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A Review

Phytoseiid mites: Successful biocontrol agents of mite pests in protected vegetables

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Abstract : Biocontrol success has forced several countries to use phytoseiids e.g., Chilean mite, *Phytoseiulus persimilis* Athias-Henriot (Acarina: Phytoseiidae) against mite pests in protected vegetable crops. The characteristics like more oviposition period, sex-ratio (female: male), longevity, consumption capacity, prey searching capability and survival at low prey densities have revealed *P. persimilis* a successful predator of two-spotted mite, *Tetranychus urticae* Koch (Acarina: Tetranychidae). Introduction of prey and predatory mite together or predatory mite slightly late gave better results than in case where predatory mite was introduced much later. Biocontrol failed in case where chemicals were applied except where predators reintroduced and chemicals were not re-applied. Predation took few days to eliminate largest number of mite pests at high temperature. At low relative humidity peak predation was noticed as there was more prey predator interaction. However, prey activity declined to zero while predator activity prolonged at high relative humidity. This review article includes various studies carried out on use of phytoseiid mites as biocontrol agents of various mite pests on protected vegetables.

Key Words : Phytoseiid mites, Biocontrol agents, Mite pests, Protected, Vegetables

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Introduction

In last five decades, the interest in research on phytoseiid mites (Acari: Phytoseiidae) as biological control agents has steadily increased worldwide which has lead to the huge literatures on their biology, ecology, taxonomy and practical utilization. Today, over 2,700 species have been described in Phytoseiidae family organized in 91 genera. Phytoseiid mites have attained great attention from the scientific community due to their potential as biocontrol agents of plant feeding mites, thrips and whiteflies. Vacante and Nucifora (1987) reported wide use of predatory mite, *Phytoseiulus persimilis* Athias-Henriot (Acarina: Phytoseiidae) against two-spotted mite, *Tetranychus urticae* Koch (Acarina: Tetranychidae) on various vegetable crops grown under greenhouse in France, Spain, Greece, Israel and Italy. Most of the successes in biological control using predatory mites under greenhouses had been reported in the Netherlands and United Kingdom (Van Lenteren and Woets, 1988). Predatory mites in family Phytoseiidae are cosmopolitan predators which were used as effective agents against a wide range of harmful insect and mite pests in biological control programmes and IPM tactics (Geoghiou, 1990; Fouly *et al*., 1995; Nomikou *et al*., 2001 and Inbar and Gerling, 2008). The two-spotted mite is one of the major pests on more than 1200 species of vegetable crops grown worldwide (Boudreaux 1956; Jeppson *et al.*, 1975; Walter and Proctor, 1999; Abdallah *et al.*, 2002 and Zhang, 2003). In addition to *T. urticae,* two more tetranychid mite species - *Oligonychus afrasiaticus* McGregor and *Eutetranychus orientalis* Klein are also considered the most abundant inhabiting leaves, buds, stems, shoots and fruits of different plant species including vegetable crops (Fouly and Al-Rehiayani, 2009). Unfortunately, high reproduction capability of tetranychid mite species attacking different plant species as well as rapid development gave spider mites, especially the aforementioned species, the potential for outbreaks that may cause considerable economic damage (Al - Shammery, 2008). Several phytoseiid mite species are commercially available for use in agriculture. Present and future biological studies may lead to the discovery of other promising species for pest control which might be more effective than the species already in use (Gerson *et al.*, 2003 and McMurtry *et al.*, 2013).

History of biological control :

Traditionally, spider mites have been controlled with chemical acaricides resulting in problems of pesticides resistance and residues on the harvested and consumed products. The protection of vegetables under protected cultivation from different insect and mite pests is primarily dependent on the use of toxic agrochemicals. However, the adverse effects of the use of these toxic chemicals are quite evident especially the problem of residues in vegetables. In view of the increasing awareness in world about the ill effects of harmful pesticides on the human health and environment, biological control becomes imperative which has assumed greater significance in the present context of organic farming in many countries. The predaceous mite, *P. persimilis* is released repeatedly on large areas of greenhouse cultivated cucumber, tomato and sweet pepper crops. This predatory mite has been used relatively infrequently on ornamental greenhouse crops, because only a low level of damage can be tolerated on these crops as compared with vegetable crops, and because the predatory mites cannot survive pesticides applied to control other pests and diseases. Since this technique of biological control where predatory mites are used to control spider mites in vegetable crops under protected cultivation has been recently introduced in India, therefore, this area of research needs important aspects to be investigated.

Parrot *et al.* (1906) for the first time reported that phytoseiid mites can be used as agents of biological control against phytophagous mites. From 1930 to 1950 entomologists began to realize that these predatory mites could significantly reduce the populations of important phytophagous mites such as European red mite, *Panonychus ulmi* Koch, *T. urticae* Koch, Carmine or red spider mite, *T. cinnabarinus* Boisduval and cyclatmen mite, *Steneotarsonemus pallidus* Banks (Acarina: Tarsonemidae) infesting various crops. As sign of resistance development to several chemicals was observed in spider mites, most of the countries instead of using chemical sprays started biological control of spider mites. Dosse (1959) and Bravenboer (1963) observed that Chilean predatory mite, *P. persimilis* is an efficient predator in reducing the number of two-spotted spider mite, *T. urticae*. For the first time, demonstrations on the efficacy of *P. persimilis* as bio-control agent against *T. urticae* were conducted (Legowski, 1966 and Gould, 1968). Phytoseiids are effective predators of plant mites all over world in diverse cropping ecosystems (Huffaker *et al.*, 1969). Thus, the first small scale application of *P. persimilis* as a biocontrol agent against *T. urticae* on greenhouse vegetables started in 1968 (IOBC, 1970). Similarly, another predatory mite, *Amblyseius fallacis* (Acarina: Phytoseiidae) was used as biocontrol agent against *T. urticae* on French bean under greenhouse conditions (Burnett, 1971). Phytoseiid mites were reported as most effective predators of mite pests in all over world in diverse cropping ecosystems (Dixon, 1973; Jeppson *et al.*,1975 and French *et al.*, 1976). The use of *P. persimilis* as an agent of biological control is worldwide while that of *A. fallacis* is rare, particularly on greenhouse vegetable crops. Some of the species of Phytoseiidae are being commercially multiplied in many countries and released for spider mite control on vegetables and ornamental plants grown under glasshouse conditions (Hussey and Huffaker, 1976). In West Bengal, of 22 mite species, mite pests - *T. cinnabarinus*, *T. neocaledonicus* and *Amblyseius lorgoensis* were noticed on brinjal (Gupta, 1986). In Netherlands and UK most successes for bio-control of predatory mites under glasshouse conditions were recorded GH (Van Lenteren and Woets, 1988). Of 37 mite species on vegetables, *T. cinnabarinus* (=*neocaledonicus*=*urticae*) was reported as important one attacking the brinjal and in India, 29 predaceous mite species were reported on plant mites (Gupta, 1991).

Predaceous mite, *P. persimilis* was reported as most effective biocontrol agent to reduce red spider mites in all seasons on vegetables (Yoldas *et al.*, 1996). In Punjab and Himachal Pradesh, *T. cinnabarinus* was noticed on brinjal with predatory mites - *A. alstoniae*, *A. finlandicus*, *Phytoseiulus roseus*, *Phytoseius* sp., *Typhlodromus* sp. and *Pronematus* sp. (Anonymous, 2000). Three predatory mite species - *A. longispinosus*, *A. indicus* and *Phytoseiulus* sp. *were* reported to feed on red spider mite in brinjal (Roopa, 2005). El-Saiedy *et al.* (2008) in his studies on efficiency of *P. persimilis*, *N. cucumeris* and *N. californicus* for controlling *T. urticae* on eggplant at Beheira Governorate reported great reduction in population density of *T. urticae* with above-mentioned predators and biochemical denatol. Several workers have reported role of different predatory mite species against phytophagous mites on various crops (Table 2).

Phytoseiid mites as successful predators :

Dhooria (1987) in a survey reported phytoseiid mites as the major biocontrol agents of phytophagous mites especially the spider mites belonging to family

Table 1 : Phytoseiid mites as successful predators of mite pests on protected vegetable crops

Predator	Prey	Host plant	Remarks	Reference
Phytoseiids	*T. urticae*	Vegetables	Successful-high mobility, voracious, wholly dependent on its prey and an avoidance of prey free environment	Chang (1961)
P. persimilis	*T. urticae*	Bean	Remarkable control	Chant (1961)
P. persimilis	*T. urticae*	Vegetables	Control is achieved rapidly in 22-35 days at predator : prey ratio of 8:20	Force (1967)
Phytoseiids	Spider mite	Vegetables	More efficient even at low prey density	McMurtry *et al.* (1970)
Phytoseiids	Tetranychids	Vegetables	Survive on low prey density due to small size	Muma and Denmark (1970)
P. persimilis	Spider mite	Cucumber	Every prey colony associated with predators 18 days after predator introduction onto every 10th plant	Bravenboer (1971)
A. fallacis	*T. urticae*	Cucurbits	97.5 % eggs and 0.18% adults consumed at temp. of 25±2ºC	Burnett (1971)
Phytoseiids	*T. urticae*	Vegetables	Proven effective	Gould and Light (1971) and Simmonds (1972)
P. persimilis	*T. urticae*	Vegetables	Detects its prey by random contact	Jackson and Ford (1973)
P. persimilis	*T. urticae*	Tomato	More dispersal	Hussey and Scopes (1977)
Phytoseiids	*T. urticae*	Vegetables	Proven effective	Hamlen (1978) and Burnett (1979)
P. persimilis	*T. urticae*	Vegetables	Control achieved rather rapidly in 15 days at predator: prey ratio of 1:10	Stenseth (1979)
P. persimilis	*T. urticae*	Cucumber	Successful -more oviposition time, longevity, fecundity and sex-ratio	Sabelis (1981)
P. persimilis	*T. urticae*	Cucumber	Efficiency of predator reduced due to poor time or sitting of release	Sabelis and Vander Bean (1983)
P. persimilis	*T. urticae*	Cucumber	Associated to prey colony until all preys eliminated	Sabelis *et al.* (1984)
Phytoseiids	Spider mite	Vegetables	Major bio-control agents in Pb	Dhooria (1987)
Phytoseiid mites	*T. urticae*	Vegetables	Proven effective	Gough (1991) and Kropczynska *et al.* (1999)
N. fallacis	*T. urticae*	Brinjal	Significantly reduced its prey	Noubar *et al.* (2003)
P. persimilis	*T. urticae*	Vegetables	Most frequently used bio-control agent	Gillespie and Raworth (2004)
N. womersleyi	*T. macfarlanei*	Vegetables	Consumes-212.8 eggs, 238.1 larvae, 53.5 PN and 29.6 DN/life	Ali *et al.* (2011)
N. californicus	*T. urticae*	Pepper	Highest prey reduction	Mahgoub *et al.* (2011)
A. longispinosus	*T. urticae*	Vegetables	Prey fed were 13.50 nymphs and 16.54 adults/day	Jeyarani *et al.* (2012)

Table 2 : Predatory mites found most effective against prey mites on vegetables grown under greenhouse conditions

Sr No.	Prey mite	Predatory mite	Host plant	References
1.	*Tetranychus urticae*	*Phytoseiulus reigeli*	Cucumber	Legowski (1966)
2.	*T. urticae*	*P. persimilis*		Gould (1970)
3.	*T. urticae*	*P. persimilis*		Hansen *et al.* (1984)
4.	*T. truncatus*	*Neoseiulus longispinosus, Amblyseius paraaerialis, Euseius macrospatulatus, Typhlodromips syzygii, A. largoensis*		Maheswary *et al.* (2015)
5.	*T. truncatus* *T. macfarlanei*	*N. longispinosus, A. paraaerialis,*	Snakegourd	
6.	*T. truncatus*	*E. macrospatulatus, T. syzygii*	Snapmelon	
7.	*T. urticae*	*P. persimilis*	Cucumber Capsicum	Pruszynki *et al.* (1985)
8.	*T. urticae*	*P. persimilis*		Jarosik and Pliva (1990)
9.	*Polyphagotarsonemus latus*	*N. longispinosus, A. paraaerialis, E. macrospatulatus, T. syzygii*	Chilli	Maheswary *et al.* (2015)
10.	*T. urticae*	*A. fallacis*	Bean	Burnett (1971)
11.	*T. truncatus* *T. macfarlanei* *P. latus*	*N. longispinosus, T. syzygii* *E. macrospatulatus ,* *E.* sp. nr. *prasadi,* *A. paraaerialis,* *A. largoensis*	Cowpea	Maheswary *et al.* (2015)
12.	*T. cinnabarinus*	*A. multidentatus*	Brinjal	Gupta (1986) and Dhooria (2001)
13.	*T. cinnabarinus*	*A. bindrai*		Dhooria (2001)
14.	*T. cinnabarinus*	*A. bhadrakaliensis*	Cucurbits Brinjal	Gupta (1986)
15.	*T. cinnabarinus*	*A. fallacies*	Carrot	Dhooria (2001)
16.	*T. cinnabarinus*	*Agistemus floridanus*	Brinjal	
17.	*T. cinnabarinus*	*A. orientalis*		
18.	*T. cinnabarinus*	*A. cucumeris*		
19.	*T. cinnabarinus*	*Phytoseius kapuri*		
20.	*P. latus*	*Pronematus sextoni*		
21.	*T. truncates,* *T.macfarlanei*	*N. longispinosus, A. paraaerialis, A. largoensis, E.macrospatulatus, E.* sp. nr. *prasadi, T. syzygii, Paraphytoseius orientalis, Phytoseius intermedius, Scapulaseius* sp.		Maheswary *et al.* (2015)
22.	*P. latus*	*A. swirskii*	Vegetables	Tal *et al.* (2007)
23.	*T. urticae*	*P. persimilis, N.cucumeris, N. californicus*	Brinjal	El-Saiedy (2008)
24.	*P. latus*	*A. swirskii*		Maanen Van *et al.* (2010)
25.	*T. urticae*	*A. californicus, P. persimilis*	Vegetables	Abdallah *et al.* (2012)
26.	*P. latus*	*A. swirskii*	Brinjal, Potato, Tomato	Onzo *et al.* (2012)
27.	*T.urticae,T.macfarlanei, Eutetranychus orientalis*	*N. longispinosus, A. paraaerialis, E. macrospatulatus, E.* sp. nr. *prasadi*	Okra	Maheswary *et al.* (2015)
28.	*T. truncates*	*N. longispinosus, A. paraaerialis, E. macrospatulatus, T. syzygii*	Bittergourd	

Tetranychidae on vegetable crops in Punjab. Gupta (2001) in his studies on the taxonomy and bio-ecology of predatory mites of India with special emphasis on Phytoseiidae reported that the predatory mite species mainly belonged to the families- Phytoseiidae, Ascidae, Anystidae, Bdellidae, Cheyletidae, Cunaxidae, Erythraeidae, Raphignathidae, Stigmaeidae and Tydeidae etc. Among these, phytoseiid mites are the most successful predators of phytophagous mites due to their higher fecundity, high population densities, good searching ability, good dispersal rate, adaptability to different ecological niches and high degree of prey specificity. Fernando *et al*. (2010) revealed *Phytoseiulus longipesas* a candidate for classical biological control of *T. evansi* by inoculative releases on tomato plants. Abdallah *et al*. (2012) used predatory mite species, *A. californicus* and *P. persimilis* and two chemical compounds (Vertimic and Denatol) to control *T. urticae* and reported predatory mites to be the more favourable strategy for suppression of *T. urticae* than chemical control. Detailed review of the phytoseiid mite as predator of various mite pests has been presented in Table 1.

Role of biological aspects in biocontrol :

Muma and Denmark (1970) reported that phytoseiid mites could survive on low populations of tetranychid mites because of small size and thus, had potential for regulating spider mite populations even at low pest densities. Sabelis (1981) studied the effectiveness of *P. persimilis* over *T. urticae* and compared some biological parameters like oviposition period, longevity, fecundity, sex-ratio and intrinsic rate of increase (rm), all the parameters were more in case of predatory mite making it an ideal candidate for its use as biocontrol agent against *T. urticae*. Kartasheva and Lesteva (1981) determined mutability of predaceous mite, *P. persimilis* for release against spider mite, *T. urticae* in greenhouse vegetables and found that in heated greenhouses the reproductive cycle of the predatory mite varied from 40-65 days, collections were possible after every 6-7 and 10 days during a cycle of 60-65 days. They also reported that in greenhouse with an area of 260m^2, 40,000 individuals could be collected after every 7-10 days. Van Lenteren and Woets (1988) in Bulgaria and USSR reported total area for the biological control of *T. urticae* with *P. persimilis* in greenhouse vegetables *viz.*, cucumber, tomato, sweet pepper, gherkin and melon to be 1250, 160, 100, 40 and 12 hectares, respectively. The predatory phytoseiid and laelapid mites are used in the biological control of mite pests and thrips on many crops in greenhouses (Reddy, 2016).

Biocontrol studies in some countries :

In Canada, Chant (1961) reported that *P. persimilis* exerted a remarkable biological control of two spotted spider mite, *T. urticae* when practiced on bean plants under greenhouse conditions.

In, England, Legowski (1966) while conducting studies on cucumber in Lea Valley E.H.S. under greenhouse condition reported more yield and successful control of phytophagous mite by predatory mites released on the same day after 21 days than where there was more or less delay in the release of predatory mites. Burnett (1971) reported that prey population which was consisted largely of eggs, 97.5 per cent of the prey population consumed by both by adult female and immature predators were eggs while immature predators of *A. fallacis* did not attack any adult prey and only 0.18 per cent of adult female prey was eaten by adults at constant temperature of 75ºF.

In Bulgaria, Kristova (1972) conducted tests on cucumber in two series by releasing ratio of prey: predator 50: 2 in both series under greenhouse conditions and concluded that *P. persimilis* provided best control of *T. urticae* after 26 days and subsequently eliminated the prey. Sabelis and Van Der Bean (1983) described that *P. persimilis* was an efficient predator of *T. urticae* on cucumbers grown under greenhouse, however, poor time or site of release could reduce its effectiveness for biological control.

Pruszynki (1984) studied use of predatory mite, *P. persimilis* against *T. urticae* in Poland with the aim of developing an integrated programme of plant protection for use in commercial greenhouses on cucumber, roses and sweet pepper. The feeding behaviour with respect to various factors on the decrease in pest population caused by *P. persimilis* was determined which indicated that use of *P. persimilis* against *T. urticae* enabled chemical treatments against the mite to be eliminated almost entirely and those against other organisms to be released.

In Greece, the two-spotted spider mite, *T. urticae* in tomato cultivation was an occasional enemy. For this reason the predatory mite, *P. persimilis* was used particularly in mixed cultivations with good results (Souliotis, 1985).

In Netherlands, studies carried over under greenhouses revealed that the biological control of *T. urticae* with predatory mite, *P. persimilis* on sweet pepper was effective (Remarker, 1987).

In countries - France, Spain, Israel and Italy, *P. persimilis* was widely used as predaceous mite for the control of *T. urticae* on different vegetable crops under greenhouse (Vacante and Nucifora, 1987).

In Czechoslovakia, of two methods *i.e.*, 'pest in first' and inundative 'after pest' of introducing *P. persimilis* as predator against *T. urticae* under glasshouse conditions, predatory mite aggregated well to its prey on pepper plants in the first method, whereas, the second method gave satisfactory control because there predators were propagated inexpensively on cucumbers. *P. persimilis* was able to survive until the end of cultivation and less than 3 per cent plants were damaged beyond yield threshold (Jarosik and Pliva, 1990).

In Austria, the climate chamber and greenhouse studies were made on biocontrol of *T. urticae* and *T. cinnabarinus* by *P. persimilis* and *N. californicus*. Inter- and intraspecific predation between both predatory mites was investigated, as well as population dynamics and persistence of both species on the same foliage. These studies showed that the use of both predatory mites in crops with a short growing season (cucumbers) did not increase spider mite control as compared to the single use of *P. persimilis*. In potted plants, *N. californicus* should be present before the occurrence of spider mites, while *P. persimilis* should be used when required (e.g., with insufficient control of spider mites by *N. californicus* (Leuprecht, 2000).

In India (Kerala), Binisha and Bhaskar (2013) recorded seven phytoseiid mite species - *Amblyseius paraaerialis* Muma, *Amblyseius largoensis* Muma, *Paraphytoseius orientalis* Narayanan, *Euseius macrospatulatus* Gupta, *Euseius* sp. nr. *prasadi*, *Typhlodromips syzygii* Gupta, *Phytoseius intermedius* Evans and *Scapulaseius* sp. on major vegetable crops. However, Maheswary *et al*. (2015) reported association of nine predaceous mites, *viz.*, *Amblyseius paraaerialis* Muma, *Amblyseius largoensis* Muma (Acari: Phytoseiidae), *Paraphytoseius orientalis* Narayanan, *Euseius macrospatulatus* Gupta, *Euseius* sp. nr. *prasadi*, *Typhlodromips syzygii* Gupta, *Phytoseius intermedius Evans* and *Scapulaseius* sp. with phytophagous mites in major vegetable crops *viz*. amaranthus, brinjal, okra, bittergourd, chilli, cowpea, coccinia, cucumber, snakegourd and snap melon.

In Cuba, *A. largoensis* was effective in controlling broad mites, *Polyphagotarsonemus latus* Banks (Acari: Tarsonemidae) in pepper crop (Rodriguez *et al*., 2015).

Physical and chemical factors in biocontrol of mite pests :

Temperature :

Sabelis (1981) in his studies on development time (in days) required for *T. urticae* and *P. persimilis* at temperatures of 15, 20 and 30ºC in glasshouse vegetables concluded that at temperature 15ºC, both prey and predator need more days to develop. Similarly, at 30ºC both species need fewer days to develop. However, at both the temperature ranges, the development period taken by *P. persimilis* is quite less than its prey *T. urticae.*

Hussey and Scopes (1982) studied the effect of temperature on elimination of prey mite by its predator mite and found that with more temperature, fewer days are needed by predatory mite for the elimination of its prey than at low temperature where more days are taken.

Rasmy and Ellaithy (1988) released predator *P. persimilis* @ 10 per plant at first sign of damage symptoms caused by *T. urticae* in two separate greenhouses in Bulgaria at 35ºC and concluded that *T. urticae* was regularly controlled on *P. persimilis* treated plants, thereby, maintaining a balance as against control plot where no introduction of predator resulted in high

Table 3 : Some factors responsible for success of biological control of mites

Sr. No.	Prey mite	Predatory mite	Factor (s)	Result	Reference
1.	*T. urticae*	*P. persimilis*	10% sucrose solution or honey as a food. Fed with water only	Prolongs life of predator four times Nil	Ashihara *et al.* (1978)
2.	*T. urticae*	*P. persimilis*	Kairomones	Increases predator's chance to find and consume more prey	Sabalis and Van Der Bean (1983)
3.	*T. urticae*	*P. persimilis*	More plant density within greenhouse Less plant density	Predators can disperse readily and can catch more number of preys Predator's ability to disperse is reduced by 70%	Takafuzi and Chant (1976)
4.	*T. urticae*	*P. persimilis*	Webbing present	Females of predator are able to find prey twice compared to when no webbings present	Schmidt (1976)

pest density.

The high temperatures also contributed to the development of the population of the predator population (Ferrero *et al.*, 2007).

Relative humidity :

Mori and Chant (1966) reported that activity of *T. urticae* and *P. persimilis* was higher at 33 per cent or less relative humidity that that at 100 per cent. The behaviour of predator was well adapted to that of its prey and therefore, had a wide range of activity beyond its prey. The predator showed its greatest activity under conditions when prey was also moving actively at 33 per cent relative humidity and gave better control of its prey because chances of prey predator interaction were maximum. On the other hand predation was low at high relative humidity.

Detrimental effects of low relative humidity was reported for *P. persimilis* (Williams *et al.*, 2004), a mite species taxonomically close to *P. longipes*.

Moisture :

Mori and Chant (1966) conducted studies in glasshouses on the role of moisture without food with three treatments *i.e.*, 1st treatment: with free water, 2nd treatment: with high humidity and no free water, 3rd treatment: with low humidity and no free water. They concluded that longevity of *P. persimilis* was more at higher relative humidity in the presence of water and considered that water was essential for its survival in first treatment than in 2nd and 3rd treatments with respective values of mean longevity 15.7, 4.0 and 2.1 days.

Chemicals :

Gould (1970) made comparative studies between biological control *i.e.*, by releasing predatory mite, *P. persimilis* against *T. urticae* and chemical control methods *i.e.*, by using petroleum oil, dicofol and tetradifon against *T. urticae* in two separate greenhouse cages on 160 cucumber plants on different dates. The yields obtained were 8918 and 7611 number of cucumbers in biological and chemical control methods, respectively. He concluded that the biological control gave better results.

Ashihara *et al.* (1978); Sabelis and Van Der Bean (1983); Takafuzi and Chant (1976) and Schmidt (1976) studied impact of factors like sucrose, water, kairomones, webbings and plant density on the biological control and reported positive results with these factors in enhancing predatory efficacy of *P. persimilis* against *T. urticae* (Table 3).

Conclusion :

The characteristics like high oviposition period, sex-ratio, longevity, consumption capacity, good searching capacity and capacity to survive on lower prey population make phytoseiids as successful predator. The careful acaricidal selection and predator release can enhance biocontrol once residues are no longer toxic. Higher the temperature more is the predation and *vice versa*. In contrast, low the relative humidity more is the predation and *vice versa*. The moisture enhances adult predator longevity. Biocontrol of mite pests is also cost effective than most of pesticidal sprays which have lead to mite outbreaks, resurgence and resistance. While it is advantageous for acarine biocontrol agent to be host specific, ecofriendly and environmentally safer, the presence of mite pests as alternative prey has been necessary to make biological control self- perpetuating.

REFERENCES

Abdallah, A.A., El- Saiedy, El-Fatih and Shoula, M.E. (2012). Effect of some biological and biochemical control agents against certain squash pests. *Arch. Phytopathol. Pl. Prot*., **45**: 73-82.

Abdallah, M.D., Belal, M.H., Rabie, M.M., Ayoup, S. and Senn, R. (2002). Effectiveness of the Neonicotenoid, Thiamethoxam compared to Imidacloprid and Pirimiphos-Methyl against Bemisia tabaci (Gennadius) to manage the tomato yellow leaf curl virus. *Bull. Entomol. Soc. Egypt. Econ. Ser*., **28**:91-101.

Ali, M.P., Naif, A.A. and Huang, D. (2011). Prey consumption and functional response of a phytoseiid predator, *Neoseiulus womersleyi* feeding on spider mite, *Tetranychus macfarlanei*. *J. Insect Sci.,* **11**: 1-11.

Al-Shammery, K.A. (2008). Biological studies on some plant parasitic mites and their control. Ph.D. Thesis, Riyadh University for Girls, Kingdom of Saudi Arabia.

Anonymous (2000). Progress Report (1998-2000), AICRP on Agricultural Acarology, University of Agricultural Sciences, Bangalore. pp.127-128.

Ashihara, W., Hamamura, T. and Shinkaji, N. (1978). Feeding, reproduction and development of *Phytoseiulus persimilis* Athias-Henriot (Acarina: Phytoseiidae) on various food substances. *Bull. Fruit Tree Stn.,* **2**: 91-98.

Binisha, K.V. and Bhaskar, H. (2013). Faunal diversity of phytophagous and predatory mites associated with some major vegetable crops of Thrissur district, Kerala. *Entomon*, **38**: 47-52.

Boudreaux, H.B. (1956). Revision of the two-spotted spider mite (Acarina, Tetranychidae) complex, *Tetranychus telarius* (Linnaeus). *Ann. Entomol. Soc. Am*., **49**: 43-48.

Bravenboer, L. (1963). Experiments with the predator *Phytoseiulus riegeli* Dosse on glasshouse cucumbers. *Mitt. Schweiz. Ent. Ges.*, **36**: 53.

Burnett, T. (1971). Prey consumption in acarine predator-prey populations reared in the greenhouse. *Can. J. Zool.,* **49**: 903-913.

Burnett, T. (1979). An acarine predator/prey population infesting roses. *Res. Popul. Ecol.,* **20**: 227-234.

Chant, D.A. (1961). An experiment in biological control of *Tetranychus urticae* in glasshouse using the predaceous mite, *Phytoseiulus persimilis. Can. Ent.,* **93**: 437-443.

Dhooria, M.S. (1987). Survey of phytophagous mites and their predators in Punjab. First Nat. Sem. on Acar. held at Bangalore- abstract no. **6**.

Dhooria, M.S. (2001). Mite pests and their management in Punjab. In: Yadav, P.R., Chauhan, R., Putatunda, B.N. and Chhillar, B.S. (Eds.) *Mites, their identification and management*, ICAR Centre of Advanced Studies, Department of Entomology, CCS Haryana Agricultural University, Hisar, India, pp. 41-47.

Dixon, G.M. (1973). Observations on the use of *Phytoseiulus persimilis* Athias-Henriot to control *Tetranychus urticae* Koch on tomatoes. *Pl. Path.,* **22**: 134-138.

Dosse, G. (1959). Uber einige neue Raubmilbenarten (Phytoseiidae). *Pflanzen. schut. Berichte,* **21**: 44-61.

El-Saiedy, E.M.A., G.M., Abou-Elella, A. and Alotaibi, S.A. (2008). Efficiency of three predatory phytoseiid mites and biocide chemical for controlling *Tetranychus urticae* Koch on eggplant at Beheira Governorate. *Res. J. Agric. and Biol. Sci.*, **4**: 238-244.

Fernando, R.D.S., Gilberto, J.D.M., Manoel, G.C., Gondim, J.R., Markus, K., Sigrid, L.R., Jefferson, L.A.P. and Guilherme, M.D.O. (2010). Efficiency of *Phytoseiulus longipes* Evans as a Control Agent of *Tetranychus evansi* Baker & Pritchard (Acari: Phytoseiidae: Tetranychidae) on Screenhouse Tomatoes. *Neotr. Entomol.,* **39**: 991-995.

Ferrero, M., Kreiter, S., Tixier, M.S. and Knapp, M. (2007). Life tables of the predatory mite *Phytoseiulus longipes* feeding on *Tetranychus evansi* at four temperatures (Acari: Phytoseiidae, Tetranychidae). *Exp. Appl. Acarol.,* **41**: 45-53.

Force, D. C. (1967). Effect of temperature on biological control of two-spotted spider mites by *Phytoseiulus persimilis. J. Econ. Ent.*, **60**: 1308-1311.

Fouly, A.H., Abou-Setta, M.M. and Childers, C.C. (1995). Effects of diets on the biology and life tables of *Typhlodromalus peregrines*. *Environ. Entomol*., **24**: 870-877.

Fouly, A.H. and Al-Rehiayani, S.M. (2009). Survey and identification of predaceous mites in Qassim Region, Saudi Arabia and their role in biological control. Qassim University, Saudi Arabia.

French, N., Parr, W.J., Gould, H.J., Williams, J.J. and Simmonds, S.P. (1976). Development of biological methods for the control of *Tetranychus urticae* on tomatoes using *Phytoseiulus persimilis. Ann. Appl. Biol.,* **83**: 177-189.

Geoghiou, G.P. (1990). Overview of insecticide resistance. *Am. Chem. Soc. Symp. Ser*., **421**: 18-41.

Gerson, U., Smiley, R.L. and Ochoa, R. (2003). *Mites for pest control.* Blackwell Science, Oxford, UK. 539pp.

Gillespie, D.R. and Raworth, D.A. (2004). Biological control of two-spotted spider mites on greenhouse vegetable crops, p. 185–199. In: K.M. Heinz, R.G. Van Driesche, and M.P. Parrella (Ed.). *Biocontrol in protected culture*. Ball Publ., Batavia, Ill.

Gough, N. (1991). Long-term stability in the interaction between *Tetranychus urticae* and *Phytoseiulus persimilis* producing successful integrated control on roses in southeast Queensland. *Exp. Appl. Acarol*. **12**: 83-101.

Gould, H.J. (1968). Observations on the use of a predator to control red spider mite on commercial cucumber nurseries. *Pl. Path.,* **17**: 108-112.

Gould, H.J. (1970). Preliminary studies on integrated control programme for cucumber pests and an evaluation of methods of introducing *Phytoseiulus persimilis* for the control of *Tetranychus urticae*. *Ann. Appl. Biol.,* **66**: 505-513.

Gould, H.J. and Light, W.I.St.G. (1971). Biological control of *Tetranychus urticae* on stock plants of ornamental ivy. *Pl. Path.,* **20**:18-20.

Gupta, S.K. (1986). *Fauna of Indian Acari: Mesostigmata Family- Phytoseiidae*. Zoological Survey of India. pp.350.

Gupta, S.K. (1991). Mites of agricultural importance and their management, Technology Bulletin No. 1. All India Coordinated Research Project on Agricultural Acarology, ICAR. Project Coordinator's Cell, UAS, Bangalore, India. P.1-256.

Gupta, S.K. (2001). Taxonomy and bioecology of predatory mites of India with special emphasis on Phytoseiidae. In: Yadav, P.R., Chauhan, R., Putatunda, B.N. and Chhillar, B.S. (Ed.) *Mites, their identification and management*, ICAR Centre of Advanced Studies, Department of Entomology, CCS Haryana Agricultural University, Hisar, India, pp. 168-181.

Gupta, V.N. and Gupta, S.K. (1985). Mites associated with vegetable crops in West Bengal. *Indian J. Acarol.,* **10**: 61-64.

Hamlen, R.A. (1978). Biological control of spider mites on greenhouse ornamentals using predaceous mites. *Proc. Fla. State Hort. Soc*. **91**:247-249.

Hansen, L.S., Jakobsen, J. and Reitzel, J. (1984). Extent and economics of biological control of *Tetranychus urticae* and *Trialeurodes vaporariorum* in Danish greenhouses. *EPPO Bull.,* **14** : 393–399.

Huffaker, C.B., Vrie, M. Van De and McMurtry, J.A. (1969). The ecology of tetranychid mites and their natural control. *Ann. Rev. Entomol.,* **14**: 125-174.

Hussey, N.W. and Huffaker, C.B. (1976). Spider mites. In: Deluchi, V. L. (Ed.) *Studies in biological control,* Cambridge University Press, Cambridge. pp. 179-236.

Hussey, N.W. and Scopes, N.E.A. (1977). The introduction of natural enemies for pest control in glasshouses: ecological considerations, p. 349-77. In: R. L. Ridgway & S. B. Vinson (Ed.), *Biological control by augmentation of natural enemies*. Plenum Press, New York and London.

Hussey, N.W. and Scopes, N.E.A. (1982). Mite management for greenhouse vegetables in Britain. *J. Hort. Sci.,* **57**: 285-297.

Inbar, M. and Gerling D. (2008). Plant-mediated interaction between whiteflies, herbivores and natural enemies. *Ann. Rev. Entomol.,* **53**: 431-448.

International Organization for Biological Control/ Western Palearctic Regional Section (1970). *Proceedings of meet work group integrated control glasshouse,* Netherlands. *Bull. IOBC/ WPRS.,* 78pp.

Jackson, G.J. and Ford, J.B. (1973). The feeding behaviour of *Phytoseiulus persimilis* Athias-Henriot (Acarina: Phytoseiidae) particularly as affected by certain pesticides. *Ann. Appl. Biol.,* **75**: 165-171.

Jarosik, V. and Pliva, J. (1990). Efficient control of two-spotted spider mite (*T. urticae* Koch) by *Phytoseiulus persimilis*- A.-H. on glasshouse peppers. *J. Appl. Ent.,* **110**: 270-274.

Jeppson, L.R., Keifer, H.H. and Baker, E.W. (1975). *Mites injurious to economic plants* 614 pp. University of California Press, Berkeley, CA, USA.

Jeyarani, S., Jagannath Singh, R. and Ramaraju, K. (2012). Influence of predator density on the efficiency of spider mite predators against two spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae). *Asian J. Biol. Sci.,* **5**: 432-437.

Kartasheva, T.T. and Lesteva, E.E. (1981). Mass multiplication and effectiveness of *Phytoseiulus persimilis* in the conditions of Krgizia. *Gntomologicheskia Issledovaniya V, Kigyii* (1981 recd 1983). **14**: 94-103.

Kristova, E. (1972). The use of *Phytoseiulus persimilis* for the control of spider mites on cucumber in the greenhouses. *Rastitelna Zashita,* **20**: 310-334.

Kropczynska, A., Pilko, A., Witul, A. and Asshleb, A.M. (1999). Control of two spotted spider mite with *Amblyseius californicus* on croton. IOBC/WPRS (Intl. Org. Biol. Integrated Control Noxious Animals Plants, West Palearctic Reg. Section), *Bull.,* **22**:133-136.

Legowski, T.J. (1966). Experiments on predator control of the glasshouse red spider mite on cucumbers. *Pl. Pathol.,***16**: 34-41.

Leuprecht, B. (2000). Occurrence of tomato rust mite in tomatoes under glasshouse. *Gemuse Munchen,* **36**: 26-27.

Maanen van, R., Vila E., Sabelis, M.W. and Janssen, A. (2010). Biological control of broad mites (*Polyphagotarsonemus latus*) with the generalist predator *Amblysieus swirskii*. *Exp. Appl. Acarol.,* **52**: 29-34.

Maheswary, J., Bhaskar, H. and Chinnamade Gowda, C. (2015). Phytoseiid mite fauna associated with major vegetable crops of Thrissur district, Kerala. *J. Biol. Control,* **29**: 183-86.

Mahgoub, M.H.A., Abdallah, A.A. and El-Saiedy, E.M.A. (2011). Biological control agents against the two-spotted spider mite on four pepper cultivars in greenhouses. *Acarines.,* **5**: 29-32.

McMurtry, J.A., Huffaker, C.B. and Vande Vire, M. (1970). Ecology of tetranychid mites and their natural enemies: A review. 1. Tetranychid enemies: The biological characters and their impact of spray practices. *Hilgardia,* **40**: 331-39.

McMurtry, J.A., Moraes, G.J. de and Famah Sourassou, N. (2013). Revision of the lifestyles of phytoseiid mites (Acari: Phytoseiidae) and implications for biological control strategies. *Sys. Appl. Acarol.,* **18**: 297-320.

Mori, H. and Chant, D. A. (1966). The influence of prey density, relative humidity and starvation on predaceous behaviour of *Phytoseiulus persimilis* A.-H. (Acarina: Phytoseiidae). *Can. J. Zool.,* **44**: 483-491.

Muma, H.H. and Denmark, H.A. (1970). Phytoseiidae of Florida. Florida Dept. Agric. Consumer Sev., Gainesville. 1950pp.

Nomikou, M., Janssen, A., Schraag, R. and Sabelis, M.W. (2001). Phytoseiid predators as potential biological control agents for *Bemicia tabaci*. *Exp. App. Acarol*., **25**: 271-291.

Noubar, J.B., Martin, T. and Jacques L. (2003). Management of the two-spotted spider mite, Tetranychus urticae [Acari: Tetranychidae] in eggplant fields. *Phytoprot.,* **84**: 1-8.

Onzo, A., Houedokoho, A.F. and Hanna, R. (2012). Potential of the predatory mite, *Amblyseius swirskii* to suppress the broad mite, *Polyphagotarsonemus latus* on the gboma eggplant, *Solanum macrocarpon*. *J. Insect Sci.*, **12**: 1-11.

Parrot, P.J., Hodgkies, H. E. and Schoene, W.T. (1906). The Eriophyidae. Part-I. The apple and pear mites. *N. Y. Agric. Stn. Bull.*, **282**: 302-303.

Pruszynki, S. (1984). Observations on the predaceous behaviour of *Phytoseiulus persimilis*. *Environ. Entomol.*, **14**: 39-44.

Pruszynki, S., Sewak, L., Aumiller, P. and Konopinstra, M. (1985). Results of biological control of spider mites (tetranychidae) using predaceous mite, *Phytoseiulus persimilis* in production glasshouses of the Naramowice state Horticultural Farm. *Prace Naukowe Instytutu Ochrony Roslin* (1983, recd 1985) **24**: 161-172.

Rasmy, A.H. and Ellaithy, A.Y.M. (1988). Introduction of *Phytoseiulus persimilis* for the two-spotted spider mite, *Tetranychus. urticae* control in glasshouses in Egypt (Acarina: Phytoseiidae, Tetranychidae). *Entomophaga,* **33**: 435-438.

Reddy, P. Parvatha (2016).*Sustainable crop protection under protected cultivation*. Indian Institute of Horticultural Research Bangalore, Karnataka, India. 447pp.

Remarker, P.M. J. (1987). Control of spider mites and thrips with Phytoseiid predators on sweet pepper. *Bull. SROP,* **10**: 158-159.

Rodriguez, H., Montoya, A., Miranda, I., Rodrigues, Y., Depestre, T.L., Ramos, M. and Badii-Zabeh, M.H. (2015). Biological control of *Polyphagotarsonemus latus* (Banks) by the predatory mite *Amblyseius largoensis* (Muma) on sheltered pepper production in Cuba. *Rev. Prot. Veg.*, **30**: 70-76.

Roopa, S.P.(2005). Investigations on mite pests of solanacous vegetables with special reference to brinjal. Ph.D. Thesis, University of Agricultural Sciences, Dharward, KARNATAKA (INDIA).

Sabelis, M. W. (1981). Biological control of two-spotted spider mites using phytoseiid predators. *I Agric Res Report* 910. Pudoc, Wugeningen, The Netherlands.

Sabelis, M. W. and Van Der Bean, H. E. (1983). Location of distant spider mite colonies by phytoseiid predators: demonstration of specific Kairomones emitted by *Tetranychus urticae* and *Panonychus ulmi*. *Entomol. Exp. et Appl.*, **33**: 303-314.

Sabelis, M. W., Vermaat, J. E. and Groeneveld, A. (1984). Arrestment responses of the predatory mite *Phytoseiulus persimilis* to steep odour gradients of a kairomone. *Physiol. Ent.*, **9**: 437-446.

Schmidt, V.G. (1976). Der einfluss der van den beutetieren hinterlassenen spuren auf such verhalten and sucherfoly von *Phytoseiulus persimilis* (Acarina: Phytoseiidae). *Z. Ang. Entomol.*, **82**: 16-18.

Simmonds, S.P. (1972). Observations on the control of *Tetranychus urticae* on roses by *Phytoseiulus persimilis. Pl. Path.*, **21**: 163-165.

Singh, S. (2001). Role of predatory mites in management of mite pests on vegetables under protected cultivation. Credit Seminar, Ent. 591. 26pp.

Souliotis, P. (1985). Control of *Tetranychus urticae* (Koch) in greenhouse cucumber in Attiki by *Phytoseiulus persimilis* (Athias-Henriot). Experts Group Meeting, Heraklion, Greece, 24-26 April, 1985, IOBC/ CEE.

Stenseth, C. (1979). Effect of temperature and humidity on the development of *Phytoseiulus persimilis* Athias-Henriot and its ability to regulate populations of *Tetranychus urticae* Koch (Acarina: Phytoseiidae, Tetranychidae). *Entomophaga*, **24** : 311-317.

Takafuzi, A. and Chant, D. A. (1976). Comparative studies of two species of predaceous phytoseiid mites (Acarina: Phytoseiidae) with special reference to their responsive studies to the density of their prey. *Ibid*, **17**: 255-310.

Tal, C., Coll, M. and Weintraub, P. G. (2007). Biological control of *Polyphagotarsonemus latus* (Acari: Tarsonemidae) by the predaceous mite *Amblyseius swirskii* (Acari: Phytoseiidae). *IOBC/wprs Bull.*, **30**: 111-15.

Vacante, V. and Nucifora, A. (1987). Possibilities and perspectives of biological and integrated control of the two-spotted spider mite in the Mediterranean greenhouse crops. *Bull. SROP,* **10**: 170-173.

Van Lenteren, J.C. and Woets, J. (1988). Biological and integrated pest control in greenhouses. *Ann. Rev. Entomol.*, **33**: 239-269.

Walter, D. and Proctor H.C. (1999). *Mites ecology, evolution and behaviour.* Wallingford: CABI Publishing. 321pp.

Williams, M.E.C., Kravar-Garde, L., Fenlon, J.S. and Sunderland, K.D. (2004). Phytoseiid mites in protected crops: the effect of humidity and food availability on egg hatch and adult life span of *Iphiseius degenerans*, *Neoseiulus cucumeris*, *N. californicus* and *Phytoseiulus persimilis* (Acari: Phytoseiidae). *Exp. Appl. Acarol.*, **32**: 1-13.

Yoldas, Z., Madadar, N. and Gul, A. (1996). Biological control practices against pests in vegetable greenhouses in Izmir (Turkey). *Cah. Opt. Médit.*, **31**: 425-434.

Zhang, Z.Q. (2003). *Mites of greenhouses: Identification, biology and control.* Wallingford: CABI Publishing. 244pp.