A review on the use of botanical pesticides in insect pest management

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Abstract: Botanical pesticides are based on plant extracts. Botanical insecticides have long been touted as attractive alternatives to synthetic chemical insecticides for pest management because botanicals reputedly pose little threat to the environment or to human health. The practice of using plant materials against field and storage pests however has a long history in many indigenous and traditional farming communities across the world. A number of plant substances have been considered for use as insect antifeedants or repellents, but apart from some natural mosquito repellents, little commercial success has ensued for plant substances that modify arthropod behavior. In conventional agriculture, botanicals face tremendous competition from the newest generation of "reduced risk" synthetic insecticides such as the neonicotinoids. In the context of agricultural pest management, botanical insecticides are best suited for use in organic food production in industrialized countries but can play a much greater role in the production and postharvest protection of food in developing countries.

Key words: Botanical pesticide, Neem, Rotenone, Cinnamomum cassia, Tobacco, Pyrethrum, Sabadilla, Annonaceous acetogenins

Introduction

Botanical pesticides are an important group of naturally occurring, often slow-acting crop protectants that are usually safer to humans and the environment than conventional pesticides, and with minimal residual effects. Moreover, thanks to the fact that botanical pesticides contain mixtures of biologically active substances, no resistance is developed in pests and pathogens. Therefore the use of plant pesticides has been recommended ever more as a suitable alternative of plant protection with minimum negative impacts (Isman 2006; Pavela 2007). Plant based insecticides (PBI) have been used for many centuries (Jacobson, 1958, 1975) among limited resource farmers in developing countries to control insect pests of both field crops and stored produce, but their potential was initially limited and ignored. Nicotine, rotenone and pyrethrum were popular among the PBI used to some extent for storage pests control and other pests in green houses (Schmutterer, 1981). Some of these plant species possess one or more useful properties such as repellency, antifeedant, fast knock down, flushing action, biodegradability, broad-spectrum of activity and ability to reduce insect resistance (Olifae et al., 1987; Stoll, 1988). However, most of them are either weak insecticidal or may require other plant species with different mode of action (depending on the ratio and rate of application) to increase their potency (Sommers, 1983; Oparaek, 2004). For instance, Xylapia ethiopica (Dunal) (A. Rich.) is found to be weak insecticidal for control of Calllosobruchus maculatus Fab. on bruchid (Oparaek, 1997; Oparaek and Bunmi, 2004) and on field pests of cowpea (Oparaek, 2004). However, ground, dried fruit of X. aethiopica (African pepper or Ethiopian pepper) mixed with chillies (Capsicum spp.) and applied to kola nuts was found to have repellant properties against kola weevils (Burkill, 1985). Extracts of chilli pepper in mixture with garlic (Allium sativum L.), onion (Allium cepa L.) bulbs extracts and lemon grass (Cymbopogon citratus (Stapf.) leaf extract were found very effective against some leaf eating insect pests of crops (Stoll, 1988). In South East Asia, rice farmers are said to use a mixture of chilli pepper, dried tobacco leaves, Tubli root, and Croton tiglum against stem borers (Anonymous, 1977). In South Eastern Nigeria, rural farmers mix chilli pepper and wood ash of Parkia spp., Elaeis guineensis, Eucalyptus spp. o r Azadirachta indica (A. Juss) to control Podagrica sp. on okra plants, Abelmoschus esculentus L. (personal communication). The natives in this area also use the mixture of Chromolaena odorata L. and Ocimum gratissimun L. leaf extracts to repel termites, “tailor ants” and “soldier ants” around their houses. Si milarly, an admixture of water from fermented cassava (Manihot esculentus Crantz) tubers and bitter leaf (Vernonia amygdalina L.) has shown potency against “tailor ants” infesting local pear fruits and leaves in eastern Nigeria. Since there is paucity of documented information on the use of plant extract mixtures in pest control, this study was aimed at assessing the efficacy of mixtures of plant extracts for management of pests of cowpea plants. Plants, herbs, and spices as well as their derived essential oils and isolated compounds contain a large number of substances that are known to inhibit various metabolic activities of bacteria, yeast, and molds, although many of them are yet incompletely exploited. The antimicrobial compounds in plant materials are commonly contained in the essential oil fraction of leaves (rosemary, sage), flower buds.
(clove), fruit (pepper, cardamom), bark (cinnamon), or other parts of plant (Malo-Vigil et al., 2005). The botanical materials include crude extracts and isolated or purified compounds from various plants species and commercial products (Liu et al., 2005). Not unlike pyrethrum, rotenone and neem, plant essential oils or the plants from which they are obtained have been used for centuries to protect stored commodities or to repel pests from human habitations and use as fragrances, flavourings, condiments or spices, as well as medicinal uses (Isman and Machial, 2006). Pesticides based on plant essential oils could be used in a variety of ways to control a large number of pests, due to the rapid volatilization of these products; there is a much lower level of risk to the environment than with current synthetic pesticides (Isman and Machial, 2006). Quantitatively, the most important botanical is pyrethrum, followed by neem, rotenone and essential oils, typical uses are as insecticides (e.g. pyrethrum, rotenone, rape seed oil, quassia extract, neem oil, nicotine), repellents (e.g. citronella), fungicides (e.g. lamarinine, fennel oil, lecithine), herbicides (e.g. pine oil), spraying inhibitors (e.g. caraway seed oil) and adjuvant such as stickers and spreaders (e.g. pine oil) (Isman, 2006).

In this review article, a brief detail of the use of botanical pesticides in insect pest management is given and its existing possible participation in the integrated pest management systems. Neem: Use of botanicals is now emerging as one of the important means to be used in protection of crop produce and the environment from pesticidal pollution, which is a global problem. Neem (Azadirachta indica) products are known in use in India from time immemorial against noxious insects. Because of its legendary insect repellent and medicinal properties, it being identified as “the most promising of all plants” and at the present moment it is the source of most promising pesticides. More than 100 protolimonoids, limonoids or tetranortriterpenoids and some nonterpenoid constituents have been isolated from various parts of neem (Koul et al., 1990). From the neem seed extract alone, over 57 components have been isolated and identified (Jacobson, 1988). It is now well established that azadirachtin, the most important phagorepellent of neem kernels protects plants against insect attack. Bernays and Chapman (1977) indicated azadirachtin as he most potent antifeedant against insects like Locusta migratoria migratorioides and Schistocerca gregaria. It exhibits strong antifeedant activity against locusts as well as growth inhibiting properties (Rembold et al., 1980). The review offer further evidence for the impact of neem products against the major forest insect pests of India. The control of forest pests like poplar defoliator, Pygaera cupreata (Bhandari et al., 1988), babul defoliator, Taragama siva (Sundararaj et al., 1995), the rohida defoliator, Patialis tecomella (, the babul whitefly, Acaudaleyrodes rachipora (Sundararaj et al., 1995; 1996, Sundararaj, 1999a, b), the teak defoliators, Eutectona machaeralis and Hyblaea puera (Kulkarni et al., 1996; Sree et al., 2008) using different neem products have been tested and found useful. Dubey and Sundararaj (2004) demonstrated neem oil as effective like that of commercial neem formulations and Chlorpyriphos in containing the nymphal populations of A. disperses infesting trees of Michelia champaca and (Sundararaj and Murugesan, 1995) B. variegata. Neem seed kernel suspension as effective repellent against the polyphagous desert locust Schistocerca gregaria was demonstrated (Pradhan and Jotwani, 1971; Singh, 1985.). Ramareethnam et al. (2002) reported insecticidal property of azadirachtin against Eurema hecabe on Cassia fistula, Ambika et al. (2007) recommend neem seed oil against Pemphla morosalis on Jatropha and Murugesan et al. (2008) recommended nimbicidin against Carveddon serratus infesting seeds of many forest trees. The application of neem cake alone or in combination with other seed cakes and VAM was recommended to control whiteflies in nurseries (Sundararaj, 2010). As the neem products proved its practical utility, they are recommended for large-scale application in forestry.

Chemical compositions of A. indica: In India, pioneering work on the isolation and identifications of A. indica constituents was initiated in 1942 and has continued in various parts of the world. Leaves have been shown to contain crude fibre (11-24%), carbohydrates (48-58%), crude protein (14-18%), fat (2.3-6.9%), ash (7.7-8.5%), calcium (0.8-2.4%) and phosphorus (0.13-0.24%), as well as a number of amino acids. Recently, a two dimensional TLC method has revealed the presence of carotenoids and other constituents in the leaves of A. indica. Its oil is rich in fatty acids and cake (the solid residue following expulsion of the oil) has a high sulfur content relative to other oil cakes. A number of sugars and polysaccharides have been identified in the gum and bark of A. indica. In addition to these general types of constituents, a number of novel compounds have isolated from most parts of the tree (Fulekar 2005. All parts of the A. indica tree possess insecticidal activity but seed kernel is the most effective. It has a multitude of pesticidal active ingredients which are together called “triterpene” more specifically “limnoids”. The four best limnoids compounds are: Azadirachtin, Salannin, Meliaintrol, and Nimbin. Azadirachtin (C35H44O16) itself is a group of compounds such as AzadirachtinA,B,C,D,E,F,G etc. Of these, azadirachtin-A (Aza A) is the most plentiful and biologically active one which has shown repellent, antifeedent and insecticidal activity against a number of insect pests and it is generally Aza A that is used for commercial insecticides Barceloux 2008.

Effectiveness of A. indica against pests of crop fields of India: Oriental army worm, Mythimna separata is an important pest of wheat in the seedling stage. It is also found to be a serious pest of sorghum along with the spotted stem borer, Chilo partellus, head bugs, Calocoris angustatus and the Yellow sugarcane aphid, Melanaphis sacchari. According to Sharma et al. 1999, extracts of A. indica and custard apple kernels were effective against all of these pests. Corn earworm, Helicoverpa zea is a major pest of corn. Reed and Reed 1985 achieved a reduction of more than 60% of this corn borer by applying seed extract of A. indica.

Some of the major insect pests of rice are rice earhead bug (Leptocorisa acuta), rice leaf folder (RLF) (Cnaphalocrocis medinalis) and white–backed plant hopper (WBPH), Sogatella furcifera (Garg D.K., 1996). The various parts of A. indica tree have been used in various agricultural fields for their effective insecticidal properties. Against L. acuta, 3 per cent oil emulsion spray of A.indica, is found to protect developing rice grains.11 Similarly, 1% of its oil spray on the rice plant reduced the incidences
of leaf folder Mohan et al 1991, whereas the cake (de-oiled) amendment in the soil @ 150 kg/ha and oil spray of A. indica at 10 days intervals were found to check the infestation of C. medinalis Krishnaiah 1990. Kernel extract of A. indica was reported to show juvenile hormone mimic activity and inhibited larval development of C. medinalis after mixing with 0.16 % teepol Schmutterer et al 1983 and it was also found to reduce the population of WBPH, when sprayed on the rice crop David 1986. Root soaking of rice seedlings with kernel extract of A. indica reduced the incidences of WBPH Saxena et al 1987, whereas its oil (1 %) spray using 7.5 kg/ha with teepol controlled the attack of S. furcifera Sontakke 1993 and showed antifeedant activity to this plant hopper Saxena et al 1984. Similarly, 5 % of A. indica cake extract spray reduced emergence of WBPH Ramraju et al 1989. The extract of A. indica and azadirachtin affects the biology of brown plant hopper (BPH), Nilaparvata lugens (Stal) Senthil Nathan 2007. Mustard aphid (Aphis erysimi) is found to be regular and major pest of vegetables and mustard in addition to its act as a vector for Yellow Mosaic Virus of blackgram. Cabbage aphid (Brevicoryne brassicae) is also reported as an important pest of cabbage in hilly areas Garg 1996. Losses due to mustard aphid (Lipaphis erysimi) could be minimized by spraying the leaf and kernel extracts of A. indica on mustard crop 25. 1.5% oil spray of A. indica showed 100 per cent mortality to this aphid Mani et al 1990.

Against cabbage aphid, Brevicoryne brassicae 12 % leaf extract of A. indica and leaf extract of Annona squamosa were found to show strong anti-feedancy to this aphid, whereas 0.5 % A. indica oil spray on cauliflower showed repellency to B. brassicae Singh and Sharma 1986. According to Ketkar 2003, 5 % seed kernel extract of A. indica can be effective against aphid or leaf beetle of brinjal, white fly, jassid and fruit boer of okre, red pupkin beetle (Raphiclolaapalpa foveicollis) of pumkin, Helioverpa armigera of tomato. Some of the important insect pests of potato like potato tuber moths (Phthorimaea opercullea, Polyphagous defoliator, Henosepilachna vigintiotoventata) are known to cause considerable losses in potato cultivation in sub-hill and hill regions. Sray application of neemrich (a A. indica based formulation) protected the crop against this pest Prakash et al 2008.

Gram pod borer (Helioverpa armigera) is found to be major insect pest of chickpea and pigeonpea, whereas white grubs like Anomala dimidiate, Holotrichia seticollis and H. longipennis; cutworm (Agrotis ipsilon) and blister beetles (Mylabris phalerata) and Epicauna mannerheimii are main pests of soybean and other kharif crops grown in Kumaon hills. Hairy caterpillar (Spilosoma obliqua) is reported to be a major pest of soybean. Against H. armigera, kernel extracts (38.57%) and oil (5%) sprays of A. indica were found to be effective in reducing the populations of this pest in chickpea Siddapajai et al 1986, whereas Nemidin-9, a A. indica - based formulation inhibited the development of this pest by 70% at 1000 mg/litre concentration spray application Nelson et al 1993.

Effectiveness of A. indica against pests of stored crops of India: The derivatives of A. indica are often used to protect harvested grains kept in bags and stores in India30. Successful control of a range of stored grain insect pest species has been reported Golob and Webley 1980. Food grain losses in India during storage at the farm level approximate 10% of the production Lal 1988. The use of A. indica can confer significant economic advantage and service to rural areas in tropical developing countries, if reliable recommendations can be made and given to farmers for the protection of stored commodities, especially food grains, animal feed, and seed, from insects. This approach requires on the spot production and field testing of A. indica-based grain protectants as well as revalidation of previous reports. Some of these are reviewed here with respect to rice, wheat, sorghum and corn, legumes and potato. In warehouses, 1-2% powdered seed kernel of A. indica mixed with harvested rice significantly reduced insect pest infestations Ketkar 1976. Mixing A. indica leaves with harvested rice, treating storage bags with 2% A. indica extract, or putting dried A. indica leaves (20-30 cm thick) between the bags and storage floor achieved similar results34. Wheat stored in jute bags treated with 5% aqueous seed extract or 20% extract of A. indica leaves was protected from insect damage for up to 6 months.35. In India, Jotwani and Sircar 1967 were the first to demonstrate that powdered A. indica kernel when mixed with wheat seed at a proportion of 1-2 to 100 (wt/wt) parts satis-factorily protected against S. oryzae, R. dominica, and Trogoderma granarium for 270, 320, and 380 days, respectively. Rahim37 found that an ethanolic kernel extract of A. indica, containing azadirachtin, at 75mg/kg protected stored wheat against R. dominica for up to 48 weeks. In warehouse trials, wheat grain treated with A. indica oil at a proportion of 8 ml to 1 kg grain, prior to storing for 8 months in gunny bags, had 50 to 70% less infestation by S. oryzae, R. dominica, T. castaneum, and Cryptolestes sp. Ketkar 1976. In India, sorghum seed mixed with powdered kernel of A. indica in a proportion of 100 to > 1.5 (wt/wt) remained protected from damage by Sitophilus oryzae Deshpande 1967. Corn seed soaked for 20 minutes in a 1% solution of A. indica oil extractive was resistant to attack by S. oryzae40. According to Jotwani and Sircar 1965, in India, green gram, chick pea, cowpea, and pea could be protected from damage by the pulse beetles, Callosobruchus spp., for 8-11 months by mixing powdered A. indica kernel with grains at 1 or 2 to 100 parts. Whereas according to Yadav 1973, A. indica kernel protected the legumes against C. chinensis and C. maculates and stopped the development of progeny even 12 months after C. chinensis was released on treated lentil seed. Likewise, chick pea and pigeon pea seeds remained undamaged up to 12 months after treatment with 2g A. indica kernel powder per 100 g seed. Application of 1 to 3 parts of A. indica oil per 100 parts of Bengal gram rendered complete protection against C. chinensis for at least 135 days, without impairing seed germination. Ali et al 1983 reported that the oil of A. indica at 1 ml/100 g seed killed all the pulse beetle grubs and adults, and no eggs were laid on treated seed. On cowpea and bambara groundnut, A. indica oil at 8 ml/kg seed not only reduced oviposition, but also killed larvae; the activity persisted more than 90 days on cowpea and for 180 days on bambara groundnuts Pereira 1983.

Cinnamomum cassia: Cinnamaldehyde obtained from an extract of Cinnamomum cassia, is a potent insecticide against adults of Sitophilus oryzae and Callosobruchus chinensis (Kim et al., 2003a). Repellent and insecticidal activities of essential oils extracted from
Table-1: Plant products other than neem reported to have pest management properties against tree pests of India

<table>
<thead>
<tr>
<th>Tree species</th>
<th>No of plant species reported</th>
<th>Nature of plant products</th>
<th>Pests species and their nature</th>
<th>Effect</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acacia nilotica</td>
<td>1</td>
<td>Leaf powder: 1</td>
<td>Seed feeders: Bruchidius sp., and Caryedon serratus</td>
<td>Insecticidal</td>
<td>Murugesan et al., 2008</td>
</tr>
<tr>
<td>Albizia sp</td>
<td>3</td>
<td>Leaf extract: 3</td>
<td>Defoliator: Atteva fabriciella</td>
<td>Antifeedant</td>
<td>Ahmed et al., 1991</td>
</tr>
<tr>
<td>Bamboo spp</td>
<td></td>
<td>Flower extract: 2</td>
<td></td>
<td></td>
<td>Borthakur &amp; Gogoi, 2009</td>
</tr>
<tr>
<td>Termites</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Meshram 2000</td>
</tr>
<tr>
<td>Dalbergia sissoo</td>
<td>5</td>
<td>Leaf extract: 5</td>
<td>Defoliator: Plecoptera reflexa</td>
<td>Antifeedant</td>
<td>Meshram et al., 1996</td>
</tr>
<tr>
<td>Feronia elephantium</td>
<td>1</td>
<td>Leaf extract: 1</td>
<td>Defoliator: Papilio demolius</td>
<td>Antifeedant</td>
<td>Singh and sulphikumar 1998</td>
</tr>
<tr>
<td>Gmelina arborea</td>
<td>1</td>
<td>Plant oil: 1</td>
<td>Defoliator: Calopepla leayana</td>
<td>Antifeedant</td>
<td>Deepa and Remadevi, 2007a</td>
</tr>
<tr>
<td>Leucaena leucocephala</td>
<td>15</td>
<td>Plant oil: 15</td>
<td>Sap sucker: Heteropsylla Cubana</td>
<td>Insecticidal</td>
<td>Sharma et al., 1992</td>
</tr>
<tr>
<td>Pongamia pinnata</td>
<td>2</td>
<td>Leaf extract: 2</td>
<td>Defoliator: Lamprosema niphais</td>
<td>Growth inhibition</td>
<td>Deepa and Remadevi, 2007a</td>
</tr>
<tr>
<td>Poplar spp.</td>
<td>3</td>
<td>Leaf extract: 2</td>
<td>Defoliator: Clostera cupreata</td>
<td>Antifeedant</td>
<td>Ahmad et al., 2008</td>
</tr>
<tr>
<td>Tamarindus indica</td>
<td>1</td>
<td>Leaf powder: 1</td>
<td>Seed feeder: Bruchidius sp., and Caryedon serratus</td>
<td>Insecticidal</td>
<td>Murugesan et al., 2008</td>
</tr>
<tr>
<td>Tectona grandis</td>
<td>36</td>
<td>Leaf extract: 5</td>
<td>Defoliator: Hyblaea puera</td>
<td>Antifeedant</td>
<td>Sundararat et al., 2004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bark extract 27</td>
<td></td>
<td></td>
<td>Ramana et al., Remadevi, 2005; Senhil Nathan and Sehoo, 2006; Ramana and himavathi, 2006; Ramana et al., 2007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seed extract: 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seed oil: 1</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Tuber extract: 1</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Wood extract: 1</td>
<td></td>
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</tr>
</tbody>
</table>

Growth inhibition

Insecticidal

Larvicidal

Ovicidal

Paliga machaerolis Antifeedant

Meshram, 1995; Kulkarni et al., 1997a; Murugesan et al., 2003; Sundararat et al., 2009

Sree et al., 2008

Table-2: Efficacy of extracts of Capparis decidua on different species of aphids

<table>
<thead>
<tr>
<th>Seed</th>
<th>Branch</th>
<th>Bark</th>
<th>Root</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aphid gossypii</td>
<td>Tecoma undulata</td>
<td>94.85</td>
<td>91.20</td>
</tr>
<tr>
<td>Spraying</td>
<td>Dipping</td>
<td>90.00</td>
<td>80.00</td>
</tr>
<tr>
<td>Lipaphis erysimi</td>
<td>Brasicca compestris</td>
<td>96.64</td>
<td>90.00</td>
</tr>
<tr>
<td>Spraying</td>
<td>Dipping</td>
<td>93.33</td>
<td>80.00</td>
</tr>
<tr>
<td>Mysus persicae</td>
<td>Brasicca oleracea</td>
<td>93.33</td>
<td>92.10</td>
</tr>
<tr>
<td>Spraying</td>
<td>Dipping</td>
<td>90.00</td>
<td>90.00</td>
</tr>
<tr>
<td>CD (P = 0.05%)</td>
<td>5.76</td>
<td>4.86</td>
<td>6.12</td>
</tr>
</tbody>
</table>

leaves of Artemisia princeps and seeds of Cinnamomum camphora (L.) Presl against storage pests Sitophilus oryzae L. and Bruchus rugimanus Bohem were investigated. Results showed that the two individual oils displayed good, but their mixture exhibited much better repellent activities (Liu et al., 2005).

Nematicidal activity of Cinnamomum cassia: Cinnamon oil possessed strong nematicidal activity against the male, female and juveniles of pinewood nematode Bursaphelenchus xylophilus (Park et al., 2005). Cinnamyl acetate, the active ingredient in the oil, at a concentration of 32.81µg/l resulted in 50% mortality of nematodes. Kim et al., (2003b), reported that at the rate of 0.2 % (weight by volume of soil) of stem bark of Cinnamomum cassia powder used for soil amendment significantly reduced by 91.1% gall number of Meloidogyne incognita infection (root gall formation) of tomato seedling compared with control.

Chilli: Chilli, hot pepper and piri-piri are some of the common names of the Capsicum genus. Capsicum sp is commonly grown in Tanzanian fields and home gardens, shambaa's, mostly for culinary purposes. A capsicum based pesticide can be prepared by crushing the fruits of the plant, mixing and soaking with water, straining before applying.

Tephrosia: Tephrosia are a genus of leguminous plants which can be found both growing wild and in cultivation in Tanzania. Plants of this genus contain rotenone which is one of the main active
compounds in Tephrosia based pesticides. According to Mr. Msabaha, who during interview brought a sample of the plant, likely Tephrosia vogelli, this plant is very potent and care must be taken to not let Tephrosia sp plant parts fall into fish ponds and such. This is because rotenone, contained in the plant, is very toxic to aquatic animals and has traditionally been used as a fish poison.

**Papaya:** *Carica papaya*, commonly known as papaya, is widely cultivated throughout the tropical world and Babati is no exception. It is often grown in the homestead garden. Besides providing humans with nutritious fruit, it has applications as a botanical pesticide. Both leaf-parts and seeds from the plant can be used. A common way to prepare it is to soak either seeds or leaves in water, sift and then apply the solution to field crops.

**Tobacco:** Tobacco, species of the genus *Nicotiana*, is often cultivated in the Babati district, at least among those with the means to grow it. As a botanical pesticide, its main active compound is nicotine, the same stimulant found in tobacco products (Isman 2000). It is commonly prepared by soaking either whole or crushed leaves in water, strained and applied as a liquid.

**Pyrethrum:** Pyrethrum refers to the oleoresin extracted from the dried flowers of the pyrethrum daisy, *Tanacetum cinerariaefolium* (Asteraceae). The flowers are ground to a powder and then extracted with hexane or a similar nonpolar solvent; removal of the solvent yields an orange-colored liquid that contains the active principles (Casida et al 1995 and Glynne-Jones 2001). These are three esters of chrysanthemic acid and three esters of pyrethric acid. Among the six esters, those incorporating the alcohol pyrethrolone, namely pyrethrins I and II, are the most abundant and account for most of the insecticidal activity. Technical grade pyrethrum, the resin used in formulating commercial insecticides, typically contains from 20% to 25% pyrethrins (Casida et al 1995).

The insecticidal action of the pyrethrins is characterized by a rapid knockdown effect, particularly in flying insects, and hyperactivity and convulsions in most insects. These symptoms are a result of the neurotoxic action of the pyrethrins, which block voltage-gated sodium channels in nerve axons. As such, the mechanism of action of pyrethrins is qualitatively similar to that of DDT and many synthetic organochlorine insecticides. In purity, pyrethrins are moderately toxic to mammals (rat oral acute LD50 values range from 350 to 500 mg kg\(^{-1}\)), but technical grade pyrethrum is considerably less toxic (1500 mg kg\(^{-1}\)) (Casida et al 1995). Pyrethrins are especially labile in the presence of the UV component of sunlight, a fact that has greatly limited their use outdoors. A recent study indicated that the half-lives of pyrethrins on field-grown tomato and bell pepper fruits were 2 hours or less (Allan et al 2002).

This problem created the impetus for the development of synthetic derivatives (“pyrethroids”) that are more stable in sunlight. The modern pyrethroids, developed in the 1970s and 1980s, have been highly successful and represent one of the rare examples of synthetic pesticide chemistry based on a natural product model. However, note that the modern pyrethroids bear little structural resemblance to the natural pyrethrins, and their molecular mechanism of action differs as well. Pyrethrum use data from California (California Department of Pesticide Regulation 2005.) in 2003 clearly demonstrate the dominance of this material among botanicals: Pyrethrum accounted for 74% of all botanicals used that year, but only 27% of that amount was used in agriculture (800 kg). Major uses of pyrethrum in California are for structural pest control, in public health, and for treatment of animal premises. Pyrethrum is the predominant botanical in use, perhaps accounting for 80% of the global botanical insecticide market (Isman 2005). For many years world production of pyrethrum was led by Kenya, with lesser quantities produced in Tanzania and Ecuador. In the past five years, Botanical Resources Australia, with plantings in Tasmania, has become the second largest producer in the world (30% of world production at present), Pyrethrum produced in Tasmania is qualitatively similar to that produced in East Africa and elsewhere, but the market share achieved by the Australian producer may not increase owing to World Bank grants and government subsidies to producers in Kenya and China (B. Chung, personal communication).

**Annonaceous Acetogenins:** Botanical insecticides have been traditionally prepared from the seeds of tropical *Annona* species, members of the custard apple family (Annonaceae). These include the sweetsop (*A. squamosa*) and soursop (*A. muricata*), important sources of fruit juices in Southeast Asia. Detailed investigations in the 1980s led to the isolation of a number of long-chain fatty acid derivatives, termed acetogenins, responsible for the insecticidal bioactivity. The major acetogenin obtained from seeds of *A. squamosa* is annonin I, or squamocin, and a similar compound, asimicin, was isolated from the bark of the American pawpaw tree, *Asimina triloba* (Johnson et al 2000, McLaughlin et al 1997). McLaughlin and colleagues (Mikolajczak et al 1988) hold a U.S. patent on insecticides based on acetogenins from *A. triloba*; Bayer AG (Germany) holds a similar patent based on *Annona* acetogenins (Moeschler et al 1987). These compounds are slow acting stomach poisons, particularly effective against chewing insects such as lepidopterans and the Colorado potato beetle (*Leptinotarsa decemlineata*). Further investigations revealed that the acetogenins have a mode of action identical to that of rotenone, i.e., they block energy production in mitochondria in both insects and mammals (Lendershausen et al 1991). In purity certain acetogenins are toxic to mammals (LD50 is <20 mg kg\(^{-1}\)), an impediment to regulatory approval, even though standardized extracts from *Annona* seeds and *Asimina* bark are much less toxic. McLaughlin and associates (Johnson et al 2000) have isolated hundreds of acetogenins from the Annonaceae, and for many their potential as anticancer agents exceeds their value as insecticides. In spite of the patents based on the insecticidal activities of these materials, no commercial development has proceeded with the exception of a head lice shampoo that contains a standardized pawpaw extract among its active ingredients (Nature’s Sunshine Products, Inc., United States). *Annona* seed extracts may prove more useful in tropical countries where the fruits are commonly consumed or used to produce fruit juice, in which case the seeds are a waste product. For example, Leatemia & Isman (Leatemia et al 2004, Isman et al 2004) recently demonstrated that crude ethanolic extracts or even aqueous extracts of seeds from *A. squamosa* collected at several sites in eastern...
Indonesia are effective against the diamondback moth (Plutella xylostella).

**Rotenone:** As an insecticide, rotenone has been in use for more than 150 years, but its use as a fish poison dates back even further (Shepard 1951). Rotenone is one of several isoflavonoids produced in the roots or rhizomes of the tropical legumes *Derris*, *Lonchocarpus*, and *Tephrosia*. Most rotenone used at present comes from *Lonchocarpus* grown in Venezuela and Peru and is often called cub’e root. Extraction of the root with organic solvents yields resins containing as much as 45% total rotenoids; studies indicate that the major constituents are rotenone (44%) and deguelin (22%) (Cabizza 2004, Fang and Casida 1998). Rotenone is commonly sold as a dust containing 1% to 5% active ingredients for home and garden use, but liquid formulations used in organic agriculture can contain as much as 8% rotenone and 15% total rotenoids. Rotenone is a mitochondrial poison, which blocks the electron transport chain and prevents energy production (Hollingworth et al. 1994). As an insecticide it is considered a stomach poison because it must be ingested to be effective. Pure rotenone is comparable to DDT and other synthetic insecticides in terms of its acute toxicity to mammals (rat oral LD50 is 132 mg kg\(^{-1}\)), although it is much less toxic at the levels seen in formulated products. Safety of rotenone has recently been called into question because of (a) controversial reports that acute exposure in rats produces brain lesions consistent with those observed in humans and animals with Parkinson’s disease (Betarbet 2000), and (b) the persistence of rotenone on food crops after treatment. A study of rotenone residues on olives conducted in Italy determined that the half-life of rotenone is 4 days, and at harvest residue levels were above the tolerance limit. Moreover, residues were concentrated in oil obtained from the olives. As an agricultural insecticide, use of rotenone is limited to organic food production. In California, about 200 kg are used annually, mostly on lettuce and tomato crops.

**Sabadilla:** Sabadilla is a botanical insecticide obtained from the seeds of the South American lily *Schoenocaulon officinale*. In purity, the active principles, cevadine-type alkaloids, are extremely toxic to mammals (rat oral LD50 is 13 mg kg\(^{-1}\)), but commercial preparations typically contain less than 1% active ingredient, providing a margin of safety. The mode of action of these alkaloids is remarkably similar to that of the pyrethrins, despite their lack of structural similarity. Sabadilla is used primarily by organic growers; in California about 100 kg is used annually, primarily on citrus crops and avocado. Another botanical in declining use is ryania, obtained by grinding the wood of the Caribbean shrub *Ryania speciosa* (*Flacourtiaceae*). The powdered wood contains <1% ryanodine, an alkaloid that interferes with calcium release in muscle tissue (National Research Council. 2000). It is used to a limited extent by organic apple growers for control of the codling moth, *Cydia pomonella*. More information on sabadilla and ryania can be found in a recent review (Weinzierl RA. 2000). Like pyrethrum and rotenone, nicotine, an alkaloid obtained from the foliage of tobacco plants (*Nicotiana tabacum*) and related species, has a long history as an insecticide. Nicotine and two closely related alkaloids, nornicotine and anabasine, are synaptic poisons that mimic the neurotransmitter acetylcholine. As such, they cause symptoms of poisoning similar to those seen with organophosphate and carbamate insecticides (Hayes WJ Jr. 1982). Owing to the extreme toxicity of pure nicotine to mammals (rat oral LD50 is 50 mg kg\(^{-1}\)) and its rapid dermal absorption in humans, nicotine has seen declining use, primarily as a fumigant in greenhouses against soft-bodied pests. However, there remains some interest in preparing stable nicotine fatty acid soaps, presumably with reduced bioavailability and toxicity to humans (Casanova et al., 2002).

**Conclusion:** In the future the use of pesticides will be tightly regulated because of well-documented environmental risks in the use of synthetic chemicals. This may lead to a growing demand for botanicals. In conventional agriculture, botanicals face tremendous competition from the newest generation of “reduced risk” synthetic insecticides such as the neonicotinoids. The real benefits of botanical insecticides can be best realized in developing countries, where farmers may not be able to afford synthetic insecticides and the traditional use of plants and plant derivatives for protection of stored products is long established. Even where synthetic insecticides are affordable to growers (e.g., through government subsidies), limited literacy and a lack of protective equipment result in thousands of accidental poisonings annually. Biodegradability of botanicals may be an important factor which will increase demand for plant-based products. On the other hand, we have found that the rapid biodegradability of botanicals may hinder the registration process. It is very difficult to obtain data indicating the spread of botanicals in water, because all measurable components break down in soil within a few days. There is no single active ingredient or decomposition product which could be used as an indicator of the leaching risk.

**References**


Devi et al.


Devi et al.


Oparaese, A. M.: Collection, identification and screening of indigenous herbal extracts and waste matter for control of insect pests of cowpea; Ph.D. thesis; Ahmadu Bello University; Zaria, Nigeria; (2004).


Ramareethnam, S., Loganathan, S., Marimuthu, S. and Murugesan, N. V.: Potential of nimbicnine (0.03% Azadirachtin) in the control of *Euryma hecabe* (L.) infesting *Cassia fistula* L. (*Caesalpiniaceae*). *Pestology*, 26: 5-10 (2002).


