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Biodiversity, Bioprospecting, Traditional Knowledge, Sustainable Development and Value Added Products: A Review

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Abstract

Biodiversity is the biological capital of the planet Earth and forms the foundation upon which the human civilization is built. The success of a nation depends upon the capability of her people to convert the biodiversity and other natural resources into wealth in an ecologically sound and economically rewarding and sustainable manner with the intervention of science and technology. The intrinsic potential of biodiversity as a key resource for developing novel value added products for food, medicine, cosmetics and other natural products of commercial importance have now been increasingly realized. The unknown potential of genetic diversity found in the biological organisms represents a never-ending biological frontier of intrinsic value. Genetic diversity will enable breeders to tailor crops to meet the ever-changing demands or needs and aspirations of humans as well as enabling to adapt to the changing climatic or other environmental conditions. The genetic resources are primarily used as source of valuable genes, chemicals, drugs, pharmaceuticals, natural dye, gum, resins, enzymes and proteins of great industrial value. Knowledge based, value added product development and its commercialization has become one of the fastest economic activities in the world. The liberalization of the global trade practice and other economic reforms evolving currently with the emergence of the United Nations Convention on Biological Diversity (UN-CBD) and the World Trade Organization (WTO) requires a deeper study and understanding, especially in the light of the latest path breaking achievements in science and technology particularly in areas like Information Technology (IT), Biotechnology (BT), Herbal technology (HT), and Nano-biotechnology (NBT). According to Mashellar) “twenty first century will be the century of knowledge” and “a nations ability to convert knowledge into wealth and social good through the process of innovation will determine its future”. A new thinking centered on the concept of ‘knowledge engineering’ for building future ‘knowledge industries’ is now getting greater attention and acceptance in the world over. Conversion of biodiversity and the associated traditional knowledge system (TKS) into value added globally competitive commercial products with appropriate safeguards for Intellectual Property Rights (IPR) protection are some of the key strategies for achieving economic prosperity and well being for the people of nations like India.

Keywords: Biodiversity; Traditional medicine; Bioprospecting; Pharmaceuticals; Intellectual Property Rights

Introduction

Biodiversity: Biodiversity is the sum total of life systems on our planet Earth encompassing the minutest microorganisms to the Mammoth elephant and man. Biodiversity exists in three levels- Species level, Habitat level and Gene level. India in general is rich in all these three levels of biodiversity. Rich biodiversity of India is matched with the equally rich cultural diversity and a unique wealth of traditional knowledge system developed, preserved, freely shared and cared by the society. India is gifted with immense faunal and floral diversity. India is 10th among the plant rich countries of the world and 4th among the Asian countries. Scheduled caste and scheduled tribe comprises about 16.6% and 8.6% respectively of India’s population according to the 2011 census. The constitution lists 1108 Scheduled castes across 25 states and about 744 Tribes across 22 states in the country. The tribals live in an around forests and other difficult terrains. They acquired unique knowledge about the use of many wide flora and fauna. Most of these are either lesser known or hither to unknown to the outside world. The treasure of traditional knowledge (TK) if subjected to scientific scrutiny could benefit human kind in many ways. The inroads of modernization are presently posing a threat to this TK and these are in imminent danger of losing out, this age- old wisdom and expertise can be lost for all times to come [1].

Traditional communities and rural folk are the real custodians of the knowledge of medicinally important plants and animals. Most of the knowledge accumulated by the traditional communities and rural people on medicinal plants and animals is unknown to the modern scientific community. Biodiversity, all over the world is facing the threat of depletion because of over exploitation. As an interdisciplinary science, ethnobotany is, therefore, in a position to preserve the wealth of traditional knowledge that indigenous people possess concerning the flora and fauna. This includes their knowledge on the utilization and maintenance of different types of plant resources on a long term basis without damaging or destroying their habitat. Hence, maximum effort should be made to document and integrate traditional knowledge and its associated biodiversity.

India’s Biodiversity

India has about 126,756 species of plants, animals, fungi and microorganisms already identified and classified (Table 1). And, it is likely that there could be another 400,000 species, most of them microbes or lower invertebrates, yet to be identified and described taxonomically. The flora of India is both rich and diverse due to wide range of variations in climate, altitude and ecological habitats. It is estimated that the floristic spectrum of India comprises of over 30000 species (excluding fungi, which are now being treated as a separate kingdom), of which the flowering plants with about 17,500 species

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	Number of Species		Percentage
TAXA	India	World	(Inida to the world)
Bacteria	1500	4000	21.25
Viruses	Unknown	4000	-
Algae	6,500	40,000	16.25
Fungi	14,500	72,000	20.14
Lichens	2,000	17,000	11.80
Bryophyta	2,850	16,000	17.80
Pteridophyta	1,200	13,000	8.46
Gymnosperms	64	750	8.53
Angiosperms	17,600	250,000	7.00
Protista	2,577	31,290	8.24
Mollusca	5,050	70,000	7.21
Arthropoda(Insecta, Crustacea, etc.)	6,0383	1,065,000	5.67
Other Invertebrates (Including hemichordata)	8,329	87,121	9.56
Protochordata	116	2,173	5.34
Pisces	2,546	21,723	11.72
Amphibia	206	5,145	4
Reptilia	485	5,680	8.54
Aves	1,228	9,672	12.69
Mammalia	372	4,629	8.03
Total	127,506	1,719,183	7.36

Table 1: India's Biodiversity.

constitute the dominant group- representing about 7% of the flowering plant species of the world. Endemism in Indian flora is now almost well documented. It is estimated that out of 17,500 species of flowering plants, 140 genera and 5285 species are endemic to the country. The endemic flora is concentrated mainly in three major hot spot centers of flora viz. The Eastern Himalayas (3500 species), the Western Ghats (1600) and the Andaman and Nicobar Islands (185) Based on the uniqueness of the phytogeographical zones and the pattern of edemism, 25 micro hot spot centers of endemic flora have been identified by Nayar (1996) [2]. The East Himalayas (Indo-Burmese region) and the Western Ghats and (Sri Lanka) are the two out of the 25 'global hot spots' of biodiversity [3].

In India species richness is complemented by enormous genetic diversity found within individual species. India is one among the 12 megagene centers of the world. The Indian Gene Centre (Vavilovian 'Hindustani' Centre) is considered the centre of origin and domestication of as many as 166 major and minor crop plant species and as many as 320 wild relatives of crop plants.

India has a very rich Gene pool of wild progenitors of crops, wild relatives and other species with potential valuable genes for both biotic and abiotic stress-such as pest/disease resistance, cold/drought resistant/tolerant environmental stress (tolerant to salt, heat, frost & cold). Wild gene pool occurring in biotically disturbed habitats is under the threat of genetic erosion and requires not only timely measures for its collection and conservation, desiccation sensitivity, water flooding/logging.

The Indian gene centre harbours at least 166 species of native cultivated plants. The crops with primary, secondary and regional centers of diversity represent a part of native and introduced species which account for over 480 species [4]. Diverse agroclimatic and agricultural practices have led to the rich diversity of crops species in the form of land races and cultivars. Besides, the centre has over 320 wild relatives and their diverse gene pools. Diverse agro climatic and edaphic variations resulted in evolving innumerable genetic and ecological variants. The genetic diversity is some plant species runs in 10,000 or more. The crop species are accessible for collection in fields, orchards, gardens, markets and with farmers. On the contrary, the wild relatives are difficult to locate as they grow in their natural habitats with other wild plants. There are also large number of lesser known or hitherto unknown species of medicinal, aromatic plants and plants yields valuable gum, resins, dye and other economically interested products. Nayar and Arora and Pandey [5], reported over 132 wild relatives of crop plants. These wild relatives of crop plants also exhibit enormous genetic variability offering immense opportunity for gene hunting for desired traits or for disease resistance.

Biodiversity performs two most important functions. Firstly, it regulates and maintains the stability of climate, water regime, soil fertility, quality of air and overall health of the life support system on earth. Secondly biodiversity is the source from which human race derives food, fodder, fuel, fibre, shelter, medicine and raw materials for meeting the multifarious needs for industrial goods required for the ever changing and ever increasing need and aspirations of human kind. Biodiversity is therefore the biological capital of our planet and forms the foundation upon which human civilization is built. Therefore it is extremely important that biodiversity shall be used only in a sustainable manner.

Traditional Knowledge

Traditional Knowledge (TK) is a community based system of knowledge that has been developed, preserved and maintained over generations by the local and indigenous communities through their continuous interactions, observations and experimentations with their surrounding environment [6,7]. It is unique to a given culture or society and is developed as a result of the co-evolution and co-existance of both the indigenous cultures and their traditional practices of resource use and ecosystem management. The accumulated wisdom, knowledge, belief and practices embodied in the TK system were handed down to generation by an unbroken tradition and culture. The medical wisdom of such traditional communities are the target of drug hunters as an effective short cut for locating new and useful compounds of great pharmaceutical value. It is now well known that the possibility of finding a potential bioactive compound through random screening of plant samples is 1 in 10,000 and that of hitting a marketable drug 1 to 4 of such potential hits. In contrast, the success rate of finding a bioactive compounds through selective screening based on traditional knowledge is 1 in 100 and that the discovery of a marketable drug is 1 in 2. Many plant derived drugs employed in modern medicine were first discovered through ethnopharmacological investigations.

The traditional knowledge associated with the biodiversity which is developed and held within the indigenous and local communities are thus found to be the most valuable lead for modern technological innovations and in developing novel food (functional food, medicinal food, and nutraceuticals), medicines (drugs and pharmaceuticals), phytochemicals and other products of commercial importance. Biodiversity and TK are thus the most powerful resources which with the interventions of science and technology can generate wealth with the advent of new tools and techniques, particularly biotechnology could convert biodiversity resources into industrially and commercially valuable products and processes having increased productivity and application in many crucial areas such as agriculture (including aquaculture) healthcare, medicines, vaccines, diagnostics, gene(s)-genetheraputics, environmental protection and bio-energy etc.

All India Co-ordinated Research Project on Ethnobiology (1982-1998)

The Indian Council of Agricultural Research convened a meeting of it's inter organizational panel for food and agriculture on September 21, 1976 under the Chairmanship of Prof. M. S. Swaminathan, the then Director General, ICAR. Prof. Swaminathan felt the urgent need to undertake an ethnobilogical study of the tribals of the country to tap and document the fast disappearing life style, knowledge system and wisdom of these people. This panel decided to form a team of experts to examine the current status of ethnobiological studies of the tribal areas and to submit a report as to how the biological resources found in these communes could be conserved and utilized for socio-economic improvement of tribals on one hand and country on the other. Dr. T N Khoshoo along with Dr. E K Janaki Ammal prepared the All India Co-ordinated Research Project on Ethnobiology (AICRPE) project proposal which was considered by the high level committee of Science and Technology, Govt. of India. Department of Science and Technology (DST) formerly launched the project in July 1982 under the Man and Biosphere Programme (MAB) of UNESCO. When the Ministry of Environment and Forest (MoEF) came in to being the MAB programme along with AICRPE was transferred to MoEF. In September 1983, MoEF set up a co-ordination unit at RRL, Jammu (now known as Indian Institute of Integrative Medicine, CSIR-IIIM) under Dr. C. K. Atal. Dr. P. Pushpangadan was appointed as the Chief Co-ordinator of this project for overall supervision, co-ordination and implementation of various programmes included in the AICRPE [7,8]. It was operated at 27 centers in the country and about 600 scientists drawn from botany, zoology, sociology, anthropology, ayurveda, chemistry and pharmacology worked in this project that lasted for 16 years (1982-1998). AICRPE project documented the use of over 10,000 wild plants used by tribals for meeting a variety of their requirements.

Bioprospecting and development of knowledge based value added products

Biodiversity, herbal technology, biotechnology and nano-biotechnology are the areas that deserve special attention from the perspectives of new rein of knowledge-based industrial ventures, international trade and IPR protection. Biodiversity has economic, ecological, aesthetic and existence value. The direct economic benefits derived from biodiversity include food, fodder, fuel, fibre, colorants, medicine, aromachemicals, flavorants, perfumes, oils, gums, resins, dyes, biopesticides, bioinsecticides, honey, phytochemicals, proteins and genes. The development of value added and standardized products using low and medium technology is known as herbal technology, intervention of more advanced scientific and technological intervention we call it as biotechnology and manipulation at subcellular/ultra molecular level i.e. upto the 10^{-9} size level, it is called Nanobiotechnology. Biodiversity thus represents (i) a priceless resource with many actual uses and potential values to humanity and (2) a complex self-sustaining ecological system that helps, maintain the integrity and resilience of biosphere. These two complementary perceptions would lead to the surmise that biodiversity is an invaluable natural resource, which needs to be conserved and sustainably utilized for the benefit of the present as well as the future generations of humankind. Humankind has tapped only a fraction of this great nature's genetic library. Bioprospecting is the systematic search for genes, natural compounds, designs and whole organisms of forest/wildlife with potential for product development. Bioprospecting has three important facets like 'chemical prospecting, gene prospecting and bionic prospecting'.

Genesis of the Subject Ethnopharmacology

Ethnopharmacology as a scientific term was first introduced at an international symposium held at San Francisco in 1967. This was used while discussing the theme 'Traditional Psychoactive drugs' in this Symposium. But later Rivier and Bruhn [9] made an attempt to define Ethnopharmacology as "a multidisciplinary area of research concerned with observation, description and experimental investigation of indigenous drugs and their biological activities. It was later redefined by Bruhn and Holmstedt [10] as "The interdisciplinary scientific exploration of biologically active agents traditionally employed or observed by man". In its entirety, pharmacology embraces the knowledge of the history, source, chemical and physical properties, compounding, biochemical and physiological effects, mechanism of action, absorption, distribution, biotransformation, excretion and therapeutic and other uses of drugs. A drug is broadly defined as any substance (chemical agent) that affects life processes. Therefore, briefly, the main component of ethnopharmacology may be defined as pharmacology of drugs used in ethnomedicines. However, none of the above said definitions captures the true spirit of this interdisciplinary subject. Ethno- (Gr., culture or people) pharmacology (Gr., drug) is about the intersection of medical ethnography and the biology of therapeutic action, i.e., a transdisciplinary exploration that spans the biological and social sciences. This suggests that ethnopharmacologists are professionally cross-trained – for example, in pharmacology and anthropology – or that ethnopharmacological research is the product of collaborations among individuals whose formal training includes two or more traditional disciplines. In fact, very little of what is published as ethnopharmacology meets these criteria.

Hansen et al., [11] has suggested that the objectives of Ethnopharmacology should focus on (1) the basic research aiming at giving rational explanation to how a traditional medicine works, and (2) the applied research aiming at developing a traditional medicine into a modern medicine (Pharmacotherapy) or to develop its original usage by modern methods (Phytotherapy).

Biopiracy

Biodiversity and the associated knowledge systems are the real strength of the biodiversity rich nations who have an equally rich cultural diversity like India. The misappropriation of traditional knowledge has been greatly enhanced by the changes brought in by certain international regulations, mainly the introduction of Intellectual Property Rights (IPR). The wealth of traditional knowledge available in different cultures, if subjected to prospecting can yield valuable leads in developing novel drugs/pharmaceuticals or phytochemicals or genes of great industrial value. It is estimated that the annual global sale of products derived from the manipulation of genetic resources with associated traditional knowledge system is between US $ 500 to 800 billion. Sales of herbal medicine derived from traditional knowledge of biodiversity rich countries alone are estimated to have exceeded US $ 12.5 billion in 1994 and Uz $ 30 billion in 2000 with annual growth rates averaging between 5% and 15% depending on the region.

Biopiracy is about stealing of bioresources and associated knowledge system from traditional or indigenous communities, individuals or from the country. The term is also used to refer to such breach of contractual agreement on the access and use of bioresources and traditional knowledge system to the detriment of the provider and bioprospecting without the consent of the local communities [12]. Some examples of Biopiracy in the name of Bioprospecting in Asia Pacific Region are given in Table 2.

Country	Biological Resource	Biopirate Country	Notes
China	Bitter Melon (*Momordica charantia*)	US	US Patent No.5484889
China	Xi Shu/Happytrees (*Camptotheca lowreyana*)	US	US Patent No. PP 11959
Malaysia	Bintangor tree (*Calophyllum lanigerum*)	Singapore US	US Patents including Nos. 6420571, 6369241, 6160131 and 6277879
Pacific	Kava (*Piper mythesticum*)	US	US Patents including Nos. 6405948, 6277396 6080410, 6025363, 5977120, 5976550 and 5770207
Pacific	Nonu (Indian Mulberry *Morinda citrifolia*)	Europe US	In 1995 Nonu Samoa Enterprises began export of nonu, a tree with medicinal properties, to the US with US collaboration
Pakistan	Basmati Rice	US	US Patent Nos.6274183 and 5663484
PNG	Coral reef sponges	US	US Patent Nos. 6281196, 6153590, 5646138 and 5494893
Philippines	Soil microbes	US	The multinational company Eli Lily has earned billions of dollars from the erythromycin antibiotic, which was developed from a bacterium isolated from a soil sample that Filipino scientist Abelardo Aguilar collected in his home province of Lloilo. Neither Aguilar nor the Philippines received any royalties.
Philippines	Llang-Ilang (*Cananga odorata*)	France	The use of the extracts from Ilang. Llangin the cosmetic industry is perhaps as old as perfume in France. There are several perfumeries in France that have used and continue to use it in their products.
Philippines	Banaba (*Lagerstroemia* sp.)	Japan, US	US Patent No. 5980904
Philippines	Nata de coco	Japan, US	US Patent Nos. 6280767, 6140105, 5962277 and 5795979
Philippines	Snails (Conus)	US	US Patent Nos. 6369193, 6344551, 6197535, 6153738, 6077934, 5633347, 5595972, 5589340 and 5514774
India	Basmati Rice	US	US Patent Nos. 5663484 and 4522838
India	Turmeric (*Curcuma longa*)	US	US Patent Nos.5401504, 5135796 and 5047100
India	Neem (*Azadirachta indica*)	US	Several US Patent including Nos. 5420318, 5391779 and 5371254; the US multinational company W.R Grace's EPO Patent No.0426257
India	Guggul (*Commiphora mukul*)	US	US Patent No.6113949 and US Patent Application 20020018757
Thailand	Jasmine Rice	US	A US plant geneticist has developed a strain of Jasmine Rice to be able to grow it in the US; he received the original seeds of the Thai Khao Dok Mail 105 (KDM 105) jasmine rice variety from the international Rice Researh Institute (IRR) in 1995.
Thailand	Plao-noi (*Croton sublyratus*)	Japan	In 1975 Sankyo of Japan extracted the active ingredient of the Thai local plant to produce the patented product Kelnac.
Samoa	Mamala tree (*Homalanthus nutans*)	US	US Patent No. 5599839
Sri Lanka	Kothala himbutu (*Salacia reticulata*)	Japan, US	Takama System, Ltd. (Yamaguchi, JP)'s US Patent No. 6376682

Table 2: Bioprospecting in Asia Pacific region.

Ironically, the very knowledge that forms much of the basis of modern scientific research and development is not regarded as a science. Scientists and industry share the profit and the traditional communities who provide the leads and raw materials gain nothing. The UN Convention on Biological Diversity (UN-CBD) signed by countries of the world in 1992 and which came to effect from 23rd December 1999 provide protection of traditional community's resources and their knowledge system Article 8 (j) and Article 15.7 recognize the need to respect the skills, practices etc. of indigenous and local communities and to ensure equitable benefit sharing of the benefits accrued from the sue of such bioresources and associated traditional knowledge. India has enacted two acts namely Protection of Plan Varieties and Farmers Act of 2001 and the Biodiversity Act of 2002. India is also the first in the world to experiment a benefit sharing experiment wherein the traditional knowledge of a forest dwelling community was subject to scientific study by scientists of Government owned national/regional laboratories and developed a value added, IPR covered and scientifically validated herbal drug which on commercialization shared the benefits(license fee and royalty) equally (1:1) by the research institute and the Kani tribe known as model/Pushpangadan model/JNTBGRI model of benefit sharing as now cited globally including the UN bodies particularly CPSD as the only model that implemented the Article 8(i) of 15.7 of CBD.

Sustainable Agriculture and Economic Development

The increasing population has exerted great pressure on land and ecosystem. Environmental crises have increased at alarming rates due to the unregulated expansion of agricultural areas by encroaching the prime forests, sustainable conception patterns and also due to the fast population growth that exceed the supporting capacity of the ecosystem. The ecodestructive propensities have deep cultural and psychological roots that divide human communities from rest of the environment. Current ecological problems lie within our attitudes, values, ethics, perceptions and behavior. Tribal areas afford a wonderful opportunity to reconceptualise our unity with the biosphere and the associated ethnic communities. We need to understand the dynamic relationship that these communities keep with the local ecosystem and its management need to integrate all those positive components in any developmental programme that are meant for them.

Crops need to be carefully selected for cultivation with all appropriate protocols for sustainable growth and development of the region. Ethnic communities have a rich fund of knowledge and heritage on agricultural practices. They have also conserved very many land races /cultivars and the agricultural practices are also almost organic. Therefore a carefully planned strategy is required to the agriculture based sustainable development.

Biotechnology and Bioprospecting-Links & Leads

Biotechnology is a set of powerful tools that has been employed not only to understand the structure and function of living cells, tissue or organisms, but also to manipulate the living systems to make or modify new products. With the advent of new tools and techniques, biotechnology has grown to the extent that much is now known to the scientific world about the structure and function of living cells, how do they retain and transmit genetic information, and how do they respond to physical and chemical changes, and so on. Just a few decade back biotechnology in common man's perception was high-tech science dealing with manipulation of genes and development of transgenic organisms with novel forms and functions. However, with rapid progress of biotechnology research during the last one decade or so, there has been a major shift in the mindset of people. Benefits of biotechnology now could reach directly to the common man in the form of many new foods, healthcare products and other consumer goods. This has led to its wide acceptance in public domain and rise in social expectation. Biotechnology is thus playing a significant role in converting biodiversity resources into industrially and commercially valuable products and processes having increased productivity and application in many crucial areas such as agriculture (including Aquaculture) health care(medicines, vaccines, diagnostics, gene therapy), environmental protection, Bio-energy, etc.

Bioprospecting

The emerging area of biotechnological application on biodiversity is known as bioprospecting, which includes "systematic search for genes, natural compounds, designs and whole organisms in wild life with a potential for product development by biological observations and biophysical, biochemical and genetic methods without disruption to nature". Bioprospecting has thus three facets like "chemical prospecting, gene prospecting and bionic prospecting.

Chemical prospecting

Modern high-throughput chemical screening and automated bioassay programmes including the activity-guided screening for identifying, isolating characterizing novel bioactive compounds from wild bioresources (higher plants, broyophytes, pteridophytes, fungi and microorganisms etc.) animals (insects and other wild invertebrates) have opened up new vistas in natural product research in general, drug and pharmaceuticals in particular. Chemical prospecting of wild plant resources is becoming increasingly applicable in agro chemistry (biopesticides), drugs and pharmaceuticals, cosmetics, proteins, enzymes, food additives and other industrially valuable chemical products.

Propsecting for phytomedicines

Prospecting of new potential pharmaceuticals from sources such as natural products which are traditional in nature or derived from folklore or which are from little known or unknown forests sources has also become an important part of the pharmaceutical industry. Biotechnology Law report 1995 mentioned bioprospecting for new and valuable agricultural and pharmaceutical products from searching farms and jungles" a modern day gold rush". With the advent of chemistry, genomics research, new molecular biological tools for developing bioassays, cell based assays, high-throughput screening (HTS) and computer aided automation including robotics has incredibly speeded up the screening, isolation, structural elucidation, semi or full synthesis of natural molecules or its derivatives etc. have further dramatized the novel drug development. Consequently, in recent years, a notable number of natural products derived agents have been discovered by employing mechanism based screening approaches. A large number of plant derived natural products are continued to be developed based on traditional or empirical local medicine practices. Therefore, a prospecting of the wild medicinal plants, particularly those with traditional folklore claims are expected to yield novel phyto medicines of molecular potential for development of molecular medicine.

Gene prospecting

DNA Fingerprinting techniques are finding wider applications in molecular systematics that aims at identification and characterization of potential genetic variants in a species or population at the DNA level. Such an approach is now gaining considerable attention and is becoming increasingly important in establishing the sovereignty IPRs of the gene-rich but biotechnology poor countries of the Third world over their own biodiversity resources. With the new patents regimes of WTO-TRIPs, wherein modified organisms, hybrids and transgenics – including higher plants and animals are patentable, there may arise serious implications on the sovereignty and IPRs of biodiversity rich poor nations. It is therefore, important for these countries to undertake appropriate research and development programmes for identifying, characterizing and evaluating their genetic resources, particularly those endemic species and characterize them at molecular level to prevent any possible biopiracy or genepiracy.

Modern molecular techniques like DNA recombinant techniques and transgenic technologies make it possible to identify, isolate, clone and introduce desirable genes from one organisms to another, transcending the biological/taxonomic barriers. Transgenic technologies are making significant herdways by facilitating transfer of the desirable agronomic traits or chemicals from one organism (plant/animal/humans) to bacteria and converting the resultant transgenic bacteria to potential chemical factories producing desired products such as enzymes, proteins and other biomolecules. Proteins is an interesting field of gene prospecting. This deals with the identification and patterns of expression of gene(s) that encodes for the synthesis of a specific protein or enzyme of interests. Bioinformatics provides the key for the biosynthesis, expression and functions of a particular protein or enzymes can be made. Study of proteins and its application in health and nutrition is known as proteomics. Proteomics offers new promises to give therapy and enzyme technologies.

Bionic prospecting

Bionic prospecting is a new area by which new designs, patterns, models and techniques are evolved based on natural biodiversity. New sensor technologies, architecture, bio-engineering and bio-modelling are some of the interesting fields in bionic prospecting.

The pros and cons of bioprospecting need to be evaluated against the backdrop of the increasing incidence of biopiracy and most seriously against the current crisis of biodepletion and the likely impacts of predicted mass extinction spasm impending in the tropicalbiomes [13]. About 5% of the earth's land surface is protected area networks, and if human activities continue in the rest of the 95% of the unprotected wild land habitats, about 50% of the species would go extinct [14]. Bioprospecting programme should, therefore, be carried out with the end in view that apart from direct economic benefits, it should consider the biodiversity. The linkages and leads generated through sustainable use of biodiversity and the associated TKS is illustrated in Figure 1.

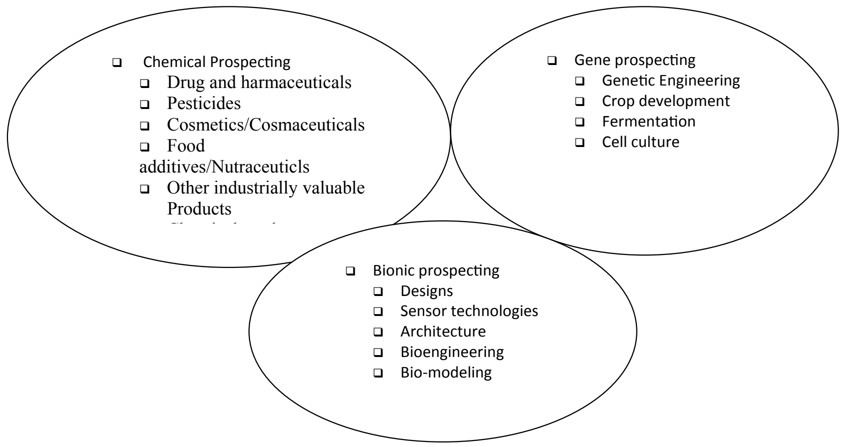

Figure 1: Bioprospecting: Major areas.

Conservation for sustainable development

Conservation of plant diversity assumes greater importance at a time when the humanity is confronted with the problems of environmental degradation, including the unprecedented loss of biological diversity. It is estimated that about 60,000 out of the 2,87,655 described plant species are facing threats of extinction due to various reasons. The situation has led to the development of several national and international initiatives, action plans, strategies, policies and legal frameworks aiming to halt the current continuing loss of plant genetic resources. The Global Strategy for Plant Conservation (GSPC) is one of such initiatives adopted by the conference of parties (COP) of CBD at its sixth meeting held in April 2002 in Hague. The GSPC initiative is aiming at practical conservation of threatened plant diversity through *in-situ* and *ex-situ* or a combination of these two methods plant conservation. In India, the National Biodiversity Strategy and Action plan identifies *ex-situ* conservation of plant diversity as a priority area of action and it suggests strengthening and enhancing the role of botanic gardens, home gardens and other *ex-situ* conservatory networks in India as important ways and means to achieve the above goals. The Ministry of Environment & Forests (MOEF) is implementing a special assistance programme to support selected botanic gardens in India to equip them with adequate infrastructure and other resources to support *ex-situ* conservation of plant diversity. Since 1992, MOEF has extended support to many botanic gardens for infrastructure development and plant conservation programmes.

India has a good network of Research & Development institutions supported by the Central Government Ministries / Departments (eg. MOEF, DST, ICAR, CSIR & ICFRE), Statements, Universities, State Agricultural Universities and NGOs (eg. FRLHT, KFRI, MSSRF, TERI, WEF. India). These institutions have undertaken research and conservation activities which include inventory of RET species and their status assessment, conservation biology of RET species, mapping distribution of RET species, *in-situ* and *ex-situ* conservation programmes, which include micropropogation techniques, gene bank, reintroductive programmes, conservation educative agrotechnology, genetic diversity assessment, characterizing the level of passport data preparation, bioprospecting and sustainable utilization programmes.

Bioprospecting and valuation of biodiversity

The potential of nature's genetic library in providing with new kind of food, medicine, industrial products is enormous. The unknown potential of genes, species and ecosystems represent a never ending biological frontier of inestimable value. The prime focus of genetics in the past was centered around the domesticated biodiversity. The scope of tapping the talent of patent potential of these otherwise lesser known bioresources will be greatly rewarding and challenging. Bioprospecting is the most efficient means to explore and evaluate the economic, genetic and chemical potentials of biological resources through modern technological intervention. The recent advances in instrumentation and enzyme technology scientists can now undertake screening of plants on a massive scale for identifying and isolating potential bioactive components. Appropriate plant extracts can be screened for their biological activity by employing 'throughput' techniques using *in-vitro* enzyme methods followed by isolation of active principles by modern chromatographic techniques such as HPLC (High Performance Liquid Chromatography), HPTLC, GLC (Gas Liquid Chromatography), MPLC (Medium pressure Liquid Chromatography) and LCMS (Liquid Chromatography Mass Spectrometry) aided by computer robotics. Gene Prospecting is another potential area of bioprospecting. With the advancements made in DNA fingerprinting technology it is now possible to study the genetic diversity available in a species.

Conclusion

The incredible ability of human kind to unravel the subtle mysteries of nature will certainly help to develop newer technologies for the sustainable utilization of our planet's limited bio-resources.

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Author Contributions

P. P conceived the idea. V.G, T.P.I, M.A.C. collected literature data. P. P and V. G wrote the paper.

Conflict of Interest

The authors declare no conflict of interest.

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