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Feasibility for Development of Comparative Life Histories and Predation of Predatory Mites in Phytoseiidae Complex and Their Experimental Manipulations for Pests Control

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Abstract

Predatory mites have been used for many years to manage small insects and mites pest in fruits, vegetables and crops. Many species of predatory mites in the family Phytoseiidae feed on some insects and mites and can provide good biological control of these pests. Predators *Neoseiulus cucumeris* (*Amblyseius*) *cucumeris* (Oudemans) and *Neoseiulus pseudolongispinosus* (Xin, Liang and Ke) (Phytoseiidae) are predatory mites capable of eating large numbers of insect and mite pests, and these move amongst the plants to find their prey. Each Phytoseiidae mite can eat many hundreds of spider mites or other pests during its life cycle, and may feed upon all stages of pest mites. These predatory mites must be introduced at the first sign of pest's infestation. Like all protectors of biological controls, predatory mites are harmless to children, pets and wildlife, and cannot become a pest in their own right. When there is a history of the pests in a greenhouse or field, conservatory it is advisable to check carefully for damage signs and mite activities early, and predatory mites should be introduced. As a basic rule to achieve good control of red spider mite in about three weeks, provide the starting ratio of red spider mites to predator no greater than 20 pest mites to 1 predatory mite. The predatory mites cannot be stored for long time, and it needs to be used immediately upon receipt from rearing insectaries and all packs of predator are sent with complete instructions. The predatory mites can be used indoors or outside provided the environment is sufficiently conducive for their growth and performance. The air temperature must be around 20ºC (68ºF) for at least part of the day, humidity should be fairly high and the temperature must not fall below 10ºC (50ºF). The biological control using predatory mites can be effected by chemical usage, as a general rule stop using botanical pesticides 4 days before, synthetic pesticides 1-2 weeks before and soft soap insecticides 1 day before their releasing. The use of single or more biological control agents in multiple agricultural systems may facilitate area-wide pest management and conservation strategies within a common region of crop land.

Keywords

Phytoseiidae, *Neoseiulus cucumeris*, Tetranychus, Tyrophagus, *Neoseiulus pseudolongispinosus*

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1. Introduction

Mites of the family Phytoseiidae have received considerable attention during the last four decades because of their potential as biological control agents of phytophagous mites and insects on various crops. As more studies are undertaken, there is increasing evidence to support the contention that phytoseiid mites can be important biological control agents and essential elements in some pest management programs (McMurtry, 1982). These economically important predators consume a wide range of food such as mites, thrips, whitefly and scale insects, which are among the most serious pests in

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a number of agricultural systems, and even can survive on pollens (McMurtry and Croft, 1997). Predatory mites are expected to be ready first among the other natural enemies targeted for mass rearing. Predatory mite can complete its life cycle from eggs to egg in 5 days or so (Litsinger, 1995). Members of family Phytoseiidae have gained maximum attention all over the world being the predators of other harmful mites and other small insects (Canlas et al., 2006).

Phytoseiids are effective at suppressing pests in landscape plants grown in greenhouse systems (Strong and Croft, 1995), but few studies have tested their ability to suppress pest mites on landscape plants grown outdoors. Some studies have evaluated the use of *Phytoseiulus persimilis* Athias-Heiuiot for the suppression of *Tetranychus urticae* Koch in landscape species grown in semi-tropical regions (Brushwein, 1991; Cashion et al., 1994). Results suggest that *P. persimilis* can reduce *T. urticae* on landscape plants below economic levels. For selecting biological control agent for suppression of spider mites on landscape plants, life history traits of *Galendromus occidentalis* Nesbitt, *Neoseiulus califamicus* (McGregor) and *Neoseiulus fallacis* (Garman) have been compared and also evaluated abilities of these predatory mites to suppress spider mites in 4 landscape plant species under field conditions. Comparing life history traits, intrinsic rate of increase was similar between the 2 *Neoseiulus* species but lower for *G. occidentalis.* Prey killed per day has been greatest for *G. occidentalis*> *N. fallacis*> *N. califomicus* (Pratt and Croft. 2000).

Bio tactic mites are small, highly active predators, orange to bright red in appearance and normally adult females are 0.5-0.6 mm long. Adult female mite lays its eggs amongst colonies of harmful mites. Both nymph and adult predatory mites actively search for their prey and can feed voraciously on all stages of pest mites from eggs through to adults. Under optimal conditions (20°C and 65% RH), a mite predator has the potential to devour up to five adult spider mites and twenty eggs and larvae per day, thus reducing pest mite populations over several weeks. Predator mites are almost dependent on small insects, spider mites can be feed on pollens as a source of food, and once all prey has been consumed these can go out in search of a new food supply. If no food is found, the mites may become cannibalistic in cropping system. Under optimal conditions, mite predators have a substantially faster life cycle than spider mites. The sex ratio of adult predator is four females to each male, and females are capable of laying up to 60 eggs in their life time. Mite predators are not considered harmful to humans and animals, and no harmful environmental impacts are expected. These factors contribute to the success of mite predator as predatory agents (Sarwar, 2012; 2015 a; 2015 b; Sarwar et al., 2013).

The tomato leafminer *Tuta absoluta* is extremely difficult to control using chemical insecticides because larvae mine within plant tissue and are thus protected at least from contact insecticides, but also because of its ability to develop resistance to insecticides makes its control quite challenging. Thus, parasitoids as well as some Pyemotidae mites are a very important component of the natural enemy complex of *T. absoluta*. Some considerations are presented, such as the parasitism mechanisms, factors affecting the parasitic efficiency, interference or interaction between parasitoids and some other natural enemies, side-effects of synthetic and botanical pesticides on parasitoids and conservation of indigenous natural parasitoids of *T. absoluta* (Ghoneim, 2014).

Experiments were conducted to evaluate the potential use of phytoseiid (Acari: Phytoseiidae) mites as control agents for spruce spider mite (*Oligonychus ununguis* Jacobi) and rosette bud mite (Acari: Phytoptidae) pests of Fraser fir (*Abies fraseri* (Pursh) Poiret), in Christmas tree production areas. The predatory mite community structure in Fraser fir plantations was characterized. Three predator families in the Prostigmata were collected as Anystidae, Bdellidae and Cunaxidae. The most abundant phytoseiid mites collected were *Arrenoseius morgani* (Chant) (56.4%), *Typhlodromips sessor* (DeLeon) (21.1%) and *Proprioseiopsis solens* (DeLeon) (5.1%). Ninety four phytoseiids were collected on trees infested with spider mites and sixty four phytoseiids collected from uninfested trees. Eighty six phytoseiids were collected from plantations with a diverse ground cover, while clover and bare-ground each yielded 17 phytoseiids and grass ground cover yielded 14 phytoseiids (Williams, 2008).

2. Conditions for Release and Storage of Predatory Mites

As storage instructions, favorable conditions for mite are temperatures above 20°C for a time during the day and a relative humidity of 65%, and these can also reproduce at temperatures and humidity that are not ideal, but increase at a slower rate (Morris et al., 1996; Croft et al., 1998).

2.1. Pre Release

Before introducing mites into crop, check residual chemical affects and ensure chemical compatibilities, and find withholding periods of products that may be applied. Mites should not be exposed to direct sunlight, do not refrigerate, and keep in darkness and in a cool environment, ideally at temperature 10-12 °C. For the best results, preferably release mite when pest populations are still low at a dose of 4 predator mites per square meter in greenhouse crops and 1 predator mite per 2.5 square meters inside field crops within

1 to 2 days once received after dispatched via courier service. As release instructions gently rotate each container to mix the contents, open one container at a time in the infested area, apply the contents immediately and sprinkle the product evenly over infested plants throughout the field.

2.2. Post Release

After 2-4 weeks, following the release of mites, growers should be able to see signs of the predator working against pests. Two spotted spider mites that have been eaten change from pale green to brown color and appear shrivelled. Possibly, use a 10 X hand lens to check specimens, as live and dead mites can appear similar to the naked eye.

Predatory mites feed on all life stages of many small arthropods and target pest spider mites, so, can provide natural pest control by eating unwanted pests. Predatory mites are commercially available to fit on most farm, landscape and garden situations. Predatory mites do not damage plants, but feed on plant pollens when prey is unavailable (Morris et al., 1996; Croft et al., 1998). Unlike most agricultural systems, outdoor landscape nurseries and crops are complex polycultures with many pests. When developing biological control in such systems, laboratory and field studies are needed to provide acceptable alternatives to the use of pesticides for control of pests of outdoor landscape and nursery plants. This article is to report on the use of a phytoseiid for control of multiple pests in indoor and outdoor commercial plants.

3. Mass Rearing of Predatory Mites

Following measure should be undertaken to locate the most suitable hosts for predator mites to their mass rearing prospective.

3.1. Life History Characteristics of Mite Predator *Neoseiulus cucumeris* on Mite and Pollen Diets

The crops diversification with species that can offer suitable pollens for the natural enemy may possibly decrease pest population on host plants by boosting up predator's efficiency. Therefore, the motivation behind this experimentation was to evaluate the plant plus animal dietary significance and its potential impacts on life parameters of phytoseiid mite *Neoseiulus* (*Amblyseius*) *cucumeris* (Oudemans) to determine possibilities for their use in practice. The predator was reared on six different plant pollens (Maize *Zea mays* L., Mungbean *Vigna radiata* L., Sweet pepper *Capsicum annuum* L., Tomato *Lycopersicon esculentum* Mill., Cucumber *Cucumis sativus* L., and Rose *Rosa multiflora* Thunb., in combination with food mite *Tyrophagus putrescentiae* (Schrank). The results of experiments showed that predator mite *N. cucumeris* was able to successfully feed, develop and reproduce when fed on ample range of plant and animal origin diets irrespective of diet offered owing to role of food utilized. Studies revealed that the predator *N. cucumeris* showed most efficient capability for life history characteristics in maize and mungbean ingested pollen grains in combination with *T. putrescentiae* which proved sufficient plant-animal diets. A mean developmental time from neonate larva to adult emergence varied between the different pollens from 7.50 to 8.32 d, with the lowest value recorded on maize and mungbean pollens, while, the highest on cucumber and rose pollens. Whereas, the respective total fecundity from 2.00 to 3.85 eggs per female per day obtained was significantly higher when reared on maize and mungbean pollens than lower when offered cucumber and rose, but moderate on sweet pepper and tomato treatments. Survivorship during immature development varied from 95.42 to 99.00% with the lowest value recorded on rose pollen. The average life span of adult female ranged from 31.00 to 39.00 d with the significantly longest recorded on maize and mungbean pollens. In conclusion, this predatory species could compromise for the establishment of biological control framework in different ornamental, field and protected crops against small arthropods of interest, as it exhibited many features, which make it promising natural enemy. Possibly, it would be able to adapt smoothly to fluctuating prey and can maintain its capability of reproduction and development even when the prey is relatively scarce and can feed on alternate botanicals diet (Sarwar, 2008).

3.2. Influence of Host Plants on the Development, Fecundity and Population Density of Pest *Tetranychus urticae* and Predator *Neoseiulus pseudolongispinosus*

The two-spotted spider mite, *Tetranychus urticae* Koch (Tetranychidae), is a pest of agricultural crops that could potentially be controlled by the predatory mite *Neoseiulus pseudolongispinosus* (Xin, Liang and Ke) (Phytoseiidae). This study investigated the development, fecundity and population density of these two mite species on three different species of bean (*Phaseolus lunatus* L., *Lablab purpureus* [L.], and *Phaseolus vulgaris* L., [Papilionaceae: Leguminosae]). The morphological characteristics of the host plants, including leaf area, thickness and hairiness, main stem diameter and plant height affected development rate, fecundity and population density of *T. urticae* and also the searching success and abundance of the predatory species, *N. pseudolongispinosus*. The *L. purpureus* was found to be a superior host plant for both predator and prey species. These findings emphasize the importance of host plant characteristics on the performance of species used for biological control (Sarwar, 2014).

3.3. Suitability of Webworm *Loxostege sticticalis* Eggs for Consumption by the Predatory Mite *Neoseiulus pseudolongispinosus*

The genus *Loxostege* has a worldwide distribution and includes an economically important group of insect pests of different crops. The effectiveness of predator *Neoseiulus pseudolongispinosus* (Xin, Liang and Ke) as a potential biocontrol agent of webworm *Loxostege sticticalis* L., was investigated by measuring rates of prey consumption and destruction by the different life stages of mite, duration and viability of immature, pre-oviposition and oviposition periods, total oviposition capacity, and longevity of adults. When eggs food was offered in similar amounts, there were variations in consumption tendency among the different life stages of predator. Mean development period was shortest for egg-fed larvae, whereas, longest in deutonymph followed by egg and protonymph, and total life cycle was completed in a mean of 12.75 days for male or female. A mean pre-oviposition period of 4.28 days was recorded in female and period of oviposition lasted for 8.71 days. The mean number of eggs recorded was 1.42 day^{-1} $female^{-1}$. Mortality was recorded in all life stages and percent viability was best in egg stage, adult females and males, and slightly less in larvae, protonymphs and deutonymphs. Further, predatory activity of mites, such as their feeding habits, number of eggs damaged, how they were damaged and oviposition were observed. It is concluded that *N. pseudolongispinosus* can be successfully reared on *L. sticticalis* eggs, which proved a good food for adults and nymphs. Laboratory data indicated that this predatory mite has the potential to act as a biological control agent of *L. sticticalis* in crops (Sarwar et al., 2012).

3.4. Evaluation of Biological Aspects of the Predacious Mite *Neoseiulus cucumeris* Due to Prey Changes Using Selected Arthropods

Supplying mite predators with alternate feeding stratagems are important in determining their survival and these could play a key role in their use for biocontrol. This paper describes the food habits of predatory mite *Neoseiulus cucumeris* (Oudemans) in the presence or absence of target insect and acarine pests. The study used well known pests, the stored food mite *Tyrophagus putrescentiae* (Schrank), the red spider mite *Tetranychus urticae* Koch, and the western flower thrips *Frankliniella occidentalis* (Pergande), as prey for the predatory mite. Survival of *N. cucumeris* was observed in relation to the prey diets offered, prey consumption, fecundity, development time, and adult longevity as influenced by changes in prey were recorded. Significant differences were observed for the types of prey diet used, *T. putrescentiae* was the most suitable prey closely followed by *T. urticae*; then *F. occidentalis* diet. Predation response observed after feeding trials began at a prey density of 15 individuals per predator; *N. cucumeris* adults displayed higher consumption rates (7.0 and 6.4 nymphs/ 24 h) for *T. putrescentiae* and *T. urticae*, respectively, than for *F. occidentalis* larvae (4.0/24 h). The duration of the developmental stages of the predatory mites reared on *T. putrescentiae* and *T. urticae* were 7.6 and 7.7 days, respectively, compared to 8.5 days when reared on thrips. Total adult female survival periods were higher (30.2 and 28.0 days) when predators were fed on these mites than when fed thrips (23.0 days). Survival periods were 27.4, 25.0, and 20.4 days, respectively, for the male predatory mite. Average fecundities of *N. cucumeris* fed *T. putrescentiae* and *T. urticae* were 3.8 and 3.4 eggs after 24 h, respectively, compared to 2.2 eggs when fed thrips. Respective oviposition periods were 20.4, 18.0, and 13.4 days. After transfer to a new prey host, adult *N. cucumeris* of which the parental stock had been fed *F. occidentalis*, showed preference for *T. putrescentiae* and *T. urticae*. Predatory mites for whom the parent generation had been reared on *T. putrescentiae* and *T. urticae* also accepted *F. occidentalis* as substitute prey but inadequate predation was apparent, as indicated by reduced egg production, growth period, and survival. Although relatively short, the periods measured were sufficient to reveal differences linked to the initial and previous diets. The predatory mite *N. cucumeris* is a promising biological control agent for thrips, spider mite, and mold mite because it can feed and survive on alternative nutritional sources when prey is absent or scarce (Sarwar et al., 2009).

3.5. Effects of Different Flours on the Biology of the Prey *Tyrophagus putrescentiae* and the Predator *Neoseiulus pseudolongispinosus*

Laboratory investigations on the biology of *Tyrophagus putrescentiae* (Schrank), a stored-food mite and the predator *Neoseiulus pseudolongispinosus* (Xin, Liang and Ke) were conducted using the flour of soybean (*Glysin max* L.), wheat (*Triticum aestivum* L.), and maize (*Zea mays* L.), as hosts. Efficiency of food was estimated according to time required for immature development, female fecundity, and survival of both sexes. Results indicated that the breeding activity of predatory mites fed on *T. putrescentiae* that had been cultured on wheat flour was more viable than that when *T. putrescentiae* were fed on maize and soybean hosts. Egg, larval, protonymphal, and deutonymphal stages of *T.*

putrescentiae that fed on *T. aestivum* had faster development compared to those fed on *Z. mays* and *G. max*. Fecundity of *T. putrescentiae* was higher (23.8) on *T. aestivum*, than on the other diets tested (17.1 eggs on *Z. mays* and 11.4 eggs on *G. max*); female longevity averaged 34.1, 27.0, and 40.8 days and male longevity was 23.5, 18.7, and 28.7 days when raised on *Z. mays*, *G. max*, and *T. aestivum*, respectively. On a diet of *T. aestivum* the mean generation time from egg to adult of *T. putrescentiae* lasted for 11.7 days compared to 15.2 and 18.8 days when fed on *Z. mays* and *G. max*, and net population growth was 119.0, 61.0, and 32.0 mites per g substrate, accordingly. The predatory mite *N. pseudolongispinosus* when fed on *T. putrescentiae* cultured on different diets could reproduce normally and completed its development as successfully as *T. putrescentiae.* Average duration of egg and nymph development of *N. pseudolongisponosus* was statistically fastest with *T. aestivum*-fed *T. putrescentiae* compared with *Z. mays* and *G. max*. Mean total longevities of the female (29.4, 25.8, and 17.7 days) and male (20.8, 16.8, and 13.1 days) were significantly longer on *T. aestivum* than on *Z. mays* and *G. max*, respectively. Mean daily fecundity of female adults also increased on *T. aestivum* (3.5 per day) but decreased (2.8 and 1.2 per day) with *Z. mays* and *G. max*, while, total developmental time was 10.1, 11.8, and 12.9 days, respectively. The assessment of macronutrients in soybean, maize, and wheat flours showed that wheat had more carbohydrate and ash but reduced protein and fat contents and merits as leading compound in supporting higher mite populations. Consequently, the mass production of *N. pseudolongispinosus* as a potential biocontrol agent under field as well as storage conditions using *T. putrescentiae* reared on a wheat diet would be an appropriate strategy (Sarwar et al., 2010).

4. Field Usage of Predatory Mites

As a basic rule to achieve good control of pests, the predatory mites must be introduced at the initial sign of pest's infestation in greenhouse or field.

4.1. Greenhouse Releases of Predatory Mites

These studies are commenced to the possibilities of predator mites to their releases in protected crops for pests management.

4.1.1. Potential of Mite Species Predators of Sucking Pests on Protected Cucumber Crop

Protected crop experiments were conducted to study the suitability and efficacy of Phytoseiid mite species as predators of western flower thrips *Frankliniella occidentalis* (Pergande), carmine spider mite *Tetranychus cinnabarinus* (Boisduval) and greenhouse whitefly *Trialeurodes vaporariorum* (Westwood) in cucumber (*Cucumis sativus* L.), under greenhouse conditions. In this study, predatory mites *Neoseiulus pseudolongispinosus, Euseius castaneae, Euseius utilis* and *Euseius finlandicus* (Oudemans) (Phytosiidae) were investigated for their potential as biological control agents in treated along with untreated check. The current findings to judge the biocontrol potential of predators showed that laboratory bred adults and nymph instars of all predators efficiently preyed upon sucking arthropods, and pests populations were drastically reduced in treated plants than in untreated control where their intensities were numerous. Among all predators, *N. pseudolongispinosus* was the most proficient and steadfast predator in controlling thrips and whitefly populations, contrary to *E. finlandicus* that proved better in reducing spider mite density in treated crop. The current findings indicated the potential of Phytoseiid predators for their augmentative releases to give best control of sucking pests in protected cucumber plants (Sarwar et al., 2011 a).

4.1.2. Evaluations of Mite Predators Released for Suppression of Spider Mite Infesting Protected Crop of Sweet Pepper

This study examined the efficacy of 4 mite predators such as *Neoseiulus pseudolongispinosus* (Xin, Liang and Ke), *Euseius castaneae* (Wang and Xu), *Euseius utilis* (Liang and Ke) and *Euseius finlandicus* (Oudemans) (Phytosiidae) released for the suppression of spider mite *Tetranychus urticae* (Koch) infesting sweet pepper (*Capsicum annuum* L.) in greenhouse. When the predatory mites were released on sweet pepper plants, their establishment was successful to control the population of spider mite at a lower level and results revealed significant differences in declining pest density among predators released and non-released plants; in addition, non-significant differences were detected in treated plants. Released predators along an untreated control treatment to manage *T. urticae* resulted decline in pest densities from 0.82 to 1.02 per leaf, compared to 1.42 observed within the plants served as control, indicating the potential of these mite predators for augmentative releases. Among all the treatments tested, mite predators recovered were higher with *N. pseudolongispinosus* and *E. utilis* in equal proportion (0.12 per leaf) followed by *E. castaneae* and *E. finlandicus* (0.11 per leaf) inside released plants in comparison to check treatment where no predators were released (0.03 per leaf). The results for allocations of the pest and predatory arthropods on the plant canopy indicated that more prey and predator mites were found on middle and bottom leaves as compared with upper leaves of plant. Observational data suggested that predation on spider mite by the existing predators fauna may have perfect potential to provide biological control of pest in greenhouse crops (Sarwar et al., 2011 b).

4.2. Open Field Releases of Predatory Mites

This section deals with predator release information over the infested plants throughout the field.

4.2.1. *Neoseiulus fallacis* as a Potential Biological Control Agent for Spider Mites

The feasibility of using *Neoseiulus fallacis* (Garman) (Acari: Phytoseiidae) as a potential large-scale biological control agent for spider mites (Acari: Tetranychidae) was examined in vineyards. Three releases of predator were made and the populations of both mites were then monitored on a regular basis to determine dispersal and distribution patterns. Recovery of the predators was low following the releases at two of the sites, probably due to lack of prey. At the third site enough predators were recovered to analyse the spatial distribution of the predator and prey populations. It appears that there is no similar aggregation pattern between the predator and prey at the same point in time although there is an indication of the predator spreading is response to the prey distribution. Although the distribution of the two populations were dissimilar, the predator was present throughout the season and did spread through the entire plot indicating that the predator may be able to colonize the vineyard if it successfully overwinters (Metzger, 2001).

4.2.2. Comparing Abundance of Predacious and Phytophagous Mites in Bt and Non-Bt Cotton Cultivars

Knowledge of the arthropod complex associated with any crop is essential for developing pest control strategies. Bt (GK-12, Lu-23 and SGK-321) and non-Bt (Zhong-12, Shiyuan-321 and Simian-3) cotton varieties were used for assessing differences in harbouring populations of the carmine spider mite *Tetranychus cinnabarinus* (Boisduval) and predatory mite *Neoseiulus cucumeris* (Oudemans). Two Bt cotton varieties GK-12 and Lu-23, and two non-Bt varieties Zhong-12 and Simian-3 appeared more supportive for maintaining *T. cinnabarinus*, whereas, SGK-321 (Bt) and Shiyuan-321 (non-Bt) clearly showed reduced pest susceptibility, but efficient in maintaining *N. cucumeris* population. Throughout the study period, the densities of *T. cinnabarinus* remained higher (1.77 and 1.40 per leaf) in Bt than non-Bt varieties following insecticides application against the cotton pest complex. The beneficial mite *N. cucumeris* remained active in both Bt and non-Bt varieties, but Bt cotton had slightly higher numbers of the predator (0.58 per leaf) than non-Bt cotton (0.40 per leaf). Consequently, there were no great impacts on the predatory natural enemy associated with Bt cotton and the predator population in Bt fields was not negatively affected in comparison with conventional cotton. All tested varieties of cotton significantly differed in relation to their morphological characteristics. Of the different factors found to affect the populations of predacious and phytophagous mites, in general, the trichome density on the lower surface of the leaf, leaf thickness and plant height had positive relations with arthropod abundance. Our results showed that SGK-321 (Bt) and Shiyuan-321 (non-Bt) could be recommended for use in creating new resistant cotton varieties as a component of an integrated pest management strategy. Hence, the differences in the response of pest and predator to host plant and leaf architectures should be considered to enhance their roles in biological control strategy (Sarwar, 2013 a).

4.2.3. Management of Spider Mite *Tetranychus cinnabarinus* Infestation in Cotton by Releasing the Predatory Mite *Neoseiulus pseudolongispinosus*

Biological control of the spider mite *Tetranychus cinnabarinus* (Boisduval) (Tetranychidae) in an open-field cotton crop (*Gossypium hirsutum* L.) by releasing the predatory mite *Neoseiulus pseudolongispinosus* (Xin, Liang and Ke) (Phytoseiidae) was investigated. The objectives were to determine the predatory efficiency of *N. pseudolongispinosus* released during different growth stages of the cotton and the different numbers of plants treated. The factors evaluated were release of predatory mites at a constant rate of five predators per plant using different plant numbers of cotton (every plant or every second or third plant treated) and timing of predator release (early, middle and late season releases). All predator released treatments were compared with a ‘‘no predator released’’ (control) trial. Based on treatment applications, the experimental data collected from biologically managed cotton fields and the untreated control showed significant differences in population densities of pest and predatory mites. Overall, the combined populations of both mites were not significantly different during early and mid-season releases, but varied significantly from late releases of predacious mite. The results also showed that populations of both pests and predators were not significantly different when each cotton plant and every second plant was treated with predator but differed significantly when every third plant was treated, where increased numbers of *T. cinnabarinus* and decreased *N. pseudolongispinosus* were observed. Consequently, field release of the predaceous mite *N. pseudolongispinosus* to reduce the incidence of *T. cinnabarinus* at an early growth stage of cotton is a potentially useful pest management strategy if every plant is treated with predator (Sarwar, 2013 b).

5. Conclusion

Predatory mites are important biological control agents of soft bodied pests in many agricultural systems. An alternative to pesticides for suppression of mites and insects is the inoculative release of predatory mites from the family Phytoseiidae. This decision to focus on predatory mites is consistent with other studies that sought a predator of small insects and mites in agricultural systems of indoor and outdoor. As shown in these studies, inoculative releases of predatory mites on plants provide suppression of insect and mite populations below damaging levels, resulting in marketable plants without the use of pesticides. Live predator mites are usually shipped when mixed in vermiculite, bran or a similar material to cushion these in transit. The carrier-mite mixture can be sprinkled directly onto the foliage of infested plants and the mites can disperse on their own. Predator mites can be released uniformly throughout the greenhouse and field or concentrated in infested patches. Uniform distribution of predators throughout the crop is the most common method of predator introductions and it provides predictable levels of control. However, introduction in patches of mite damage can often result in better control than their uniform distribution. Predatory mites are most effective when introduced while spider mite populations are still low. Most failures of biological control occur when the predator is released too late. Spider mite populations should be monitored by observing foliage of susceptible plants at least on weekly basis. In greenhouses with a history of spider mite problems, the first releases should be made one week after plant emergence. Additional predator releases may be necessary after every 2-4 weeks to achieve good control within 6 weeks. Further, studies are needed to determine how alternative foods may enhance predator's conservation in landscape or nursery systems.

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