Prospects of botanical pesticides in sustainable agriculture

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Botanical pesticides can be recommended as an ecochemical and sustainable strategy in the management of agricultural pests. Because of their biodegradable nature, systemicity after application, capacity to alter the behaviour of target pests and favourable safety profile, it is hoped that plant-based pesticides play a significant role in achieving evergreen revolution.

Sustainable agriculture aims at reducing the incidence of pests and diseases to such a degree that they do not seriously damage crops without upsetting nature's balance. One of the aims of sustainable agriculture is to rediscover and develop strategies whose cost and ecological side-effects are minimal. The use of synthetic pesticides has undoubtedly resulted in achievement of green revolution in different countries through increased crop production. However, in recent years there has been considerable pressure on consumers and farmers to reduce or eliminate synthetic pesticides in agriculture. This concern has encouraged researchers to look for better alternatives to synthetic pesticides.

Botanical pesticides: current status

The *Bible* and other early literature mention plant diseases such as rusts, mildews, blights and blast. The use of locally available plants in the control of pests is an ancient technology in many parts of the world. Some plants, viz. *Derris*, *Nicotiana* and *Ryania* were used to combat agricultural pests during prehistoric period. Used widely until 1940s, such botanical pesticides were partly substituted by synthetic pesticides which seemed easy to handle and lasted long.

Higher plants harbour numerous compounds which provide them resistance to pathogenic organisms. During course of evolution, the selection pressure caused by pathogens and herbivores has probably been highly acute and intense and resulted in a vast chemical diversity in higher plants. Unlike compounds synthesized in the laboratory, secondary compounds from plants are virtually guaranteed to have biological activity, protecting the plant from pathogen, herbivore or competitor. In general, plant secondary metabolites are considered to have co-evolved with herbivory.

Knowledge of the pests to which the secondary compounds produced in the plants are resistant may provide useful leads in predicting which pests may be controlled by compounds from a particular plant species. This approach has led to the discovery of different botanical pesticides.

Neem pesticides do not leave any residue on the crop. They also work as systemic pesticide; absorbed into the plant, transported to all the tissues and are ingested by plant feeding insects. Azadirachtin is considered nontoxic to mammals, fish and pollinators, having low mammalian toxicity with LD_{50} of >5000 mg/kg for rat. It is classified by Environment Protection Agency (EPA) as class IV. It is felt that none of the synthetic pesticides developed so far has the excellent virtues of neem in pest management. Pyrethrum, another old and safe insecticide, extracted from the dried flower buds of *Chrysanthemum* sp. was used in the early 19th century to control body lice during the Napoleonic wars. Pyrethrum is a mixture of four compounds: pyrethrins I and II and cinerins I and II. Pyrethrum is nontoxic to most mammals, making it one of the safest insecticides in use. Sabadilla, also known as 'cevadilla' is derived from the seeds of the sabadilla lily (*Schoenocaulon officinale*), a tropical lily that grows in Central and South America. The active ingredient is an alkaloid known as veratrine which is commonly sold under the trade names 'Red Devil' and 'Natural Guard'. Sabadilla is considered as the least toxic botanical insecticide, with an oral LD_{50} of 4000 to 5000 mg/kg. Carvone, a monoterpene of the essential oil of *Carum carvi*, is a nontoxic botanical pesticide with the trade name TALENT. It inhibits sprouting of potato tubers during storage and protects them from bacterial rotting without exhibiting mammalian toxicity. Thus, it enhances the shelflife of stored fruits and vegetables, and inhibits microbial deterioration without altering the taste and odour of the fruits[1]. Such plant chemicals can improve shelflife, quality and nutritional value of stored food commodities. Different crude extracts and plant materials rich in polyphenolics are becoming increasingly important in food industry because of their antifungal, antiaflatoxigenic and antioxidant activity[2].

Many aromatic plants commonly used as culinary herbs and spices and their essential oils have attracted the attention of scientists regarding their exploitation as botanical fumigants against storage losses of food commodities by pests and mycotoxins. Such products possess favourable safety profiles having comparatively low mammalian toxicity and are generally exempted from toxicity data requirements by EPA. Mycotech Corporation has formulated Cinnamite-TM and ValeroTM, which are used as aphidicides/miticides as well as fungicides for glasshouse and horticultural crops, viz. grapes, berry crops, citrus and nuts. Both products are cinnamon oil based, with cinnamaldehyde as the active ingredient. EcoSMART Technologies have formulated several essential oil-based pesticides. Some essential oil constituents, for example, d-limonene, pulegone, citronellal and 1,8-cineole are active ingredients of commercially available flea shampoos, mosquito repellents and different agrochemicals[3].

An eco-chemical and biorational approach

Some higher plant secondary metabolites have also been reported to alter the behaviour and life cycle of insect pests without killing them. Such chemicals are termed as semiochemicals by the Organisation for Economic Cooperation and Development[4]. Semiochemicals act by modifying the behaviour of pest species rather than killing them and are target specific. Some of the essential oils and their components show chemosterilant activity. β-asarone extracted from rhizomes of *Acorus calamus* possesses antigonadial activity, causing complete inhibition of ovarian development of different insects. The products showing chemosterilant activity are highly required in integrated pest management programmes to limit the chances of physiological (resistant) race development by insects. Many of the essential oils and their products are included in the Generally Recognised as Safe (GRAS) list fully approved by FDA and EPA for food and beverage consumption. They can be regarded as low risk and the data requirements are not as enormous as for synthetic chemical substances.

It has long been observed that plants repel pests from stored products, houses and field crops. Repellents and attractants modify the behavioural response of insects. This is the basis for the principle of behavioural insect control, whereby a given species is either attracted to a bait, or pheromone; or repelled from a host plant by a repulsive agent[5].

Pesticidal compounds of plant origin are effective against pests, mostly through diverse modes of action and can express several properties such as growth retardation, feeding deterrent, oviposition deterrent and reduction in fertility. Such allelochemicals need proper attention of plant biologists to exploit plant–pest chemical ecology in integrated management of plant pests. Most of the essential oils of higher plant origin act in biorational mode of action interrupting the function of octapamine receptors found in insects but absent in mammalian system[6]. Hence, their exploitation in pest management would be an ideal ecochemical approach.

A push-pull or stimulo-deterrent diversionary strategy has been developed in South Africa for minimizing damage due to maize stem borer insects. This strategy involves selection of plant species employed as trap crops to attract stem borer insects away from maize crop or some plant species are used as intercrops to repel insects. The trap and repellent plants contain some semiochemicals which attract or repel the insects. The push-pull strategy is also employed in control of *Heliothis* sp. in cotton fields[7]. The push-pull strategy exploiting chemical ecology of plants is an indigenous and readily available concept in management of insect population in field crops. Plant flowers like marigold and certain kinds of vegetables help to control pests in or around the main crop. Such a strategy is sometimes called 'companion planting' in pest management.

Conclusions

Reports on negative effects of synthetic pesticides and environmental risks resulting from their indiscriminate application have renewed interest towards botanical pesticides as an ecochemical approach in pest management. In the context of agricultural pest management, botanical pesticides are well suited for use in organic food production and may play a great role in the production and protection of food in developing countries[8]. The current trends of modern society towards 'green consumerism' desiring fewer synthetic ingredients in food may favour plant-based products which are 'generally recognized as safe' (GRAS) in ecofriendly management of plant pests as botanical pesticides[9].

Natural plant chemicals will play a significant role in the future for pest control in both industrialized and developing countries. Biodiversity-rich countries should quickly bioprospect their traditionally used flora to document pesticidal plants in order to check future cases of biopiracy and establish their sovereign right on the botanical pesticides developed from such plants.

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Clustering instability in jets of granular materials

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A jet or stream of liquid flowing out of a tap breaks up into drops, as a result of the well-known Plateau–Rayleigh instability; the surface tension of the liquid magnifies perturbations of the liquid–gas interface that reduce the interfacial area, and eventually the stream breaks up into a train of spherical droplets. In a recent paper published in *Nature*, Royer *et al.*[1] have found that streams of glass beads display much the same behaviour – a continuous jet of grains flowing out of the circular orifice of a container breaks into clusters of particles (Figure 1). Though granular materials are composed of macroscopic, discrete particles, they are often treated as continua in solving flow problems. However, there is an