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Review Article

Neem and Environment: Integration of Neem in Insect Pest Management

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Abstract

Neem (*Azadirachta indica* A. Juss) based insecticides have broad spectrum usage in the pest management. About 450 insect species are found to be sensitive to neem compounds especially for azadirachtin which acts through behavioural and physiological means and at the same time spared the higher animals in sprayed ecosystems. Natural enemies, on the other hand, provide acceptable control but safety of the neem products has become debatable issue since both the pest species and the natural enemies belong to the same class, Insecta. So, several studies have been conducted on the side effects of neem based insecticides on entomophages (parasitoids and predators) and entomopathogens (fungal, bacterial and virus) in the laboratory and field. Egg parasitoid adults are sensitive to neem but the immature stages of the parasitoid developing inside the host eggs are totally safe and had normal adult emergence. The parasitisation by larval parasitoids was not much influenced by the neem while immature stages of predators are slightly sensitive to the neem. In general, the field doses of neem based insecticides do not reduce the beneficial capacity of the parasitoids and predators. It is suggested that for the use of parasitoids / predators along with neem based insecticides, presampling and timing of application are necessary. Entomopathogens have also been reported compatible with neem. Hence, combined use of natural enemies especially with neem based insecticides based on ecological and behavioural aspects of crop pests is suggested for "integrated biological control".

Keywords: entomopathogens, neem, parasitoids, pest management, predators

INTRODUCTION

Agasthiar, the great saint of India, around 5000 years before once remarked to his disciples that sow the seeds of neem and let the benefits of its medicinal properties go to the mankind for many more years to come. Neem, *Azadirachta indica* A. Juss belongs to Meliaceae is part and parcel of Indian medicine and culture. In India, the neem tree is called as *Limba, Limbo, Neem, Nim, Nimb, Nimba, Vembu, Vepa* or *Veppam* (and 100 more names); in Indonesia: *Imba, Intaran, Mimbo* and *Mindi*; in Iran: *Azad-drakht-I-hind* (free tree of India); in Sri Lanka: *Kohomba* and in Thailand: *Dao, Kwinin* and *Sadaoindia* (Schumutterer, 1995). Neem's products and derivatives have been found use in agriculture, forestry, medicine and household purposes. On the basis of the uses of neem, the ancient Indian names for the neem tree include *probhadra* (very useful), *paribhadrak* (spreading its utility over large distances), *sarvobhadrak* (Useful in every way) and *rajbhadrak* (best among all the useful trees), all of which point to its immense usefulness in Indian way of life (Dhaliwal *et al.,* 2004). The tree could provide shade to cattle and man, and the leaves are used as fodder for ruminants. The wood is used as fuel, timber for household furniture, and for agricultural implements. The seeds can provide oil for use in household lamps, lubricant and soaps. The seed cake, after washing, can be used in small amounts in poultry and cattle feed, as a source of organic manure, for conservation of nitrogenous fertilizers and for the elimination of nematodes (Koul, 1996, 2004). Hence, neem tree is the subject for agricultural scientists, physicians and industrialists because of its plant allelochemicals possess insecticidal properties (Saxena, 1989; Raguraman and Saxena, 1994; Jacobson, 1995; Singh, 2000;Kraus, 2002; Jayaraj and Ignacinuthu, 2005; Chandrasekaran, 2007; Raguraman, 2007) are a source of nitrogenous fertilizers, useful in plant disease control and elimination of nematodes, its use in *Ayurvedic, Siddha* and allopathic medicines and in manufacture of soaps (Koul and Wahab, 2004).

Physical and Chemical Diversity within Species

Neem, the genus *Azadirachta* has two species, *i.e. A. indica* A. Juss. (syn. *Melia indica* Brandis, *Melia azadirachta* L.) and *A. excelsa* (Jack) Jacob (Syn. *A. integrifolia* Merr., *Melia excelsa* Jack) (Dhaliwal *et al.,* 2004). *A. indica siamensis* Vales is indigenous to Thailand (Oo, 1987).

Neem tree in India grows under different ecological regimes and fruiting takes place during different months of the year with consequent variation not only in morphological features but also in extract yields and chemical constituents. In Tamil Nadu, the neem trees set for flowering from April to June and mature fruits from May to August. There are also vast differences in extract

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yields and bioefficacy of neem ecotypes, *i.e.* those growing in dry areas have higher bioactivity than those growing near the sea (Singh, 1987) and major bioactivity occurs due to the presence of a limonoid, azadirachtin. Trees growing in Northern India are bigger in size than those growing in Southern India. Biologically active materials are concentrated in the seed of the tree and hence seed parameters and yield are very important. Azadirachtin content in various species of *Azadirachta* show a lot of variation. Singh *et al.*, (1998) reported 0.35 per cent azadirachtin A in *A. indica* and *A. indica siamensis*, and 0.38-0.56 per cent in *A. excelsa*. There have been vast differences in azadirachtin content of seeds obtained from different countries (Ermel, 1995). However, the highest amount of azadirachtin was detected in samples from south and Southeast Asia i.e. India, Myanmar and Thailand (Table 1.)

Table 1. Azadirachtin and oil contents of neem seed kernels from Asian countries

Country	Azadirachtin (mg/g)	Oil (%)
Iran	2.75	45.4
India	5.14	47.6
Myanmar (Burma)	6.10	48.8
Sri Lanka	3.40	50.1
Thailand	5.20	45.0
Yemen	4.44	49.7

Source: Ermel (1995)

Rengasamy *et al.*,(1996) reported that azadirachtin content in neem seed kernels from eight agroecological regions of India varied from 0.14 to 1.66 per cent. The ecotypes growing in regions with moderate climate, red laterite and shallow medium black soils and altitudes less than 500 m above mean sea level were rich in azadirachtin content, whereas ecotypes growing in high altitude alluvial soils with extreme hot and cold climates had very low azadirachtin content. The azadirachtin content of neem fruits collected from an agroclimatic zone in Rajasthan varied from 0.19 to 0.67 per cent (Gupta and Prabhu, 1997). Similarly, azadirachtin content in neem seeds collected from 12 different locations in Tamil Nadu varied from 3.47 to 6.70 g/kg of kernel and oil content varied from 261 to 436 g/kg of kernel (Sridharan and Venugopal, 1998). These studies indicate a negative influence of total rainy days during fruiting season (April to August) on the azadirachtin content and significant positive influence of sunshine hours during off-season (September to March) on the oil content of the seeds.

Role of Neem as Biopesticide

Neem and its allelochemicals have variety of effects on insect pests, pathogenic fungi, bacteria and nematodes. It has a long history of use primarily against household and storage pests in Asian continent. However, a breakthrough was made by Pradhan *et al.* (1962) who successfully protected the crops by spraying them with 0.1 per cent neem seed kernel suspension during a locust invasion in Northern India. Till date neem products have been evaluated against 450-500 species of insects in different countries around the world and 413 of these are reportedly susceptible at different concentrations (Schmutterer, 1995). In India alone, neem has been evaluated against 103 species of insects, 12 nematodes and many pathogenic fungi (Arora and Dhaliwal, 1994; Schmutterer and Singh, 1995; Suresh *et al.*, 2004).

Insect Pest Management

Neem based insecticides exhibited a wide range of biological effects on the target insects. The repellent and antifeedant effects of neem have been reported against a wide range of insect pests including desert locust, *Schistocerca gregaria*; migratory locust, *Locusta migratoria;* rice planthoppers, *Nilaparvata lugens* and *Sogetella furcifera*; the leaf folder, *Cnaphalocrocis medinalis;* and the ear-cutting caterpillar, *Mythimna separate* (Saxena, 1989). Even starved *N. lugens* avoided feeding on plants sprayed with neem oil (Raguraman and Saxena, 1994; Raguraman and Rajasekaran, 1996). Concentrations ranging from 0.001 to 0.4 per cent of various neem seed kernel (NSK) extracts have generally been found to deter the feeding of most of the insects evaluated so far (Singh, 2000). The growth inhibitory effects of neem derivatives result in various developmental defects and even mortality in insect larvae. The larvae of various lepidopterous pests like *Plutella xylostella, Spodoptera frugiperda, Helicoverpa zea, Pectinophora gossypiella* and *Ephestia kuehniella* studied in various developing countries in Asia show impaired development on neem treated diet (Saxena, 1993).

Neem products also affected insect vigour, longevity and fecundity. Neem compounds sterilized females of *Epilachna varivestis* and *Leptinotarsa decemlineata*, while reproductive maturation was inhibited in *N. lugens* males. At higher concentrations, most females did not emit normal male eliciting signals (Saxena, 1998). Neem products have also been found to act as ovipositional deterrent for *Dacus cucurbitae, Helicoverpa armigera, Spodoptera litura, Callosobruchus* spp., etc. (Parmar and Singh, 1993). Ovicidal activity of neem products has also been reported in other insect species including *Corcyra* *cephalonica*, *Earias vittella* and *S. litura* (Arora and Dhaliwal, 1994).

A number of studies have been carried out in several countries of Asia to evaluate neem alone or in combination/alternation with conventional insecticides and other approaches against insect pests of agricultural crops. In the Philippines, plots treated with a 2:10 neem cake and urea mixture applied at 120 kg/ha had lower incidence of ragged stunt, grassy stunt and tungro viruses and yielded significantly more than control plots in both dry and wet seasons. Also, weekly spraying of 50 per cent neem oil-custard apple mixture in 4: 1 proportion (v/v) using ultra low volume sprayer at 8 litres/ha protected seedlings to the maximum tillering stage, significantly reduced tungro incidence and increased grain yield (Kareem *et al.*, 1987). In field trials conducted in India, neem treatments were found effective against brown planthopper, green leafhopper, yellow stem borer, rice gall midge, rice leaf folder and grasshopper (Dhaliwal *et al.*, 1996; Raguraman and Rajasekaran, 1996). Sprays of NeemAzal 5% @ 1.0 and 0.5 ml/l were as effective as monocrotophos 5-6 ml/l against rice leaf folder, *Cnaphalocrocis medinalis* and yellow stem borer, *Scirpophaga incertulas*, respectively (Dhaliwal *et al.*, 2002).

Neem products applied in combination with synthetic pyrethiroids effectively controlled the cotton pests (Gupta *et al.*, 1999). An azadirachtin-rich insecticide, RD-9 Repelin, controlled the bollworm complex on cotton in Punjab (Dhawan and Simwat, 1996) and in Andhra Pradesh on par with quinalphos (Rosaiah and Reddy, 1996). Alternate application of neem products and conventional insecticides made at the economic threshold level of 6-8 proved quite effective against *Bemisia tabaci* adults (Mann *et al.*, 2001). NeemAzal and Rakshakgold @ 2 l/ha when alternated with endosulfan and chloropyriphos effectively checked *B. tabaci* below economic threshold. In field trials conducted in Karnataka, neem seed kernel powder extract (4%) was found to be effective against *P. xylostella* and *Crocidolomia binotalis* (Moorthy and Kumar, 2000). Thus, neem has bright prospects in managing insect pests of major agricultural crops as integral component of biointensive pest management.

Integration of neem pesticides with bioagents

Although neem pesticides are environment-friendly, they are not as effective as insecticides because of their low toxicity, slow action and quick degradation. Hence, integrating them with other components of IPM, *viz.*, entomophages (parasitoids and predators) and entomopathogens (viruses, bacteria, fungi and protozoans) will be more useful for sustainable crop protection. A recent review indicated that neem products are safer to egg and larval parasitoids and predators including spiders and can be used along with entomopathogens in various agro-ecosystems (Raguraman *et al.*, 2004; Jayaraj and Ignacimuthu, 2005).

Parasitoids: The safety of neem products (NSKE 2%) on the egg-laying behaviour of the parasitoid *Telenomus remus* on *Spodoptera litura* egg-masses was shown. Jayaraj *et al.* (1993) reported that neem oil 50 EC (3%) as safe to *Trichogramma japonicum*. Aqueous, ethanolic and hexane extracts of neem seed kernel were found to deter oviposition and feeding of *Trichogramma chilonis* Ishii but no physiological and IGR effects were noticed (Raguraman and Singh, 1995, 1999). Azatin, Neem EC and Azadirachtin at 50 g/ha, had no significant effect on *T. minutum* Riley (Lyons *et al.*, 1996). However, Saminathan (2000) observed that direct exposure of *T. chilonis* reduced the adult emergence (15.5-18%) and parasitization (44-64%). The unfortified oils reduced the population of *Bracon brevicornis* up to 34% 7 days after treatment in field trials. Raguraman and Singh (1998) suggested combined use of the larval parasitoid, *Bracon hebetor* and neem - based insecticides by presampling for stage of the parasitoid in the field and release the adult parasitoids after 4-5 days of neem sprays.

Predators: Among various predators, spiders are more tolerant to neem products. There was no toxicity of certain neem products to the spider *Chiracanthium mildei* under lab conditions. The wolf spider, *Pardosa pseudoannulata*, a potential predator on rice leafhoppers is not harmed by spraying neem oil and NSKE showing good compatibility with botanical pesticides. Ineffectiveness of neem extracts against myriid bug *Cyrtorhinus lividipennis* (Reuter) was reported by several works. Dhaliwal *et al.*, (1999) reported that neem formulations were comparatively safer to the predator *Coccinella septempunctata* L.

Nucleo Polyhedro Virus (NPV): Although (NPV) has been reported effective against many insects, its prolonged incubation period, slower action and sensitivity to ultra-violet rays are few bottlenecks in using this pathogen against economic pests. Neem bitter 0.1% in combination with *Sl*NPV and crude sugar (1%) inflicted significantly higher mortality on *S. litura* and this combination recorded the shortest LT_{50} (Jayaraj and Ignacinuthu, 2005).

Bacteria: An additive effect of a neem product *viz.*, AZT-VR-K was observed with various *Bacillus thuringiensis.* var. *kurstaki*, which resulted in enhanced mortality of *Spodoptera frugiperda* larvae (Hellpap and Zebitze, 1986). Combined use of Neemix^R and *B.t.* var. *kurstaki* significantly increased the mortalityof *H. virescens* larvae much more than the individual treatment. Increased efficacy of mixture of Align^R (neem formulation) and Xentari^R (*B.thuringiensis* formulation) against *P. xylostella* was reported by Mau *et al* (1995).

Fungi: The growth of the fungi *Metarhizium anisopliae* var. *anisopliae* and *Beauveria brongniartii* was not affected by a neem product, Neemark[R] (Vyas *et al.*, 1999). Combinations of sub-lethal concentrations of NSKE with sub-lethal concentration of entomopathogenic fungi showed efficacy on the mortality of *S. litura* and *H. armigera* (Saminathan, 2000).

Neem and bioagents are nature's twin gifts to mankind for their utility in the IPM of agricultural pests, without endangering the agro-ecosystems. In fact, biological control has been most commonly used to enhance the activity of native organisms. NPV and *Bt* are highly compatible with neem products. In the case of parasitoids/predators, presampling and timing of application are necessary in order to avoid the ill effects of neem products, if any, on them. It is obvious that new millennium will look forward to "integrated biological control" that will include natural enemies *viz-a-vis* other biopesticides synchronizing with ecological and behavioural aspects of pests (Raguraman *et al.*, 2004).

Future Prospects

Neem tree has its origin in Asian country as indicated by its natural spread throughout this continent. Ecotypes show its adaptability to survive varied climatic conditions. Hence, neem is a versatile tree with immense potential to protect the environment and developing sustainable agriculture in tropical Asia. There is, thus an urgent need to popularize its cultivation on marginal lands and also bringing about awareness about the benefits and economic advantages of neem cultivation. It has been estimated that 150-250 million neem trees are required in South Asia to meet the requirements of limited resource farmers, which would need one million hectares of land to be brought under neem (Ahmed, 1995). Taking into consideration millions of hectares of semi-arid lands lying under-utilized in South Asia, this target do not appear to be difficult to achieve. As the demand for neem products increases further, more land would be needed to be brought under neem in South Asia and elsewhere. There is also need to tap the potential of already existing trees as in India less than 20 per cent of the seed crop is harvested due to unorganized scattered plantations (Walia *et al.*, 2002).

India has a potential of exporting the azadirachtin @150 tonnes/year from an optimistic assumption of azadirachtin content of 5g per kg of dried kernels (Rembold, 1996). Hence, agroforestry and reforestation programmes have to be geared up for planting more trees in India. Variations in azadirachtin content in neem are indicative of various ecotypes and genotypes. There is thus strong need to conduct thorough survey for elite trees for possible variations and propagate the elite ones through tissue culture to harness the maximum benefit in terms of azadirachtin yield.

A number of neem-based products have become available in market in India and other Asian countries, particularly for pest management. However, there are many reports of inconsistency in the field performance of these products. Hence, there is need for stabilization of neem products against photo, thermal and microbial degradation with simple formulations that are ready-to use at farm.

Quality control of neem-based products is also a major problem. There is a large variation in the quality and quantity of extractives obtained from a plant due to variation in ecotypes, environmental factors, etc. Such variations affect the performance and shelf life of formulated products. There is an urgent need to develop and prescribe suitable standards for registration of neem products in various Asian countries. Above all it is most important that farmers' profitability shall be worked out from long term trials in farmers' fields in representative areas, taking environmental perspectives including social factors into consideration.

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