Bioprospecting the renewable forest resources: An overview

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Tropical deforestation is considered an essential factor in global biodiversity, in view of the vast majority of terrestrial species occurring in tropical moist forests. The challenge of biodiversity management and conservation is to sustain ecosystem functions that generate ecosystem services enabling maintenance of resilience of ecosystem to change. By ecological functioning we mean those basic processes of ecosystem such as nutrient cycling, biological productivity, as well as ability of ecosystem to recover from external stresses. Although substantial biodiversity loss occur due to forest clearing and degradation, such practices as establishment of plantation and secondary forests can restore a significant amount of biodiversity. Large scale losses of tropical forests have caused increasing concern, besides the ecological and economic implication of these changes. In this connection bioprospecting tends to be an effective process enabling a better appreciation of the availability of wild plants and animals as commercials vulnerable and important biochemical resources. Needless therefore to emphasize that in human welfare, biodiversity conservation, ecological sustainability and economic viability are intricately linked. In view of the ecological impacts of overall biodiversity loss the need for bioprospecting has become essential resulting in the manifestation of global biodiversity in terms of exploration of wild plants and animals for their utilitarian value. Needless to indicate that the main focus on bioprospecting was developed in the late 1980's and further strengthened by the convention on Biological diversity, and today this has manifested as the potential for major benefits in terms of commercially valuable and useful biochemical resources.

The exploration of wild plants and animals for commercially valuable and biochemical resources is "Bioprospecting" = Biodiversity prospecting. The main focus of Bioprospecting was developed in late 1980's further strengthened by Convention on Biological Diversity (CBD). This has manifested itself globally as the potential for major benefits which has caused substantial growth in the industry.

Terrestrial and marine animals, plants, insects and microorganisms produce numerous secondary metabolites. Some are for self-defense, symbiosis, sexual attraction, or to fulfill a variety of other purpose. Bioassay-directed isolation, purification and structure elucidation resulted in several natural products from plants and microbe with potential agricultural, forestry and other biological application. India is one of 12-mega biodiversity centers having about 10% of the world's biodiversity wealth, which is distributed across 16 agro-climatic zones. Out of 17,000 species of higher plants reported to occur within India, 7500 are known to have medicinal uses (Shiva, 1996). Today, natural products (and their derivatives and analogs) still represent over 50% of all drugs in clinical use, with higher plant-derived natural products representing 25% of the total. The World Health Organization estimates that 80% of the people in developing countries of the world rely on traditional medicine for their primary health care, and about 85% of traditional medicine involves the use of plant extracts. This means that about 3.5 to 4 billion people in the world rely on plants as sources of drugs. This proportion of medicinal plants is the highest known in any other country against the existing flora of that country (Kala *et al*., 2006). The *Charak Samhita*, an age-old written document on herbal therapy, reports on the production of 340 herbal drugs for curing various diseases (Prajapati, 2003). Currently, about 25% of drugs are derived from plants and many others are synthetic analogues built on prototype compounds isolated from plant species in modern pharmacopoeia (Rao *et al*., 2004). *A. marmelos* Corr. (Rutaceae) commonly known as bael, is one of the most useful medicinal plants in Indian Ayurvedic Medicine. Different parts of the plant have been used in the treatment of diarrhea, dysenteries and diabetes mellitus (Nadkarni, 1976). In fact, as per document (1500 B.C.), no drug has been longer or better known by the inhabitants of India than the bael (Chemexcil, 1992). *A. marmelos* is used in indigenous systems of medicine in India, China, Burma and Srilanka (Kirtikar *et al*., 1935). On this account the plant is considered to be extremely auspicious. The leaves in particular are venerated highly and have been used in indigenous systems of medicine and are found to possess many medicinal qualities (Dymock *et al*., 1890). *A.marmelos* is variously reported to possess analgesic, antipyretic, anti-inflammatory properties, pharmacological, and phytochemical studies on roots of *A. marmelos* have been carried out (Pitre *et al*., 1987).The roots are used in ethnomedicine as an anti-diarrhoeitic, and as an antidote to snake venom. Four isomeric lignan-glucosides were isolated from the bark of *A. marmelos*. The bark of *A. marmelos* has been used to treat diabetes in Indonesia (Ohashi *et al*., 1994). The presence of a new constituent, p-Menth-1-en-3beta, 5beta-diol and anthraquinones from leaf oil and heartwood of *A. marmelos* respectively were detected (Garg *et al*., 1995). The chemical transformation and 13 –C NMR isolation of three alkaloidal amides belonging to Cinnamide class from the leaves of bael were reported (Shweta *et al*., 2005).

Natural Resources in India are already recognized as a leader and an important contributor to world's bioeconomy with its research in the area of forest bioproducts (e.g. antioxidants and therapeutics). Naturally-occurring chemicals (antioxidants) extracted from forest plants (trees, herbs, shrub, etc.) form the foundation for a broad range of forest bioproducts and are required in large volumes for commercial production of bioproducts.

Bioprospecting associated with forest resources

The focus of bioprospecting in India will be on discovering antioxidants because of their ability to help prevent, halt and repair damage from diseases that are triggered by overactive internal defense reactions in our bodies. Antioxidants naturally occurring in many plants found in Indian forests could form the basis of new therapies for many diseases.

Renewable forest resources and renewableness

A wide range of renewable resources such as timber and fibre from trees, lac from lac-producing insects, starch and other polysaccharides from the plants are available from the forest. There is a constant availability of resources such as grasses, seeds, shrubs and other plants with medicinal value for our use. These resources are replenished in the next season by the quick propagation of the plant species by vegetative growth or from the seeds and are hence available for use in the following year.

Non-timber forest products (NTFPs) are plants or plant parts that have perceived economic or consumption value sufficient to encourage their collection and removal from the forest for utilization within the household or marketed or have social, cultural or religious significance. These include plants and plant materials used for food, fuel, storage and fodder, medicine, cottage and wrapping materials, biochemical, as well as animals, birds, reptiles and fishes, for food and feather. NTFPs which are harvested from within and on the edges of natural and disturbed forest, may be all or part of living or dead plants, lichens, fungi, or other forest organisms. NTFPs come from a large variety of plant parts and are formed into a diverse set of products: leaves & twigs that may be component of decorative arrangements, food items such as fruits, fungi and juices, wood carved or woven into pieces of art or utilitarian objects and roots, leaves and bark processed into herbal remedies or medicines (Adepoju *et al*., 2007).

Higher plants are mostly hosts to one or more endophytic microbes. These organisms reside in the tissues between and among living plant cells. The opportunity of finding new and interesting microorganisms within the myriad of the world's plants is great. In addition, in the case of a microbe being symbiotic, new and unusual organic substances may be discovered that contribute to the host–microbe relationship while at the same time providing new and interesting bioactive compounds that may find uses in medicine, industry, and agriculture. Some of the compounds that we have discovered in endophytic microbes are taxol, cryptocin, cryptocandin, and ambuic acid (Strobel, 2002).

Bioprospecting the renewable forest resources

Currently, the commercial source of podophyllotoxin is the rhizomes and roots of *Podophyllum emodi* Wall., Berberidaceae (syn. *P. hexandrum* Royle), an endangered species from the Himalayas (Foster, 1993). Recent findings concluded that the leaf blades of the North American mayapple (*P. peltatum* L.) may serve as an alternative source of podophyllotoxin production, since leaves are renewable organs that store lignans as glucopyranosides (Canel *et al*., 2001; Moraes *et al*., 2002).

Endophytic microbial products

Cryptosporiopsis quercina is the imperfect stage of *Peziculacinnamomea*, a fungus commonly associated with hardwood species in was isolated as an endophyte from *Tripterigeum wilfordii*, a medicinal plant. *C. quercina* demonstrated excellent antifungal activity against some important human fungal pathogens - *Candida albicans* and *Trichophyton* spp causing diseases of skin and nails because of the presence of cryptocandin, (3-hydroxy-4-hydroxy methyl proline) a known antimycotic compound. Cryptocin, a unique tetramic acid, is also produced by *C.quercina.* This unusual compound possesses potent activity against *Pyricularia oryzae* as well as a number of other plant-pathogenic fungi. A newly described species of *Pestalotiopsis*, namely, *Pestalotiopsis jesteri*, produces jesterone and hydroxy-jesterone, which exhibit antifungal activity against a variety of plant-pathogenic fungi possess antibiotic activity.

Colletotrichum sp., isolated from *Artemisia annua*, produces bioactive metabolites that showed varied antimicrobial activity as well. *A. annua* is a traditional Chinese herb that is well recognized for its synthesis of artemisinin (an antimalarial drug) and its ability to inhabit many geographically different areas.

Anticancer agents

Paclitaxel, (also produced by endophytic fungi) a highly functionalized diterpenoid, is found in each of the world's yew (*Taxus*) species. The mode of action of paclitaxel is to preclude tubulin molecules from depolymerizing during the processes of cell division. This compound is the world's first billion-dollar anticancer drug. Some of the most commonly found endophytes of the world's yews are *Pestalotiopsis* spp. One of the most commonly isolated endophytic species is *P. microspora* . An examination of the endophytes of *Taxus wallichiana* yielded *P.microspora*, and a preliminary monoclonal antibody test indicated that it might produce paclitaxel. A rubiaceous plant, *Maguireothamnus speciosus*, yielded a novel fungus, *Seimatoantlerium tepuiense*, that produces paclitaxel.

Antioxidants

Two compounds, pestacin and isopestacin, have been obtained from culture fluids of *P. microspora*, an endophyte isolated from a combretaceaous plant, *Terminalia morobensis*, growing in the Sepik River drainage of Papua New Guinea. Both pestacin and isopestacin display antimicrobial as well as antioxidant activity. Isopestacin was suspected of antioxidant activity based on its structural similarity to the flavonoids.

Immunosuppressive, antidiabetic, antiviral and insecticidal agents

Immunosuppressive drugs are used today to prevent allograft rejection in transplant patients and in the future they could be used to treat autoimmune diseases such a rheumatoid arthritis and insulin-dependent diabetes. The endophytic fungus *Fusarium subglutinans*, isolated from *T. wilfordii*, produces the immunosuppressive in order to be more predictive about which higher plants to seek, study, and spend time isolating microfloral components. The fungus *Tolypocladium inflatum*, from which cyclosporine, a hugely beneficial immunosuppressant, was isolated. A nonpeptidal fungal metabolite was isolated from an endophytic fungus (*Pseudomassaria* sp.) collected from an African rainforest near Kinshasa in the Democratic Republic of the Congo. This compound acts as insulin mimetic and, unlike insulin, is not destroyed in the digestive tract and may be given orally. Two novel human cytomegalovirus protease inhibitors, cytonic acids A and B, have been isolated from the solid-state fermentation of the endophytic fungus *Cytonaema* sp. Several endophytes are known to have anti-insect properties. Nodulisporic acids, novel indole diterpenes that exhibit potent insecticidal properties. Nodulisporic compounds were isolated from an endophyte, a *Nodulisporium* sp., from the plant *Bontia daphnoides*. Another endophytic fungus, *Muscodor vitigenus*, isolated from a liana (*Paullina paullinioides*), yields naphthalene as its major product. Naphthalene, the active ingredient in common mothballs, is a widely exploited insect repellant. A novel *seco-trisnor*-oleanane and *seco*-benzyltetrahydroisoquinoline, were isolated from from *Calophyllum gracilipes* and *Polyalthia insignis*, respectively. Many substituted coumarins of potential against

HIV protease activity were isolated *Calophyllum* plants including *Calophyllum teysmannii*.

Drugs of plant origin

Here are a few plants and plant ingredients used in many conventional drugs. *Senna alexandrina*, a shrubby perennial, was introduced as a laxative. Preparations of the plant and its cathartic pods are still widely used today in popular brands of drugstore laxatives. *Mentha* (mint) species are the natural sources of menthol, an aromatic alcohol which is also known as peppermint camphor. Menthol is an active ingredient in topical preparations. Peppermint oil, which can still be found in drugstores, is a centuries-old remedy. *Gaultheria procumbens*, or wintergreen, is a source of methylsalicylate, which is widely used in topical ointments and liniments.

Papaver somniferum, the opium poppy, yields a sap of narcotic opium, from which the potent pain killer morphine is made. In the eighth century, Persian caravans bore both opium and its methods of euphoric use to India and China. In 1546 a French naturalist named Belon drew European attention to widespread opium abuse among Turks. Opium dens proliferated in Europe throughout the 1800's, while the opium trade became an enormous industry. Simultaneously, opium and its products heroin and morphine established themselves among drug users and in the field of medicine. Both uses continue to this day. In modern medicine, morphine and its analogues remain unsurpassed pain killers. *Digitalis purpurea*, the purple foxglove, is a popular garden plant cultivated as a source of digitoxin, a cardiac drug. The plant was recommended for medicinal purposes in the seventeenth century, and has appeared in the French Pharmacopoeia since its first printing in 1818. Digitoxin is used in the treatment of congestive heart failure and other cardiac disorders. *Digitalis lanata*, the woolly foxglove, is cultivated commercially as a source of digoxin, a cardiotonic used for the same purposes as digitoxin. An Indian named M. Manal discovered that elephants in captivity were often fed a particular type of root reputed to produce a calming effect. Intrigued, Manal brought samples of the plant back to India, where he conducted tests on its properties. The plant, *Rauwolfia serpentina*, named after famous 16th century German physician and explorer Leonhart Rauwolf, demonstrated both tranquilizing and anti-hypertensive properties. These effects were due to the presence of the alkaloid reserpine. In 1934 Serpina, the world's first-ever anti-hypertensive drug, was launched. Today reserpine is used both as an antihypertensive and as a sedative to relieve some types of psychiatric disorders. Ecuadorian *Cinchona pubescens*, a fast-growing evergreen, as well as other species of cinchona, stand among the greatest life-saving medicines of all time. According to legend this plant was brought to light in the 1620's when Ecuadorean physician Juan del Vega used a Quichua native remedy known as "quina bark" on the Countess of Chinchon, wife of the Viceroy of Peru, who had contracted malaria, a potentially fatal disease caused by a protazoan in the stomach of the female Anopheles mosquito. The Countess recovered, and "quina bark" became known as "Countess bark." Word of the cure spread, and cinchona was popularized by an apothecary's assistant named Robert Talbor in the late 1660's. Over the next 150 years a huge trade in cinchona bark developed. In the early 19th century, the Dutch established cinchona plantations in Java. In 1820, quinine was isolated from cinchona, and a successful treatment for malaria was established. Today cinchona is cultivated in several tropical regions, and the approximately 10,000 tons of bark harvested annually yields 500 tons of quinine and related alkaloids quinidine, cinchonine, and cinchonidine. A novel *seco-trisnor*-oleanane and *seco*-benzyltetrahydroisoquinoline, were isolated from from *Calophyllum gracilipes* and *Polyalthia insignis*, respectively. Many substituted coumarins of potential against HIV protease activity were isolated *Calophyllum* plants including *Calophyllum teysmannii*.

Today there are approximately 1000 natural product crude plant extracts and 800 purified compounds library is available in the world and many of which are novel natural products and possess antioxidant properties. There are about 18,000 known species of plants in India, medical implications of a large number them is still mystery. There are at least 120 distinct chemical substances derived from plants that are considered as important drugs currently in use in one or more countries in the world. Few of them are listed below in Table 1.

Table 1: List of drugs, their property and plant source

S.No.	Drug/Chemical	Type of plant	Action/Clinical Use	Plant Source
1.	Allyl isothiocyanate	Annual weed	Rubefacient	*Brassica nigra* L.
2.	Picrotoxin	Climber	Analeptic	*Anamirta cocculus* (L.) Wight & Arn.,
3.	Qulsqualic acid	Creeper	Anthelmintic	*Quisqualis indica* Linn.
4.	Caffeine	Evergreen shrub	CNS stimulant	*Camellia sinensis* (L.) Kuntze
5.	Ajmalicine	Herb	Circulatory Disorders	*Rauvolfia serpentine* (L.) Benth. ex Kurz
6.	Andrographolide	Herb	Baccillary dysentery	*Andrographis paniculata* (Burm.f.) Wall. ex Nees
7.	Bromelain	Herb	Anti-inflammatory, proteolytic	*Ananas comosus* (L.) Merr.
8.	Cissampeline	Herb	Skeletal muscle relaxant	*Cissampelos pareira* L.
9.	Codeine	Herb	Analgesic, antitussive	*Papaver somniferum* L.
10.	Menthol	Herb	Rubefacient	*Mentha species*
11.	Morphine	Herb	Analgesic	*Papaver somniferum* L.
12.	Neoandrographo-lide	Herb	Dysentery	*Andrographis paniculata* (Burm.f.) Wall. ex Nees
13.	Nicotine	Herb	Insecticide	*Nicotiana tabacum* L.
14.	Noscapine	Herb	Antitussive	*Papaver somniferum* L.
15.	Pachycarpine	Herb	Oxytocic	*Sophora pachycarpa* C.Meyer
16.	Papavarine	Herb	Smooth muscle relaxant	*Papaver somniferum* L.
17.	Rescinnamine	Herb	Antihypertensive, tranquillizer	*Rauvolfia serpentine* (L.) Benth. ex Kurz

18.	Reserpine	Herb	Antihypertensive, tranquillizer	*Rauvolfia serpentine* (L.) Benth. ex Kurz
19.	Scopolamine	Herb	Sedative	*Datura species*
20.	Silymarin	Herb	Antihepatotoxic	*Silybum marianum* (L.)Gaertn
21.	a-Tetrahydrocanna-binol (THC)	Herb	Antiemetic, decrease occular tension	*Cannabis sativa* L.
22.	Rotundine	Herbaceous vine	Analagesic, sedative, traquillizer	*Stephania sinica* Diels
23.	Tetrandrine	Herbaceous vine	Antihypertensive	*Stephania tetrandra* S. Moore
24.	Asiaticoside	Herbaceous, Annual	Vulnerary	*Centella asiatica* (L.) Urban
25.	L-Dopa	Leguminous	Anti-parkinsonism	*Mucuna sp*
26.	Glycyrrhizin	Leguminous	Sweetener, Addison's disease	*Glycyrrhiza glabra* L.
27.	Convallatoxin	Rhizome	Cardiotonic	*Convallaria majalis* L.
28.	Curcumin	Rhizome	Choleretic	*Curcuma longa* Linnaeus
29.	Deserpidine	Shrub	Antihypertensive, tranquillizer	*Rauvolfia canescens* L.
30.	Gossypol	Shrub	Male contraceptive	*Gossypium species*
31.	Stevioside	Shrub	Sweetner	*Stevia rebaudiana* Bertoni.
32.	Vasicine	Shrub	Cerebral stimulant	*Vinca minor* L.
33.	Vinblastine	Shrub	Antitumor, Antileukemic agent	*Catharanthus roseus* (L.) G.Don
34.	Vincristine	Shrub	Antitumor, Antileukemic agent	*Catharanthus roseus* (L.) G.Don
35.	Arecoline	Tree	Anthelmintic	*Areca catechu* L.
36.	Camphor	Tree	Rubefacient	*Cinnamomum camphora* (L.) Sieb
37.	Chymopapain	Tree	Proteolytic, mucolytic	*Carica papaya* L.
38.	Danthron	Tree	Laxative	*Cassia species*
39.	Glaucarubin	Tree	Amoebicide	*Simarouba glauca* DC
40.	Hesperidin	Tree	Capillary fragility	*Citrus species* L.
41.	Papain	Tree	Proteolytic, mucolytic	*Carica papaya* L.
42.	Rutin	Tree	Capillary fragility	*Citrus species* L.
43.	Sennosides A, B	Tree	Laxative	*Cassia species*
44.	Strychnine	Tree	CNS stimulant	*Strychnos nux-vomica* L.
45.	Theobromine	Tree	Diuretic, vasodilator	*Theobroma cacao* L.
46.	Theophylline	Tree	Diuretic, brochodilator	*Theobroma cacao* and others

Over 50% of the most common prescription drugs originate from plants, animals, fungi and bacteria (Grifo *et al*., 1997) and over 60% of anti-cancer and anti-infective agents developed between 1984–95 are of natural origin (Cragg *et al*., 1993, Cragg *et al*., 1997). Hence, the drug discovery process continues to rely considerably on screening extracts or compounds from natural sources. Currently, commercial interest in finding novel genes for use in agriculture and in herbal medicinal products is also high. In addition, many, if not most, new drugs from natural products for agriculture and forestry are likely to come from countries that are high in biodiversity. In fact, the search for drugs and genes from natural sources holds the potential to enhance the research and commercial capacities of biodiversity-rich countries.

Developing nations must obtain experience in the scientific, legal and commercial aspects of bioprospecting before them, along with industry, can effectively exploit biodiversity and thereby obtain benefit. The tropics contain the most diverse habitats in the world, yet are increasingly threatened with destruction. However, this trend might be slowed if the economic value of keeping a forest intact were greater than that of destructive uses, such as logging or agriculture. One promising mechanism for generating sustainable revenue from intact ecosystems is the commercialization of drugs, genes or herbal medicinal products derived from natural sources (Reid *et al*., 1993). If bioprospecting is to be embraced by industry and biodiversity-rich nations as a tool for economic development and conservation, it is imperative to produce successful examples quickly (Inamdar *et al*., 1999).

Plants with promising anti-infective activity

Garcinia kola, bitter kola (Guttiferae), is found in moist forest and grows as a medium size tree, up to 12 m high. The seeds are used as purgative, antiparasitic, antimicrobial. They relieve cough. The constituents include—biflavonoids, xanthones and benzophenones responsible for the antimicrobial properties of this plant. *Aframomum melegueta* (Zingiberaceae) Grains of Paradise, is a spicy edible fruit that is cultivated and occurs throughout the tropics. It is a perennial herb. The medicinal uses include aphrodisiac, measles, and leprosy, taken for excessive lactation and post partem hemorrhage, purgative, galactogogue and anthelmintic, and hemostatic agent due to the constituents, the essential oils—such as gingerol, shagaol, paradol (Iwu, 1993). An evergreen, aromatic tree *Xylopia aethiopica*, Ethiopian Pepper (Abbibacceae), growing up to 20 m high with peppery fruit. Medicinal uses of the plant are, as a carminative, as a cough remedy, and as a post partum tonic, lactation aid and other biological uses (Smith *et al*., 1996). Key constituents are diterpenic and xylopic acid. In studies, the fruit as an extracts has been shown to be active as an antimicrobial against gram positive and negative bacteria. Though it has not been shown to be effective against *E. coli* (Iwu, 1993). Xylopic acid has also demonstrated activity against *Candida albicans* (Boakye-Yiadom *et al*., 1977). A shrub, *Cryptolepis sanguinolenta* Lindl. Schltr. (Periplocaceae), that grows in the rainforest and the deciduous belt forest. Its main medicinal are inflammatory conditions, malaria, hypertension, microbial infections and inflammatory conditions, stomach aches colic (Iwu, 1993). Active principals identified are indo quinoline alkaloids. Studies show inhibition against gram negative bacteria and yeast (Silva *et al*., 1996). Additionally studies have shown this plant to have bactericidal activity. Clinical studies have shown extracts of the plant were effective in parasitemia. Recent in vitro study shows activity against bacteria specifically, enteric pathogens, most notably *E. coli* (but also staphylococcus, *C. coli*, *C. jejuni*, pseudomonous, salmonella, shigella, streptococcus, and vibrio) and some activity against *candida* (Sawer *et al*., 1995). It has shown histamine antagonism, hypotensive, and vasodilatory activities (Iwu, 1993). In addition it has demonstrative antihyperglcyemic properties (Bierer *et al*., 1998). *Chasmanthera dependens* Hoschst (Menispermaceae), a woody climber that grows wild in forest margins and savanna. The plant is cultivated. It is used medicinally for venereal disease, topically on sprained joints and bruises and as a general tonic for physical and nervous debilities. The constituents include berberine type alkaloids, palmatine, colombamine, and jateorhizine. In a report about *Nauclea latifolia* Smith (Rubiaceae), a shrub or small spreading tree that is a widely distributed savanna plant, it was found in the forest and fringe tropical forest. Medicinal uses are due to the key constituents reported such as indole-quinolizidine alkaloids and glycoalkaloids and sapponins (Lamidi *et al*., 1995). There are studies showing the root has antibacterial activity against gram positive and negative bacteria and antifungal activity (Iwu, 1993). It is most effective against Corynebacterium *diphtheriae*, *Streptobacillis* sp., *Streptococcus* sp., *Neisseria* sp., *Pseudomonas aeruginosa*, *Salmonella* sp. (Deeni *et al*., 1991). *Araliopsis tabouensis* (Rutaceae), is a large evergreen tree. The bark infusion is drunk for gonorrhea (Irvine, 1961). Its major constituents are alkaloids. Seven alkaloids have been isolated from the root and stem bark (Fish *et al*., 1976).

Podophyllotoxin

Podophyllotoxin is a natural lignan that is currently being used as a precursor to semi-synthetic anticancer drugs etoposide, teniposide, and etopophos. These compounds have been used for the treatment of lung and testicular cancers as well as certain leukemias (Stahelin *et al*., 1991, Imbert, 1998). In addition, podophyllotoxin is also the precursor to a new derivative CPH 82 that is being tested for rheumatoid arthritis in Europe and other derivatives for the treatment of psoriasis and malaria (Leander *et al*., 1988, Lerndels, 1996). Podophyllotoxin preparations are also on the market for dermatological use to treat genital warts (Beutner, 1996) and recently, immunostimulatory activities of podophyllotoxin have been reported (Pugh *et al*., 2001). Podophyllotoxin is extracted from *Podophyllum hexandrum* Royle (Berberidaceae) a herbaceous, rhizomatous species. The rhizomes of *P. hexandrum* yield cytotoxic lignan podophyllotoxin and resin due to which *Podophyllum* possesses anti-tumour activity. Podophyllotoxin and podophyllin (*Podophyllum* resin) are considered as active constituents in dermatologic products for therapy of genital warts (Mishra *et al*., 2005). Among the plethora of physiological activities and potential medicinal and agricultural applications, the antineoplastic and antiviral properties of podophyllotoxin congeners and their derivatives are arguably the most eminent from a pharmacological perspective (Canel *et al*., 2000). Leaves of Eastern red cedar (*Juniperus virginiana* L. Cupressaceae) have been reported to contain podophyllotoxin, a pharmaceutical compound used to manufacture drugs for treatment of cancer, rheumatoid arthritis, genital warts, psoriasis, and multiple sclerosis (Cushman *et al*., 2003). Total synthesis of podophyllotoxin is an expensive process and availability of the compound from natural resources (*Podophyllum* spp and *Juniperus virginiana*) is an important issue for pharmaceutical companies that manufacture these drugs (Canel *et al*., 2000).

Plant/ plant products for pest management

The effect of hexane extract of neem seed kernel on the growth and reproductive performance of *S. litura* was assessed by feeding various doses of the extract to 1st- or 2nd-instar larvae. Significantly more mortality was observed in the larval period than in the pre-pupal and pupal stages (Kaur *et al*., 2001).

The toxicity of neem formulations viz., Bioneem, Nimbicidine, Neemarin and Neemazal to *S. litura* infesting tobacco was determined under laboratory conditions. Larval mortality after 72 h of application of Neemarin at 1.5% resulted in the highest larval mortality followed by Neemazal, Econeem, Bioneem and Nimbicidine. Neemarin and Neemazal at all tested concentrations reduced pupation, whereas Econeem completely suppressed pupation, resulting in half larvae and half pupae. Application of Neemarin resulted in the excretion by the larvae of greenish fluid and shrinking of the larvae. Bioneem and Nimbicidine application resulted in deformed and under weight pupae, and reduced longevity of males (Kumar *et al*., 2003).

The biological activity of azadirachtin, nimbocinol, azadiradione and salannin isolated from *A. indica* was assessed alone and in combination against the cotton bollworm, *Helicoverpa armigera* and cluster caterpillar, *S. litura*. Azadirachtin was the most active neem allelochemical against both insect species. In nutritional analysis, only nimbocinol and azadiradione reduced the efficiency of conversion of ingested food (ECI) in feeding experiments, indicating toxicity rather than antifeedant effects (Koul *et al*., 2004).

Azadirachtin-A (Aza-A) was subjected to a variety of synthetic transformations and the antifeedant activity and toxicity of the azadirachtin derivatives were assessed against second instar larvae *S. litura* on castor leaves in comparison with the crude material. A probable mechanism for the base initiated fragmentation of the diketocarbonate into a decalin fragment and a spiroketal moiety has been proposed. A combination of insect toxicity and antifeedancy of azadirachtin provides good crop protection (Deota *et al*., 2005).

The efficacy of neem and mustard cakes as organic amendment, Econeem (neem formulation) as seed treatment and carbofuran as soil treatment was tested against *M. incognita* infesting lettuce. Neem and mustard cakes and Eco neem when used either singly or in combination with carbofuran at 10 and 20 mg/kg soil improved growth of lettuce and significantly decreased root galling, fecundity and final nematode population (Pathak *et al*., 2004).

Nutritional, socio-economic and ecological values of entomophagy

Entomophagy, is the habit of eating insects as food. Insects are traditional foods in some cultures in many parts of the world including Central and South America, Africa, Asia and Australia, but uncommon and even taboo in some societies. It is an age old practice and a well accepted socio-cultural attribute among the local inhabitants in various parts of India especially northeast India. Most of the edible insects are pests and also have high nutritional qualities constitute an important part of their daily diet. Research studies of the past and present proved that edible insects are a good protein supplement in the diet. Earlier studies indicated that insects generally have higher food conversion efficiency than more traditional meats.

The nutritional analysis of some of the edible insects, such as Locusts (*Schistocerca gregaria*) and crickets (*Acheta domesticus* and *Anabrus simplex*) proved this point (Das, 1945, Finke *et al*., 1989). The social, economic and nutritional value of edible insects is often overlooked. Over 1,500 species of edible insects have been recorded in 300 ethnic groups from 113 countries. In some ethnic groups, insects provide 5–10% of annual protein input as well as fats, calories, vitamins and minerals (MacEvilly, 2000). The nutritional value of fourteen species of edible insects in southwestern Nigeria, it was concluded that because of the high nutritive value and ubiquitous presence, insects present a potential sustainable food source for humans (Banjo *et al*., 2006). Eighty-three (83) edible species are listed for the Eucadar, none of them are a main dish but many of the insects are used to complement other animal protein sources in the diet. The most common edible insects belong to the orders Coleoptera and Hymenoptera, which are consumed either in the larval or adult stage (Onore, 1997). Similarly, in Thailand, over 50 species of insects are edible and consumed throughout the year. The most popular are silk worm pupae, bamboo worms, locusts, beetles, crickets, red ants, and other insects (Yhoung *et al*., 1997). Insects generally have higher food conversion efficiency than more traditional meats. When reared at 30°C or more, and fed a diet of equal quality to the diet used to rear conventional livestock, house crickets show a food conversion twice as efficient as pigs and broiler chicks, four times that of sheep, and six times higher than steers when losses in carcass trim and dressing percentage are counted. Protein production for human consumption would be more effective and cost fewer resources than animal protein (Capineral, 2004).

Need for linking entomophagy with food security system and conservation

In a recent International workshop sponsored by United Nations Food and Agriculture Organisation on “Forest Insects as Food: Humans Bite Back” covered three main themes: (1) edible forest insects as a natural resource, (2) models of sustainable insect management for food and other products, and (3) development potential for edible forest insects. It identified that there are major knowledge gaps in our information on the extent of entomophagy and was also considered a matter of high priority for documentation of indigenous knowledge. There are examples of sustainable harvesting of edible insects based on traditional ecological knowledge, such as the harvesting of *Gynanisa maja* and *Gonimbrasia zambesina* caterpillars by the Bisa people of northern Zambia (Mbata *et al*., 2002). Edible insects provide an opportunity for insect conservation by combining food security and forest conservation issues (Vantomme *et al*., 2004, Senthilkumar *et al*., 2008). In Mexico, the grasshopper *Sphenarium purpurascens* is collected for sale as food, but it is also controlled by organophosphorous insecticides. The effectiveness of control through the manual harvesting of this species was compared to chemical control. Although harvesting was less effective than the insecticides, it still significantly reduced numbers of the grasshopper and it generated additional income source, reduced insecticide cost, and reduced chemical runoff and contamination (Cerritosa *et al*., 2008). Wild harvest of insect pests in established crop or horticultural systems may be more practical (Banjo *et al*., 2006). Therefore, there is an urgent need to assess insect biodiversity as a whole and the role of ethno-entomophagy in particular in conserving this valuable natural resource and the local traditional knowledge for posterity. It is also suggested that there is a good scope to exploit this socio-cultural attribute in finding ways to tackle the increased pest incidences as a consequence of global climate change in the fragile tropical forest ecosystems here and elsewhere in the world under similar ecosystems. Mass collection of pest insects may not be for food but rather for production of food supplements or feed for livestock and also helps in maintaining healthy environment. There is also a scope to make an effort to increase their commercial value as food and feed for live stock specially chicken and availability on demand in a sustainable manner. On a long run this may serve the twin purpose of insect (natural resource) use as food (food products and feed) and conservation.

Like plants, insects also possess medicinal properties that can be exploited for the benefits of human beings. Ample information is available on entomophagy (use of insects as food). The use of insects as food by three tribes namely, Bodo, Dimasa and Sonowal Kachari in different parts of Assam and the use of nearly about eight species of insects as food and medicine among the various tribes in the State of Manipur in northeastern India have been studied earlier. A glimpse of this information is presented below in Table 2 (Senthilkumar *et al*., 2008).

Table 2: List of insects and their medicinal uses

S.No	Insect used	Order and family	Stage of the insect	Medicinal uses
1	*Xysterocera globosa* Oliv	Coleoptera Cerambycidae	Larvae	Antiseptic
2	*Balaninus c-album* Heller	Coleoptera Curculionidae	Larvae	Respiratory disorders
3	*Cimex lectularis* L.	Hemiptera Cimicidae	Adults	Epilepsy, piles, Urinary disorder, snake bite and hair growth. Headaches, constipation, ulcers, arthritis to baldness
4	*Hieroglyphus banian* Fabricious	Orthoptera Acrididae	Nymphs and adults	Liver disorders
5	*Xylotrupes gideon* Linn	Coleoptera Scarabaeidae	Larvae	Scrofula and ulcer
6	*Blatta orientalis* Linnaeus	Dictyoptera Blattidae	Adults	Asthma and tuberculosis
7	*Acridium (= Agridium) malanocorne* Linn.	Orthoptera Acrididae	Nymphs and adults	Protein supplement
8	*Zonabris pustulata* L	Coleoptera Meloidae	Larvae	Problems in urino genital system
9	*Cyclopelta siccifolia* Westw.	Hemiptera Pentatomidae	Adult	Paralysis
10	*Pellis cicadae* Fabricius	Homoptera Cicadilidae	Parasitized by the fungus *Cordyceps soboliferea*	For infantile convulsions, tetany and tetanus
11	*Xylocopa violacea* (Linnaeus)	Hymenoptera Apidae	By stings	Arthritis
12	*Vespa orientalis* Linn	Hymenoptera Vespidae	Larvae	Arthritis
13	*Odontotermes feae* Wasmann.	Isoptera Odontotermitidae	Adults	Anemia and Weakness
14	*Macrotermes gilvus* Hagen.	Isoptera Termitidae	Nymphs	Anemia and Weakness
15	*Aeschna petalura* Martein	Odonata Aeschnidae	Nymphs	Anemia and Weakness
16	*Antheraea assama* Westw.	Lepidoptera Saturniidae	Pupa	Impotence
17	*Pericyma cruegri* (Butler)	Lepidoptera Noctuidae	Pupa	Stomach disorder
18	*Antheraea roylei* Moore	Lepidoptera Saturniidae	Pupa	Stomach disorder
19	*Apis mellifera* Linn.	Hymenoptera Apidae	Egg, larva, pupa	Spleen and stomach disorders

CONCLUSION

Forest products other than wood (minor forest products) such as food products (fruits, oil producing seeds, honey, mushrooms), fibers (bamboo, rattan), rubber, gums, resins, waxes, tannins and pharmaceutical and cosmetic and specialty products also have a substantial contribution towards the economy of the world. In the future, biologically active plant derived chemicals can be expected to play an increasingly significant role in commercial development of new products for regulating plant growth, insect and weed control, and as drug entities and model compounds for drug synthesis.

Phytochemicals from wild plants remain the crucial source of lead for drug discovery. In spite of the ongoing debate regarding the fruitfulness of bioprospecting, a large number of firms such as Merck, Novartis, Glaxo, Sankyo, and Smith Kline Beecham are investing considerable amount of resources in the search for drugs, pesticides and related processes of study and further demonstrating that the bioprospecting potential of biodiversity is substantial. In its early stage, various forms of biodiversity like insects, algae and microorganisms of different ecosystems (e.g. grassland and marine) have been explored with considerable success. In recent years, prospecting largely centered on plants from the forest ecosystem. Flora especially forest flora found in nature has been in use for pharmaceutical and phytoceuticals purposes in different parts of the world for centuries. Plants from the family Annonaceae provide many cytotoxic and insecticidal compounds such as styrylpyrone derivatives, acetogenins and aporphine derivatives. From among the folklore plants, vaguely referred to as for treatment of neoplastic conditions, the strongly cytotoxic 5,6- dihydroxyindole from *Rhaphidophora korthalsii* was isolated by bioassay guided fractionation.

In India *Alocacia indica* Sch., *Asparagus officinalis* DC., *Chlorophytum comosum* Linn., *Cordia myxa* Roxb., *Eulophia Ochreata* Lindl., *Momordica dioicia* Roxb., *Portulaca oleracia* Linn. and *Solanum indicum* Linn. are the major sources of phenolic compounds in the human diet having antioxidant property.

Bioprospecting has been an important phenomenon of discovering new products, over 800 plant species are currently in use by the Indian herbal industry alone. Even though pharmaceutical firms and scientists are to continue to find useful application of compounds from nature, their research methods and application have changed. The economic value of the resources are enormous and benefiting not only the pharmaceutical company but also the host country and indigenous people. With advancement in molecular biology and availability of sophisticated diagnostic tools for screening, it has become pretty effective for pharmaceutical firms to conduct research through bioprospecting. Discovery of several life saving drugs including anti-neoplastic, anti HIV and anti AIDS drugs in recent past has renewed the interest of pharmaceutical industries in bioprospecting. Bioprospecting collaborations between pharmaceutical companies and countries supplying raw materials offer not only the revenue source but also opportunities for society for better education and employment avenues.

Therefore, future India's bioprospecting research should focus on the discovery of novel natural products possess antioxidant properties which will increase the potential discovery of viable compounds for use in therapeutics from renewable forest resources in partnership between academia and industry. We hope, this provides information from such disparate scientific fields as forestry, medicine, botany, and economics to determine the economic potential of bioprospecting in India. The cross-pollination of such knowledge will advance scientific awareness of bioprospecting and provide several key economic benefits.

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