Plant Genetic Resources and Traditional/Indigenous Knowledge: Potentials and Challenges

1

Romesh Kumar Salgotra
and Bharat Bhushan Gupta

Abstract

Genetic resources and indigenous/traditional knowledge are the major resources on which human being has relied for their very livelihood and their demand will increase in the future due to increase in global population. The relation between plant genetic resources and traditional knowledge is of recent origin. Plant genetic resources are the heritable materials contained within and among plant species of present and potential value. On the other hand, traditional/indigenous knowledge is the outcome of intellectual practice in a traditional perspective. The genetic resources and indigenous knowledge protect biological resilience that exists in a natural way. The problems of food security are of global significance and are further compounded by precedential increase in world population resulting in over-exploitation of genetic resources and diversity. Nevertheless, these resources are lost at alarming rates due to anthropogenic effects such as climate change, pollution, genetic erosion, gross mismanagement of these resources and population growth. A vast amount of genetic resources are threatened and endangered, and some have even gone extinct due to genetic erosion and environmental changes. In order to meet current global challenges, it is obligatory for all nations and institutions to discover, collect and conserve potentially valuable plant genetic resource and traditional knowledge and utilise them sustainably.

R.K. Salgotra, Ph.D. (✉)
School of Biotechnology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu 180009, Jammu and Kashmir, India
e-mail: rks_2959@rediffmail.com

B.B. Gupta, Ph.D.
Division of Plant Breeding and Genetics, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu 180009, Jammu and Kashmir, India
e-mail: dr_bbgupta@ymail.com

R.K. Salgotra, B.B. Gupta (eds.), *Plant Genetic Resources and Traditional Knowledge for Food Security*, DOI 10.1007/978-981-10-0060-7_1

1.1 Introduction

The food security of the world could be endangered if we fail to conserve the wild relative species which are genetically related to crop species. The increased world population from 2.5 billion to 6.3 billion in the last five decades and the population explosion threatens that another 3 billion people will inhabit the planet by 2100. Currently, about 854 million people are chronically malnourished (FAO 2012). More than half of the world population suffers from malnutrition. The low crop productivity remains the main cause of poverty and malnutrition in the world especially in Africa and Asia. In these developing and underdeveloped countries, a number of diseases are the results of malnutrition. It is estimated that more than 60 % of malaria deaths are caused by malnutrition (Sanchez and Swaminathan 2005). Today about 30 crops are providing 95 % of food energy in the human diet. Out of the 30 main crops, wheat, rice, maize and potatoes are the main crops providing more than 60 % of energy. Keeping in view the importance of a these crops in maintaining the world food security, it is imperative to maintain and conserve the genetic diversity within these crop species (FAO 1996). As a small number of plant species are supplying the world's protein and energy in human diet, it is immensely important to maintain the diversity within these species.

The ever-increasing demand for food and other basic needs has necessitated the sustainable utilisation and conservation of Plant Genetic Resources (PGR) and traditional knowledge (TK). It is immensely important to conserve the diversity particularly in agricultural sector in terms of addressing the accompanied challenges associated with increasing crop productivity. The utilisation of PGR in agriculture has not only brought about profound changes in the crop productivity and quality but has also opened up newer and unforeseen potential vistas including improvement of novel traits by domestication, manipulating plant architecture and molecular farming. Challenges like biotic and abiotic stresses, gradually reducing crop productivity and environmental safety, and demand for newer products have been constantly addressed successfully in terms of phytoneutraceuticals, exotic plant types, healthy planting materials, postharvest losses, export quality plant products and designer agricultural crops using genetic resources. A major challenge of sustainable livelihood in the developing and underdeveloped nations can be met with the judicious and rational use of PGR along with other equally powerful crop production systems. PGR and indigenous knowledge constitute our invaluable assets to meet up the growing demand of the population, particularly in developing countries. PGR are the plant genetic material possessing the potential values which determine their characteristics and ability to adapt and survive (Hammer 2003). These genetic resources start to establish as a result of growing worries about the erosion of biodiversity, its conservation and sustainable utilisation (Gepts 2006). No doubt numerous international programmes have been working to control the population growth rate, but global food security is a major challenge for the future generations (Hoisington et al. 1999). To conserve and secure PGR and TK for future human kind, it has become a priority for most of the countries. Total gene pool of crop species includes crop varieties, landraces, wild relatives, advanced breeding material, inbred lines, genetic stock, modern varieties, obsolete varieties, etc. (Varaprasad and Sivaraj 2010). These genetic resources constitute the basic material for crop improvement programmes to secure the food security for the future.

PGR and TK constitute a unique global heritage, and their conservation and sustainable utilisation are of immediate concern to increase crop production. The available genetic information on PGR and the loss of genetic diversity of agricultural crops have resulted in great effort for the collection of these genetic resources (Briggs 2000). On the other hand, TK is dynamic in nature which modifies its character when the requirements of the people change. Moreover, TK is deep-rooted in indigenous people's lives which is very difficult to separate from them. It is advocated that TK and traditional practices are contributed to enhancement and preservation of

biological diversity (Greaves 1996). The indigenous and native people's lifestyles and traditional practices are devised in such a way so that the environment as well as biodiversity can be preserved.

1.2 What Are PGR?

PGR are the building blocks for the improvement of agricultural and industrial crops and the agro-processing sector. PGR are the pillars upon which world food security depends especially with expanding global population (Ogwu et al. 2014). PGR include materials considered of systematic importance and applicable in cytogenetic, phylogenetic, evolutionary biology, physiological, biochemical, pathological and ecological research and breeding. They encompass all cultivated crops and those of little to no agricultural value as well as their weedy and wild relatives (Ulukan 2011). The growing global demand for food and bio-based renewable materials, such as biofuels, is changing the conditions for PGR development and bio-resource production worldwide. Most of the developing countries' Gross Domestic Product (GDP) depends on agriculture is an agrarian type. To feed the ever-increasing population is a great confrontation in the development of many parts of the world, but the problems are worst in sub-Saharan Africa, where there has been stagnation and even decline in the agricultural productivity of small-scale farmers.

The conservation research, improvement and sustainable use of PGR are the components of a complex system in a dynamic interaction which is based on relationships among different types of representative with specific functions within a system called the "plant genetic resources system". The indigenous farmers and communities, research institutions, breeder, private seed companies, curators, collectors and farmers are the different representatives in the PGR system which performs functions within a framework of legal rules (Fig. 1.1).

Development and utilisation of the PGR base and the connected knowledge are central in such efforts. International conventions and treaties together with the rapid bioscience development have led to new conditions for the access of PGR and TK. The Convention of Biological Diversity (CBD) and the requirements under World Trade Organization (WTO)/Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) have led to stricter mechanisms for access to PGR for protection of biological diversity. To access the PGR through the CBD is directly under the control of sovereign states. These corporations are forcing to bargain with the developing countries rich in genetic diversity for direct access to these resources.

The survey, collection, preservation and sustainable utilisation of genetic resources in an organised way are the utmost responsibility of all nations. To best conserve and sustain utilisation of existing biodiversity for the benefit of society in a country, all the policymakers, planners and scientists are engaged to get the best out of it (Tanksley and McCouch 1997). With the introduction of newly developed crop varieties and domestication of crop species, the genetic diversity among the genotypes is declining (Hyten et al. 2009). In order to prevent vulnerability of crop species and genetic erosion, there is a need to preserve and sustainably use these valuable collected germplasm (Frankel 1984). To have the maximum plant genetic diversity of the entire collected germplasm, the concept of developing core sets was introduced (Brown 1989). The evaluation and characterisation of germplasm on the basis of morphological characters does not reflect the maximum genetic diversity; however, the use of molecular markers gave the maximum diversity at the genic levels (van Hintum 1999).

In India, particularly Northwest Himalaya is well known for their rich biodiversity of PGR among field and vegetable crops (Wani et al. 2003). Among the field crops there exists a wide range of scented/aromatic rice (*Oryza sativa* L.) – Mushkbudji, Safed budji, Qadir ganai, black rice, Kamad and Tila zag – which are prominently grown in southern Kashmir particularly in specific areas of Kokernag, Saagam, Larnoo and Khudwani, and thus these places can be developed as hot spots for seed production by farmers, thus helping in the in situ conservation of the

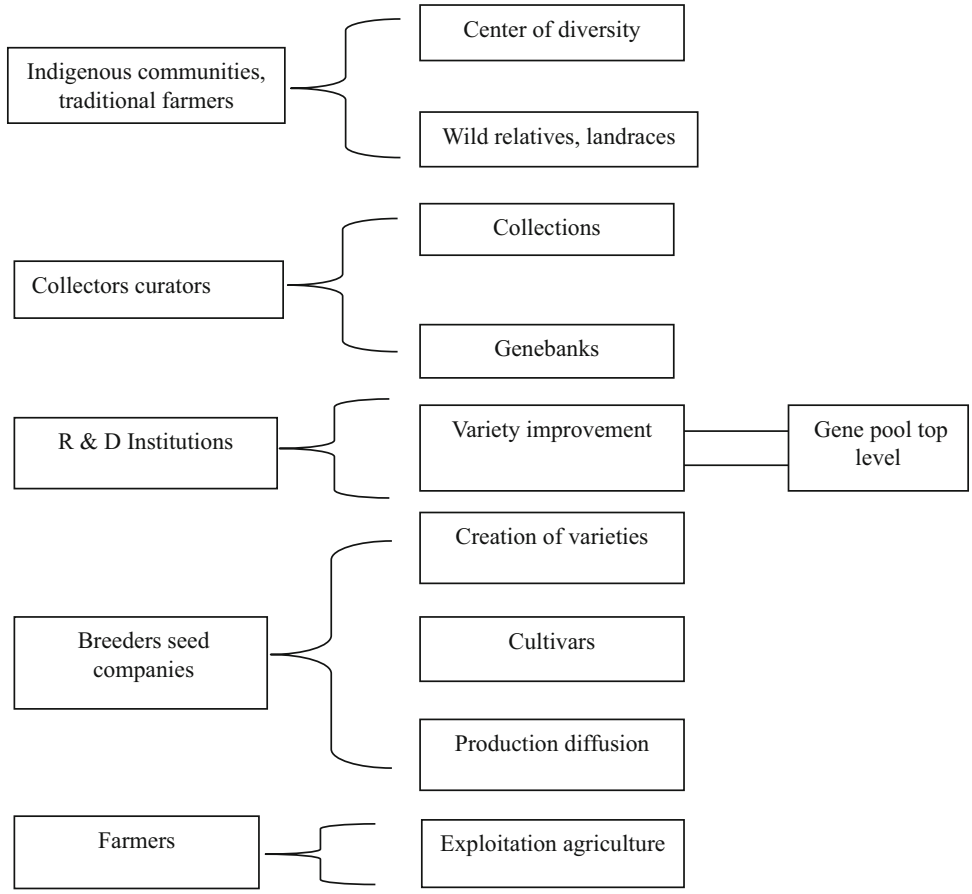

Fig. 1.1 Plant genetic resources system

valuable PGR. Basmati rice grown in Jammu region of Jammu and Kashmir is world famous for its palatability and aroma (Salgotra et al. 2015). Non-aromatic rice – Mehwan (green), Laer Beoul and red rice – are also in great demand because the staple food of the local inhabitants is rice (Gupta et al. 2009). There also exists great genetic diversity among maize local races in Gurez and parts of southern Kashmir possessing tolerance against biotic and abiotic stresses. Some of them include Anantnag Safed, Tangwin safed and Aru wuzg. Herbal vegetables grown in the state are wild garlic (*Allium ursinum*), top onion (*Allium cepa* L.), *Taraxacum* (*Taraxacum officinale*) (Haand), mallow (Sochel), *Rumex* (*Rumex crispus*) (Obuj) and red gourd (*Cucurbita pepo*) (Parim). Potatoes (*Solanum tuberosum*) grown in Hurpur (Shopian), rajmash (*Phaseolus vulgaris* L.) mixed with maize (*Zea mays* L.), local moong (*Vigna radiata*) and broad bean (*Vicia faba*) are potential pulse crops grown in pockets of Shopian, Uri, Bhaderwah, Mandi, Poonch, Budhal and Gurez (Salgotra and Gupta 2005). Underwater vegetable lotus stem (Nadroo) has a rich potential due to great local demand. Kashmiri red chillies (*Capsicum annuum* L.) due to their bright red colour and moderate pungency are very famous in industrial and processed products and are important export commodities, grown over an area of more than 1700 ha, and if exploited could form one of the most potential high-value commodities for export.

Underutilised cereal crops like medicinal buckwheat and sweet buckwheat/duck wheat which are grown for human purposes also serve as the feed for livestock and poultry as well as

Fig. 1.2 Natural genetic diversity in plant genetic resources

green manure. The buckwheat honey has a very high potential in difficult hilly terrains of Leh, Zanskar and Gurez and adjoining areas to meet the livelihood and food security of the people (Wani et al. 2003). There is a vital need to pay attention for conservation and utilisation of these PGR which will further lead to improvement of food, nutritional and livelihood security of diverse inhabitants of Jammu and Kashmir states (Fig. 1.2).

1.3 Traditional Knowledge (TK)

TK is the mature, long-standing traditional practices, knowledge and wisdom of local communities and indigenous people of a region. To sustain the indigenous people and local communities and their culture, TK is used to maintain the PGR for their survival. "TK and associated genetic resources" encompass all forms of technology-based knowledge, beliefs, know-how skills and traditional practices which come overtime and generations in a particular environment (Dowd 2009). TK is the mental inventories of PGR which include landraces, wild relatives and other indicator plant species which show soil salinity and flower at the beginning of the rains. Traditional production techniques of agriculture such as seed treatment, crop planting, intercropping, introducing new plant species into farming system, harvesting and different seed/grain storage methods are all included in TK. TK also includes belief systems, and indigenous peoples depend upon it for their livelihood, health (introducing a healer test of a medicine plant) and protecting the environment (Dowd 2009).

TK is the indigenous knowledge of local communities which is based on traditions and does not entail that this knowledge is old and non-technical in nature. This is a "traditional" because the knowledge is developed on the reflections of traditional practices and knowledge of the indigenous communities and does not develop by nature itself. TK is a collective effort of the local communities and is the property of entire indigenous people who have created and developed it over generations. TK is maintained by the local cultures and indigenous communities and transmitted through demonstrations, orally, elders, specialists and few people within a community (Hirwade and Hirwade 2012).

TK has got a lot of attention nowadays due to its utility all over the world and has become a focus in international forums. The CBD has paid due attention for protection of TK under Intellectual Property Rights (IPRs) of indigenous knowledge. The local and indigenous people also have their traditional festivals, local songs, practices, stories, etc. as a method of transmitting TK to other people and young generations. TK is also preserved and transmitted from father to next generations on some specific artefacts. TK can be found in a multitude of fields such as food,

nutrition, agriculture and fisheries, human health, veterinary care, handicrafts, performing arts, folk songs, religion and astrology and many other day-to-day customs and practices (Hirwade and Hirwade 2012). Therefore, the protection of this knowledge by indigenous communities is very imperative for most of the developing countries.

Indigenous knowledge plays a significant role in boosting the economic growth of the countries, particularly the developing countries. The utilisation of this TK is to attain developmental goals of the developing countries such as increased agriculture production, health and preservation of biological diversity. The countries are the owners of genetic resources and have their sovereign right for access to potentially exploitation of their natural resources under the CBD. Under the CBD, all the countries are responsible for accessing the genetic resources and equal sharing of benefits arising out of their utilisation. To access these resources prior information content (PIC) is needed as per mutual agreement conditions (Gupta 2006). The major objective and goal of the CBD is to preserve the genetic resources in their territories, while the goal of TRIPS is to stimulate technological advancement, giving individual rights to the inventor through IPRs. The World Intellectual Property Organization (WIPO) and Intergovernmental Committee on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore (ICGTK) are functioning on the issue of contractual practices. The WIPO Member States have complied indigenous knowledge databases and registries with sui generis possible system for its protection. The Traditional Chinese Medicine (TCM) Patent Database contains more than 12,024 deeply indexed records of China. The Korean Intellectual Property Office (KIPO) has planned to devise information of a database of TK. The Traditional Knowledge Digital Library (TKDL) in India has documented and digitised the TK available in the public domain and translated into five international languages, i.e. English, German, Japanese, French and Spanish.

India is the country which has been nurturing a tradition of civilisation over about 5,000 years, and ancient scriptures consist of four Vedas, 108 Upanishads, two epics, Bhagavad-Gita, Brahma sutras, 18 Puranas, Manusmriti, Kautilya shastra and smritis. The rich heritage of India has already documented over 47,000 plant species besides more than 350 wild-related species and landraces of agricultural crop species. The vast repository of diverse genetic resources of TK in India further helped to enrich the eighth Vavilovian centre of origin. The diverse biological resources and multitude of natural wealth have created a renewed interest in the traditional medicinal system, which includes the Ayurveda, Yoga, Unani, Siddha and Homeopathy (AYUSH) systems. Ayurveda is the oldest and most effective systems of medicine in developing and least developing countries. The ancient scriptures of the Ayurveda are full of instances where medicinal properties of herbs were used not only for curative purposes but for increasing physical and mental efficiency (Hirwade and Hirwade 2012).

1.4 PGR and TK for Food Security

The PGR diversity is the major component for the improvement of crop varieties to secure the food security. The conservation and sustainable utilisation of these resources are vital and important to secure food security for future generations. For the continuous improvement of these crop varieties, these resources should be easily available to the plant breeders and the farmers. On the other hand, TK is completely based on the traditional know-how of the indigenous and local people in a particular environment which also helps in the preservation of PGR and their sustainable utilisation. In most of developing and underdeveloped countries, farmers are using their own saved seeds for sowing purposes to secure their livelihood and food security. The Leipzig Declaration (1996) emphasised to save the seed and planting material to avoid the genetic vulnerability and shortage of food under adverse conditions.

The importance of PGR is reflected in every facet of human endeavour as it provides the gene pool from which resistant and improved varieties can be developed. The studies conducted by

Alston et al. (2000) and Evenson and Gollin (2003) have been well documented to know the economic values of increase in agriculture productivity through the introduction of improved and newly developed crop. Similarly, Koo et al. (2004) and Smale and Koo (2003) have also estimated the cost-benefits of preserved PGR in gene banks which are commercially for use by farmers. Thus, genetic resources including TK can play roles in ensuring food and income security especially for developing and underdeveloped countries where majority of livelihood is hinged upon these biological resources.

The plant species diversity loss has been significantly increased in the last four decades due to climate change and mainly due to the activities of the earth's dominant species. Land clearing for agriculture and infrastructure development, wars and deforestation all impacted negatively to destroy natural habitats and the diversity contained therein. Sodhi and Erhlich (2010) emphasised that the earth dominant species have destroyed, degraded and polluted earth's natural habitat which is a key in life support. More so, serious illnesses and ecological destruction can be attributed to the drilling of oil which has caused widespread destruction of rainforest (Hvalkoff 2001). The deforestation not only narrow down the genetic diversity of plant species but also sometimes completely diminished in some crop species due to genetic vulnerability and over-exploitation of species by the human being as well as by adverse conditions of the climate.

PGR and TK have great scopes for economic as well as social growth of the developing countries. These will also offer a sustainable food security in the future. To realise the maximum benefits from exiting diversity in genetic resources in most of the countries, particularly in in situ conservation, building close relationship between the development and preservation and sustainable utilisation of these resources are needed (FAO 2001). To achieve this challenge, there is a need that all stakeholders including plant breeders, farmers, government policymakers, seed banks and other agencies work in close for systematic conservation, development, access to information, PGR diversity and new technologies. To promote this linkage among the different stakeholders, the Food and Agriculture Organization (FAO) is providing technical know-how and regulatory mechanisms to the entire world. This will definitely open new opportunities for the global communities to develop linkage for efficient use and management of these resources (FAO 2001). To establish and strengthen the system of accessing and sharing of benefits arising from these resources, the stakeholders and policymakers must frame the national regulations and laws through the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA).

For proper preservation and sustainable utilisation of PGR, the Global Plan of Action (GPA) helps the utilisation of per se capacity of the local communities to save their farm seeds and share and market their Plant Genetic Resources for Food and Agriculture (PGRFA) to secure the food security. This emphasises need for diversified agriculture system with maximum utilisation of traditionally local landraces and underutilised crop species. The FAO also emphasised that the TK of local communities should be recognised for further conservation of diversity to enhance food security in the future. A harmony was developed in 1992 between the International Undertaking on Plant Genetic Resources (IUPGR 1983) and the CBD for the conservation of PGR under the umbrella of the Earth Summit of the United Nations Conference on Environment and Development (UNCED).

1.5 Potentials of PGR

The diverse PGR are the main resources used for the improvement of crop varieties to meet the ever-increasing demand for food in the developing countries. These plant species have the ability to survive and adapt in a diverse environment (Varaprasad and Sivaraj 2010). PGR profile includes landraces, wild relatives and improved varieties of crops which are conserved by indigenous people for food and health. The biological resource conservation without use has little point and importance; moreover, using these resources

without conservation leads to completely vanishing these resources, and there will be no PGR for the future (Hammer and Teklu 2008). Genetic resources have great potential to strengthen food security and make agricultural systems more productive and resilient to climate change. Using PGR for crop improvement can increase yields and nutritional value and make crops more resilient to pests, diseases, drought and flooding, thus reducing the region's dependence on food imports.

Although there are many genetic resources of plant species that meet smaller and often local need, the plant species that moved into greatest world prominence are those that met the greatest number of food needs in the widest range of world food systems. As a result of global movement of favoured crop species with travellers and immigrants around the world and, in more recent times, because of global trade in plant-derived commodities, only 50 species now account for most of the cultivated world crop acreage. There are four major crops such as wheat, rice, maize and potatoes which contribute more than 60 % of food energy in the world. There is a very uneven distribution of these crop species, whether they are cereal grains, pulse crops, vegetables, fleshy fruits or root crops. This contribution is even greater in developing and least developing countries, where meat products are consumed at a lower level because of cultural custom, high cost or limited availability. The much higher dependency on plants as a source of food and essential protein in developing compared to developed countries is also very evident in these statistics (Hammer and Teklu 2008). This difference also leads to a greater primary dependency on biological resources in developing countries, although this trend is known to change as developing countries become more affluent and diversified in their food demands towards greater use of meat products (Table 1.1).

Table 1.1 Distribution of PGR to meet the nutritional needs in the developed or developing countries

	Digestible energy (%)			Protein		
Source	World	Developed	Developing	World	Developed	Developing
Plant products						
Cereals	50.2	26.4	57.7			
Pulses and nuts	3.9	2.4	5.6			
Roots and tubers	6.9	3.7	6.2			
Sugars	9.1	13.0	9.7			
Vegetable oils/fats	4.9	4.8	4.4			
Stimulants/alcohol	3.9	6.7	1.5			
Subtotal	83.7	68.3	91.4	65	44	79
Animal products						
Meat	7.6	15.3	3.1			
Milk and cheese	4.4	8.5	3.1			
Animal oils/fats	2.5	4.7	1.1			
Eggs	0.9	1.6	0.4			
Fish	0.9	1.6	0.7			
Subtotal	16.3	31.7	8.6	35	56	21
Total kcal (per person per day)	2,630	3,390	2,350			
Total (M) (per person per day)	11.0	14.2	9.8			
Total protein (g person per day)				68	99	57

Source: Crop evolution, adaptation and yield, Cambridge, UK

1.5.1 PGR: A Source of Germplasm in National Depository

The use of exotic and wild relatives of crop species in crop improvement programmes to increase the yields has been significantly enhanced for the last three decades due to systematic development of PGR information in all Member States of the CBD (Bonham et al. 2010). For effective use of PGR in crop improvement programmes, there is a need to further evaluate and characterise these PGR on the basis of various morphological characters. For proper documentation of genetic resources in the gene banks, characterisation on the basis of molecular markers is essential. Networking is another important way of widening the use of PGR which helps in bringing all stakeholders to work together and share their tasks and priorities related to PGR. This will also help in conservation of genetic resources in a collective manner. Today more than 150 countries have PGR networking which is easily available on the worldwide networks which are being shared among these nations for crop improvement programmes (Hammer and Teklu 2008). Due to this all the nations shared responsibilities for conservation of PGR, development of new technology and establishment of common strategies for efficient utilisation of these resources based on their interests (Hammer and Teklu 2008).

1.5.2 Role of PGR in Agriculture

PGR play a significant role in the agriculture, particularly in crop variety development and improvement programmes. PGR diversity provides the major sources of important genes such as diseases and insect pest resistance and yield and quality improvement.

1.5.2.1 Core Collections and Utilisation of Germplasm for Food Security

"Core collections" are the core sets that represent genetic diversity of entire germplasm which is otherwise difficult to handle. However, these core sets are prepared on the basis of morphological characters and passport data of these germplasm. The newly developed core sets will become more useful to the plant breeders as well as the farmers in crop improvement programmes. The scientists are not using these resources extensively because of lack of detailed information available about the important traits. The scientists are now evaluating these core collection sets at multilocation trials for evaluation instead of evaluating the entire collected germplasm.

1.5.2.2 New Sources of Germplasm

Newly developed core sets of collected germplasm will be evaluated at multilocations to identify the diverse parent with particular character of interest. Their use in breeding programmes would result in broad-based cultivars. To strengthen crop improvement programmes, core sets of chickpea, pigeon pea and groundnut have been developed and evaluated at multilocations at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) for screening of diverse genotypes for specific trait of interest. For identification of specific trait, these genetic resources should be characterised using molecular markers, such as Random Amplified Polymorphic DNA (RAPD), Restriction Fragment Length Polymorphism (RFLP) and Simple Sequence Repeat (SSR) markers. The available techniques and information will be used for population structure analysis which helps to know the association between the specific trait of interest and the molecular markers.

1.5.2.3 Landrace Varieties

The traditional varieties developed and selected by the indigenous communities are termed as landrace varieties. These landrace varieties possess a number of desirable traits to be used in crop improvement programmes. These landrace varieties have numerous important characters like resistance to disease, insect pests, heat stress, salinity, etc. No doubt that the landraces are adapted to a specific environment and region, but these are the reservoir of various desirable traits to be used in plant breeding programmes.

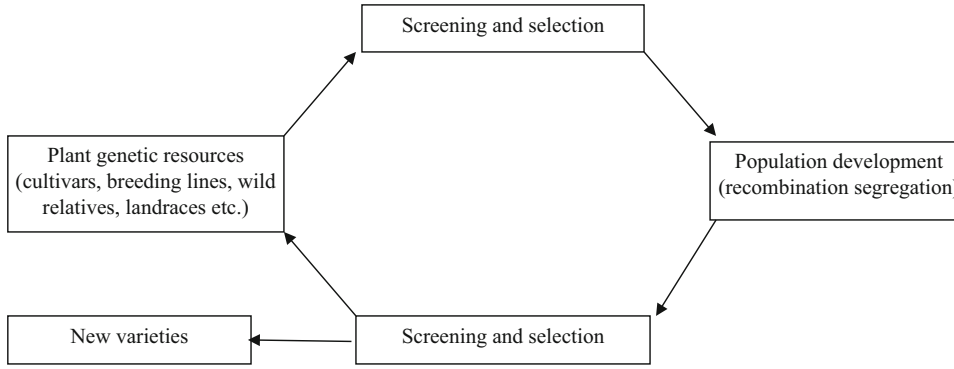

Fig. 1.3 Plant genetic resource for development of new cultivars

1.5.2.4 Wild Relatives

The wild relatives of plant species contribute a major portion in PGR. Like landraces, wild relatives of crop species also possess desirable characters for crop improvement. Compared to landrace varieties, wild species are difficult to cross with cultivated varieties due to some crossability barriers. To overcome these barriers, techniques like embryo rescue, protoplast fusion and genetic engineering are being used to transfer the desirable characters from the wild relatives to cultivated varieties.

1.5.2.5 Use of PGR as Varieties

PGR contain diverse genotypes which enable the plant breeders and the farmers to make selection among the diverse genotypes with specific characters. The potential and promising PGR can be used directly as cultivar. The diverse PGR genotypes are adapted to specific environment with potential yield and can be released as a promising variety. These released varieties can be used in breeding programmes for the transferring of the desirable traits to other well-adapted varieties. The use of PGR as a direct cultivar is more desirable if trait of interest is easily identifiable among the germplasm (Fig. 1.3).

1.5.2.6 Source of Resistance to Plant Diseases and Insect Pests

The varietal resistance is the most effective method for developing resistance varieties. The diversity in PGR is a rich source of resistance genes for plant diseases and insect pests. These resources can be effectively utilised in plant breeding programmes for the improvement of crop varieties. Modern plant breeding methods, particularly the molecular breeding, involve the transfer of resistance genes in a widely cultivated variety through Marker-Assisted Selection (MAS) and Marker-Assisted Backcross Breeding (MAB) methods. The pyramiding of different resistance genes has been successfully introduced in a number of crop varieties (Singh et al. 2001; Xu et al. 2006; Sundaram et al. 2010).

1.6 Challenges in PGR

The impact of humans upon biological plant biodiversity has gradually increased with growing industrialisation, technology, population, production and consumption rates. Food security and accessibility along with gross mismanagement are contending issues which impact on PGR. Since the inception of green revolution, the landraces and the wild relatives of crop species are being eroded which narrow down the genetic diversity of PGR. This is further compounded by issues arising from patent rights. Most of the developing countries are continuously facing the problem of climate change, population growth and biotic and abiotic stresses in agriculture which directly cause instability in food production.

1.6.1 Habitat Loss and Modification

The over-exploitation of PGR to meet the daily needs of people affects the habitat to a great extent. The utilisation of PGR without conservation vanishes these resources completely. For example, the extraction of oils with deforestation leads to air pollution and degradation of environment (Olubisi and Oluduro 2012). Therefore, intensive measures should be undertaken for conserving these valuable resources and sustainable utilisation to secure the food security for the next generations.

1.6.2 Climate Change

A significant negative impact of climate change has been observed on the PGR and related resources. The climate change affects the environment and often leads to perturbations such as drought, flood and disease. Sometimes extreme weather conditions also likely to affect the crop production and diminish crop productivity in many areas. The rise in sea level, causing loss of coastal land and saline water intrusion, also leads to PGR depletion (Pisupati and Warner 2003). This will impact on the distribution of PGR and most likely alter their physiognomy.

1.6.3 Insect Pest and Diseases

The effects of human activities have introduced certain levels of stress to natural resources including PGR. This stress will overtime weaken the immunity of the affected population. More so, PGR are now susceptible to different new diseases and insect pests absent in the original population. Reduction in gene pool increases vulnerability to various diseases and insect pests. It has been observed that varietal resistance is the most effective method of crop protection against the diseases and insect pests (Bhullar et al. 2012).

1.6.4 Alien Species

The plant species which are introduced in a new area of their origin are termed as the alien species. These species are invasive in nature and outcompete the native and indigenous plant species which sometimes completely vanish the habitat of that area. The nonindigenous plant species become noxious and the native crop completely lost, threatening the genetic diversity of PGR which is the second most important threat after habitat loss (CBD 2005). The genetic diversity loss of plant species is now comparable to habitat loss if it occurs on an island (Baillie et al. 2004). With the invasion of alien genotypes, the ecosystem of that region is completely distorted by changing the composition of different plant species existing in that area (McNeely et al. 2001). Not all alien plant species are invasive, but policies should be framed to check and avoid the invasive behaviour of these species to prevent the loss of biodiversity.

1.6.5 Patent Rights for the Protection of PGR

The protection of PGR in developing countries is important to avoid the over-exploitation of genetic resources by the developed nations. Moreover, there is a huge difference in Intellectual Property Rights (IPRs) given to the farmers or indigenous people and the plant breeders. The farmers and indigenous people are the main stakeholders who are preserving and sustainably using these resources. The indigenous communities are facing the challenge of complete loss of these genetic resources by over-exploitation. The PGR protection policies should be made in order to avoid the over-exploitation of these important resources by the developed countries. All these are challenges because they consider plant species not for what they are but for the value that can be derived thereof.

1.6.6 Genetic Erosion

The genetic erosion of PGR is of great concern for most of the developing countries. Most of the genetic resources are being extinct from their native area due to various biotic and abiotic factors, climatic factors and the development of modern varieties. The replacement of landrace varieties with modern varieties is one of the main causes of genetic erosion of PGR (Rosendal 1995). Although seed banks and gene banks play an important role in conserving and maintaining these varieties, but these resources are being lost even in the gene banks due to improper handling and management of these resources (FAO 1998).

Creating and maintaining crop genetic diversity and their varieties in production systems can help to reduce vulnerability and can be said to impact on ecosystem stability. In current plant breeding methods, we are mostly favouring the selection of few desirable traits controlled by single gene/allele. This will narrow down genetic diversity in PGR (Prada 2009). This process reduces the levels of genetic diversity. Moreover, most of the modern cultivars are descended from landraces which significantly reduced the diversity in plant species (Bhullar et al. 2012).

1.6.7 Conservation of PGR

Conservation of PGR is the process that actively retains the diversity of the gene pool with a view of actual or potential utilisation. Utilisation is the human exploitation of that genetic diversity. The main aim of genetic resources conservation is to explore, collect and preserve adaptive gene complexes for present or future use (Hammer and Teklu 2008). The conservation of PGR is very important for sustainable utilisation of these resources to secure the food security for the future. The farmers have domesticated these plant species including wild relatives, landraces and economically important medicinal plants. They preserved these materials for future planting to secure their livelihood. At that time indigenous people are unaware about the importance of these resources for commercial use. Later on the plant breeders used these diverse materials in breeding programmes for the development of new crop varieties (Hammer and Teklu 2008).

1.7 Potentials of TK

TK is the experience obtained over years through traditional practices and is the common property of the local and indigenous communities. Each member in the community contributes towards this knowledge over time. Over the last two and a half decades, the knowledge of these resources has been significantly increased in the developed as well as developing countries (Sinclair and Walker 1999). TK may be different from the Western knowledge which is based on global experiences, scientific discoveries and other cultures (Greaves 1996). The indigenous people are linked with these traditional practices for various social, religious, economic and cultural activities (Agrawal and Gibson 1999).

1.7.1 TK in Agricultural Practices

Traditional and local technical knowledge are often used by the local and indigenous people in their agricultural practices. Traditional practices used by the indigenous communities in farming system help to maintain the genetic diversity in genetic resources also. TK practices in agriculture have been ignored with introduction of modern scientific methods of farming system in agriculture. With the inception of green revolution, most of the traditional practices are wiped out from the agriculture mainly in Asian countries. But TK practices are being recognised again in the developed and developing nations. These are being preserved and utilised in agricultural crop productions in most of the countries. The growing knowledge and information on vast potentials of TK help the people to use these resources on sustainable basis. According to Agrawal and Gibson (1999), scientists, policy-makers, nongovernmental organisations (NGOs) and community-based organisations (CBOs) have collected the information on traditional

practices being used in agricultural practices. But this information is very meagre, and we have to collect more information on TK practices being used by the farming communities in agriculture.

Indigenous knowledge developed through traditional practices over generations and the information are being transferred orally as well as through practices. These traditional practices may be agricultural crop production techniques or related to health (Anuradha 2007). TK has multiple roles in agriculture practices and in curing human health. The traditional practices in agriculture provide the food security to local and indigenous people on sustainable basis without disturbing the genetic diversity.

1.7.2 Prevention of Soil Erosion

It is estimated that the frequency of soil erosion has been significantly increased with the inception of modern agricultural practices. Compared to modern practices of crop production, indigenous practices have less soil erosion. This may be due to cultivation of various landrace crop varieties in different combinations, i.e. deep-rooted crop followed by shallow crops, growing of different crops in the same area to avoid the disease and insect pest outbreaks, traditional methods of conserving soil moisture, etc. Keeping the crop residues after harvest prevents the soil from direct exposure to wind and water. Soil and water conservation is also promoted by residue of remains on the surface of soil. To avoid erosion of soil, the farmers are planting deep-rooted ornamental crops at the base (Fig. 1.4). The indigenous people also have diversified system of farming. The indigenous farmers are growing different agricultural and horticultural crops in different combinations to prevent the soil erosion and conservation of soil moisture. These practices are very helpful for conserving soil and water and nutrient management and reduce soil erosion and genetic diversity.

1.7.3 Intercropping

In this system different crops are grown in the same season and in the same field. Despite the strong campaign for promoting the modern system of crop production such as monoculture, intensive agriculture and high-yielding varieties (HYVs), the indigenous farmers are still using traditional practices for the cultivation of different crops. They are using their own techniques for the production of different crops in a diversified system and grow the crops in different combinations. The indigenous people are generally growing the deep-rooted crop with shallow-rooted crops,

Fig. 1.4 Soil conservation by planting ornamental crops in the slope

Fig. 1.5 Soil and water conservation by planting lemon grass on the bunds of paddy field

pulses with cereals to conserve the nitrogen in the soil and tall varieties with small varieties to act as windbreak. Farmers are planting lemon grass at the bunds of paddy field to conserve soil as well as water in the field and to get additional income from lemon grass (Fig. 1.5). The lemon grass protects the soil from erosion and conserves the water inside the paddy field. These practices no doubt conserve soil and water but also provide extra income to the farmers by extracting oil from the lemon grass. The intercropping practices are very important where erratic rainfall occurs. In this case farmers can get some income from at least one crop even if its companion crop fails.

This cropping system also provides continuous source of income to the farming communities. The growing of different crop species on the same field also conserves the biodiversity of that region. It is estimated that the diversity in plant species is more in developing countries compared to developed nations. The livelihood of indigenous people in most of the developing countries depends on this type of farming system which provides continuous source of income and food security.

1.7.4 Indigenous Knowledge of Crop Plants

The indigenous communities have the knowledge of importance of each valuable crop plant. They cultivate these crop plants depending upon their need. The farmers know the value of crop plants, production techniques, nutrient value, taxonomy, market value, etc. The indigenous farmers are well aware about biological diversity and the dietary values of crop plants for food security. It is estimated that about 614 racial groups in Africa depended on wood from forest for their livelihood (Makombe 1993). They recognise crop varieties suited to different ecological conditions, i.e. in alkaline soils, sodic soils, wet lands, etc. The indigenous farmers are very conscious to use different crop plants and varieties for particular seasons, tolerant to drought, heat and others stress tolerance factors. They know that the newly developed modern crop varieties are less resistant to various biotic and abiotic stresses. Farmers have a strong commitment to use particular variety in different situations to avoid the complete crop failure.

1.7.5 TK Methods for Storage of Seeds

The indigenous farmers have various traditional methods of storing their farm produce and seeds for the subsequent seasons. These methods are well adapted to various ecological conditions. They generally mixed ash with grains of different cereal and leguminous crops kept in bins. The maize crop seeds are stored in the cobs itself and placed or hanged on the trees. In some cases the farmers mix their grain with leaves of neem tree for long storage and to save their produce from the attack of any insect pests and diseases. Some farmers used sand for storage of leguminous crops. The sand is mostly used in humid conditions to keep the storage bins dry and to avoid any attack from insect pests.

1.7.6 TK in Treatment of Seeds before Sowing

The seed treatment is generally given before sowing the crops to eliminate the infested seeds from diseases or insect pests. This technique also promotes good and fast germination of seeds. Generally farmers soak their seeds overnight and sow the seeds next day for fast germination. The farmers also mix ash in water before soaking the seeds. Some farmers mix the ash with the wet seeds after soaking. Sometimes the leaves of neem trees are mixed with water before soaking the seeds. This will disinfect the seeds and reduce the infestation of any diseases before sowing.

1.7.7 Traditional Methods of Foodstuff Storage

Traditional technologies are being used by the indigenous people for storing the processed foodstuffs in the form of dried fruits and vegetables, butter converted into cheese or ghee and other fermented food items during the lean period to avoid any bacterial or fungal attacks. The foods stored by using these traditional methods are more nutritional compared to modern methods, as in traditional methods of storage of food items, there were no chemicals used to increase the longevity of food items. For fermentation and processing of other material, traditional biotechnology is more effective even today. Keeping in view the nutritional importance of storage food by traditional methods, the Western nations are interested to use these techniques.

1.7.8 TK to Control Pests and Diseases

The insect pests in crop production areas are causing a huge loss to crops. Indigenous people are having the deep knowledge of breeding cycles of various insect pests and diseases in a season. The farmers are also aware of the congenial environment for the multiplication of these insect pests. The farmers clear their land immediately after the harvest of crops to avoid the breeding cycle of the insect pests and diseases. In the cropping seasons, the farmers keep sanitation in the fields by clearing the bunds. Other methods to reduce the incidence of insect pests and diseases are to use well-rotten farmyard manures in the field before sowing. This will completely destroy the pests and avoid the multiplication of diseases, as fresh farmyard manure is the alternate host for some insects. The indigenous people are rarely using the insecticides, fungicides and fertilisers for the production of crops which adversely affect the ecosystem. To control the insect pests and diseases, farmers are using traditional practices such as timely sowing of suitable varieties, proper tillage of soil, burning of crop residue after harvest, zero tillage to capture the soil moisture and botanical control of diseases and insect pests. To avoid the vulnerability the indigenous people are using diversified system in agriculture.

1.7.9 TK in the Development of Healthcare Products

Most of today's medicines are originated from the ancient system of medicine production in

which traditional practices have been used. These traditional practices are likely to be used in the future also (Ameenah 2011). Presently, the natural products or their derivatives are contributing a major portion in the medicine system. Today drug development and discovery prepared by using natural resources are in great demand because of numerous drawbacks in developing new synthetic molecules from active components or pure chemicals. In the traditional method of medicine production, most of the drugs are developed on the basis of pharmacokinetics. In the modern system of medicine production, drugs are developed like a bullet which strike at the particular target place (Gangadharan 2005). In the future, we will be able to redesign systems by modification or drugs to have completely new systems properties (Hood 2003). All of modern drugs are created within the confines of a chemical paradigm of medicine and drug therapy (Gangadharan 2005). In Ayurveda, a drug brings the equilibrium of the body and corrects the damages brought by imbalance of the *doshas*. For example, when Triphala (*Terminalia bellirica*) is taken as purgative, it removes the unwanted materials from the system, but does not in any way disturb the intestinal flora in the process. According to Patwardhan et al. (2003), indigenous medicine knowledge and drug development can reduce the toxicity effect of medicine compared to allopathic medicines.

1.8 Challenges in TK

The commercialisation of TK starts with the rise in industry. Indigenous people were unaware about the importance of their genetic resources. After the inception of modern techniques, the concept of protection of indigenous peoples' knowledge on traditional practices as well as resources has risen. IPR was enforced to protect the interest of these people. IPR is a legal concept that deals with creations of human ingenuity. After the inception of IPR protection norms, farmers are getting their equal shares from the benefits arisen out of TK. Modern technologies and TK are not just about incompatible values, attitudes and practices but also relate to rights within a legal framework. Moreover, whenever we talk about innovation, we fail to recognise the innovation done by artisans, farmers, tribes or other grass-roots innovators; therefore, these informal innovators have nurtured, refined and generated a rich system of the TK (Chandra 2010).

The indigenous communities are not aware about IPRs and protection of their traditional resources. Rather than protecting TK of indigenous people, IPR has facilitated the taking and commercialisation of this TK by individuals or entities without giving any royalties or compensation to the communities who have generated such knowledge. This use or taking of this valuable knowledge without consent or compensation has been characterised as "biopiracy" or "misappropriation". No doubt indigenous knowledge has been easily available to everyone for commercialisation, but now IPRs play a significant role to safeguard the interests of indigenous communities. TK of indigenous people can be protected under IPRs system and some benefits arisen out of it can be utilized for conservation and sustainable utilization of these resources. To provide the complete benefits to indigenous people, TRIPS Agreement was introduced. The main objective of this Agreement is to provide the claim and rights to holders on the TK. In TRIPS, indigenous knowledge is completely associated with social and cultural norms. However, some of the indigenous people are not aware of TRIPS and are getting full benefits of sharing their TK.

Despite TK is having rich information on utilisation and economic values, there are some barriers which prevent its extensive utility. Moreover, the indigenous knowledge is known in local languages, and their widespread is very less compared to modern practices. The international debates are going on in most of the countries for its globalisation, protection and sustainable utilisation (Chandra 2010). TK is having its own importance, and it is being acknowledged by the world communities. Now, most of the developed and developing countries are emphasising for its protection. The current IP rights regimes fail to provide any rewards to the public domain foundations also known as "traditional knowledge",

on which the innovations may be based. Thus, it becomes a matter of great concern when the IP regime is extended to the biodiversity and TK domain (Mandal 2011).

Indigenous peoples' social and cultural activities are totally based on TK, and most of them depend for their food security (Varkey 2011). These people have deep knowledge of TK for creations and innovations, and they develop all these things in an environment where they dwell. According to the World Health Organization (WHO), it is estimated that most of the world population relies on traditional medicine (Erstling 2011).

1.9 Key Common Factors Eroding PGR and TK

There are numerous factors responsible for degradations of genetic resources, but some of the important key factors responsible for erosion of PGR and TK are listed below:

1. Encouragement of newly released crop varieties and other subsidiaries provided by the government from time to time.
2. Change in demand of consumers for newly developed products by the modern technologies and R&D institutions all over the world. With the popularity of these products, the demand for traditional products decreased subsequently.
3. The increase in population growth also leads to the fragmentation of landholding of farming communities. The farming communities have changed their profession and used this land for other purposes which directly affect the over-exploitation of PGR.
4. New policies and treaty have been framed for the protection of newly developed high-yielding varieties (HYVs) and new products. Recently, the newly developed varieties have been protected under Plant Breeders' Rights (PBRs) and Protection of Plant Varieties and Farmers' Rights (PPV&FR) Act, but no such effective policy has been since long for the protection and over-exploitation of traditional resources.
5. Very less incentives have been given to the indigenous communities to protect and sustain utilisation of these traditional resources.
6. With adoption of modern culture and inception of Western culture, the living, cultural values and traditions of the people have been changed. People from the rural areas rich in traditions start moving to cities to change their occupations. All these urban styles directly and indirectly lead to change in preferences of the people which significantly affected the conservation and sustainable use of PGR and TK.

Moreover, for the protection of traditional resources, no effective policy has been framed by the international organisations. Recently, some policies have been framed, but their effective implementation is not there. It is estimated that the erosion of PGR also leads to the erosion of TK and its related resources.

1.10 Key Common Factors Sustaining PGR and TK

Recently, keeping in view the importance of PGR and TK to secure food, health and traditional cultures, a number of demands are being going on all over the world. With the inception of CBD in 1992, scientists and policymakers have given due consideration for the protection of these valuable resources. To protect and sustain these resources, the following are the key identified factors which need to be implemented successfully:

1. With the inception of green revolution, modern crop varieties have been introduced and the local landrace varieties wiped out of cultivation. For protection of PGR and TK, there is a need to revive these landraces for cultivation so that the biological diversity can be maintained.
2. There is a need to revive the traditional festivals and cultural events related to preserve TK and associated knowledge in the rural areas.
3. Reform should be made to avoid fragmentation of landholding of indigenous communities so that the traditional PGR would not be disturbed.

4. Regular demonstrations and field days should be organised by national and international agencies related to protection, conservation and their sustainable utilisation.
5. Emphasis should be given for exploration, collection and in situ conservation of PGR and associated knowledge.
6. There is a need for the farming communities to be aware about the importance and values of PGR and traditional resources. They should also be aware about their rights for commercialisation of these resources.

1.11 National and International Policies on PGR and TK Management

With the rise of global trade, PGR and TK come under threat due to over-exploitation of these resources. The economic pressure and privatisation have a great demand for PGR. The developed countries are trying to use these genetic resources for commercial purposes. The major global issues impacting PGR and TK for sustainable utilisation include the international treaties, conventions and agreements; global climate change; use of biotechnology and other technological advances in agriculture; and biosecurity and biosafety. The rights and access to these resources are provided by the CBD (Byerlee and Fischer 2002). Member countries of CBD including India brought new acts establishing their sovereignty on PGR and TK occurring within their geographical boundaries. The USA is not a signatory to CBD.

The WTO deals in the formulation of rules and regulations related to commercialisation of goods among the different countries. TRIPS and Sanitary and Phytosanitary (SPS) agreements under WTO have direct impact on PGR activities. IP on PGR, microbiological processes and microorganisms are covered under TRIPS rules and regulations. Amendments to the existing patent act and the protection of PGR in WTO are directly controlled by TRIPS. The preservation and sustainable utilisation of Plant Genetic Resources for Food and Agriculture are included under GPA. These resources are maintained and conserved as in situ or on farm to preserve genetic diversity in genetic resources.

The main mandate of ITPGRFA is the conservation and sustainable use of PGRFA and the fair and equitable sharing of the benefits arising out of their use, in harmony with the CBD, for sustainable agriculture and food security. It has been emphasised and recognised that the indigenous communities and local farmers have significantly contributed and are contributing towards collection of economical important PGR, their preservation and sustainable utilisation. ITPGRFA has provided recognition to the farmers and sharing of benefits arising out of the utilisation of these resources under revised Standard Material Transfer Agreement (SMTA) that has relevance to the food security. For protection of TK and to discuss IPR-related issues of accessing the PGR, the WIPO has set up ICGTK in 2001 (Varaprasad and Sivaraj 2010). TK is legally protected in association with the biological resources.

To secure the food security in India, the PGR and TK values are recognised in harmony with several international treaties; the government has come up with the initiatives such as enactment and implementation of the Biological Diversity Act (BDA) in line with CBD and PPV&FR Act, providing unique rights to farmers on par with qualified breeders. The Patent Act was modified suitably ensuring approval for all the patents involving biological resources from the National Biodiversity Authority (NBA). Provisions to protect and conserve threatened plant species through notification are being implemented through BDA. The National Bureau of Plant Genetic Resources (NBPGR) issued a plant quarantine order under the Destructive Insects and Pests Act which facilitates the safe import of plant material authorising for PGR. Interministerial committees such as Genetic Engineering Approval Committee (GEAC) are functioning to facilitate genetic transformation research and import of genetically modified plants (Varaprasad and Sivaraj 2010).

1.12 Conclusion

The improvement of crops largely hinges on immediate conservation of PGR and TK for their effective and sustainable utilisation. A vast amount of PGR is threatened and endangered, and some have even gone extinct mostly due to genetic erosion and environmental transformation by anthropogenic effect. In order to meet current global challenges, all countries and institutions must as a matter of primary obligation discover, collect and conserve valuable and potentially valuable PGR and sustainable utilisation. In order to reduce the potential losses of PGR and TK resources, the knowledge of distribution of biodiversity in species as well as in ecosystems is important, and this can be achieved through efficient survey, inventory, appropriate research, field studies and analysis. Sustainable agriculture should be promoted by using diverse crop varieties in farming system, bringing more underutilised crops for cultivation and their commercialisation. The management of PGR should be integrated with the best utilisation of indigenous knowledge. Modern technologies should be combined with traditional practices for the protection, conservation and improvement of the resources.

For PGR and TK more natural reserved areas should be created, and those existing should be properly managed and financially supported, and an effective enforcement of laws should guard them. In order to make PGR more accessible to farmers and the plant breeders, proper documentation of these resources is required. Multi-institutional support is needed for conservation and potential use of indigenous knowledgeable medicinal plants for health and related purposes. Moreover, sharing of benefits to access traditional practices and other genetic resources is imperative for uniform development and to secure the livelihood of the farmers. Such access to PGR and TK and equal sharing of benefits with the indigenous and local people should be provided under certain norms and conditions. PGR and TK should be recognised on priority basis by the world communities to secure the world food security. More awards and respectful recognition should be given to the indigenous people and farmers who are really involved in conservation of valuable genetic resources. There is a need to create more awareness among the farmers for proper conservation of these resources to save the biodiversity. Approaches for better management of PGR and TK need to look for more species and genes to provide bio-alternatives and use both traditional approaches and modern technologies.

References

Agrawal A, Gibson CC (1999) Enchantment and disenchantment: the role of community in natural resource conservation. World Dev 27(4):629–649

Alston JM, Chan-Kang MC, Marra PP, Wyatt TJ (2000) A meta-analysis of rates of return to agricultural R&D: ex pede herculem? Research report 113. Intl Food Policy Res Institute, Washington, DC, p 118

Ameenah GF (2011) Traditional roles and future prospects for medicinal plants in health care. Asian Biotechnol Dev Rev 13(3):77–83

Anuradha RV (2007) Biopiracy and traditional knowledge. http://www.hinduonnet.com/folio/fo105/01050380.htm

Baillie JE, Hilton-Taylor C, Stuart SN (2004) IUCN red list of threatened species. A global species assessment. IUCN- World Conservation Union, Gland, p 25

Bhullar NK, Zhang Z, Wicker T, Keller B (2012) Wheat gene bank accessions as a source of new alleles of the powdery mildew resistance gene *Pm3*: a large scale allele mining project. BMC Plant Biol 10:88

Bonham C, Dulloo E, Mathur P, Brahmi P, Tyagi V, Tyagi RK et al (2010) Plant genetic resources and germplasm use in India. Asian Biotechnol Dev Rev 12(3):17–34

Briggs KG (2000) Plant genetic resources. Manag Agric For Fish Enterp 1:1–8

Brown AHD (1989) The case for core sets. In: Brown AHD, Frankel OH, Marshall DR, Williams JT (eds) The use of plant genetic resources. Cambridge University Press, Cambridge, pp 136–155

Byerlee D, Fischer K (2002) Accessing modern science: policy and institutional options for agricultural biotechnology in developing countries. World Dev 30(6):931–948

CBD (2005) Invasive alien species. Convention on biological diversity. http://www.biodiv.org/programmes/cross-cutting/alien/

Chandra R (2010) Knowledge as property, issues in the moral grounding of intellectual property rights. Oxford University Press, New Delhi, p 292

Dowd D (2009) Inequality and the global crisis. Pluto Press, London, pp 144–145

Erstling J (2011) Using patent to protect traditional knowledge. Tex Wesleyan Law Rev. www.wmitchell.edu/cgi/viewcontent.cgi?article=1187&context=facsch

Evenson RE, Gollin D (2003) Assessing the impact of the green revolution, 1960 to 2000. Science 5620:758–762

FAO (1996) Report on the state of the world's plant genetic resources for food and agriculture. International technical conference on plant genetic resources, Leipzig

FAO (1998) The state of the world's plant genetic resources for food and agriculture. FAO, Rome, p 89

FAO (2001) International Treaty on Plant Genetic Resources for Food and Agriculture. http://www.fao.org/ag/cgrfa/it/ITPGRe.pdf

FAO (2012) Food and Agriculture Organization. The State of Food and Agriculture. ftp://ftp.fao.org/docrep/fao/009/a0800e/a0800e.pdf

Frankel PH (1984) Genetic perspective of germplasm conservation. In: Arber W, Llimensee K, Peacock WJ, Starlinger P (eds) Genetic manipulations: impact on man and society. Cambridge University Press, Cambridge, pp 161–170

Gangadharan GG (2005) Potential of traditional knowledge in the development of healthcare products. Indian J Tradit Knowl 4(2):139–142

Gepts P (2006) Plant genetic resources conservation and utilisation: the accomplishments and future of a societal insurance policy. Crop Sci 46:2278–2292

Greaves (1996) Tribal rights. In: Brush, Stabinsky (eds) Valuing local knowledge: indigenous peoples and intellectual property rights. Island Press, Covelo

Gupta VK (2006) Documentation of traditional knowledge for protection: preservation and wealth creation. In: Proceedings of the international conclave on traditional medicine, New Delhi

Gupta BB, Salgotra RK, Bali AS (2009) Status paper on rice in Jammu and Kashmir. Rice Knowledge Management Portal (RKMP). http://www.rkmp.co.in

Hammer K (2003) A paradigm shift in the discipline of plant genetic resources. Genet Resour Crop Evol 50:3–10

Hammer K, Teklu Y (2008) Plant genetic resources: selected issues from genetic erosion to genetic engineering. J Agric Rural Dev Trop Subtrop 109:15–50

Hirwade M, Hirwade A (2012) Traditional knowledge protection: an Indian prospective. J Libr Inf Technol 32(3):240–248

Hoisington D, Khairallah M, Reeves T, Ribaut JM, Skovmand B, Taba S, Warburton M (1999) Plant genetic resources: what can they contribute toward increased crop productivity? Proc Natl Acad Sci U S A 96:5937–5943

Hood L (2003) Principles, practice and future of systems biology. Drug Disco Today 8(10):436–438

Hvalkoff S (2001) Outrage in rubber and oil. In: Zerner C (ed) People, plants and justice. Columbia University Press, New York, p 56

Hyten DL, Smith JR, Frederick RD, Tucker ML, Song Q, Cregan PB (2009) Bulked segregant analysis using the Golden Gate assay to locate the *Rpp3* locus that confers resistance to soybean rust in soybean. Crop Sci 49:265–271

IUPGR (1983) International Undertaking on Plant Genetic Resources for Food and Agriculture. http://www.fao.org/ag/cgrfa/IU.htm

Koo B, Pardey PG, Wright BD (2004) Saving seeds: the economics of conserving crop genetic resources *ex situ* in the future harvest centers of the CGIAR. CABI Publishing, Wallingford, p 67

Leipzig Declaration (1996) International technical conference on plant genetic resources, Leipzig. http://www.fao.org/FOCUS/f/96/06/more/declar-f.htm

Makombe K (1993) Sharing the land: wildlife, people and development in Africa. IUCN, Regional Office of Southern Africa, Harare

Mandal PK (2011) "Challenges to India's Patent Regime-"Traditional Knowledge sharing". www.papers.ssrn.com/sol3/papers.cfm?abstract_id=1393363

McNeely JA, Mooney HA, Neville LE, Schei P, Waage JK (2001) Global strategy on invasive alien species. IUCN – the World Conservation Union, Gland, p 46

Ogwu MC, Osawaru ME, Ahana CM (2014) Challenges in conserving and utilizing plant genetic resources. Intl J Genet Mol Biol 6(2):16–22

Olubisi F, Oluduro OF (2012) Nigeria: in search of sustainable peace in the Niger Delta through the amnesty programme. J Sustain Dev 5(7):4–7

Patwardhan B, Chopra A, Vaidya ADB (2003) Herbal remedies and the bias against Ayurveda. Curr Sci 84(9):1165

Pisupati B, Warner E (2003) Biodiversity and the millennium development goals. IUCN/UNDP, Colombo, p 8

Prada D (2009) Molecular population genetics and agronomic alleles in seed banks: searching for a needle in a haystack? J Expt Bot 60:2541–2552

Rosendal GK (1995) Genbanker-bevaring av biologisk mangfold (Genebanks-conservation of biodiversity). In: Stenseth NC, Paulsen K, Karlsen R (eds) Afrikanatur, samfunn og bistand. Ad Notam Gyldendal, Oslo, pp 375–392

Salgotra RK, Gupta BB (2005) Variability and correlations among different quantitative traits of rajmash (*Phaseolus vulgaris* L.). Abstracts of fourth international food legumes research conference, New Delhi, India, p 502

Salgotra RK, Gupta BB, Bhat JA, Sharma S (2015) Genetic diversity and population structure of basmati rice (*Oryza sativa* L.) germplasm collected from North Western Himalayas using trait linked SSR markers. PLoS One 10(7):e0131858. doi:10.1371/journal.pone.0131858

Sanchez PA, Swaminathan MS (2005) Cutting world hunger in half. Science 307:357–359

Sinclair FL, Walker DH (1999) A utilitarian approach to the incorporation of local knowledge in agroforestry research and extension. In: Buck LE, Lassoie JP, Fernandes ECM (eds) Agroforestry in sustainable agricultural systems. CRC Press LLC, Boca Raton, pp 245–275

Singh S, Sidhu JS, Huang N, Vikal Y, Li Z, Brar DS, Dhaliwal HS, Khush G (2001) Pyramiding three bacterial blight resistance genes (*xa5, xa13* and *Xa21*) using marker-assisted selection into *indica* rice cultivar PR106. Theor Appl Genet 102:1011–1015

Smale M, Koo B (2003) Genetic resources policies: what is a gene bank worth? Research at a glance. Briefs 7–12. IFPRI, IPGRI, and the Systemwide Genetic Resources Program, p 34

Sodhi NS, Erlich PR (2010) Introduction. In: Sodhi NS Erhlich PR (ed) Conservation biology for all. Oxford University Press, Oxford, p 1

Sundaram RM, Sakthivel K, Hariprasad AS, Ramesha MS, Viraktamath BC, Neeraja CN, Balachandran SM (2010) Development and validation of a PCR-based functional marker system for the major wide-compatible gene locus *S5* in rice. Mol Breed 26:719–727

Tanksley SD, McCouch SR (1997) Seed banks and molecular maps: unlocking genetic potential from the wild. Science 277:1063–1066

Ulukan H (2011) Plant genetic resources and breeding: current scenario and future prospects. Intl J Agric Biol 13:447–454

van Hintum TJL (1999) The general methodology for creating a core collection. In: Johnsons RC, Hodgkin T (eds) Core set for today and tomorrow. International Plant Genetic Resources Institute (IPGRI), Rome, pp 10–17

Varaprasad KS, Sivaraj N (2010) Plant genetic resources conservation and use in light of recent policy developments. J Plant Breed 1(4):1276–1293

Varkey E (2011) Traditional knowledge-the changing scenario in India. www.law.ed.ac.uk/ahrc/files/67varkeytraditionalknowledgeinindia

Wani SH, Wani SA, Ishfaq Abidi, Dar ZA, Lone A, Gull Zaffar, Khan MN (2003) Plant genetic resources of Kashmir region – prospect for crop improvement. National Conference on Status and Conservation of Biodiversity in India, Kashmir University, Kashmir

Xu K, Xu X, Fukao T, Canlas P, Maghirang-Rodriguez R, Heuer S, Ismail AM, Bailey-Serres J, Ronald PC, Mackill DJ (2006) *Sub1A* is an ethylene response factor like gene that confers submergence tolerance to rice. Nature 442:705–708