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Use of indigenous plant products for management of pests and diseases of spices and condiments: Indian perspective

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Abstract

Plant derived preparations and formulated commercial products have great potential for eco-friendly management of pests and diseases of spice and condiment crops in India. These products act as antifeedant, growth regulator, repellent and a direct mortality factor against pests and as inhibitor of sporulation and development of hyphae of fungal pathogens. However, further research on field application, residual toxicity, synergistic action and hazardous effects on non-target organisms are needed.

Keywords: condiments, diseases, IPM, pests, plant products, spices.

Introduction

The productivity of most of the spice and condiment crops is considerably low in India due to various factors among which infestation by pests and pathogens is a major factor. Several species of insects, mites, nematodes and pathogens attack these crops in the field and also during storage. Synthetic pesticides have been used extensively earlier to reduce crop damage and increase crop profitability leading to pesticide residues in the produce, harmful side effects on beneficial organisms, mortality of pollinators, environmental pollution and resistance to pesticides. Since spices are high-value and export-oriented commodities, levels of pesticide residues are to be kept well below tolerance limits in view of the stringent standards set by the importing countries (Devasahayam 2005). Thus, the growing concern over pesticide misuse (excessive and indiscriminate) has led to the development of IPM schedules for sustainable management of pests and diseases in recent years. Plant products form an important component in the development of IPM schedules.

Among indigenous plant species, neem (*Azadirachta indica* A. Juss.) has been extensively studied for bioactive constituents in different plant parts and over 50 commercial products containing the major bioactive isomer, Azadirachtin (AZ) are now available in the market for general use (Gahukar 1998; Shanker & Parmar 1999). Farmers use local traditional preparations such as, neem seed kernel extract (NSKE), neem seed extract (NSE), neem leaf extract (NLE), neem crude extract (NCE), neem cake (NC) and neem oil (NO) for the management of insect pests. Different modes of action (antifeedant, repellent, insect growth regulator, oviposition deterrent and pesticidal) of the limonoids, terpenoids, flavonoids and other alkaloids present in plant products have been known through research findings (Gahukar 1995). Apart from neem, *karanj/pongam* (*Pongamia pinnata* (L.) Pierre) and *nirgudi* (*Vitex negundo* L.) are also being used in traditional preparations (crude extract, water extract, cake) and commercial products. Therefore, it is now possible to minimize the application of hazardous chemical pesticides. This paper reviews the information available on plant products used on spice and condiment crops in India and outlines suggestions for further improvement in this aspect.

Betelvine (*Piper betle* L.)

Sap sucking insects (aphids, thrips, whiteflies and scale insects) and mites are major pests and leaf spots, blight and rots are common diseases. In some places, infestations of nematodes have also been reported. Among the several species of mites infesting betelvine, the red mite (*Tetranychus neocaledonicus* Andre) is a major pest. The nymphs and adult mites suck sap from young leaves that turn yellow and drop. Nakat *et al.* (2000) tested the bioefficacy of NSKE (5%), tobacco decoction (2%) and dicofol 18.5 EC (0.05%) under laboratory and field conditions. All treatments provided satisfactory control but plant products were recommended as they are safer to predators. A spray of NSKE (5%) or NO (2%) has been recommended against linear scale (*Lepidosaphes cornutus* Ramkrishnan) (Chandra & Sagar 2004) on betelvine.

Neem leaf extract (2%) or extract of NC (0.5%) was recommended against *Phytophthora capsici* Leonian causing foot rot disease. Mixing of soil with chopped leaves of *Calotropis* sp. and neem (Chandra & Sagar 2004), or a mixture of neem cake and saw dust (Acharya & Padhi 1988) at planting time has been suggested against nematodes, *Meloidogyne incognita* (Kofoid & White) and *Hoplolaimus indicus* Sher. Neem cake applied @ 2 t ha^{-1} also controlled wilt disease caused by a fungal complex (Lal 1993).

Black pepper (*Piper nigrum* L.)

The major pests of black pepper include *pollu* beetle, scale insects, and nematodes and major diseases include *Phytophthora* foot rot and slow wilt. The *pollu* beetle (*Longitarsus nigripennis* Mots.) is the most destructive insect pest of black pepper. The beetles feed on leaves, growing shoot tips and tender spikes. The grubs bore into growing shoot tips, spikes and berries and feed on internal contents. Bioassay of plant based pesticides indicated that commercial neem products such as Repelin®, Neemgold® and Neemazal-F® (2%-3%), and leaf extracts (3%) of *Strychnos nux-vomica* L., *Chromolaena odorata* L. and *Annona squamosa* L. caused 90% antifeeding effect in laboratory bioassays and Neemgold® was the most effective treatment in the field (Devasahayam & Anandaraj 1997; Devasahayam & Leela 1997). Root bark extract of *Uvaria narum* (Dunal) Blume and *U. hookeri* King also caused >90% feeding inhibition at 0.01%-0.05% concentrations in the laboratory (Babu *et al.* 1996). For effective pest management, Devasahayam & Koya (1999) recommended regulation of shade during May-June, spraying with quinalphos 25 EC (0.05%) during July followed by Neemgold® (0.6%) during August-October at 21-day intervals. In case of scale insects (*Lepidosaphes piperis* Green and *Aspidiotus destructor* Sign.), spot application of monocrotophos (0.1%) or dimethoate (0.1%) followed by Neemgold® (0.6%) proved to be effective (Selvan *et al.* 1996; Devasahayam & Koya 1999).

Extracts of five plant species on growth stages of *P. capsici* were evaluated in laboratory bioassays among which *C. odorata* caused 100% inhibition of mycelial growth, sporangial production, zoospore production, release and germination (Anandaraj & Leela 1996). Essential oil of allspice (*Pimenta dioica* L. Merr.) leaves and its major constituent eugenol exhibited promising nematicidal activity above 660 μg ml^{-1} against root knot nematode *M. incognita* (Leela & Ramana 2000).

Cardamom (*Elettaria cardamomum* Maton)

Thrips, shoot and capsule borer, root grubs and hairy caterpillars are considered as major pests; capsule rot (*azhukal* disease), leaf blight, necrosis and mosaic (*katte* disease) are major diseases.

Cardamom plants are heavily infested by thrips (*Sciothrips cardamomi* Ramk.), resulting in shedding of flowers and immature capsules and formation of malformed capsules with corky, scab-like encrustation. Since plant products such as, Neemgold® (3%), Econeem® (0.03%), NSKE (4%) and NO (3%) could not control the pest on capsules, many chemical pesticides have generally been recommended (Naik *et al.* 2004). In nursery, young larvae of shoot and capsule borer (*Conogethes punctiferalis* Guen.) bore into and feed on the internal contents of unopened leaf buds, panicles and immature capsules while later instars bore into pseudostems and cause dead hearts due to drying of growing shoot. Amongst the neem products experimented in the field, Neemgold® (3%) and NO (3%) were promising (Naik *et al.* 2004). Colonies of aphid (*Pentalonia nigronervosa* f. *caladii* Van der Goot) remain inside leaf sheaths and suck plant sap in the nursery and plantation. These species are also a vector of the virus that causes the dreaded *katte* disease. Laboratory bioassays and field trials revealed that seed extract of *A. squamosa*, leaf extract of *Lawsonia inermis* L. and *Leucas aspera* (Willd.) Spreng., rhizome extract of *Acorus calamus* L. and two neem products (Bioneem®, Margolin®) significantly affected the settling and colonization behaviour and multiplication of aphids in cardamom (Venugopal 1999). Gopakumar *et al.* (1996) recommended NO (3%) or a water extract (5%) of *Lantana camara* L. leaves against whiteflies, *Dialeurodes cardamomi* David & Subr. which cause depletion of sap from leaves. These products act as repellents and prevent their population build-up in the plantation.

Chilli (*Capsicum annuum* L.)

The chilli crop is mainly infested by thrips, aphids, whiteflies, jassids and mealybugs on foliage and pod borer on fruits. Attack of root grubs and yellow mite is also severe in certain seasons. Anthracnose, damping off, bacterial wilt, root rot, grey mould, bacterial brown rot and blossom end rot are common diseases; viral diseases include leaf curl, mosaic and yellow dwarf.

The sucking pests suck sap from young and mature leaves and shoots resulting in curling of leaves, wilting and yellowing of young shoots, drying of flowers, and stunted growth of seedlings. Whiteflies also act as vectors of viral diseases such as, chilli mottle virus and tomato leaf curl. Sprays of neem-based commercial products such as, Achook®, Nimin®, Nimarin® (1%) applied @ 62.5 g a.i. ha^{-1} after mixing with urea @ 62 kg ha^{-1} resulted in less mortality of whitefly, *Bemisia tabaci* Genn. than with monocrotophos 36 SL (0.05%) (Saha *et al.* 2005). Therefore, a mixture of monocrotophos and Achook® or Nimin® and urea (Keisa & Varatharajan 1995) or monocrotophos (0.03%) alone had been suggested by Saha *et al.* (2005). The spraying against whitefly could also prevent the spread of leaf curl virus (Saha *et al.* 2005). Against broad mite (*Polyphagotarsonemus latus* (Banks)), sprays of Groneem® (0.015 EC) or NSKE (5%) were not effective, whereas a spray of synthetic miticide, Omite® 300W-WP (0.228%) resulted in 74% pest mortality (Kumar *et al.* 2005 b). Chilli thrips (*Scirtothrips dorsalis* Hood), is a major pest throughout the year. Although neem products controlled the pest effectively (Keisa & Varatharajan 1995), sprays of imidacloprid 200 SL (0.5 ml^{-1}) mixed with NO or *P. pinnata* oil (0.2%) were more effective (IIHR 2008). Two major pod borers namely, *Helicoverpa armigera* (Hbn.) and *Spodoptera litura* (F.) destroy fruit buds and bore into developing fruits and devour the inner content making the fruit unsuitable for marketing. An alkaloid derived from *Saphora* spp. (sold as Oxymatrine® 98%) reduced fruit damage and was significantly better than synthetic pesticides (endosulfan, chlorpyriphos, carbaryl) (Sekhar & Ram 2004). The gall midge (*Aspondylla capscici* Barnes) feeds on interior content of flower bud resulting in the formation of galls and fruit formation is inhibited. By spraying NO (1%) or NCE (5%) mixed with a sticker, Sandovit® (0.05%), during flowering stage, the pest infestation was reduced up to 57% but these treatments were not at par compared to phorate (10%) or carbofuran (3%) granules incorporated into soil @ 1 kg a.i. ha^{-1} (David *et al.* 1990). In order to reduce the application cost of treatment against sucking pests and pod borers, Rao *et al.* (1998; 1999 a, b) suggested the following IPM module: (i) incorporation of NC into soil before transplanting @ 500 kg ha^{-1} (ii) dipping seedling roots in NO (1%) (iii) weekly sprays of NO (1%); these treatments were at par with dimethoate (0.03%) in bioefficacy. Jain & Ameta (2006) suggested two sprays of imadacloprid 200 SL (750 ml ha^{-1}) followed by betacyfluthrin 0.25 EC (750 ml ha^{-1}) because Nimbecidine® (0.3%) was only moderately effective. There was increase in yield and cost: benefit ratio due to significant reduction in pest population and plant damage in all treatments except control.

Pest injury to fruits and larval frass/excreta left inside, attracts *Aspergillus flavus* (Link.) Fres. which is responsible for fruit rotting. Therefore, efforts were made to inhibit development of fungal hyphae by spraying NSKE, Nimbecidine® or oil of *P. pinnata* (5%) in the field (Kumar *et al.* 2005 a). In the field, the disease incidence was reduced from 98% to 24%-30% with sprays of water extract (5%) of *Allium sativum* L., *Datura metel* L., *Eucalyptus globules* Labill. or *Prosopis juliflora* (Sw.) DC, though carbendazim 50 WP (0.1%) spray was the most effective treatment (18% incidence) (Raj *et al.* 2006). Root rot caused by *Alternaria tenuis* Nees was checked by spraying (100-115 days after sowing) with water extract (10%) of *Aegle marmelos* (L.) Corr. or *Prosopis juliflora* (Sw.) DC (Sivaprakasam & Seetharaman 1997). Choudhary *et al.* (2000) experimented soil incorporation of a mixture of *Trichoderma viride* (Pers.) (15 g kg^{-1} soil) + chestnut compound (25 ml kg^{-1} soil) + NC (100 g kg^{-1} soil) and obtained 97% control of wilt disease caused by *Sclerotium rolfsii* Sacc. and cent per cent survival of the seedlings.

Several neem-based preparations have been tested successfully against root nematodes, especially, those belonging to the genera *Meloidogyne, Heterodera* and *Globodera*. Water extract of neem leaves or neem cake for root dipping; NO for seed coating and root dipping, and commercial products for root dipping were promising against these nematode species (Akhtar 2000). Recently, Rao (2007) recommended soil application of NC or *P. pinnata* @ 500 g m^2 in the nursery a fortnight before sowing, and @ 500 kg ha^{-1} in the field.

Cinnamon (*Cinnamomum zeylanicum* Blume)

Fruit borer on fruits and leaf miner on foliage are major pests. Major diseases of cinnamon are brown root rot, grey leaf spot, stripe canker, leaf blight and pink disease. In the laboratory, the growth and development *Phtytophthora cinnamomi* Rands causing root rot could successfully be inhibited by 5% water extract of eucalyptus (*Eucalyptus* sp.) leaves (Sivasithambaram *et al.* 1981).

Cumin (*Cuminum cyminum* L.)

Aphids are serious pests of cumin. Fungal diseases such as leaf blight, wilt, powdery mildew and rots are commonly observed. Nymphs and adult aphids (*Myzus persicae* Sulz.) suck sap from young and mature leaves which subsequently curl, dry and shed off. NO (4%) was effective in achieving cent per cent control and reducing plant injury (Vir & Yadav 2007).

Curry leaf (*Murraya koenigii* (L.) Spreng.)

Psyllid and lemon butterfly are major pests; *Diaphorina* pink disease and leaf spot are major diseases of curry leaf. Larvae of lemon butterfly (*Papillio demoleus* (L.)) defoliate the plants throughout the year. When Nimbecidine® (0.3% AZ) was sprayed on grown up trees, the neem product acted as antifeedant, insect growth regulator and pesticide against all larval instars (Ramarethinam & Loganathan 2001).

Ginger (*Zingiber officinale* Rosc.) **& Turmeric** (*Curcuma longa* L.)

Shoot borer, leaf roller, thrips and rhizome scale are major insect pests in the field. The cigarette beetle and drug store beetle are major pests on stored rhizomes. Nematode infestation occurs occasionally. Among the diseases, collar rot, soft/rhizome rot, bacterial wilt, leaf spot and leaf blotch are major diseases.

The shoot borer (*Conogethes punctiferalis* Guen.) is the most destructive pest of ginger and turmeric. The larvae bore into pseudostems and feed on central growing shoot causing dead hearts. Evaluation of NO (1%) and Nimbecidine® (1%) indicated that these products were effective only on ginger when sprayed at fortnightly intervals during July-October (IISR 2003). An integrated approach consisting of mulching of neem leaves @ 10 t ha^{-1} and spraying with NSKE (5%) during high pest incidence resulted in an increase in yield by 50%-72%; and this treatment was as effective as quinalphos (0.05%) in controlling the pest (Lalnuntluanga & Singh 2008). The injury of scale insect (*Aspidiella hartii* Sign.) to rhizomes is seen as encrustations on the rhizomes and severely infested rhizomes wither and dry. Storage of ginger rhizomes in dry leaves of *S. nux-vomica*, *Clerodendron infortunatum* Linn. or *Glycosmis cochinchinensis* Pierre was promising in checking the pest infestation (Devasahayam & Koya 1999; IISR 2003).

In water logged ginger fields, soft rot is a common fungal disease caused by a complex of *Fusarium* spp. and *Pythium* spp. In the laboratory, a water extract (5%) of neem, *Agave americana* L., *Cassia fistula* L., *V. negundo* and *Eucalyptus* sp. reduced radial growth of hyphae of *Fusarium* and *Pythium* (Panday *et al.* 1992; Sharma 1998) whilst in the field, the disease incidence was lowered by about 50% by mulching with neem leaves (Das 1999; Mezhatsu *et al.* 2008). The same fungal rot in turmeric could be managed by soil incorporation of NC @ 2 t ha^{-1} or organic manure @ 50 kg ha^{-1} mixed with *T. viride* powder (1 kg ha^{-1}). Both the treatments increased rhizome yield significantly (Ramarethinam & Rajagopal 1999).

Onion (*Allium cepa* L.)

Among the major pests, thrips, mites, cutworms, onion maggot and head borer are most common. Purple blotch, stem *Phylium* blight, *Colletotrichum* blight, damping off, downy mildew, bacterial brown rot and yellow dwarf disease are common diseases. Leaf blight caused by *Alternaria* spp. becomes serious during later stages of plant growth. In laboratory and field trials, a commercial product containing palmrosa (*Cymbopogan martini* (Roxb.) Wats) oil applied at 0.1% concentration, inhibited hyphal growth and proved as effective as mancozeb (0.25%) (Karthikeyan *et al.* 2006).

Challenges and perspectives

Though plant products have been evaluated against a many insect and nematode pests of spice and condiment crops they are yet to be experimented for the management of many major pests such as mirid bugs (*Disphinctus politus* (Westw.), *D. measarum* Link.) on betelvine; defoliators (*Lnoudera vittata* (Wlk.), *Eupterote* spp., *Arcilasisa plagiata* Mots., *Euproctis lutifacia* (Hamps.) on cardamom and leaf webber (*Udaspes folus* Cram.) on chilli. Among diseases, plant products have been evaluated against a few diseases only.

Water extracts of plants are easily washed off plants due to heavy rains. Also, because of slow effect, poor contact action and less residual toxicity, more frequent applications of plant products than that of chemicals are needed (Gahukar 1995; Lakshmisubramanian *et al.* 1998). Hence farmers must be convinced of extended pest mortality and ecological and economical benefits that they would derive from IPM including use of plant products. When plant products are mixed with each other or other pesticides, the synergism may show better effect than individual treatment. There is also an urgent need to work on cheaper and locally available stickers and additives to prolong storage period of preparations, increase residual toxicity, improve effectiveness and minimize cost of treatment.

Plant products were found safer to coccinellid beetles, *Chilocorus cicumdatus* Gyllen and *C. nigra* (F.) predating on scale insects on black pepper (Devasahayam & Koya 1999), and thrips (*Scolotrhips* spp.) and mites (*Amblyseius congoensis* Fain) predating on red mite on betel vine (Nakat *et al.* 2000). Similarly, feeding activity of another coccinellid beetle *Cryptolaemus montrouzieri* Mulsant which is a major predator of *Trialeurodes vaporariorum* (Westw.), was not affected at 1000 ppm of (Simmonds *et al.* 2000). However, in laboratory experiments, growth of two important beneficial fungi, *Metarrhizium anisopliae* (Metch.) Sorokin and *Beauveria bassiana* (Bals.) Vuill., was adversely affected by the toxic effects of plant products such as AZ at 2000 ppm (Gupta *et al.* 2002); NSKE (5%) and water extract (5%) of *Ocimum sanctum* L., *A. sativum*, *A. calamus* and *Tribulus terrestris* L. (Devaprasad *et al.* 1989). Development period of chrysopid larvae was prolonged due to NSKE (5%) and Neemark® containing 1500 ppm of AZ (5 ml L^{-1}) (More *et al.* 2005). Direct toxic effects on other natural enemies, pollinators, honey bees and entomopathogens are required to be studied intensively and only safe indigenous products should be recommended.

The content of biologically active constituents in plants differs as per ecotypes (Senguttuvan *et al.* 2005), genetic diversity (Vir 2007) and climatic conditions (Gupta *et al.* 2010). It is therefore necessary to identify those ecotypes with higher content of AZ and other limonoids. These synthesized commercial products and traditional preparations from such geographical areas must be patented (Gahukar 2003). There is also an industrial perspective for plant products due to abundance of indigenous resources for plant-based pesticides (Suresh *et al.* 2001). Education of farmers on proper methods of collection, storage and preparation of plant based preparations would also help to popularize plant products for the management of pests and diseases of spice and condiment crops.

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