Role and perspective of phytochemicals in pest management in India

R. T. Gahukar

Indian plants represent a rich source of phytochemicals for biopesticides and raw material for agro-industries. Among them, neem (Azadirachta indica) has been in the limelight in recent years as it has been exploited for commercial products and found suitable for environmental protection. Plant products are biodegradable leaving no residues on plants; effective against insects, plant pathogens, nematodes and non-insect pests; and cheaper, non-polluting, easy to prepare and compatible with several biopesticides and synthetic pesticides. They are therefore recommended for large scale application in agriculture in general and plant protection in particular.

Since the green revolution in the late sixties, synthetic pesticides have been used to reduce pest populations (insects, mites, birds and animals) and plant diseases caused by bacteria, fungi, viruses and nematodes. Farmers were happy with the efficacy of chemicals due to significant increase in crop productivity. However, improper dosages of active ingredients and faulty application equipment have been common errors in spraying operations. There has been resurgence of secondary pests and a 50–100 fold resistance has been developed in some insects against common pesticides. The survival and conservation of natural enemies of insect pests has been threatened. Enormous pollution in agroecosystems has created an imbalance and posed a serious risk to human health.

Generally, farmers and consumers of farm produce are not aware of the risk to human health and toxic effects of chemical pesticides in the environment. The chemicals are being recommended for plant protection even though the ill effects are obvious. Nevertheless, suitable alternatives to chemical pesticides are being tested through research and development projects in India. The reasons why plant products are preferred over chemicals are: plant products are biodegradable breaking down quickly and unlikely to lose efficacy due to build-up of genetic resistance in pests; resurgence of secondary/minor pests is not possible; hazardous residue of chemicals is not left in the crop; plant products are non-toxic and non-persistent; when plant products are combined with other measures, they are compatible, ecofriendly, and due to synergistic action, the dose of chemical pesticide can be halved; spray solutions can be prepared easily by farmers; the raw material is cheap and easily available even in villages; and environmental pollution is avoided.

Today's consumers are more concerned than ever before with the way their food is produced. There is an upward trend in consumerism. The consumers prefer organic foods and are ready to pay a sustainable premium of up to 20%. Subsequently, this demand has driven a similar increase in organically managed crops. In India, the efforts to boost organic production are being made by government agencies, NABARD and NGOs (IFOAM, BAIF, AFRO, AMEF, ILEIA, MOFF, VOFA, etc.).

Development of plant products

In India, biodiversity is immense to the extent that 45,000 species of plant community are found in different climatic zones. But with continuous deforestation and cutting of plants/trees on the roadside, field bunds, barren land, etc., local ecotypes are vanishing rapidly. From an array of several plant species, neem (*Azadirachta indica*) has secured an important place due to various uses as in, ayurvedic and unani medicines or traditional preparations used for human health, veterinary purposes, and commercial/proprietary products in agriculture. In recent years, the tree has gained special significance as a miracle tree for solving global environment problems.

The name *Azadirachta* (family Meliaceae) is of Indian origin (Azadarakht-I-Hind means 'free tree of India'). Neem has an evergreen canopy and is used as remedy for several diseases (popularly called Sarva Rog Nivarini, Kalpavruksha or Arista). Mitra[1] first extensively examined the chemistry of bioactive constituents from different parts of the neem tree. Later, research on isolation, identification, quantification and synthesis of these chemicals was possible due to advanced techniques such as selection of solvents and purification methods, flash chromatography, HPLC, gas chromatography, etc. About 150 compounds have been isolated and their structures defined[2]. There are at least 40 phytochemicals (biologically active compounds) including limonoids, flavonoids, polysaccharides and sulphur compounds. Among limonoids, azadirachtin (AZ) with A, B, C, D, E, F, G, H, I, J and K isomers is the most widely utilized compound commercially though it is very sensitive to acids, alkalies and highly photosensitive. Other major compounds include salanin, meliantriol, nimbin and nimbidine.

Mode of actions

Over 100 insects belonging to 10 different orders (Orthoptera, Dictyoptera, Lepidoptera, Homoptera, Heteroptera, Diptera, Coleoptera, Hymenoptera, Isoptera and Thysanoptera) and another 100 non-insect pests can be controlled successfully by using plant products[2]. Some of the indigenous plants with phytochemicals and modes of action are listed in Table 1. Although plant products are basically stomach poisons, contact and systemic actions have been reported in some instances. They act as pest repellants, disruptors of mating and sexual communication, sterilants, growth retardant, oviposition deterrents, antifeedants and lethal toxins. Plant products also act as inhibitors of spore germination and growth retardants of bacteria and fungi, and prevent penetration of root nematodes.

Table 1. Some Indian plant species containing phytochemicals used in pest control

Plant species (plant part used)	Family	Phytochemical/bioactive constituent	Mode of action
Acorus calamus (rhizome)	Araceae	Cisarmie transasarone trans-innamaldehyde propen-2, B-asarone	AF, IGR
Aesculus indica (leaf)	Hippocastanaceae	Lipophilic substances	PE
Ageratum mexicanum (flower)	Compositae	Precocene I, II	AF
Allium sativum (rhizome)	Alliaceae	Allicin	BA, FU
Angelica glauca (root)	Umbelliferae	Coumarins	FU
Annona squamosa (seed)	Annonaceae	Annonin, neoannonin, acetogenin	PE
Artemisia vulgaris (leaf, whole plant)	Compositae	Capillin	FU
Azadirachta indica (leaf, seed, kernel)	Meliaceae	Azadirachtin, salanin, nimbin, nimbecidin	AF, IGR, OD, PE, RE
Balanites roxburghii (seed, root)	Balanitaceae	Diosgenin, saponin, sapogenin	AF, FU
Curcuma longa (rhizome)	Zingiberaceae	Curcumin	FU, PE, RE
Cuscuta repens (vine)	Convolvulaceae	Cuscutin	IGR
Daphne oleoides (fruit)	Thymelaeaceae	Odoracin	PE
Derris elliptica (root)	Papilionaceae	Rotenone	PE
Dioscorea sativa (root)	Dioscoreaceae	Batasin, dioscin, sapogenin	FU
Eugenia aromaticum (flowerbud)	Myrtaceae	Eugenol	FU
Lycopersicon lycopersicum (leaf)	Solanaceae	Tomatin	AF
Melia spp. (leaf, seed)	Meliaceae	Toosendanin	AF, IGR
Murraya koenigii (leaf)	Rutaceae	Carbazoloquinone	PE
Parthenium hysterophorus (whole plant)	Compositae	Parthenin	PE
Piper nigrum (fruit)	Piperaceae	Isobutylamides	PE
Plumbago zeylanica (root)	Plumbaginaceae	Plumbagin	PE
Pongamia pinnata (seed)	Papilionaceae	Pongagobol, globone, pongone	PE
Pyrethrum cinerarifolium (flower)	Compositae	Pyrethrin I, II	PE
Santalum album (wood)	Santalaceae	Santalol	FU
Saussurea lappa (root)	Compositae	Costunolide	FU
Solanum indicum (root)	Solanaceae	Solanin, solanidine	AF
Tabenaemontana divaricata (seed)	Apocynaceae	Alkaloids	OD, PE
Tagetes spp. (root)	Compositae	L-terthienyl	PE
Tephrosia vogelii (root)	Papilionaceae	Amorphone/rotenonoids	PE
Zea mays (leaf)	Gramineae	Methoxybenzoxazolinone	AF

AF, Antifeedant; BA, Bactericidal; FU, Fungicidal; IGR, Insect growth regulator; NE, Nematicidal; OD, Oviposition deterrent; PE, Pesticidal (including stomach, contact, systemic and mitochondrial poisons and neurotoxins); RE, Repellent.

Application

Traditionally, plant parts (root, bark, leaves, seeds, kernels) or seed cakes are soaked overnight in water, filtered and soap water is added to this extract which is then sprayed on crops with knapsack sprayer at 250–500 l/ha depending upon crop type, plant canopy, crop stage and height.

Neem seed kernel extract is more effective than extracts of other plants. Neem oil (2–3%) is mixed with emulsifier and sprayed. At present there are >50 proprietary/formulated neem products available in the market[3] and commercial products of other plants are being developed. Neem products are mainly emulsifiable concentrates based on solvent (organic) extract or oil containing 300–10,000 ppm of AZ. Generally, 3–5 ml of the product is mixed with a litre of water and sprayed. Neem cake which is the solid residue after extracting oil from kernel has high content of sulphur compared to other oil cakes. Cake is mixed into soil at 500 kg/ha. Also, neem-coated urea has been found effective in improving soil properties and has shown antimicrobial and nematicidal actions. Application of a mixture of urea and neem cake (9 : 1) inhibits nitrification for 2–3 weeks because conversion of ammonia into nitrate is slowed down and thus loss due to evaporation and leaching is prevented.

Limitations and suggestions

• The number of neem trees in India is estimated to be around 18 million with potential of 540,000 tonnes seeds/year. But only 25% of the seeds are collected. Regenerative resources of plant origin are available in villages and preparations are easy and economical. But lot of raw material (neem kernel, seeds; leaves of lantana and *Vitex negundo*, stem of parthenium, etc.) goes waste. At present, training to farmers on correct methods of harvesting/collection and storage of plant material, and preparation of crude extract is most urgent.

• The content and stability of the active toxic ingredients in plants vary considerably as per agroclimatic zones and neem ecotypes with higher content of biologically active constituents have been identified in India[4] which should be recommended to farmers for planting around their fields, on streets and in fallow lands.

• Presently, Indian market for plant products is only 0.5–1%. However, good quality neem products can boost export potential and fetch higher prices in Indian and international markets.

• Water-based sprays are easily washed off from plants due to heavy rains. Plant products are also degraded in the field due to high temperature[3].

Frequent applications are therefore needed which increases the application cost. It is suggested that addition of cheap local materials like gum Arabic, egg white, etc. or commercial products (Sandovit®, Saver®, APSA-80®), and protectants of UV rays (soap water, antioxidants) may be added to help extend the residual efficacy of spray solution.

• Storage of raw material for a longer period with poor ventilation may lead to poor quality of spray liquid. Proper storage facility is needed for storing depulped dried fruits, kernels, cake, etc. containing 9–10% moisture up to 8–10 months.

• Toxicity to beneficial fauna (honey bees, pollinators, predators, parasitoids, entomopathogens) and health risk to humans need to be verified because there are reports demonstrating toxic effects of plant products; for example, AZ at 2000 ppm (ref. 5), 5% water extract of neem, *Ocimum sanctum*, *Allium sativum*, *Acorus calamus*, *Tribulus terrestris*[6], NSKE (5%), Neemark (5 ml/l)[7], etc.

• Plant products possess poor contact toxicity and must be ingested by pests. Also, degradation of plant products in soil is triggered by soil microorganisms and residual systemic action is reduced.

• Rules for registration are stringent and procedure is time consuming. The technical formalities prescribed for chemical pesticides are also prescribed for plant products. These procedures should be changed in future to encourage new formulations.

• In India, patents on plant products are few because there is no awareness on importance and advantages of patents related to the geographical indications[8]. Several plant species are indigenous to only certain region(s). They form a part of biodiversity and are valuable assets for the local people.

• Many plants possessing pesticidal properties are found abundantly in different climatic zones in India but remain unexploited not only for traditional preparations but also for commercial formulations, probably because the process of isolation, synthesis and formulation of phytochemicals is long and expensive[9]. Also, non-homogenous, active and inert natural products present in extracts pose problems for preparing stable formulations. Despite these difficulties, if such ventures are undertaken on the lines of commercial production and village industry it would be advantageous[10]. Precautions are however necessary as some of the plant species are protected by forest rules and regulations against exploitation.

Future needs and perspectives

Movement of organic production may be strengthened by inviting NGOs and farmers cooperatives to adopt improved practices. However, they need to be convinced of cost-effectiveness, superior bioefficacy and higher market demand than commodities produced with chemical means.

Generally, farmers will buy ready-to-use chemical pesticides even at higher price because of good advertisement of the product, quick response in term of pest mortality, and easy availability in the market. There is need to educate the farmers about the ecological/nature-friendly benefits of plant products through awareness campaigns.

Integrated pest management (IPM) is found to be economical and effective against several pests and appreciated by farmers. When neem products are mixed with kerosene, the joint action enhances bioefficacy of the mixture and is safe to predators and parasitoids of mealybugs[11]. Synergism of synthetic pesticides and neem seed powder extract[12] or vegetable oils[13] has been reported. Besides, IPM is ecofriendly and socially acceptable to consumers because it provides planned diversification of control methods; it protects and conserves environment including biodiversity; it checks adverse side-effects to target and nontarget organisms of ecosystems and thus prevents imbalance in nature; it provides efficient and cheaper control and thus makes plant protection feasible, safe and economical even for small farmers.

Knowledge-based alternatives to chemicals should be integrated *a priori* in crop management systems by which at least major pests should be controlled. Also, quick pest detection techniques when made available by extension agencies to farmers may help them to monitor pest populations in their fields. This monitoring helps in establishing working models to predict pest attack well in advance and to recommend appropriate control measures in a particular zone. Therefore, long term policy should consider the baseline surveys and simulation models.

Considering ever-increasing cost of farm inputs, reduction in production costs and increase in productivity are the current challenges. Research on these lines would benefit farmers with a commitment towards environmental safety through utilization of plant products for pest control.

1. Mitra, C. R., *Neem*, Indian Central Oilseeds Committee, Hyderabad, India, 1963.
2. Gahukar, R. T., *Neem in Plant Protection*, Agri-Horticultural Publishing Company, Nagpur, India, 1995, 1st edn.
3. Gahukar, R. T., *Pestology*, 1998, **22**, 15–41.
4. Senguttuvan, K., Kuttulam, S., Manoharan, T. and Gunasekaran, K., *Pestology*, 2005, **29**, 34–36.
5. Gupta, R. B. L., Sharma, S. and Yadava, C. P. S., *Indian J. Entomol*., 2002, **64**, 48–52.
6. Devaprasad, V., Jayaraj, S. and Rabindra, R. J., *J. Biol. Contr*., 1989, **3**, 133.
7. More, S. K., Kabre, G. B. and Saindane, Y. S., *J. Insect. Sci*., 2005, **18**, 111–113.
8. Gahukar, R. T., *J. Intell. Prop. Rights*, 2003, **8**, 9–22.
9. Jaglan, M. S., Khokhar, K. S., Malik, M. S. and Taya, J. S., *Indian J. Agric. Sci*., 1997, **31**, 167–173.
10. Suresh, D. R., Karoshi, V. R. and Hegde, G. V., *Indian Farmers' Digest*, 2001, **34**, 31, 44.
11. Gokuldas, K. M., Bhat, P. K. and Ramaiah, P. K., *J. Coffee Res*., 1989, **19**, 17–29.
12. Tripathi, M. K. and Singh, H. N., *Indian J. Entomol*., 2003, **65**, 373–378.
13. Kadam, G. M. and Ghorpade, S. A., *J. Insect Sci*., 1999, **12**, 165–167.

R. T. Gahukar lives at Plot 220, Reshimbag, Nagpur 440 009, India.
e-mail: rtgahukar@gmail.com