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Biological Control of Phytophagous Mites: A Review

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A B S T R A C T

Phytophagus mites are gaining importance at present since their incidence is high. Farmers rely only on acaricides and other chemical pesticides for the management of these mites results in destruction of natural enemies, pesticide resistance and pesticide residues in crops, environment pollution etc. Hence, there is a need to find alternate to manage the phytophagous mites. Exploitation of natural enemies viz., predaceous insects, predatory mites and acaropathogenic fungi are the tools in pest management programmes. Among the predatory mites, the family Phytoseiidae is known to have potential predators which have proved their efficacy against several mite pests in different crops. Classical, augmentative and conservation biocontrol programmes using some of the important biocontrol agents remained as success stories in developed countries. However, the potential use of s biocontrol agents of mite pests is yet to be exploited in developing countries like India. In this context, the present review is about updated information on predaceous insects, predatory mites and acaropathogens against phtophagous mites.

Introduction

Phytophagous mites attack most of the agricultural and horticultural crops. These pests are distributed worldwide causing loss of quality and yield or death of host plants by sucking out the cell-contents of leaf. Yield loss due to these pests may vary in different crops viz. cereals (5-50%), sugarcane (5-20%), cotton (20-30%), tea (5-50%), brinjal (13-31%) in bhendi (23-25%), gourd (36%), cucumber (14%) and ornamental crops (5-15%) (Ramaraju and Bhullar, 2013). Indiscriminate use of pesticides to control these pests resulted in destruction of natural enemies, pesticide resistance, pesticide resurgence and residues in crop and cause health hazards to consumers. These issues necessitated the development of alternative pest control strategies.

In the present scenario, the exploitation of natural enemies as a tool in pest management is essential for the sustainability and food security. Phytophagous mites are naturally controlled by predatory mites, predatory insects and acaro pathogens viz., viruses, fungi and bacteria.

Insect predators

Insect predators of phytophagous mites are found in the following orders (Fathipour and Maleknia, 2016).

Coleoptera (Coccinellidae –*Stethorus* sp, Staphylinidae- *Oligota* sp)

Certain specialist ladybirds belonging to genus *Stethorus* are potential biocontrol of tetranychid mites, especially at high density of mites (Biddinger *et al.*, 2009). The feeding potential of various *Stethorus* sp. has been studied by many researchers and they observed that prey was detected by contact (Fleschner, 1950). The grub sucked the inner contents of the chorion of the eggs and discarded the empty shells. The body of mobile stages of mite was first punctured and then their inner contents were sucked. It was observed to be an extra oral digestion in which salivary secretions help in liquefying the body contents of the prey. It was found that 50–100 eggs or 15–17 adults of *Panonychus citri* (Tanaka, 1966) or over 40 females of *Tetranychus cinnabarinus* (McMurtry *et al.*, 1970) were needed per day by females of *Stethorus punctillum* to oviposit. The grubs and adults consumed 11.2 to 18.2 and 9.0 to 17.4 prey individuals per day, respectively under *in vitro* conditions. Under screen house conditions, the ratio of 1:50 predator (adult beetle)/prey (mixed population) resulted in 79.5% control of *T. urticae* at 2 days after release on okra leaves (Gulati and Kalra, 2007). Due to high feeding, reproductive capacity and synchronization with the pest population, this can rapidly reduce high mite populations to low levels. The predator is highly mobile, within minutes of release, beetles searched for mites on plants near the release site or flew to neighbouring plants. It was found to be effective for mite control on green house peppers and cucumbers. *Stethorus* sp. released at 400–500 beetles per tree reduced the brown mite in avocado. *Clanissorews*, *Scymnus* sp. and *Brumus suturalis* F. are predaceous on *Oligonychus coffeae*. Other potential predatory coccinellids for mites are *Menochilus sexmaculatus*, *S. pauperculus*, *Coccinellasepte mpunctata*, *Chilochorus nigratus*, *Brumus suturalis*, etc. Each adult female may consume 30–60 mites per day. Total fecundity ranges from 123 eggs in *S. tridens* (Fiaboe *et al.*, 2007), 279 in *S. punctillum* (Roy *et al.*, 2003).

Oligota pygmaea is a specialist predator, feeding on red spider mites where the larvae and adults suck their body fluid. These beetles are occasionally found in large numbers in tea fields and in such cases they contribute to the reduction of *Oligonychus coffeae* populations.

Hemiptera (Anthocoridae)

Anthocoris neuromus and *Orius* sp. are known predators of *P. ulmi*, *T. urticae* and *P. citri*, respectively.

Neuroptera (Chrysopidae, Hemerobiidae)

The most active predators of spider mites belong to the families Chrysopidae and Coniopterygidae. Chrysopids are another group of insects which feed on mites. *Chrysoparla carnea* is reported to consume 1000 to 1500 citrus red mites daily but fails to complete its life cycle on a mite diet. *Chrysopa vulgaris* is known to have better searching ability than *Stethorus* and consumes 30–50 European red mite larvae per hour.

Thysanoptera (Terebrantia: Thripidae- *Scolothrips* sp., *Aeolothrips* sp.)

Several species of thrips, *Scolothrips sexmaculatus*, *S. indicus*, and *S. longicornis* are known predators of tetranychids and reduce the pest population rapidly. The larva of *Hyplothrips faurii* consumes approximately 143 eggs of European red mite within 8–10 days of its development.

Predatory mites

Predatory mites come under families Phytoseiidae, Cheyletidae, Anystidae, Bdellidae, Erythraeidae, Tydeidae, Cunaxidae, Stigmaeidae and Ascidae. Among these families, members of Phytoseiidae are considered to be potential predators because of their specific nature, ability to feed on alternate sources of food and survive even in the absence of their prey. Because of the variety of research conducted on this family, they serve as excellent models for highlighting important concepts in biological control. However, many phytoseiid mites have comparatively shorter life cycle, equivalent reproductive potentials as of their prey, good host searching capacity and also ability to survive on relatively few prey and thus are comparatively more effective predators and promising better in management of several phytophagous mites in both greenhouses and field conditions (Dhooria, 2016).

Upon realizing the important service provided by phytoseiid mites, research began to focus on how to better use these predators for biological control. This includes their introduction, conservation, and release (Hoy, 2011). Phytoseiids are a highly diverse group of predators, making it possible to study both specialists and generalists (McMurtry *et al.*, 2013).

Biology of phytoseiid mites

Phytoseiid mites are free-living terrestrial mites commonly found on many plant species, soil, and debris in all parts of the world, except the Antarctica. Most of the species move faster than their prey and they have same size as spider mites (200-500 microns). They are white to brown in appearance; however, body color of mites in general may vary depending upon their prey. Life cycle is also similar to spider mites and consists of egg, larva, protonymph, deutonymph and adults. Total developmental period varies from 4-12 days. It depends on prey, host plant, and environmental factors viz., temperature and humidity. The most effective species are capable of producing 22-60 eggs during their life and have a tendency to lay 1-6 eggs per day during oviposition period of 10-25 days (Rahman *et al.*, 2013). Duration of *N. longispinosus* on okra leaves, under laboratory conditions at a temperature of 27 ± 2°C and relative humidity of 75 ± 10%. From egg to adult stage was 4.33 ± 0.52 days. Egg period was longer compared to other stages and it accounts for 41.12% of total developmental time. Development period of egg, larva, protonymph and deutonymh were 1.78 ± 0.28, 0.60 ± 0.13, 0.95 ± 0.3 and 1.00 ± 0.15 respectively. Pre-oviposition, oviposition and post oviposition periods were found to be 2.04 ± 0.12, 11.12 ± 0.95 and 2.36 ± 0.74 days respectively. It laid maximum of 25.32 ± 3.20 eggs. Males lived longer than females with duration of 25.09 ± 0.54 and 18.25± 2.36 respectively. Among the emerged adults 75 per cent were females with sex ratio of 3:1 (Rao *et al.*, 2018).

Food habits of phytoseiid mites

Phytoseiid mites feed on a variety of food and have developed different feeding habits. They can be classified as diet specialists and diet generalists. More precisely, specialist phytoseiids feed primarily on spider mites with profuse webs such as *Tetranychus urticae* Koch. Generalists, may utilize and reproduce with various kinds of animal and non-animal food including mites, insects, fungi, pollen and/or plant exudates. Life-styles of predatory mites are as follows: Type

1, specialized predators of *Tetranychus*species represented by the *Phytoseiulus* species; Type II, selective predators of tetranychid mites (most frequently associated with species that produce dense webbing) represented by *Galendromus*, some *Neoseiulus*; Type III, generalist predators represented by some *Neoseiulus* sp., most *Typhlodromus* and *Amblyseius* sp.; Type IV, specialized pollen feeders/generalist predators represented by *Euseius* sp. (McCurry *et al.,* 2013).

Foraging behavior

Foraging behavior of predators, like functional response, numerical response, mutual interference, and are usually affected by a number of factors viz., temperature, host plant, prey stage, experimental condition and pesticides.

Functional response

The functional response describes the predation rate of one predator as a function of prey density. Many predators that have been released as biocontrol agents have shown to exhibit a type II response, reaching a satiation point at certain prey density (Xiao and Fadamiro, 2010).

Laboratory studies on *N. longispinous*, revealed that the number of prey consumed by predator levelled off at densities 30-40 in case of *T. urticae* nymphs whereas, at 15-25 for adults (Rao *et al.,* 2017).

Numerical response

Numerical response probably has more importance than the functional response. It can be defined as the change in a predator's reproductive output at varying prey densities. It may be considered as a strategy of female predators to augment their offspring at different prey densities (Cedola, *et al.,* 2001).

Mutual interference

Mutual interference denotes the adverse influence of predator density on the instantaneous success of individual predator**.** Mutual interference occurs commonly in the laboratory (Farazmand *et al.,* 2013) but it has rarely been reported in field studies. Understanding this mutual interference is necessary to predict the success of biocontrol programmes, as it assists with mass-rearing efforts and can facilitate the explanation of observed outcomes in the field.

Releasing strategies of predatory mites

Predatory mites sold in different types of packages, which represent different ways of field release. Bulk material usually comes as a tube or buckets with predatory and prey mites mixed in a carrier material viz., bran or vermiculite. Predatory mites are broadcasted on the crop viz. 1) Hand sprinkling in which predatory mites along with carrier material are transferred into plastic squeezing bottle or cardboard tubes and operator dispenses the material directly on leaves spilling it from the bottle and intervening on a row at a time. 2) Sachet method, the sachets can be hung in the crop or placed at the base of the crop. 3) Mechanical release method, the main limitation to mechanical release is that the beneficial organisms may be damaged during their handling and distribution due to possible contact with mechanical elements and abrasion against carrier materials. However, mechanical application of predatory mite is consistent with that obtained with manual application (Lanzoni *et al.,* 2017). Releasing rate of predators is based on pest species, crop, prey density and releasing strategy. However, several workers observed that predator prey ratios between 1:10 to 1:50 were effective in reducing the spider mites below the damaging levels in green house or ornamental crops (Rao *et al.,* 2017).

Acaro pathogens

Viruses

Relatively few viruses are known from mites, The first record on a virus disease in a spider mite was made (Muma, 1955) and diseased mites were observed in a natural population of the citrus red mite (CRM) in Florida, USA. Infected mites showed signs of diarrhea and the cadavers were adhered to the leaf surface by a black resinous material that was excreted from the anus. The disease has later also been reported in California (Smith *et al.*, 1959). Spherical particles inside diseased mites were observed and assumed that these were virus particles. Later, it could be demonstrated that a rod shaped, non-inclusion virus is the cause of the disease (Reed and Hall, 1972). The virus particles are approximately 194 × 58 nm in size and enclosed in an envelope of circa 266 × 111 nm. The virus is formed inside the nuclei of epithelial cells of the midgut, but later it moves out of the nucleus, into the cytoplasm. The pathogen is transmitted when healthy mites ingest the feces of infected mites. The virus disease is common in citrus groves in California and Arizona and causes a considerable reduction in the population density of the CRM (Reed, 1981).

Bacteria

Isolates of *Bacillus thuringiensis* was found to show toxicity towards spider mites and house dust mites (Payne *et al.,* 1994). *B. thuringiensis* strain isolated from dead two spotted spider mites, *T. urticae* (Jung *et al.*, 2007). *Pseudomonas putida* biotype B strongly reduced egg production and no hatching of the eggs was noted (Aksoy *et al.*, 2008). The results showed that the bacterium may be very effective in causing mortality in *T. urticae* populations. Further research is required to find out whether this organism may be developed to a microbial miticide.

Fungi

The first record of an entomophthoralean fungus infection in spider mites was observed by Fisher (1951) and noted adult mortality from 32 to 95% in populations of the citrus red mite *Panonychus citri*. A fungus was isolated from the Texas citrus mite *Eutetranychus banksi* and described it as *Entomophthora floridana* (Weiser and Muma, 1966). The fungus has since been reported from several other spider mite species: it was observed in *Tetranychus tumidis* on cotton in the humid subtropical regions of Florida (Saba, 1971), in *T. evansi* on tomato crops in Brazil (Humber *et al.*, 1981), in *T. ludeni* on bean in India (Ramaseshiah, 1971), Bridge and Worland (2008) observed a Neozygites infection in the cryptostigmatic mite *Alaskozetes antarcticus* (Ameronothridae). This has resulted in the isolation of a *Neozygites* sp. that is very specific for the cassava green mite in Brazil (Delalibera *et al.*, 1992).

Beauveria bassiana (Balsamo) Vuillemin dust formulation produced 71 per cent mortality in two spotted spider mite (Dresner, 1949). The red palm mite, *Raoiella indica* Hirst (Tenuipalpidae) was infected by *Hirsutella* sp., in Florida on palms (Pena *et al.*, 2006). So far, *Lecanicillium psalliotae* Treschew has been the only other fungus reported in association with *R. indica* in Saint Lucia (ARSEF, 2009).

Cladosporium is one of the largest genera of hyphomycetes (Crous *et al.*, 2007) isolated from insects and mites. An unidentified species of this genus was isolated from the two spotted spider mite (ARSEF 2009). *Fusarium semitectum* formulation suppressed the population of *Zolyphagotarsonemus latus* (Banks) on pepper (Mikunthan and Manjunatha, 2006).

Beauveria, Metarhizium, Isaria and *Verticillium* have not been found infecting spider mites under natural conditions. Several isolates of *B. bassiana* and *Metarhizium anisopliae* (Metschnikoff) have been reported as pathogenic to various group of mites (Alves *et al.,* 2002). They have been considered to have potential for practical use in inundative or inoculative approaches in agriculture (Maniania *et al.,* 2008).

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