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Prasanna HS
Department of Plantation, Spices, Medicinal and Aromatic Plants, College of Horticulture, Bengaluru, University of Horticultural Sciences, Bagalkot, Karnataka, India

Swami DV
Dr. YSR Horticultural University, Venkataramannagudem, Andhra Pradesh, India

Bhagya HP
Indian Institute of oil palm Research, Pedavegi, Andhra Pradesh, India

Bhavishya
Central Plantation Crops Research Institute, Regional Station, Vittal, Karnataka, India

Shivakumar SN
Department of Plantation, Spices, Medicinal and Aromatic Plants, College of Horticulture, Bengaluru, University of Horticultural Sciences, Bagalkot, Karnataka, India

Correspondence
Prasanna HS
Department of Plantation, Spices, Medicinal and Aromatic Plants, College of Horticulture, Bengaluru, University of Horticultural Sciences, Bagalkot, Karnataka, India

Botanicals: Potential plant protection chemicals: A review

Prasanna HS, Swami DV, Bhagya HP, Bhavishya and Shivakumar SN

Abstract
The medicinal and aromatic plants are traditionally used in pest and disease control from time immemorial. The MAPs extracts/botanicals are easy to prepare and use, locally available, eco friendly, biodegradable, do not persist in soil and water and less or no toxic to vertebrates (fishes, birds and mamamals). As upon regular using of synthetic PPCs the appearance of resistant strains is observed i.e., > 500 insect and mite species are resistant to one or more insecticides (World Resources Institute, 1994). So the application of double and triple rates of synthetic PPCs has to be used to maintain control. These synthetic PPCs also cause environmental hazards. As the persistency of synthetic PPCs is more and they have long degradation periods it can accumulate in the food chain and also results in the generation of high and acute toxicities. These synthetic PPCs also causes carcinogenicity, mutagenity, hormonal imbalance, spermatotoxicity etc... and interfere in human health issues. The estimation done by World Health Organization (WHO) says that 2 lakh people/year are killed worldwide due to pesticide poisoning. The synthetic PPCs have very less selectivity so that they kill both beneficial and harmful organisms. These synthetic PPCs also results in groundwater contamination & secondary pest outbreaks. So in order to avoid these problems use of MAPs is one of the necessary step in pest and disease management. The active ingredients of medicinal plants are N containing compounds (Alkaloids, glycosides etc.) and aromatic plants are essential oils. These EOs are complex mixture of terpenoids (C 10 & C 15) & and aromatic phenols and their oxides, ethers, alcohols, esters, aldehydes and ketones. These were used Flavour and fragrances, condiment or spice, medicines, antimicrobial/insecticidal agents, insect repellent or protect stored products. Also as fumigant and contact insecticidal activities. Botanicals can be used as fumigant in storied pest & soil born pathogens. These botanicals also has anti fungal, anti bacterial & anti viral activities and can be used to control the diseases. The drawback of botanicals is Poor availability of raw material and the efficacy v/s synthetic pesticides is very low. So technology validated & commercial formulation should be available, along with these many other MAPs should be explored and efficacy of botanicals should be improves through biotechnology & nanotechnology.

Keywords: Botanicals, potential plant, protection chemicals

1. Introduction

Plants have been one of the important sources of medicines since the beginning of human civilization. In spite of tremendous developments in the field of allopathy during the 20th century, plants still continue as one of the major source of drugs in modern as well as traditional medicine throughout the world. Approximately one third of all pharmaceuticals are of plant origin. Over 60 percent of all pharmaceuticals are plant based. There has been a tremendous upsurge in demand for phyto-pharmaceuticals/botanicals of Indian origin in western nations. There is also an increase in domestic demand for raw materials used for biopesticidal units. The demand for traditional botanicals is also increasing at a fast pace mainly because of the harmful effects of synthetic chemicals drugs. Being strategically located, geographically India could become a potential supplier of phyto-pharmaceuticals/botanicals.

The aromatic plants contain essential oils in specialized glandular cells. The utilization of essential oils is very extensive and covers a wide range of human activity. To mention a few of the important uses of which they are put are as ingredients in the manufacture of soaps, cosmetics, perfumes, medicines, pharmaceuticals, plastic goods, textiles, leather, confectionery, perfumed tobacco, pan masala, aerated water, syrups, disinfectants, insecticides, fungicides, baby foods, biscuits, paper writing pads, cards etc. The natural essential oils have the potentiality of being very safe insecticides.

One good example in this regard is of the essential oil obtained from *Acorus calamus* which has ß-asarone as active principle, produces sterility among the variety of insects in either sex. It has been found very effective and safe for the production of food grains.

1.1 Yield benefitting and yield preventing Factors.

If we consider the yield depends up on various factors

i.e., Y= f (x_1, x_2, x_3… x_n)

- Y = Yield
- x_1, x_2, x_3, …, x_n = Yield Benefiting Factors(YBFs) and Yield Preventing Factors (YPFs)
- YBFs: Season, Nutrients, Irrigation,
- YPFs: Pest, Diseases, Weeds, Abiotic Stress…

In general the season, nutrients and irrigation etc. induces the crop yield where as pest, diseases, weeds, abiotic stress etc.. reduces the crop yield. There is a global crop loss of 25-50% of agricultural produce due to weeds, pathogens and insects infestation. Ooerke in 2006 reported that the crop yield can be reduced up to 34% due to weeds. In Agrow report (2007) it is reported that that the World agrochemical market is about US $31–35 billion (herbicides 48%; insecticides 25% and fungicides 22%) and in developed countries the consumption of synthetic plant protection chemicals (PPCs) is 3000 g/hectare.

1.2 Synthetic plant protection chemicals: Problems inherited

As upon regular using of synthetic plant protection chemicals the appearance of resistant strains is observed i.e., more than 500 insect and mite species are resistant to one or more insecticides (World Resources Institute, 1994). So the application of double and triple rates of synthetic plant protection chemicals has to be used to maintain control. These synthetic plant protection chemicals also cause environmental hazards.

As the persistency of synthetic plant protection chemicals is more and they have long degradation periods it can accumulate in the food chain and also results in the generation of high and acute toxicities. These synthetic plant protection chemicals also cause carcinogenicity, mutagenity, hormonal imbalance, spermato toxicity etc... and interfere in human health issues. The estimation done by World Health Organization (WHO) says those 2 lakh people/year are killed worldwide due to pesticide poisoning.

The synthetic plant protection chemicals have very less selectivity so that they kill both beneficial and harmful organisms. These synthetic plant protection chemicals also results in groundwater contamination, secondary pest outbreaks.

1.2.1 Alternate solutions to avoid problems of synthetic plant protection chemicals.

- By following of natural pest and disease control methods like cultural, mechanical, biological methods
- By using natural plant products/ botanicals/phyto-pharmaceuticals, including essential oils, holds a good promise
- Use of extremely biodegradable synthetic and semi-synthetic products
- Use of resistant varieties & transgenic plants

1.3 Green Pesticides

Green pesticide is defined as **“**All types of nature-oriented and beneficial pest control materials that can contribute to reduce the pest and disease and increase food production”. These green pesticides are Safe and Ecofriendly and are Compatible with the environmental components than synthetic chemicals (Isman and Machial, 2006) [11]. The green pesticides are classified under nitrogen compounds (primarily alkaloids), terpenoids, phenolics, proteinase inhibitors and growth regulators.

Green pesticides includes

- Plant extracts/Botanicals**,**
- Hormones and pheromones,
- Toxins from organic and microbial origin,
- Microbes and
- Entomophagous nematodes

1.3.1 Green pesticides action to control the pest

- Green pesticides control the pest by killing and repellent activity,
- Green pesticides effect the insect growth and development
- Green pesticides also control pests by their antifeedant and arrestant effects etc…

1.3.2 Green pesticides action to control Disease

1.3.2.1 Antifungal: Many plant essential oils and their major constituents have demonstrated antifungal activity against a range of plant pathogenic fungi including those responsible for both pre and post-harvest diseases. Antifungal activities of certain effective essential oils or their components like palmarosa oil, red thyme, clove bud oil, ginger oil (*Z. officinale), Salvia officinalis*, *Melissa officinalis*, *Cymbopogon spp.* oils, oregano oil, peppermint oil, lavender oil, mint oil, cinnamon, cinnamaldehyde, basil, marjoram, citronellal and eugenol are effective against *Botrytis cinerea, Monilinia fructicola, Rhizoctonia solani, Fusarium moniliforme, Sclerotinia sclerotiorum, F. oxysporum, Cymbopogon nardus*, *Aspergillus niger*, *P. citrinum, F. solani, R. solani, Pythium ultimum and Colletotrichum lindemuthianum* etc…..

Unlike insects, different fungal species show more consistent results. Thymus spp. showed strong antifungal activity, however higher than Mentha sp., whereas both oils have much higher antifungal activity than commercial fungicide, bifonazole, therefore, used as natural preservatives and fungicides

1.3.2.2 Antiviral: Plant essential oils and pure isolates have been mentioned as containing substances which interfere with or inhibit infection of viruses. Essential oils of *A. conyzoides, Callistemon lanceolatus, Carum copticum, O. sanctum* and *Peperomia pellucida* have been evaluated for inhibitory activity against cowpea mosaic virus (CPMV), mung bean mosaic virus (MBMV), bean commonil mosaic virus (BCMV) and Southern bean mosaic virus (SBMV). *O. sanctum* at 3000 ppm gave the best inhibition of 89.6, 90, 92.7, and 88.2% against CMV, MBMV, BCMV, and SBMV, respectively. The essential oil of *Melaleuca alternifolia* in concentrations of 100, 250, 500 ppm has been found to be effective in decreasing local lesions of TMV on host plant *Nicotiana glutinosa*. Another report has shown 62% inhibition against tobacco mosaic virus. The fresh hydrodistilled carrot leaves yielded 0.07% essential oil and twenty nine compounds have been identified and the major constituents are sabinene (10.93%), linalool (14.90%), linalyl acetate

(8.35%), and carvone (8.77%) which are active against viral agents (Rao *et al*., 1986) [23].

1.3.2.3 Antibacterial: The leaf essential oil of *Psidium guiense*, *Picarpus spicatus* showed strong antibacterial activity against gram negative *Pseudomonas eugorianus* and gram positive *Straphyloccus aerius* bacteria.

2. Extracts of Medicinal & Aromatic plants / Botanicals

2.1 Aromatic plants & Essential oils

There is a long history for use of aromatic plants and essential oils. These were used Flavour and fragrances, condiment or spice, medicines, antimicrobial/insecticidal agents, insect repellent or protect stored products and also as fumigant and contact insecticidal activities. (Isman, 2006) [10, 11].

These EOs are complex mixture of terpenoids (C_{10} & C_{15}) and aromatic phenols and their oxides, ethers, alcohols, esters, aldehydes, ketones has important defence strategy against herbivorous insect pests and pathogenic fungi.

These EOs also acts as attractants for pollinators through their fragrance and also act as signalling molecules.

Being tried as potential candidates in weed, pest and disease management the EOs are easily extractable, ecofriendly and biodegradable, they do not persist in soil and water and low or no toxicity against vertebrates i.e., fishes, birds and mamamals (Enan, 2001)[7].

2.1.1 Essential oils action on Pests and diseases

The EOs interfere in the basic metabolism, biochemical processes, physiological processes and behavioural functions of insects and pathogens and control the pest and diseases. These essential oils also kills insect pests and pathogens by neurotoxicity (Priestley *et al.*, 2003; Enan, 2005) [8].

2.1.2 Essential oil in pest control: The Essential oils are used in the forms of

2.1.2 A Fumigants: Monoterpenes being volatile are more useful as insect fumigants. Several studies have been undertaken in the past to explore the potential of essential oils and their constituents as insect fumigants. Example: In vapour phase toxicity bioassays against *C. cautella* larvae, rosemary and niaouli oils were effective with LC50 values (after 24 hr) from 64.6‒64.7 mg/l air.

2.1.2 B Chemosterilants: The medicinal and aromatic plants extract which the chemical compound cause sterility in insects are called as chemosterilants.Example: Essential oil obtained from *Acorus calamus* which has ß-asarone as active principle, produces sterility among the variety of insects in either sex.

2.1.2 C Repellents: It has long been observed that certain essential oils repel insects of stored products and households. Plants whose essential oils have been reported to have repellent activity against various insects include citronella, cedar, verbena, geranium, lavender, pine, cinnamon, rosemary, basil, thyme, black pepper oil and peppermint. Most of these essential oils provided short-lasting protection usually lasting less than 2 h. Example: The essential oils *Eucalyptus globulus* (Myrtaceae) and *Ocimum basilicum* (Lamiaceae) has repellent activity against two major economic important stored-grain insect pests red flour beetle *Tribolium castaneum* Herbst. and rice weevil *Sitophilus oryzae* L. adults. The repellency of both insect pests increased with concentration from 0.05% to 0.40% at exposure time of 4 h.

2.1.2 D Antifeedents & Deterrents: Antifeedant chemicals may be defined as being either repellent without making direct contact to insect, or suppressant or deterrent from feeding once contact has been made with insects. Example: Essential oil constituents such as thymol, citronellal and α-terpineol are effective as feeding deterrent against tobacco cutworm, *S. litura* and synergism or additive effects of combination of monoterpenoids from essential oils have been reported against *S. litura* larvae.

2.1.2 E Larvicide: Larvicidal activities have been observed in many plant oils such as neem, basil, cinnamon, citronella, camphor, eucalyptus, lemon, and pine. Combined formulations of different essential oils, which have more active substances than individuals, have also been investigated as larvicides and some mixtures were found to be more effective than neem (*Azadirachta indica*) extract. Neem and neem-based products have been widely acknowledged and currently available as the prominent biopesticides because of their pesticidal potential with larvicidal and growth regulating activity. Example: Essential oil of *E. camaldulensis*, *E. viminalis, E. microtheca, E. grandis* and *E. sargentii* were found to be toxic on *T. confusum* larvae and on *T. castaneum* larvae. So these can be used as a natural pesticide for control of these pests.

2.1.2 F Ovicide: Various essential oils and their constituents have ovicidal and oviposition deterrent activity against insects. Essential oil of *Chloroxylon swietenia* and its constituents geijerene and pregeijerene deter oviposition in *S. litura*. The ovicidal effects of volatiles from garlic oil on eggs of four cotton insect pests, spotted bollworm, *Earias vitella* Fab, *D. koenigii*, *S. litura* and *H. armigera* have also been reported. Garlic oil which is also an oviposition deterrent has been found to be highly toxic to eggs of *P. xylostella* and 99.5% reduction in egg hatching has been recorded in *S. obliqua* at 250 mg oil/50 eggs using essential oil of *Aegle marmelos*. *A. calamus* oil at 0.1% prevents oviposition of *C. maculatus* and similar activity has been reported against melon fly.

2.1.2 G Attractants: Some essential oils or the components there in do attract insects. Attraction of Banana weevil, Cosmopolites sordidus Linn. cudweed grasshopper, *Hypochlora alba* and Mexican fruit fly, *Anastrepha ludens* Loew. to 1,8-cineole has been determined. Methyl eugenol has been used to trap oriental fruit fly, *Dacus dorsalis* Hendel, whereas geraniol and eugenol are attractants and are used as lures in traps. Aphids (*Carvariella aegopodii*) feeds on the aromatic Apiaceae (Apiales) species in summer due to presence of carvone attractant. Limonene found in sour oranges (*Citrus aurantium) is* toxic to adult bean weevils (*Callosobruchus phasecoli), but highly* attractive to male Mediterranean fruit flies.

2.2 Medicinal plants in pest and disease management

The medicinal plants are traditionally used in pest and disease control from time immemorial. The active ingredients of medicinal plants are N containing compounds (Alkaloids, glycosides etc.). These compounds are easy to prepare and use and are locally available**.** Jacobson and Crosby (1971) [12], reported some of the botanical pesticides traditionally used for pest control in agricultural crops (Table 1).

2.2.1 Neem (*Azadirachta indica*: Meliaceae*)*

Neem is ative to the Indian sub-continent, it possess fungicidal, nematicidal, bactericidal, *and* pesticidal properties.There is a report that Swarming desert locusts in Sudan defoliated almost all local flora except neem trees due to insecticidal properties of neem (National Research Council, 1992). Azadirachtin the most potent locust antifeedant discovered to date. It is used to controls leaf miners, whiteflies, thrips, loopers, caterpillars, and mealybugs as well as some of the plant diseases, including certain mildews and rusts. It acts as an insect growth regulator by disruption of moulting, growth inhibition, and malformation that may contribute to mortality. There are also effects on allatropin and juvenile hormone. Antifeedant effect is highly variable among pest species, and even those species initially deterred are often capable of rapid desensitization to azadirachtin but it is light sensitive so it will lose ½ life per day.

Table 1: Botanical pesticides traditionally used for pest control in agricultural crops.

pesticide	Main source	Country/region
Neem	*Azadirachta indica* A. Juss.	India
Dharek	*Media azedarah* L.	China, India
Pyrethrum	*Chrysanthemum cineriaefolium*	Middle and Near East, Europe
Rotenone	*Derris elliptica* *Amorpha fruiticosa*	China, East Africa, South America
Nicotine	*Nicotiana tabacum* *N. rustica*	Europe
Ryanodine	*Ryania speciosa* Vahl.	Argentina, Uruguay
Pellitorine	*Anaclyus pyrethrum*	Algeria
Quassin	*Quassia amara* L..	Central America, Venezuela
Sabadilla	*Sabadilla officinarum*	Venezuela

2.2.2 Pyrethrum

Pyrethrum is the widely and heavily used Terpenoid. It is an Axonic poison (paralysis). Pyrethrum is extracted from *Chrysanthemum* in Kenya and Equadar but generally extracted from *Tanacetum cinerariaefolium (Asteraceae)* flowers. ½ of the production of pyrethrum is from Australia.

In pyrethrin based insecticide without synergists, there is a chance that insects may recover. Synergists increase insect mortality and the shelf life of the product. The Pyrethroids are semi synthetic, long lasting and effective.

2.2.3 Rotenone - An isoflavonoid

Rotenone is obtained from roots or rhizomes of *Derris, Lonchocarpus,* and *Tephrosia* (tropical legumes). It is a a contact and stomach poison.

A broad spectrum cytotoxin, inhibits the e^{-n} transport chain in mitochondria (between NAD^+ and coenzyme Q) and cause for the failure of the respiratory functions.

2.2.4 Nicotine –an alkaloid

Nicotine (and nornicotine and anabasine) are obtained from Tobacco (*Nicotiana spp.:* Solanaceae*)* and *Anabasis aphylla* (Chenopodiaceae). These are highly insecticidal (mimic neurotransmitter – acetylcholine)

Nicotine also kills insect by synaptic poison, similar to organophosphate and carbamate insecticides. It is also toxic to human. These are generally called as Nicotinoids and Neonicotinoids.

2.3 Toxicity of botanicals to higher animals

The botanicals are not only harmful to microbes and small insects, they also shows toxicity to higher animals at various concentration (Table.2). *trans*-Anethole is a botanical compound shows toxicity to Human (60 kg) at 125g LD_{50}. (Dev and Koul (1997); FAO; Koul (2005) [13].

Table 2: Mammalian toxicity of some essential oil compounds

Campound	Animal tested	Route	LD $_{50}$ (mg/kg body weight)
Apiol	Dogs	Intravenous	500
Anisaldehyde	Rats	Oral	1510
trans-Anethole	Rats	Oral	2090
Carvone	Rats	Oral	1640
1,8-Cineole	Rats	Oral	2480
Cinnamaldehyde	Guinea pigs	Oral	1160
	Rats	Oral	2220
Citral	Rats	Oral	4960
Dillapiol	Rats	Oral	1000–1500
Eugenol	Rats	Oral	2680
d-Limonene	Rats	Oral	4600
Linalool	Rats	Oral	> 1000
Menthol	Rats	Oral	3180
Methyl chavicol	Rats	Oral	1820
Methyl eugenol	Rats	Oral	1179
γ-terpinene	Rats	Oral	1680
Terpinen-4-ol	Rats	Oral	4300
Thymol	Mice	Oral	1800

4. Draw Backs and Future Prospectus of Botanicals

Even though the botanicals has many advantages, their practical application is limited due to many reasons. Some of the main reasons are the efficacy v/s synthetic pesticides is very low, greater application rates (i.e., > 1%), active ingredients of most essential oils evaporate rapidly except PMD (para-menthane 3, 8 diol) so frequent application is needed, poor availability of raw material, lack of protection of technology and regulation and lack of uniform quality and varied chemical composition

Along with many advantages and dis-advantages there is more scope for botanicals in future studies. Some of the main future strategies are pH and salinity of solution should be taken out as it potentiate the final activity of formulation (Lachowicz *et al.*, 1998) [14]. These are eco friendly carriers so can be evaluated to deliver the active ingredient & enhance life Carrier efficacy should be enriched by hydrophilic.

4.1 Encapsulation & nano technology: Prolong repellence of citronella oil up to 30 days on treated fabric stored 22 °C, when the oil was encapsulated in gelatin-arabic gum microcapsules (Miro Specos *et al.*, 2010).

There is a wider Biodiversity so many plants can be exploited for their botanical value. Alternate sources for secondary metabolites can identified through tissue Culture (ex: Azadirachtin - Neem tissue culture) and botanical insecticides by phytopharming (BT cotton)- genes of active ingredient from medicinal and aromatic plants can be transferred to agricultural crops (Isman, 2006) [10, 11].

5. Conclusion

The MAPs extracts/botanicals play a important role in pest and disease management. Botanicals are easy to prepare and use, locally available, eco friendly, biodegradable. Essential oils can be used as fumigant in storage pest & soil born pathogens. Mainly neem based botanical are used in India. The synergistic or combined effect is more than the individual plant extract. But the drawback of botanicals is poor availability of raw material and the efficacy v/s synthetic pesticides is very low. So technology validated & commercial formulation should be available, along with these many other medicinal and aromatic plants should be explored and efficacy of botanicals should be improved through biotechnology & nanotechnology.

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