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Chapter

ECO-FRIENDLY MOLLUSCICIDES, PISCICIDES AND INSECTICIDES FROM COMMON PLANTS

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ABSTRACT

Mosquitoes and snails are still the world's number one vectors of human and animal diseases and are conspicuous nuisance pest as well. Mosquitoes are potential vectors of malaria, filaria, yellow fever, brain fever, dengue fever etc. and many aquatic snails act as vectors for the larvae of trematodes and thereby cause two diseases i.e. fascioliasis and schistosomiasis. Presence of predatory fishes in fish culture ponds is also a serious problem due to their faster growth rate and better utilization of cultured carp habitats and food. Due to their carnivores nature they engulf the fingerlings of cultured carps and adversely effect the aquaculture production. The WHO and FAO have tested several thousands of synthetic compounds for the control of these vectors and predatory fishes. Though effective, these pesticides have so far not proved themselves to be entirely satisfactory. With a growing awareness of environmental pollution, efforts are being made to find out molluscicidal, piscicidal and insecticidal products from plant origin. Being products of biosynthesis, these are potentially biodegradable in nature. Several groups of compounds present in various plants have found to toxic to target organisms. Thus, saponins, tannins, alkaloids alkenyl phenols, glycosides, glycoalkaloids, flavonoids, sesquiterpenes lactones, terpenoids and phorbal esters have been found to be poisonous to target organisms at acceptable doses ranging from < 1 – 100 ppm. These compounds come from 56-60 families of angiosperms. Although, at present a very little literature available on the control of vector snails, mosquitoes larvae and predatory fishes through plant origin pesticides. An attempt has been made by this review to present current information on products of plant origin, which might be useful for the control of snails, mosquitoes and predatory fishes.

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INTRODUCTION

The intensive application of pesticides in modern agriculture and public health operation systems has resulted in serious environmental problems (Minelli and Rebeiro 1996; Dua et al., 1998; Waliszewski et al., 1999; Singh et al., 2004 b). The pesticides that have received most attention include Pentachlorophenol (PCPs), Polychlorinated biphenyls (PCBs), Atrasine (S-triazines), Organochlorines (OCs), organophosphates (Ops) and Carbamates, since they are widely used and are highly persistent compounds. The freshwater bodies adjoining to agriculture fields are continuously being contaminated by the toxic wastes of chemical pesticides (Bourgeois et al., 1993; Nayak et al., 1995) and pose a potential direct threat to freshwater organism, particularly to sensitive animals, such as fishes and prawns (Saravanan et al. 2003; Selvarani and Rajamanickam, 2003 and Park et al., 2004).

Basic research for over more than fifty years in biology and biochemistry has made it possible to envisage not only how new pesticides may be synthesized but also a completely new approach for the control of vectors using secondary plant products which may be toxic to a specific vectors yet harmless to non-target organisms. In recent years, considerable attention has been directed to the research and application of molluscicides, insecticides, larvicides, insect growth regulators of juvenile hormones analogus in protection of human being and their domestic animals. These substances have been used successfully on large scale in vectors management programme, also (Srivastava et al., 2003). More than 2,000 plant species belonging to different families and genera have been reported to contain toxic principles, which are effective against insects. Among the well represented plant pesticides is 'Pyrethrums' obtained from *Chrysanthmum cinariaefolium*, which is mainly used as a domestic insecticide because it is non-toxic to man and warm-blooded animals and is highly sensitive to light.

In recent time, the use of plant products has gained unprecedented impetus, all over the world. The people of North – Eastern region of India, in particular the rural and tribal people living in some remote areas, primarily depends upon the folk and traditional medicine. Indigenous knowledge of these plants used for the different purpose in different areas. A large number of plant families have furnished many classes of product, which may vary with the degree of pesticidal activity. Several countries have promoted the use of plant product with a wide range of ideal properties, are as

- High pesticidal properties.
- Easily availability.
- Easily biodegradable with less hazard of environmental contamination.
- Low mammalian toxicity.
- Solubility in water.
- Low cost.
- Grow abundantly in endemic areas and safe for operator.

The above-mentioned properties of plant product have opened a new vista. In reference of India, our country possess a rich biodiversity of medicinal plants are used for many purposes. The plant products (extracts also) have been used from the immemorial. The Vrikshayurveda is the branch of Ayurveda that deals with plant health and recommends drugs possessing specific qualities of treatment of insect attack. During the co-evolution of plants and insects, plant has bio-synthesized a number of secondary metabolites to serve as defense chemicals against pest attack. Although only 10,000 secondary metabolites have been chemically identified so far, the total number may exceed 400,000 (Swain, 1977).

A list of various plants/ products have been tested during past on a decade and have been shown to possess molluscicidal, piscicidal, insecticidal, larvicidal, growth inhibitor chemosterilant and repellent effect against mollusc, fishes and mosquitoes. The present article deals with botanical products, which have demonstrate their efficacy in the management of disease vectors as alternative of synthetic pesticides

MOLLUSCICIDES OF PLANT ORIGIN

Mollusc is the second largest group of invertebrate animals, in variety, after insect, occupying all possible habitats except aerial. Although the exact number of existing molluscan species is still a matter of speculation, Abbott (1954) has estimated a total of about 1,10,000 living species, 80,000 amongst which are gastropods, 10,000 bivalves, and 5,000 belonging to the other three classes of mollusca. Godan, (1983) on the other hand believe the number of living species is about 1,20,000.

Terrestrial snails and slugs cause considerable damage to both cultivated and useful non-cultivated plants. The animals can make their appearance in any damp area, but damage can occur also during relatively dry weather. Along with slugs, terrestrial snails also cause considerable damage to vegetable gardens, agricultural crops and fruits orchards. Singh and Agarwal, (1981) reported that *Pila globosa* an amphibious snails causes damage to paddy crops in northern part of India. In freshwater, the larvae of parasite trematodes also pass part of their life. Many aquatic snails act as vectors for the larvae of trematodes and there by, cause a number of diseases. Schistosomiasis is caused by *Schistosoma*, it is a devastating disease of mankind second only to malaria in its deleterious effect (Lambert, 1966; Jobin, 1973; Bali et al., 1986).

Fascioliasis caused by *Fasciola hepatica*, the large liver fluke, common in sheep, cattle, goat and other herbivorous animals throughout the World. Froyed (1975) reported that about 21% cattle and 7% sheep were infected with liver fluke in Great Britain. In India, the freshwater snails *Lymnaea acuminata* and *Indoplanorbis exustus* are the intermediate host of *Fasciola hepatica* and *Fasciola gigantica* (Hyman, 1970), which causes immense harm to domestic animals of this country.

The best method of controlling both the diseases such as schistosomiasis and fascioliasis is chemotherapy. Using orally-administered drugs for individuals with moderate or severe level of infection. The disadvantage of this approach is that it does not eliminate the infection entirely, the cost of recurrent treatment may become prohibitive and drug resistance may become a problem. A sure way to tackle the problem of schistosomiasis and fascioliasis is destroy the carrier snails and remove an essential link in the life cycle of the flukes. This can be accomplished in a number of ways including the use of many synthetic or plant molluscicides (Agarwal and Singh, 1988; Ndamba et al., 1995; Singh et al., 1996b).

Several plants of family leguminosae have compounds highly toxic to harmful snails (table 1). Of the 153 crude extracts of Panamanian plants of different families, *Hymenaea* *coubaris* (Leguminosae) is most effective against *Biomphalaria glabrata* (Marston et al., 1996). *Ambrosia maritima* (Asteraceae) have significant molluscicidal activity against snail species *Biomphalaria*, *Bulinus* and *Lymnaea*, examined in fields (El-sawy et al., 1981). Sesquiterpene lactones are responsible for the molluscicidal activity of Brazilian spp. Vernonia (Callegari lopes, 1991). Shoeb et al., (1993) screened many plants of family agavaceae for their molluscicidal activity against freshwater snails. *Agave attenuata* powder shows effective molluscicidal activity against *Biomphalaria alexandrina*, *Bulinus truncatus* and *Lymnaea cailliaudi* (Shoeb et al., 1993). Members of the family Guttiferae are shown to contain compounds highly effective against *Biomphalaria glabrata* (Cepleannu et al., 1994). *Anacardium occidentale* and *Spondias mombin* belongs to family Anacardiaceae shows strong molluscicidal activity against freshwater snails *Biomphalaria glabrata*. (Laurens et al., 1997). Aqueous and alcoholic extracts of *Asparagus racemosus* (Chifundera et al., 1993) and *Uriginia epigea* leaves (Amusan et al., 1997) of the liliaceae family, exhibit high mortality rate (100%) against *Lymnaea natalensis* (LC_{50} 1.0 mg/L) and *Bulinus africans* (LC_{50}, 50-100 ppm), respectively.

Table 1. A list of plants having molluscicidal activity.

Plant	Plant part Tested	Class of active moiety	Extracts	Species	References
ACANTHACEAE					
Brillantaisia vogelinae	S	Unknown	Water	*Bulinus globosus*	Adewunmi & Sofowora, 1980
Crossandra flava	F	Unknown	Water	-	-
Lankesteria elegans	L	Unknown	Water	-	-
Nelsonia canescens	L	Unknown	Methanol	-	Okunji & Iwu, 1988
AGAVACEAE					
Dracaena arborea	L	Sterols, Saponins	Water	*Lymnaea natalensis*	Okunji & Iwu, 1988
D. manni	S, F		Methanol	*B. globosus*	Adewunmi & Sofowora1980
Sanseviera trifasciata	L	Unknown	Water	*B. globosus*	
Yucca aloifolia	I	Spirostonal	Ethanol	*Biomphalaria glabrata*	Kishor & Sati, 1990
ANACARDIACEAE					
Anacardium occidentale	C	Alkenyl phenols	Water	*B. glabrata*	Sullivan et al, 1982
ANNONACEAE					
Annona senegalensis	S	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
Cleistopholis patens	R	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
APOCYANACEAE					
Alstonia booneide	L, S	Unknown	Methanol	*B. globosus*	Johns et al, 1982
Hunteria umbellata	L	Unknown	Ethanol	*B. globosus*	Fronczek et al, 1984
Alstonia scholaris	La, S	Glycosides	Water	*L. acuminata*	Singh & Singh, 2003a
Nerium indicum	La	Unknown	Water	*L. acuminata*	Tomassini & Matos, 1979
Rauvolfia caffia	S, R	Unknown	Water	*B. globosus*	Liu & Nakanishi, 1982
R. vomitoria	L, F	Alkaloids, sterols, Triterpenes	Water	*B. globosus, L. natalensis*	Adewunmi & Sofowora, 1980

Voacanga africana	S	Unknown	Methanol	*B. globosus*	Adewunmi & Sofowora, 1980
Thevetia peruviana	La, S	Thevetin	Water	*L. acuminata, I. exustus*	Singh & Singh, 2003a, b, c, Singh et al. 2000
ARACEAE					
Culcasia scandens	L	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
ARALIACEAE					
Hedera helix	-	Triterpenes, Saponins Saponin	Methanol	*B. globosus*	Adewunmi & Sofowora, 1980
Polyscias dichroostachya	L	-	Methanol	*B. globosus*	Adewunmi & Sofowora, 1980
ASTERACEAE					
Ambrosia confertiflora	W	Sesquiterpene lactones	Water	*B. glabrata*	Vagas et al, 1986
A. maritima	-	Sesquiterpenes	Hexane	*B. glabrata, Bulinus quernei*	Belot et al, 1991
Baccharis trimera	-	Diterpenes	Water	*B. globosus*	Fibo et al, 1980
Eupatorium odoratum	F	Unknown	Ethanol	*B. globosus*	Adewunmi & Sofowora, 1980
Heliopsis longipes	R	Amide (affin)	Hexane	*Physa occidentale*	Johns et al, 1982
Podachaenium emiens	-	sesquiterpenes	Hexane	*B. globosus*	Fronczek et al, 1984
Wedelia scaberrima	L	Diterpenes	Hexane	*B. globosus*	Tomassini & Mattos, 1979
BALANITACEAE					
Balanites aegyptiaca	R	Spirostanol, Saponins	Methanol	*B. glabrata*	Liu & Nakanshi, 1982
BIGNONIACEAE					
Kigelia africans	F	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
BOMBACACEAE					
Bombax costatum	S, R	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
CAESALPINACEAE					
Cassia singuena	S	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980

Delonix regia	S	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
Detarium senegalense	R	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
Dialium guineense	F	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
Tamarindus indica	S	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
CANNACEAE					
Canna indica	L, R	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
CHENOPODIACEAE					
Artriplex nummularia	F	Saponins	Water	*B. globosus*	Christensen, 1985
CLUSPIACEAE					
Garcinia kolo	S	Serols/triterpene, tannins	Water	*B. glabrata*	Okunji & Iwu, 1988
COMBRETACEAE					
Combretum delichoprtalum	L	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
C. ghasalense	S, R	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
Terminalia avicennioides	S	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
T. macroptera	S	Uknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
T. mollis	S	Unknown	Water	*B. globosus*	Adewunmi & Sofowora, 1980
EBENACEAE					
Diospyros usambarensis	-	Naphthoquinones	Methanol	*B. glabrata*	Marston et al, 1984
ERICACEAE					
Arctostaphylos uva-ursi	L	Tannins	Water, Methanol	*B. glabrata*	Schaufelberger & Hostettmann, 1983
EUPHORBIACEAE					
Acalypha ornata	L, R	Unknown	Methanol	*B. globosus*	Adewunmi & Sofowora 1980
Alchornea cordifolia	F	Alkaloids, Sterols	Water	-	Okunji & Iwu, 1988
Bridelia atroviridis	S	Unknown	Methanol	*B. globosus*	Adewunmi & Sofowora 1980
B. ferruginea	L	Sterols, Saponins	Water	*B. glabrata, B. pfeifferi*	Okunji & Iwu, 1988

Cryptogonone argentea	R	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980
Euphorbia antisyphlitica	La	Unknown	Water	*L. acuminata*	Singh & Agarwal, 1987
E. lactea criststa	La	Unknown	Water	*L. acuminata*	Singh & Agarwal, 1988
E. neutra	La	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980
E. pulcherima	R	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980
E. royleana	La	Unknown	Water	*L. acuminata*	Singh & Agarwal, 1984a.
Jatropha gossypifolia	La	Jatrophane	Water	*B. globosus*	Adewunmi & Sofowora 1980
Manihot glaziovii	S	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980
Schima argenta	-	-	Water	*B. globosus*	Cheng, 1971
Thea olesosa	-	-	Water	*B. globosus*	Amin. 1972.
Uapaca guinensis	S	Sterols, Saponins	Methanol	*B. glabrata, B. pfeifferi*	Okunji &Iwu, 1988
Croton tiglium	La, S	Saponins, Tanins	Water	*L. acuminata, I. exustus*	Yadav & Singh 2002, Yadav et al. 2004b
Codiaeum variegatum	La, S	Saponins, Tannis	Water	*L. cuminata, I. exustus*	Yadav & Singh, 2001, 2003, Yadav et al. 2004a
Euphorbia pulcherima	La, S	Ellagic acids	Water	*L. cuminata, I. exustus*	Singh et al, 2004a
Euphorbia hirta	La, S	Ellagic acids	Water	*L. cuminata, I. exustus*	Singh et al, 2004a
FABACEAE (PAPILIONACEAE)					
Amphimas pterocarpiodes	S	Tannins, Sterols	Water	*B. glabrata, B. pfeifferi*	Okunji & Iwu, 1988
Dioclea reflexa	R	Unknown	Methanol	*B. globosus*	Adewunmi & Sofowora 1980
Erythrina senegalensis	F	Unknown	Water	*B. globosus*	Okunji & Iwu, 1988
Indigofera kerstingii	L, R	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980
I. secundiflora	S, R	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980
I. spicata	S	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980
Stylosanthes biscosa	S	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980
Tephrosia bogelii	L	Flavonoids	Petrolium ether	*B. glabrata*	Marsaton et al 1996.
FAGACEAE					

Quercus spp.	S	Tannins	Water, methonal	*B. glabrata*	Schaufelberger & Hostettmann, 1983
HAMANELIDACEAE					
Hammelis virginiana	L	Tannins	Methanol	*B. glabrata*	Schaufelberger & Hostettmann, 1983
HIPPOCASTANACEAE					
Aesculus indica	S	Triterpines, glycosides	Petrol	*B. glabrata*	Okunji & Iwu, 1988
HIPPOCRATEACEAE					
Hippocratea welwitschii	R	Unknown	Ethanol	*B. globosus*	Sati & Rana, 1987.
ICACINACEAE					
Icacina trichanta	L	Unknown	Methanol	*B. globosus*	Okunji & Iwu, 1988
Pyrenacantha staudtii	L	Unknown	Ethanol	*B. globosus*	Okunji & Iwu, 1988
KRAMERIACEAE					
Krameria triandra	R	Tanins	Methanol	*B. glabrata*	Schaufelberger & Hostettmann, 1983
LAMIACEAE (LABIATAE)					
Hyptis pectinata	L	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980
H. suaveolens	L	Unknown	Water	*B. globosus*	Okunji & Iwu, 1988
Ocimum canum	L	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980
LAURACEAE					
Cassytha filiformis	Ap	Unknown	Ethanol	*B. globosus*	Okunji & Iwu, 1988
LECYTHIDACEAE					
Napoleona vogelii	L	Unknown	Water, methanol	*B. globosus*	Okunji & Iwu, 1988
LILIACEAE					
Allium sativum	B	Allicin	Water	*L. acuminata*	Singh & Singh, 1993
Asparagus curillus	-	Spirostanol saponins	Water	*B. glabrata*	Sati et al, 1984
Eriospermum abyssinicum	R	Unknown	Water	*B. glabrata*	Adewunmi & Sofowora 1980
LONGANIACEAE					

Anthocleista djalonensis	L	Unknown	Methanol	*B. trunctatus*	Okunji & Iwu, 1988
MELIACEAE					
Azadirachta indica	S	Tanin	Methanol	*B. glabrata*	Ayoub & Yankov, 1986
Ekebergia senegalensis	L	Unknown	Water	*B. glabrata*	Adewunmi & Sofowora 1980
MENISPERMACEAE					
Dioscoreophyllum cumminssi	L	Alkaloids, saponins, tannin	Water	*B. glabrata*	Okunji & Iwu, 1988
D. tenerum	L	Alkaloids, saponins, tannin	Methanol	*B. glabrata*	Okunji & Iwu, 1988
Rhigiocarya racemifora	L	Alkaloids, saponins, tannin	Ethanol	*B. glabrata*	Okunji & Iwu, 1988
MIMOSACEAE					
Acacia catechu	W	Tannins	Water	*B. glabrata*	Schaufelberger & Hostettmann, 1983
A. dudgeoni	L, S	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980
A. nilotica	L, S	Tannins	Water	*B. globosus*	Ayoub, 1985.
Albizza adianthiofolia	L	Unknown	Methanol	*B. globosus*	Okunji & Iwu, 1988
A. amara	S	Tannin	Methanol	*B. pfeifferi*	Ayoub & Yankov, 1986
A. coriaria	S	Tannin	Methanol	*B. trunctatus*	Ayoub & Yankov, 1986
A. lebbeck	S	Tannin	Methanol	*B. trunctatus*	Ayoub & Yankov, 1986
A. zygia	L	Tannin	Methanol	*B. trunctatus*	Ayoub & Yankov, 1986
Culpurnia aurea	L	Alkaloids	Methanol	*B. trunctatus*	Marston & Hostettmann,1985
Dalbergia nitidula	S	Tannins	Water	*B. glabrata*	Schaufelberger & Hostettmann, 1983.
Dichrostachys glomerata	L	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980
Entada africana	S	Tanin	Water	-	Ayoub & Yankov. 1986.
Tetrapleura tetraptera	F	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980
MORACEAE					
Ficus exasperata	L	Unknown	Methanol	*B. globosus*	Okunji & Iwu, 1988
F. glumosa	S	Unknown	Water	*B. globosus*	Adewunmi & Sofowora 1980

S= stem bark, L= leaf, O= oil cake, F= fruit, R=root, W=whole plant, La= latex, I=inflorescence, C= cashew nut shell, Se= seed, A=aerial part

Pestoban, a herbal pesticide manufactured by Indian Herbs, Research and Supply Co. Pvt. Ltd, India, is a liquid concentration of *Cedrus deodara* Linn oil and *Azadirachta indica* oil extracted from their seed, and the powder of seeds of *Embelia ribes,* dissolved in a non-ionic emulsifier, srichaskshar has high molluscicidal activity against harmful snails *Lymnaea acuminata* and *Indoplanorbis exustus* (Singh and Singh, 1994; Singh et al., 1995). In another study Singh et al., (1998) studied the synergism of an oil of *Azadirachta indica*, a powdered of *Allium sativum* bulbs and an oleoresin of *Zingiber officinale* rhizome by piperonyl butaoxide and MGK-264 against the snails *Lymnaea acuminata* and *Indoplanorbis exustus*. The response of snails to the synergised mixtures was both time and dose dependent.

Singh and Agarwal (1984a) observed that the crude latex of *Euphorbia royleana* caused 100% snail mortality within 24h at concentrations as low as $2.7x10^{-5}$ (v/v), the snail mortality was dose-dependant and the toxic moiety of the latex was stable even at 100°C. Snails exposed to latex of *Euphorbia royleana* exhibited typical symptoms of nerve poisoning and death took place within 24h. It was shown that the latex was an acetylcholinesterase inhibitor and its anti-AChE activity in the snail *Lymnaea acuminata* was very high in comparison to any synthetic organic pesticides. In another study, Singh and Agarwal (1984b) also observed that the latex of *Euphorbia royleana* reduced the level of 5-hydrodxy-tryptamine (5-HT) and dopamine in the nervous tissues of *Lymnaea acuminata*. Singh and Agarwal, (1992 a) reported that, the latices of several euphorbious plants significantly reduced the alkaline and acid phosphatase activity in nerve tissue of *Lymnaea acuminata*. Cheng, (1971) and Amin, (1972) have recorded the molluscicidal properties of *Thea olesosa*, *Croton tiglium*, *Sehima argenta* and *Jatropha* spp. Adewunmi and Morquis, (1980) studied the molluscicidal properties of methanolic extracts of the fruit of *Jatropha gossypifolia* and *Jatropha podaqrica*.

Pharmacological action of *Croton tiglium* is due to the presence of alkaloids (Rizk, 1987). The alkaloids are naturally occurring organic bases, which contain at least one nitrogen atom either in the heterocyclic ring or linked to an aliphatic skeleton. They are found in vascular plants and rarely occur in gymnosperms, cryptogams and monocotyledons. Okunji and Iwu, (1988) screened several plants of different families for molluscicidal properties and suggested that the toxic properties of these plants may be due to the presence of alkaloids. Toxicity in codiaeum spp. is due to the presence of tanin in the latex (Wealth of India, 1985). Tanin are complex phenolic compounds, divided in to two groups (i) The hydrolysable tanins, which are esters of garlic acid and also glycosides of these esters and (ii) The condensed tanins, which are polymers derived from various flavonoids. The molluscicidal activity found to be related to the free phenolic groups of the tanins. Ayoub and Yankov (1986), screened several tanin-bearing plants of different families for their molluscicidal activity. On assumption was made by him, that the molluscicidal activity of the tanin-bearing plants is proportional to the amount of tanin present in the various morphological parts.

Several species of family Euphorbiaceae, which contain diterpenes, show molluscicidal properties. Those with known molluscicidal properties are *Euphorbia royleana*, *E. antisyphilitica*, *E. lacteal acristata*, *E. pulcherima*, *E. neutra* and *Jatropha gossypifolia*, *Croton tiglium*, and *Codiaeum variegatum*, (Singh and Agarwal 1984 a, 1984b, 1987, 1988, 1990, 1991, 1992 a 1992 b, Singh, 1991, Singh and Singh, 2003a, Singh and Singh, 2003b, Singh, 2000, Singh and Singh, 2004, Yadav, 2000, Yadav and Singh, 2001, 2002,). Recent work has demonstrated that the toxicological actions of the latex can be attributed to a new class of diterpenes, which are esters of phorbol (12-deoxyphorbol, 12-deoxy-16-hydroxy-phorbol, ingenol, 5-deoxy-ingenol, resiniferotoxin and tinyatoxin) (Kinghorn and Evans, 1975). It has been reported that phorbol esters interact with and activate the recently discovered protein kinase-C (Takai et al., 1977).

A list of various plants / products, which have been shown to possess molluscicidal activity against harmful snails is given in table 1.

PISCICIDES OF PLANT ORIGIN

Fishing with the aid of plant toxins was formerly very common. Today this easy method of fishing is still practiced in remote areas. The method is simple – the poisonous ingredients are pounded and thrown in to a pool or dammed up sections of a small river. After a short time the fish begin to rise to the surface and can then readily be taken by hand. The fish can be eaten without health problems (Singh, 2001). Several bio-cidal plants have been in use for fish catching practices by the tribal communities in large numbers including Tharu, Bhotia, Kol, Gond, Kharwar and Korwas that inhabit remote villages and forest areas of the State Uttar Pradesh and Bihar (Prakash and Singh, 2000).

According to Neuwinger (1994), 258 fish poisonous plants are present in Africa, based on 25 years of field research by the author in tropical Africa and evaluation of herbarium notes. 10-20 percent fishing poisonous are probably still unknown. They are spread among 167 plant genera and 60 families. The evaluation shows a clear dominance of the leguminosae (Caesappiniaceae, Mimosaceae, Papopmaceae) in the hierarchy of fish poisoning plants. It also remarkable that a great proportion are in euphorbiales.

The latices of several genera of the Euphorbiaceae and in particular of different species of *Euphorbia* have been used extensively by fisherman in different countries as fish poison of high biological activity (Watt and Breyer–Brandijk, 1976; Novock et al., 1980). The rhizome of *Euphorbia biglandulosa* are pounded in order to release the latex in stagnant water of rivers. The rapidly dissolving poison first paralyses and then kills the fish. The sap though causes irritantation in the human skin and has no toxic effect on the people who handle the latex or eat the fish. *Argemone mexicana* belong to family–Papaveraceae and commonly known as pila kantaila. The leaf, seed and fruits of this plant have strong piscicidal activity (Dutta Munshi et al., 1991). Bhatt and Dhyani, (1990), have studied the lethality of pesticidal compounds of plant origin on some freshwater animals like water beetle, water scorpion, back swimmer, water bug, freshwater fish (*Bsrillus bendelisi*, Hom) and different stage of tadpole larvae of *Buffo melanostictus* (Boul.).

Piscicidal activity of *Madhuca indica* (Sapotaceae) has been compiled by Bhakuni et al., (1969); Talwar and Jhingaran, (1991); Satyavati and Gupta (1987). Choubey et al., (1989) evaluate the relative toxicity of oil cake of *Madhuca indica* in different species of animal viz. *Paratelphusa jacquomontii* (crab), *Pheretima posthuma* (earthworm), *Lebistus reticulates* (fish), *Pila globosa* (snail) and tadpole of *Rana tigrina*. Tadpoles were found to be most sensitive to aqueous extracts of oil cake of this plant to the presence of sterol glycoside, saponins and flavonol glycosides. A terpene, 4-deoxyphorbal the active component of plant *Euphorbia tirucalli* is highly poisonous to fish (Kamat and Muthe, 1995).

The toxic effect of ripe fruit pulp of hingan, *Balanites roxyburghii*, containing saponin on fishes *Glossogobius giurius*, *Chanda nama*, *Sarotherodon mossambica* and *Channa marulius* have been evaluated in the laboratory. *Channa marulius* was found more resistant to the toxic effect of hingman fruit than other three fishes. The hingman fruit pulp used for eradication of weed and unwanted fishes from the culture ponds. Same result was also found in case of karanj, *Pongamia pennata* seed on different fishes i.e. *G. giuris*, *Chanda nama*, *Oreochromis mossambicus* (Mohapatra and Nayak, 1998; Mohapatra and Sovan sahu, 2000). The piscicidal compounds came from 20 families of angiosperms summarised in table 2.

Table 2. A list of plants having piscicidal activity.

Plant	Plant parts tested	Class of active moiety	Extracts	Fish spp.	References
Apocynace					
Nerium indicum	L	Oleandrin	Water	*Channa punctatus*	Tiwari and Singh 2004
Nerium indicum	L	Oleandrin	Acetone	*C. punctatus*	Tiwari and Singh 2003
Nerium indicum	L	Unknown	Water	*C. punctatus*	Singh and Singh 2000
Anacardiaceae					
Lannea coromandelica	S	Unknown	Water	*Ophiocephalus punctatus*	Kulakkattolickal, 1989
Semecarpus anacardium	F	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Anonaceae					
Miliusa veluntina	S	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Miliusa veluntina	L	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Cannabinaceae					
Cannabis sativa	L	Unknown	Water	*O punctatus*	Kulakkattolickal, 1989
Combretaceae					
Terminalia chebula	F	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Terminalia alata	R	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Euphorbiaceae					
Codieum varigatum	S	Taraxerol	Ether	*Channa punctatus*	Yadav et al. 2004a
Euphorbia royleana	S	Unknown	Water	*C. punctatus*	Singh and Singh 2000
Euphorbia tirucalli	S	4-deoxy phorbol	Water	*C. punctatus*	Tiwari et al. 2001
Euphorbia tirucalli	La	4-deoxy phorbol	Water	*C. punctatus*	Tiwari et al. 2001
Glochidion velutinum	S	Unknown	Water	*Ophiocephalus punctatus*	Kulakkattolickal, 1989
Mallotus	S	Unknown	Water	*O. punctatus*	Kulakkattolickal,

philippensis					1989
Manihot esculenta	R	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Labiatae					
Colebrookea oppositifolia	L	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Lecythydiaceae					
Careya arborea	R	Unknown	Water	*O .punctatus*	Kulakkattolickal, 1989
Leguminosae					
Acacia catechu	S	Unknown	Watewr	*O. punctatus*	Kulakkattolickal, 1989
Acacia pennata	S	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Dalbergia sp.	S	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Lythraceae					
Lagerstroemia parviflora	S	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Meliaceae					
Azadirachta indica	S	Nimbisidine	Water	*O. punctatus*	Kulakkattolickal, 1989
Myrtaceae					
Syzygium cumini	S	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Papilionaceae					
Derris elliptica	S	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Indigofera sp.	S	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Polygonaceae					
Pterospermum hydropiper	S	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Polygonum neplense	W	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Polyonaceae					
Polygonum hydropiper	L, B, R	Plygodial	Water	*Heteropneustes fossilis*	Barnes and Lodder 1962
Rosaceae					
Artybotria sp.	R	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Rubiaceae					
Adina cordifolia	S	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Catunaregam spinosa	F	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Rutaceae					
Aegle marmelos	L	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989
Sapotaceae					
Madhuca indica	O	Rotenone	Water	*Lebistus*	Choubey et al.

				reticulatus	1989
Madhuca indica	O	Rotenone	Water	*Channa punctatus*	Perschbacher and Sarkar,1989
Solanaceae					
Nicotiana tabacum	L	Unknown	Water	*Ophiocephalus punctatus*	Kulakkattolickal, 1989
Solanum xanthocarpum	F	Unknown	Water	*O. punctatus*	Kulakkattolickal, 1989

S= stem bark, L= leaf, O= oil cake, F= fruit, R=root, W=whole plant, La= latex

INSECTICIDES OF PLANT ORIGIN

In all existing insect pests, mosquitoes are greater public enemy (Chandler and Read, 1981) and responsible for more human illness than any other group. About 3000 species of mosquitoes have been identified all over the world (Hati, 1991). Out of them 400 species of mosquitoes belonging to 19 genera and 42 sub-genera are recorded in India. Of these, only four genera, viz; *Anopheles, Culex, Aedes, Mansonia* are the vectors of various mosquito born diseases (Tewari, 1995). They alone carry Malaria, Yellow fever, Dengue, and Bancroftian filariasis. They also carry several types of encephalitis and occasionally involved in the mechanical transfer of Tularemia and Anthrax (Stefferud, 1952).

Malaria, the great disabler, prevails through out the tropics and temperate regions. Species of *Anopheles* mosquitoes are the carriers of human malaria. Dengue was considered to be urban disease in India but in the recent past several epidemics have also occurred in rural areas (Mourya and Joshi, 2002). *Aedes aegypti* is the main vector of dengue and yellow fever. Elephantiasis a disfiguring malady of peoples in the tropic and sub- tropic caused by *Wuchereria bancrofti* is transmitted by *Culex quinquefasciatus* mosquito (Menon and Rajagopalan, 1980). Japanese encephalitis (JE) being primarily a zoonosis, vertebrate hosts such as pigs and birds play an important role in the maintenance and amplification of the virus (Pant, 1979). In 1973 large outbreak of Japanese encephalitis occurred in the state of West Bengal and this was the first recognized epidemic of JE in India (Chakrovarthy et al., 1975). Japanese encephalitis virus was first isolated from mosquitoes of culicine species including *Culex tritaeniorhynchus* in Japan (Mitamura et al., 1938).

In recent years, there has been revival of interest in plant- derived insecticides, which are selectively toxic, do not bio-accumulate, and exhibit relatively short persistence in the environment (Shanker and Solanki, 2000). Attempts have been made to search for new classes of insecticides derived from plants owing to low toxicity and less persistence in nature (Marston and Hostettmann, 1985; Singh et al., 1996b; Kloos and Mc Cllough, 1987). Some of plant products like alkaloids, vegetable oils, plant extracts, triterpenoids, rotenone and azadiractine have lead to discovery of new molecule from botanicals as alternative pest control agents (Shankar and Solanki, 2000). Plant products can be obtained either from the whole plant or from a specific part by extraction with different types of solvents such as aqueous, methanol, chloroform, hexane etc., depending on the polarity of the phytochemicals, Studied carried out so for have shown that some chemical act as general toxicant (insecticidal / larvicidal) against both adult as well as larval stages of mosquitoes, while others interfere with growth and development (growth inhibitors) or with reproduction (chemosterilant) or produce olfactory stimuli thus acting as repellent or attractant.

Deshpanday and Tipnis, (1971) reported that the essential oils of *Ocimum basilicum* have been found to be insecticidal and larvicidal towards mosquito. Recently Bhatnagar et al., (1993) identified methyl chvicol the major constituents of *Ocimum basilicum* oil as more effective than eugenol or component of *O. sanctum* oil which was found to active against three species of mosquitoes *Anopheles stephensi, Aedes aegypti and Culex quinquefasciatus.* Kumar and Dutta (1987), reported toxicity of many essential oil towards 4^{th} instars larva of *Anopheles stephensi*, the oils are *Cedrus deodara, Cymbopogon nardus, C. flexuosus, C. martini, Lavandula officinale (L. angustifolia), Mentha arvensis, Ricinus communis, Eucalyptus globules, Melia azadirachta, Caryptophyllus (Syzygium aromaticum)*. A large number of essential oils have evaluated for their repellent activity against mosquitoes, the most effective oils being those of *Daerydum franlint* (Huonpine wood), oil of leaves of *Bakhousia myritifolia, Melaleuca bractia and Zieria smithi* (Sharma et al., 1994; Singh et al., 2001). In fields trails *Cinnamomum camphora* oil protected from various *Anopheles* for about 12 hours (Ansari and Razdan, 1995; Bhatnagar et al., 1993).

The effect of essential oils upon insects depends on several parameters including chemical composition and species susceptibility of insects as the physiological responses of each insect species towards the same crude plant extract or essential oil was not same (Bhatnagar et al., 1993). Available reports reveal that lipophilic nature of compounds, alkyl side chain, free phenolic, hydroxy or methylene dioxy group are significantly for insecticidal activity, while aliphatic straight chain Ketone and aryl Ketone compound exhibit strong repelling activity, further importance of specific position of side chain in few molecules enhance the activity (Singh et al., 2001).

A large number of plant extracts have been reported to have mosquitocidal larvicidal, growth inhibitor chemosterilant and repellent activity against mosquito vectors given in Table 3.

Table 3. A List of plants producing repellant, larvicidal and insecticidal activities against mosquitoes.

Name of the Plants	Properties	References
Allium sativum	Larvicidal	Amonkar and Benerjee, 1971
Angelica	Insecticidal	Singh et. al. 2001
B. myrstifolid	Repellant	Sharma et al., 1994
Cedrus deodara	Insecticidal	Singh et. al. 2001
C.camphora	Repellant	Ansari and Razdan 1995; Bhatnagar et al. 1993
C. lyrata	Insecticidal, Repellent	Sharma, 1991
C.citratus	Repellent, larvicidal	Singh et. al. 2001; Selander et al. 1974
C.nardus	Repellent	Singh et. al. 2001
C. domestica	Larvicidal, Repellent	Singh et al. 2001
C. martini varsofia	Repellent	Singh et. al. 2001
C. martini var motia	Repellent	Singh et. al. 2001:Selander et al.1974
Daucas carata	Insecticidal	Purohit et al. 1983

Duerydium franklint	Repellent	Sharma et al.1994
Denettia tripetala	Insecticidal	Maradufu, 1978
Eucalyptus species	Repellent	Sharma et al. 1994
Eucalyptus globules	Larvicidal	Singh et. al. 2001
E. ugenia	Larvicidal	Singh et. al. 2001
Larix decidua	Repellent	Trigg,1996
L. angusifoliat	Repellent	Singh et. al. 2001
Linaloe	Repellent	Sharma et al. 1994
Melaleuca bractea	Repellent	Yusufoglu and Hasdemir, 1996
Melia azadiracta	Repellent, Larvicidal	Singh et. al. 2001
Mentha arvensis	Larvicidal	Singh et. al. 2001
Nepta catane	Repellent	Iwvabe et al. 1981
Ocimum sanctum	Repellent, larvicidal	Hayashi, 1995; Hebalkar et al. 1992
Origanum majorana	Larvicidal	Singh et. al. 2001:Selander et al.1974
Ricinus communis	Larvicidal, Repellent	Singh et. al. 2001
Rose	Repellent	Singh et. al. 2001
Tridax procumbers	Repellent, Insecticidal	Nayak et al.1995
Vitex negundo	Repellent	Klock et al.1987
Zingiber officinale	Repellent	Singh et. al. 2001
Euphorbia roleyana	Insecticidal	Srivastava et al. 2003
Nerium indicum	Insecticidal	Srivastava et al. 2003

ACTIVE COMPOUNDS

Plants are the richest source of renewable bioactive organic chemicals. The total number of plant chemicals may exceed 40,000 of these 10,000 are secondary metabolites whose major role in the plants is reportedly defensive (Swain, 1977; Cooper and Johnson, 1984). Numerous defensive chemicals belonging to various categories (terpenoids, alkaloids, glycosides, phenols, tannins, etc.) that cause behavioural and physiological effects on pests have already been identified. Some important compounds are as given below:

Saponins- Saponins are naturally occurring plant glycosides, which form a soapy lather with water they consist of a sugar moiety and an aglycone unit. Monodesmosidic saponins (Sugar moiety only at position C-3) possess toxic activity whereas biodesmosidic saponins (sugar moiety both at C-3 and C-28 are inactive).

Alkaloids- Alkaloids are naturally occurring organic bases, which contain at least one nitrogen atom either in the hetrocyclic ring or linked to an aliphatic skeleton. They are usually colourless, crystalline, non-volatile solids, slightly soluble in water but soluble in ethanol, ether and chloroform.

Flavonoids- The term flavonoids embraces all compounds whose structure is based on flavone. Flavonoids are C_{15} compounds (exclusive of O-alkyl groups and secondary substituents), which are composed of two phenolic nuclei connected by three Carbon unit.

Diterpeneoids- The diterpenoids from a group of compounds having general molecular formula C_{20} H_{32}. They are not steam volatile and are usually obtained from plants. A new class of diterpenes which are esters of phorbol (12-deoxyphorbol, 12-deoxy-16 hydroxy-phorbol, ingenol, 5-deoxy-ingenol resiniferotoxin and tinyatoxin) possess highly toxic activity against pests.

Monoterpenoids: Monoterpenoids are made up of two isoprene units (C_{10} H_{16}) and are the chief constituents of essential oils.

Sesquiterpenes lactones: Sesquiterpenoid lactones are those compounds, which possess a sesquiterpene skeleton having an additional lactone ring.

Iridoids: Iridoids are those monocyclic monoterpenoids, which possess a lactone ring instead of having the ρ-menthane skeleton.

Furanocoumarins: Furanocournarins are a group of compounds in which the 1, 2 benzopyrene skeleton is fused with a furan ring.

Tanins: Tanins are complex phenolic compounds which can be divided into two groups, (i) the hydrolysable tannins, which are esters of gallic acid and also glycosides of these esters and (ii) the condensed tannins, which are polymers derived from various flavonoids.

CONCLUSION

There are a very large number of plants, which contain compounds lethal to target as well as non-target organism at doses, which are much below those for synthetic pyrethroids (Marston et al., 1996; Singh et al., 1996a; Amusan et al., 1997; Singh, 1991; Singh and Singh, 2003a,b; Singh and Singh, 2004; Singh et al., 2004 b). Use of such products has the additional advantage that these contain biodegradable compounds, which are less likely to cause environmental contamination. After all such compounds are not only confined to the plants in which they are found but also possibly gets distributed in the environment. We strongly feel that if these herbaceous products are used as molluscicides, piscicides and insecticides they would not only control the vector snails, predatory fishes and mosquitoes but would also have the advantage of easy availability, low cost, easy biodegradability and greater acceptance amongst the users. Further more we feel that with further progress in biotechnology, such products could be raised form sources other than those plants in which they are currently found. Production of plant pesticides could, in long run also becomes an important industry using biotechnological methods.

Most of the studies cited in this article however suffer form one common drawback. While there is much information on the toxicity and lethal doses of these plant pesticides, very little literature available on their mode of action and effect on other organisms. We are hopeful that pesticides of plant origin will find practical use as many of the plants having molluscicidal, piscicidal or mosquitocicidal activity have been used by mankind for Integrated Pest Management Programme (IPM) without polluting their environment.

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