the pinnacle of the international development strategies. Plant genetic resource and traditional knowledge conservation and utilization have been the source of dramatic scientific changes over the course of the last few decades. Precise evaluation and documentation of plant genetic resources and traditional knowledge are a prerequisite for their sustainable utilization to secure the food security.

6.1 Introduction

This is really tough to know how many species have been developed in 3000 million years since the Earth was created. We really don't know how many of them disappeared or how many are being generated. However, it is assumed that approximately 10 % of the species that came into

M. Hasan, Ph.D. (✉)
Department of Genetics and Plant Breeding,
Bangabandhu Sheikh Mujibur Rahman Agricultural
University, Gazipur 1706, Bangladesh
e-mail: saikathu@yahoo.com

H.M. Abdullah, Ph.D.
Department of Agroforestry and Environment,
Bangabandhu Sheikh Mujibur Rahman Agricultural
University, Gazipur 1706, Bangladesh
e-mail: hasan.abdullah@bsmrau.edu.bd

R.K. Salgotra, B.B. Gupta (eds.), *Plant Genetic Resources and Traditional Knowledge for Food Security*, DOI 10.1007/978-981-10-0060-7_6

existence received scientific names which is about 250,000–300,000 species. Of these 20 % species have supplied 90 % of our food requirements; nine species provided 75 % of our main food necessities, and only four species, i.e., rice, wheat, maize, and potatoes, have supplied 60 % (FAO 2012). We can now easily guess the reasons which have led to the erosion of many of our genetic resources.

Plant diversity is characterized by an estimated 300,000 species of higher plants. Only about 7000 species have been domesticated till now and cultivated by humans over the millennia for various proposes. Our nutrition is actually supplied by mere 30 plant species. It provides 95 % of dietary energy or protein (http://www.nbpgr.ernet.in/Why_Conserve_PGR.aspx). Every year a small number of new varieties are released around the world according to the need for a particular terrain. But nature has given us a tremendous amount of diversified plants along with their wild relatives. These diversified plants provide the sources for breeding new materials which can withstand biotic and abiotic stress environment and can be grown in different regions of a particular territory.

6.2 Importance of Genetic Diversity in Plant Genetic Resources

Plant Genetic Resources (PGR) can be considered as any type of reproductive or vegetative propagating material of cultivated varieties and newly developed varieties, obsolete cultivars, landraces, wild and weedy species, near relatives of modern cultivars, and particular genetic stocks inclusive of elite and current breeders' lines and mutants. In other words, it can be considered as any living material of present and plausible value for mankind. PGR include all plants that possess valuable traits including all of our agricultural crops along with their wild relatives. The genes, DNA fragments and RNA, and other genomic resources are also included as PGR, therefore, are nowadays conserved in gene banks for their specific hereditary functions.

Genetic diversity of plants ensues principally as variation in the nucleotide sequence of DNA of any species. A small portion changes due to a mutation which is observed into protein variation and into marker polymorphisms, characters, and physiological and morphological variation in agronomic traits that results into varieties given different names by the respective authority (http://www.fao.org/docrep/013/i1500e/i1500e20.pdf). In sexually producing organisms like higher plants and animals, the offspring is produced through the union of reproductive cells from two genetically different parents. So, the offspring produced from this cross-pollination are genetically dissimilar from their parents.

Sexual reproduction is very crucial for upholding genetic diversity contained by a species since it coalesces the parental genetic material, ensuing genetically diverse offspring different from their parents. When a population of an organism is characterized by a large gene pool, which means the population has a broad genetic base, the organisms have a better opportunity of existing and flourishing than a population which has a narrow genetic base. In this case, some of the plants of this particular population may have some traits which would make them resistant to any kind of biotic or abiotic stress or they may have some traits which would give them better chance for survival. According to "natural selection," the fittest individuals survive and go on to imitate. So, if there is an epidemic condition which threatens a particular species, the more genetic variability there is contained by that species, the higher the likelihood that at least some of the individuals will show resistance and will endure. In the lab, through recent advancements, there are a lot of techniques which can be useful for plant breeders to improve the accessible varieties and also to generate a new genetic variant. Through conventional breeding, scientists do their utmost effort to breed for biotic and abiotic stress-resistant varieties, for superior fruit production, or for other desirable characteristics.

Genetic diversity also decreases the danger of transmitting undesirable traits. In a narrow genetic base, plants may not have much choice to breed with an array of other individuals of the population. They are then forced to breed with their close relatives resulting in inbreeding depression. The genetic makeup of the individuals in the population turns out to be more and more identical. Genetic error becomes an issue. Things may turn out very badly when closely related organisms interbreed. The hidden lethal genes in the parents can be multiplied which may show the deleterious effect phenotypically in the offspring. For instance, any organism can be a carrier of a particular disease the symptom of which may not be seen phenotypically. Closely related individuals are more likely to have the identical mutations, and when they mate the offspring may divulge the symptoms of that meticulous disease. In a population with a narrow genetic base, it is more likely that the carriers will interbreed, and after a certain period of time, the total population will be destabilized.

So, genetic diversity reinforces a population by escalating the possibility that measurably some individuals will be able to endure foremost turbulences and by building the individuals less vulnerable to inherited turmoil. Biological diversity is the disparity present in any type of organism, their hereditary material, and the environment in which they transpire. Based on this, the diversity can be classified into three levels: genetic diversity, species diversity, and ecosystem diversity. The significance of biodiversity for humanity has been evidently established in the recent time, and some may dispute that diversity is crucial for the sustainable development of diverse individual events. Biological diversity is the source of poor people to congregate their food and nutritional requirements and hold the edifying diversity of countries all over the world thus maintaining social and economic balance of the country (Shiva 1994). When we talk about the importance of biological diversity, we should understand the term "genetic erosion."

6.3 Genetic Erosion

The genetic erosion is the main threat to genetic diversity since an enormous number of individuals and their habitat can be eliminated quite quickly. The main cause of genetic erosion is the substitute of landraces by modern varieties, and the obsolete varieties in farming communities are replaced by newly developed ones. Additionally, the absolute number of local varieties is repeatedly reduced when profitable varieties are incorporated into conventional farming systems. Genetic erosion can also be caused by the appearance of new races of diseases, insect-pests, weeds, ecological degradation, and urbanization.

As it is already mentioned, genetic diversity is very important for the changing environmental condition. Diversified plant species play a vital role in adopting stress environment. For long-term viability and species' fitness, genetic diversity is important. Plant populations that are having narrow genetic bases may be more susceptible to biotic and abiotic stresses or other environmental stresses.

Genetic erosion can have tumble effects all over the ecosystem. Due to natural selection and genetic drift, some trouncing of genetic diversity can be observed under natural environment. However, these losses are usually not disastrous, since it can often be balanced by mutation and gene flow. Usually, thrashing of genetic diversity is a more severe danger to species that were previously more pervasive and have lost habitat. The genetic erosion influences the local plant species and the environment such as damages of habitat and the local crop populations, raising plants from a narrow genetic base, etc. The threat of genetic erosion in local plant species can be reduced in precise revegetation.

Seeds and planting material should be collected in such a way that genetic diversity of the geographic area would be preserved. While collecting the materials, the following things should be considered:

1. The geographic source or provenance
   The number of parental material
2. Total number of seeds (or propagules) per plant
3. Their plant-to-plant distance
4. Biography of a plant species.
   If the vegetative parts are collected from a dioecious plant, the ratio of male and female should be in equilibrium.

5. In the asexually reproducing organisms, collection should be done from different clones.

Even while purchasing plants from a nursery, the geographic source information should be obtained. This information will facilitate to know if the purchased materials are genetically diversified or not. With the geographic source information, materials' growing condition should also be mentioned. Care should be given while planting local species. Ample disparity is present in plants which are marked as cultivars subject to the original collection and the procedure it has gone through preceding its release. So, utilizing cultivars is not necessarily responsible for the genetic erosion. However, the cultivar originating from a narrow genetic base when used broadly to suppress the older plant population is more likely to cause genetic erosion of the local population.

Such nursery management activities should be encouraged where the goal is to make the best use of seeds which grow to be the vigorous seedlings. High-quality nursery management established on wakefulness of potential genetic variation in seed distinctiveness, germination necessities, and development system helps to circumvent unplanned selection and reduce the effect of the genetic erosion on the original collection.

6.4 Genetic Vulnerability

Genetic vulnerability occurs from the shape of use or indigence of genetic diversity. Populations are genetically vulnerable when they are in short of the required diversity to combat with the biotic and abiotic stresses. The perception of vulnerability entails a scarcity or low intensity of genetic diversity, most clearly recognized when enormous parts of an area are occupied with a sole cultivar. In this case, if one individual is attacked by a recently occurring disease, biotype, or any other climatic stress, the total field of the area will react correspondingly. This is because of their communal genetic makeup mainly for the genes concerned in the host plant's susceptible (or compatible) attitude (Marshall 1977; Wolfe and Barrett 1977).

6.4.1 Kinds of Genetic Vulnerability

Generally, genetic vulnerability is of the following four kinds:

1. *Genetic homogeneity*. The crop population is of a sole genotype. It may also consist of a few varieties or genotypes.
2. *Mutational vulnerability*. A single mutation can damage the entire crop population.
3. *Migrational vulnerability*. The plants are resistant to locally available biotic stress. When a new pathogen or pest migrates from another place, they become susceptible.
4. *Environmental vulnerability*. The plants in the population are resistant to the current abiotic stresses, but it lacks the adaptive mechanisms for any type of environmental stresses that may arise over time.

6.4.2 Causes of Genetic Vulnerability

6.4.2.1 Narrow Genetic Base of Crop Varieties

The genetically uniform cultivars have narrow genetic base and are thought to be the main reason of genetic vulnerability. The local plant populations may experience natural disasters, but they are genetically capable of tolerating the stresses because of their broad genetic base, while modern varieties are genetically identical that their population is rigid enough to avoid the genetic vulnerability (de Boef et al. 1996; Simmonds 1979). Local plant population may have either low genotype or environment interaction, facilitating it to stand under both stress and non-stress situations, in a mixed population (de Boef et al. 1996). It could be speculated that, in local population, the tolerant plants to the present race of the pathogen generates more offspring than the vulnerable ones because of the comparative reproductive effectiveness. Additional genetic improvement along with improved adaptation is achieved after every round of generation advancement. On the other hand, in a genetically identical population, comparative reproductive advantages cannot be achieved as the population is genetically uniform, unless there is any mutation alteration in the pathogenic race (de Boef et al. 1996).

The development of hybrids through crossing genetically highly uniform inbred lines has decreased the genetic diversity which cannot be observed in the open-pollinated varieties (Simmonds 1979). Additionally, numerous high-yielding and stress-resistant varieties are repeatedly developed through crossing with the locally adapted materials, and these works significantly shrinkage the genetic bases of the varieties.

Genetically diversified plants are more stable and easy for crop production as compared to the uniform population. The following reasons can be mentioned here.

1. It is hard for the pathogen to develop matching genes for a big number of resistance genes present in genetically diversified genotypes. So, when the population is having good number of resistance genes, the pathogen cannot match all the corresponding resistance genes simultaneously (Sharma 2001).
2. The use of mixture cultivars is advantageous due to either spatial or temporal complementarities. Spatial and temporal complementarities may happen when the allied crops are capable of using available resources over space and time.
3. The buffering effects of the components of a mixed cultivar decrease danger of natural hassle as all components of a mixed cultivar would not be at risk to a particular stress at a time.
4. If any component of a mixed cultivar becomes vulnerable to a specific stress, other components are there to control the harm.
5. The reproductive gain of the mixed cultivar produces more resistant offspring after each successive generation resulting more adaptive progenies.
6. Communal environmental alteration can be observed for the component plants.

6.4.2.2 Wide Spread of Dominant Varieties

One or a few genetically identical varieties when widely spread in a large area cause the genetic vulnerability. It creates the perfect state for the pathogens and insect-pests as well. So, the narrow genetic base of the modern cultivars is not the only reason of genetic vulnerability. It is deceptive that identical varieties from a narrow genetic base may overcome the stresses only for a short period of time after its release and be cultivated in a large land and then may suffer from serious thrashing such as unpredicted disease epidemics. The unremitting production of a sole variety year after year will also ease disease epidemics especially when host plant resistance is beaten by the mutation of disease and insect-pests.

6.4.2.3 Failure of Vertical Resistance

Varietal resistance may stop working in a shorter period of time than it takes for the improvement of a modern variety. Vertical resistance is the single gene resistance, and its collapse is considered as another cause of genetic vulnerability related with a narrow genetic base. The vertical resistance is considered as monogenic or oligogenic; the horizontal resistance is controlled by many genes (polygenic). It is, thus, exceedingly specific and accountable to alterations in races of pathogens. It is easier for a pathogen or an insect-pest to interact with the host plant having vertical resistance as the pathogen or the insect-pest needs to beat a single or a few genes of the host.

6.4.2.4 Unplanned Breeding for Susceptibility

Unplanned breeding for susceptibility followed by the introduction to disease of a variety not recognized in advance may also result in vulnerability to unpredicted diseases. One instance of unplanned breeding for vulnerability was seen in the 1970s when a new corn genotype (Texas male sterile, TMS) was released in the USA. The TMS hybrids had a lot of desirable characteristics which include resistance to the most common corn diseases. Conversely, they were not resistant to a previously insignificant strain of a fungal disease, the southern corn leaf blight (*Helminthosporium maydis*). The TMS trait was covered in 90 % of the corn sown in the USA in the 1970s and became susceptible to this pathogen. The fungus colonized all the field of susceptible host and wiped out corn crop. If the corn field hadn't been such a monoculture, the fungus wouldn't have been capable to extend as speedily, as it would have faced obstacles of genetically resistant varieties (Smolders 2006).

6.4.3 Corrective Measure against Genetic Vulnerability

Modern plant breeding applications practically direct toward breeding high-yielding varieties (HYVs) based on narrow genetic bases of different crops. It is not only the ambition of private-owned companies' Research and Development (R&D), but farmers' choice is also one of the reasons behind the substitution of landraces with genetically identical varieties (Agrios 1978). Moreover, the farming is getting more competitive, and farmers prefer to cultivate the most excellent and highest-yielding cultivars accessible to them. The extensive exercise of one or a few genetically identical varieties over large fields sometimes appears to be inevitable, which offers ideal situations for diseases, insect-pests, and other natural calamities. Such technological danger will be very stern especially to marginal farmers in areas where not only environmental variations are enormous but also the economic potential of the farmers is unlikely to permit the exploitation of procured inputs like chemicals that concede crop protection. The extent of genetic diversity dwindles with the decrease in the total number of varieties being cultivated and added concentration of fields planted to a few desirable varieties. Hence, the effect of genetic vulnerability should be reduced by utilization of appropriate breeding methods and by the efficient gene exploitation (Safeeulla 1977).

6.4.3.1 Breeding for Specific Adaptation

The rational yields with less danger are desirable than high yields with high uncertainty due to any type of stress condition for a resource-poor farmer existing under extremely susceptible condition. In such areas varieties are acquainted to fit the environmental condition rather than to change the environment to suite for the varieties. In the trivial fields where dispute of diseases, insects, and environmental fluctuations and threats are enormous, broad genetic-based varieties are preferred to grow rather than narrow genetic-based varieties. The area-specific and region-wise cultivars should be developed and grow a land area with diverse varieties to avoid any outburst of diseases and insect-pests. Precise adaptation to local situations, rather than wider adaptation and giving priorities to varieties that are more strongly placed to the producer's desires, increases genetic diversity in a specific area. It is also apparent that the accessibility of alternate varieties facilitates to change old varieties in case of any collapse.

The practice of growing narrow genetic-based varieties over a large area under marginal situations is not advisable, and the excessive homogeneity by current plant breeding has been dispraised all over the world. In such cases, it is fairly assumed that uniformity is not biologically essential or even preferred but diversity can, at least from time to time, improve effectiveness and stability (Simmonds 1979). Preferences of resource-poor farmers in the trivial areas include yield stability, resistance to biotic and abiotic stresses, and less reliance on external inputs. Farmers attain these by consciously generating genetic diversity at intra- and interspecific levels. Breeding exercises to deal with resource-poor farmers should be focused on farmers' activities and priorities to complement them and not to substitute their exercises. The physical environment and price proportions between external inputs and production outputs do not permit the exploitation of the big amount of procured inputs, mainly agrochemicals.

6.4.3.2 Systematic Gene Deployment

The objective of plant breeding programs in the prospective areas may be to boost production and efficiency through the utilization of yield escalating technologies like high-yielding varieties (HYVs) and agrochemicals for the control of diseases and insect-pests. Genetic diversity can still be preserved through efficient gene exploitation under prospective situations in various ways without preventing the necessity for mechanization to decrease the threat of genetic vulnerability. It is advisable that we should enhance the preference of germplasm accessible to farmers rather than to protect the adoption of a single or a few varieties over huge areas (Marshall 1977; Wolfe and Barrett 1977; Simmonds 1979; Rubenstein et al. 2005). The farming of closely located fields into varieties with different resistance genes (spatial gene deployment) may disperse the effects of diseases and insect-pests. Similarly, different varieties having different vertical resistance genes may be utilized in alternate years (temporal gene deployment) so that the mutation of the pathogen will be controlled (Rubenstein et al. 2005). It is established that growing of different multiline varieties gave more resistance compared to the single or few genes of deployed varieties. Few information is available that when places vertical to the way of the wind are sown with alternative varieties with a different genetic history (spatial gene deployment), each variety may perform as a barrier to the pathogen.

6.4.3.3 Maintaining Broad Genetic Base in Varieties

Extensive breeding programs may be applied to preserve variability within crop varieties and reduce the consequent threats of genetic vulnerability. Variability may be managed by ceasing homogeneity while there is still some remaining heterogeneity left or by combining late generation lines selected after purification. Mass selection can be considered as a good selection method for maintaining genetic variability in the population. Varieties developed through this method would have substantial genetic variation because numerous similar-looking plants which are variable for quantitative traits are preferred for selection and bulked. For example, the improvement of synthetic varieties has been efficient in escalating yield and stability in faba bean (*Vicia faba* L.) because heterozygosity is improved, while the threats of genetic vulnerability from varietal homogeneity is decreased (Suso et al. 2005).

Utilization of multiline varieties, i.e., mixtures of numerous similar pure lines with different genes for biotic and abiotic stress resistance in self-pollinated crops, may be anticipated to endure diseases and insect-pest aggression better than the pure lines. Mixtures with suitable resistance genes could also facilitate to decrease stringencies of various pathogens. It should be realized during the development of multiline varieties that morphologically similar-looking plants can be genetically fairly dissimilar. Successful instances of multiline varieties have been recorded in different countries. If any component of multiline varieties becomes susceptible to pathogenic races, it should be withdrawn and replaced with new resistant lines.

The risks of genetic homogeneity can be escaped if plant breeders utilize diverse sources of genes in their breeding objects (Russel 1978). The crosses between parents of distant relatives would not only be more perceptive to development, they are expected to generate higher heterosis and suitable genetic recombination and segregation in the offspring. This will also facilitate to create varieties having broad genetic bases that are not prone to genetic susceptibility. There is evidence that, like many other characters including grain yield, heterosis may be evident through biotic and abiotic stress resistance.

The perception of protecting the diversified materials is receiving little acknowledgement in various developing countries, but works have already been initiated to breed in larger diversity in some cereal crops (Rubenstein et al. 2005). Current studies in cotton also exhibited a significant decrease in levels of genetic homogeneity due to the reduction in the ratio of area planted to well-known varieties and buffering with the releases of substitute varieties by the rising number of seed companies utilizing diverse genetic makeup.

6.4.3.4 Utilization of Interspecific Varietal Mixtures

In tropical and subtropical countries, farmers have been applying intentionally interspecific varietal mixtures not only to maximize the yield and diversification but also to minimize the production risks since remote ages. It has been observed and established that the utilization of interspecific varietal mixtures decreased disease injury both on major crops and intercrops. Mixing of faba bean with field pea and maize with haricot bean or sweet potato decelerated the speed of disease spread and helped producing higher yields of diverse crops as compared to the corresponding individual cultures (Frey et al. 1977; Rajaram and Dubin 1977). It is usually assumed that interspecific diversity assists the components flee breakdown by decreasing susceptibility to particular biotic and abiotic stresses. It was experienced in practice that escalating interspecific diversity may reduce disease and insect-pest problems in each species. It is, consequently, desirable to identify a commonly favorable set of crop species. An incidence with the productivity of released varieties of faba bean and field pea under single and mixed cultures displayed that the occurrence of chocolate spot (*Botrytis fabae*) was greater in all varieties of faba bean under mixed cultures than the individual ones, while, defiantly, the occurrence of *Ascochyta* blight (*Mycosphaerella pinodes*) in field pea was constantly inferior in all the cultivars of field pea under mixed cultures than the single ones. As faba bean has naturally a rigid physique with enhanced air movement when mono-cropped, the insertion of field pea as an intercrop would certainly generate overmuch below the canopy and then decrease open air flow, build more humid state as anticipated, and worsen the intensity of chocolate spot occurrence. Furthermore, field pea covers its all or part of the biomass on the soil and when mono-cropped and based relatively in an erect situation when mixed cropped with faba bean. Hence, it is rational to anticipate that mixed cropping could rather generate a reasonably drier microenvironment disadvantageous for the growth of *Ascochyta* blight in field pea in comparison to mono-cropping.

6.4.3.5 Incorporation of Horizontal and Vertical Resistances

The horizontal resistance is more stable and less responsible to changes in pathogenic races in comparison to vertical resistance. Vertical resistance is recognized for its race specificity, while horizontal resistance is well known for nonspecificity (Higgins et al. 1998). In order to get rid of the drawbacks of vertical resistance, currently, the integration of vertical (monogenic) resistance with polygenic resistance and pyramiding of genes for vertical resistance against a numerous pathogenic races were recommended to protect hinder races of diseases (Sharma 2001; Asfaw 2004).

6.4.3.6 Escalation of Local Breeding and Informal Seed System

In trivial areas where resource-poor farmers prevail and circumstances are extremely vulnerable, the improvement of local breeding should be considered as one of the best approaches to conquer troubles linked with genetic susceptibility of modern crop varieties. Farmers have been breeding the crop varieties since remote ages, and the key point in local crop improvement is its protection of genetic diversity, both between and within species (de Boef et al. 1996). Framers' or local breeding implies the protection of local cultivars and their further development through enhancement with exotic materials and selection and the supply of seed system (production, selection, treatment, storage, and exchange).

6.4.3.7 Utilization of Molecular Techniques

The modern technologies are growing at extremely rapid speed and opening up new potentials almost quicker than the potentials are envisaged. Full genomic sequencing of cultivated plant species and their several wild relatives is now possible. Further, it is achievable to collect a huge number of sequence data on a rising number of diverse genes and on a comparatively immense number of individuals. This technical aptitude impacts on all fields of biological studies and signals for genetic diversity, genetic erosion, and genetic weakness. Although there is incredible growth in the capability of these modern techniques, they are still very expensive in financial resources. These rising molecular techniques help in analyzing, resolving, or developing indexes for adequate management of PGR (Brown and Brubaker 2002).

Molecular techniques offer the command to check genetic variation at the DNA sequence position. It is currently possible to evaluate organisms from the genomic level (FISH) and genomic in situ hybridization (GISH) down to the point of single nucleotides (DNA sequencing and single nucleotide polymorphisms (SNPs). Such knowledge would augment the legitimacy and reliability of indicators by escalating the clearness of analysis. The instant and apparent advantage is the suppleness and accuracy by which genetic diversity can be evaluated. Molecular systems can be tailored to particular organisms to accommodate diversity in breeding systems and comparative levels of genetic diversity (Hasan and Raihan 2015) and can be scaled based on the number of accessions to be checked, how many loci are required, and which genomic sequences are to be evaluated. In addition, numerous random DNA markers such as restriction fragment length polymorphisms (RFLPs) and amplified fragment length polymorphisms (AFLPs) can be employed in mapping the genome. With sequence-tagged sites (STSs) established from expressed sequence tags (ESTs), it is even possible to utilize expressed genes definite to life history stages rather than random sequence variation to assess the genetic dissimilarities among accessions. There is a basic achievement in genetic understanding, and it is possible to confirm that two organisms differ and they can be positioned in a phylogenetic ladder depending on their shared progenitor (Hasan and Raihan 2014). When this is accomplished, the phylogenetic diversity of the materials can be predicted. This phylogenetic diversity of the materials permits the expansion and development of main collections of the gene pools of wild relatives. The measurement of phylogenetic diversity can also be applied to classify a division of related wild species that enlarges the genetic information distribution of the collection.

It is clear that the biological resources are very important for food security of a country. The rising consciousness of the significance of maintaining a holistic view of agricultural biodiversity and of concerning conservation with feasible use and improvement is a must. Collaboration between countries is required for efficient conservation and utilization of our universal biodiversity.

6.5 Participatory Plant Breeding: A Way to Empowering Farming Communities

Participatory Plant-Breeding (PPB) is the farmers' participatory breeding method which is controlled by plant breeders to various degrees of farmer involvement. It involves farmers to select advanced breeding material, on farm and according to their needs. This is a formal plant breeding approach of farmers which replaced diverse landraces or farmers' varieties with a few high-yielding homogeneous varieties and triggered monoculture farming in some areas where complex, diverse, and risk-prone (CDR) agriculture was the traditional feature. The consequences were erosion of agrobiodiversity and Traditional Knowledge (TK) and overexploitation of natural resource bases. These led to aggravating ecological problems, declining crop yields, and damaging morale of farmers as innovators. This approach has heightened the need for mutual service and education between scientists and farmers to develop sustainable production systems. Sustainable development can be achieved through participatory approaches that support local innovation and adaptation to augment diversity and enhance local capacities. In this case, the farmer is capable of performing the majority of activities in breeding programs and the breeder can take advantage of the land, the labor, and the indigenous knowledge of the farmer. Farmers' involvement would help the breeder to design breeding programs keeping in view the identified priorities of farmers.

6.5.1 TK and Participatory Plant Breeding

CDR agriculture works in small scales that differ from their surroundings such as silt-trap fields, pockets of fertile soil, flood recession zones, patches of high groundwater, etc. Such specialized, in many cases marginal, environments are generally missed by conventional soil surveys and land system studies because of their small size and dispersion. These are also overlooked by agricultural professionals. Local knowledge is often the best guide to not only where a particular wild species, crop landrace, or area of high diversity may be found but also to the understanding of local practices and preferences and how best to utilize these resources and practices (Guarino 1995). The knowledge of varieties that local men and women acquire, refine, maintain, and exchange can help the breeder in determining priorities and in making decisions how to design breeding programs.

In contrast indigenous knowledge is an interdisciplinary, holistic, and diachronic approach that farming system research and related techniques seek to emulate (Guarino 1995). The importance of indigenous knowledge in plant breeding was not fully realized in the past. The flaw has now been recognized as revealed by Article 8 of the CBD to preserve and maintain knowledge, innovations, and practices of indigenous and local inhabitants embodying traditional lifestyles relevant for their conservation and sustainable use of biological diversity.

6.6 Bringing the Farmer in the Main Stream

6.6.1 Nature of the Institutional System of Breeding

The institutional breeding starts from a broad genetic base which is rapidly narrowed down, through the selection process, to a genetically uniform variety. Such a process usually aims to satisfy a limited set of objectives as perceived by the breeder. It assumes some ability to adapt or change environments to the requirements of the variety through the use of inputs like fertilizers, water, agrochemicals, etc. This is called the “blue print” agriculture with the same crop variety(ies) and alike soil and water management system, irrespective of local peculiarities. Practical observations dictate us that “blue print” agriculture can be harmful in the long term, if not in the short term. Therefore, “blue print” agriculture cannot be the panacea for agricultural development where CDR agriculture is the fundamental feature.

6.6.2 Community System of Breeding

The community systems have maintained genetic diversity in a continuous process of selection (natural or artificial) followed by on-farm conservation of genetic resources. The diversity has been maintained as a part of the farming system to cope naturally with biotic and abiotic stresses. The farmer uses the diversity within and between species that provides sustainability and an ability to adapt to changing environmental conditions (Hardon 1995). The community approach is in harmony with the nature for sustainable utilization of resources.

6.6.3 Mutual Benefit

There are fundamental differences between the institutional system and the community or informal system of breeding. No doubt, both systems have comparative advantages. These advantages can be and need to be exploited for mutual benefit of the breeder and the farmer. The choice then would be to bring the farmer in the main stream, as a partner. At the same time, farming households, consumers, seed producers, and postharvest processors should also have their roles to play. However, farmers’ involvement will be determined by:

1. Genetic diversity of potential interest to farmer/community systems in an environment
2. Development of breeding populations with specific characters like pest resistance, stress

tolerance, local market preferences, etc. for use in the development of crop varieties suited to local conditions
3. Cooperation between different forms of farmer/community systems and the institutional system, with divisions of labor and responsibilities as appropriate to a situation

It is interesting to note that, given the opportunity, the farmer is capable of performing the majority of activities involved in the breeding process. This has several implications such as:

1. Restoring the confidence of the farmer as an innovator
2. Reducing the cost of breeding through utilization of farmers' land and labor, as compared to the high costs involved in institutional breeding
3. Saving the time of the breeder from the field work which the farmer can supplement
4. Increasing biodiversity through farmers' individual selection from segregating populations in a number of locations (assuming that the selection process will take place in several locations)
5. Spontaneous adoption of lines/varieties developed and thereby spontaneous technology transfer

Local testing of breeding lines under farmers' conditions is essential to include and maintain a range of farmer and user preferences (Hardon 1995). If the local breeders and farmers access to heterogeneous segregating and early generation materials and graft them on local landraces, presumably this will lead to a plethora of region-specific and perhaps even village-specific cultivars, rather than just a few cultivars. This would imply that PPB can lead not only to generation of biodiversity but also to conservation of biodiversity (Ryan 1992).

The maintenance of plant genetic resources can be intricate to sell, but the stakes are high. There is pressing need for all those who are interested in PGR conservation and use to be more involved in all the aspects of genetic diversity such as to study, understand, enhance, conserve, and use it. To do so, we need to understand the extent and distribution of plant diverseness in species and ecosystems applying proper research, field studies, and analysis. Any conservation effort should be an effort that guides to integrated maintenance, i.e., a balance of ex situ and in situ methods. There is a need to stimulate international cooperation or joint ventures on all aspects of PGR. Genetic diversity should be understood at all the three levels, i.e., at the level of species, at the level of genus, and at the level of ecosystem. Additionally, various relations that influence allelic diverseness and variation in allelic frequencies within and between populations need to be understood. We need to survey genetic diversity using all available methods of measuring, before identifying the areas and species to be conserved ex situ and in situ. There remain many unresolved questions about the extent and distribution of genetic diversity in valuable crop species. To what dimensions and in what ways are ecological factors important for the distribution of diversity in crops and forages or for their wild relatives? It is important that these are tackled in a precise way and not by the continued addition of data in an almost random fashion that is often is the case. This will involve collaboration between scientists, research centers, and countries. In the light of increased utilization of molecular techniques for analyzing plant genetic diversity, there is also the need to link the information on molecular variation to PGR management in a more meaningful way than it is presently done, and this could be done on particular crop gene pools (Rigges 1990). The major elements that confer value on genetic diversity and its organization are:

1. The genetic principles of evolved populations and taxa or samples of these
2. The environments and ecosystems that support both the diversity and its structure
3. Its relationship with the ecosystem

The key to genetic conservation is maintaining these three elements. To attain this we need to improve access to existing knowledge as much as possible, maintain genetic continuity and integrity wherever possible, and integrate and coordinate different conservation efforts. Recently, scientists utilize a new tool named Geographic Information Systems (GIS) to carry out spatial analyses to identify diversity patterns of genetic resources. GIS can be used to interpose genetic parameters between sampled populations to apply resampling of georeferenced samples within a defined buffer zone or to develop grid-based genetic distance models. GIS is an essential tool to prioritize areas for conservation of PGR. Scientists have used spatial analysis techniques to develop conservation strategies for PGR based on molecular marker data. Moreover, GIS can be exposed in an apparent way on maps, which promotes the incorporation of these findings into the formulation of conservation strategies and the implementation of conservation action.

6.7 GIS to Augment Conservation of PGR

Geo-spatial tools are rarely utilized to conserve and manage diversity of PGR. With respect to selecting sampling locations and emphasizing the conservation of PGR, spatial analyses of diversity have been carried out mainly at the species level for crop gene pools. Only a few records have mapped intraspecific diversity to enhance the conservation of genetic resources of specific plants, grouped samples using a grid to compare diversity between geographic areas of similar size, whereas applied resampling to enable the calculation of diversity estimates with high degrees of confidence. Several diversity estimates are important to prioritize areas for conservation including recommended parameters like allelic richness and the number of locally common alleles. Since the application of molecular tools is becoming cheaper, intraspecific diversity analysis with large datasets will probably be more common in the near future. GIS tools and diversity information along with biotic and socioeconomic spatial database can identify possible drivers behind diversity and genetic erosion. This can be useful information in the development of adequate policies and measures to promote in situ conservation of PGR on farms and in natural ecosystem. GIS can also be used to link genetic data to available spatial information relevant to conservation of PGR to reveal short-term threats such as accessibility and long-term threats such as climate change. With this type of analysis, vulnerable hotspots of diversity could also be identified.

6.8 Role of International Conventions in Conservation of Genetic Resources

For conservation of genetic resources and indigenous knowledge, a number of international treaties and conventions came into force for sustainable utilization. It is obligation of all the countries to develop national strategic plans or programs for conservation and sustainable use of biological diversity. The following are some of the conventions which are dealing with sustainable utilization and conservation of biological resources.

6.8.1 Convention on Biological Diversity (CBD)

The CBD was proposed at the United Nations Conference on Environment and Development (UNCED) in June 1992. It represents a major global initiative directed toward the conservation of biodiversity (FAO 1994). This is perhaps the most comprehensive intergovernmental agreement concerning conservation, sustainable utilization of genetic resources, and sharing of the benefits arising out of such use in an equitable way. The convention provides a broad legal framework to conserve and use biodiversity. It became an international agreement on 29 December 1993 when more than 30 countries ratified it. Over 160 countries have signed the convention.

The preamble of the CBD recognizes and reaffirms (UNEP 1992):

1. The intrinsic value of biological diversity
2. The sovereign rights of states over their biological resources

3. The fundamental requirements of in situ conservation of ecosystems and national habitats
4. The supporting role of ex situ conservation
5. The decisive task of regional communities and women in the protection and feasible use of biological diversity
6. The desirability of allocating reasonably the advantages originating from the utilization of TK, skills, innovations, and practices
7. The importance of and need to promote regional and global cooperation for conservation
8. The requirement of substantial investments to conserve biological diversity

The objectives of the convention are:

1. The conservation of biological diversity
2. The sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources and by proper dissemination of technologies
3. Taking into account all rights over those resources and to technologies by appropriate funding (UNEP 1992; Chauhan 1996)

At UNCED, governments reached a consensus on a global action to promote sustainable development known as Agenda 21. Both Agenda 21 and the convention emphasize the significance of improving and strengthening the capacity of countries to benefit fully from biological resources available to them. Access to new technologies and their managed use for training, information, and financial assets will facilitate developing countries to better conserve and use their biodiversity. Article 3 of CBD, which is now an international law, confers sovereign rights to nations over the biological resources that originate from a specific country ("the supreme rights to utilize their own resources pursuant to their own environmental policies"). While CBD provides the rights, it also places certain responsibilities/obligations on each country. These national responsibilities will help in caring for and preserving the biodiversity. CBD also promotes cooperation "with other contracting parties, directly or, where suitable, by expert international institutions" (Article 5).

The CBD places the obligation squarely on the countries to develop national strategic plans or programs for conservation and sustainable use of biological diversity. This obviously implies greater coordination within the existing setup of national programs to meet such needs focused on conservation and use of biodiversity including PGR. The countries that adhere to CBD require identifying different components of biodiversity and monitoring and paying attention to those that require urgent conservation measures (Article 7).

6.8.1.1 PGR Conservation Aspects in the Convention

In situ *conservation*: the CBD requires that the countries develop guidelines for selecting areas for in situ conservation, create confined areas, direct the utilization of resources so as to make a sustainable use, and protect ecosystems and the threatened species and natural habitats. It also requires that the countries promote environmentally sound development, rehabilitate degraded lands and ecosystems, and eradicate exotic species that may threaten the existence of native species, ecosystems, or habitats. It stresses on compatibility between conservation of biodiversity and sustainable use, taking equally the role of local communities, indigenous knowledge, etc.

Ex situ *conservation*: the countries are required to establish and maintain facilities for ex situ components of conservation and research on plant, animal, and microorganism biodiversity and carry out recovery and rehabilitation of threatened species. Countries also need to regulate and manage collections of biological resources without damaging the ecosystem and in situ populations following appropriate codes of conduct and policies considering cost controls, ownership determination, ex situ crop control, threat management, and building of use capabilities (MSSRF 1996).

Proper utilization of biological diversity: it is necessary for a national program to integrate the conservation and proper utilization of biological resources into nationwide decision-making policies and adopt measures to avoid or minimize adverse effects on biological diversity. CBD implies that countries should protect and encourage use of biological resources based on customary cultural traditions compatible with conservation and support local populations to develop and employ corrective action in despoiled places where biological diversity has been reduced. It also urges nations to encourage collaboration with its governmental and nongovernmental agencies, including the private sector in developing methods for sustainable use of biological resources.

6.8.2 Global Plan of Action

The GPA is part of the FAO Global System for the conservation and sustainable utilization of PGRFA which is an important element for the Commission on Genetic Resources for Food and Agriculture in fulfilling its mandate, though requiring also other important elements to complete it. The commission required the development of a rolling GPA on PGRFA with programs and activities focused on satisfying the gaps, minimizing obstacles, and managing emergency situations identified in the FAO Report on the State of the World's Plant Genetic Resources. The occasionally updated works will allow the commission to recommend priorities and to promote the rationalization and coordination of efforts. A discrete GPA for PGRFA is warranted because of their great importance to world food security and, within the greater background of biological resources, because of several features of this particular form of biodiversity.

The main aims of the GPA are (FAO 1996):

1. To ensure the conservation of PGRFA as a basis for food security
2. To promote sustainable utilization of PGRFA, to foster development, and to reduce hunger and poverty particularly in developing countries
3. To support a reasonable and unbiased distribution of the benefit arising from the use of PGRFA, recognizing the desirability of allocating equitably advantages originating from the utilization of traditional knowledge, innovations, and practices relevant to the conservation of PGRFA and their feasible use

Establishing the necessities and individual rights of farmers was recognized by national rules to have unbiased entrance to germplasm, information, technologies, financial resources, and research and marketing channels needed for them to carry on to manage and improve PGR. Developing and promoting fair and unbiased distribution of advantages originate from the use of PGRFA in their exchange between communities and within the international community was needed:

1. To assist countries and institutions responsible for conserving and using PGRFA to identify priorities for action
2. To strengthen, in particular, national programs, as well as regional and international programs, including education and training, for the conservation and utilization of PGRFA and to enhance institutional capacity

The GPA has 20 priority activity areas that are organized into four main groups. The first group deals with in situ conservation and improvement, the second with ex situ conservation, the third with utilization of PGR, and the fourth with institutions and capacity building. As the GPA is a set of integrated and intertwining activities, the placement of the activities into four groups is intended simply to help in the presentation and guide the reader to areas of particular interest. Many activities will be related and be relevant to more than one group.

6.9 Conclusion

PGR and TK constitute a unique global heritage, and their conservation and utilization are of immediate concern. A diversity of PGR and TK has long been viewed as a means of increasing both global and local food security. These genetic resources are important source of income security for livelihood to farmers in the less developed regions of the world. Genetic diversity is important both to individual farmers and farming communities and to agriculture in general. The importance of PGR and TK and threats to them have led to the creation of conservation programs to preserve these resources for future generations. Concern about the future vulnerability of agricultural production, food security, and environmental adaptability has shifted the conservation and sustainable use of genetic resources to the top of the international development agenda. To avoid the genetic vulnerability, a broad genetic base is necessary for the development of varieties. In spite of its inclusive advantage and support by the international community, in situ and ex situ conservation is still inadequate. The CBD emphasizes the conservation and sustainable use of biodiversity and advocates the equitable sharing of the benefits arising from such use. The CBD provides a broad legal framework and comprehensive intergovernmental agreement for conserving, sustainable utilization of genetic resources, and sharing of the benefits arising out of such use in an equitable way. It further obliges the wider application of such indigenous knowledge with the approval and involvement of the farmers and local people and encourages the equitable sharing of the benefits arising from the utilization of these resources.

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