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Biology and Ecology of Some Predaceous and Herbivorous Mites Important from the Agricultural Perception

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Abstract

Mites are numerous species of minute arthropods, members of class Arachnida subclass Acari or Acarina and pests of many economic prominence living in a wide range of habitats. Mites are predators and parasites, performing crucial means of biological control, essential herbivores and detritivores, acting fungivorous and saprophytic, vectors of diseases, and play vital role in soil formation. These live on plants and animals, in the depths of ocean, in soil and fresh or brackish water, in lungs of birds and animals, in stored grains and stored products, on leaves of rainforest, and in human clothes and bedding. In spite of magnificent diversity of predaceous, phytophagous and granary mites found on plants and stored grains, these are often overlooked, and even skilled zoologists may be unaware of their importance. This chapter aims to provide an updated analysis of their biology, life history, reproduction and ecology to fill gap in our understanding of these fascinating creatures for pests controlling.

Keywords: arthropod, Acari, mite, pest, Phytoseiidae, control

1. Introduction

Mite complex is worldwide in its distribution in all regions of globe and more prominent in tropical as well as subtropical climates. Mites can be either inflicting damage to humans and animals [1, 2], or pestilent that feed on plants [3] and stored commodities [4–23], otherwise predaceous which are the carnivorous of leaf-feeding mites and other pests [24]. All harmful types of mites are able to devastate agricultural crops, fruits and vegetables [25, 26]. During the previous few decades, owing to increasing concerns over health, environment and pest resistance risks accompanying with chemical control, and the use of alternate pest management strategies has received considerable attention [27, 28]. In this context, the uses of generalist predators that can perform as a broad spectrum fighters against pests have been greatly encouraged [29–31].

Currently, mites belonging to the family Phytoseiidae (Arachnida: Mesostigmata) are economically important predators of some phytophagous mites and insects in greenhouses or field crops. Amongst others predators, mass reared phytoseiid mites are commercially available and used, against spider mites, thrips

and whiteflies infestations on plants. Phytoseiid mites use odors (kairomones) associated with mite-infested plants to locate their prey or when predators contact spider mite webbing, these intensify their search for prey and may identify prey eggs and distinguish these from non-prey objects. The existence of a water-soluble feeding stimulant on prey eggs as well is postulated [32].

Predator mites which fit to the family Phytoseiidae, are categorized by long legs, with the front pair pointing forward and comparatively have few hairs (<20 pairs) on their back. The color of mites can differ from deep red to pale yellow liable to the prey items eaten. Mites that feed on whiteflies and thrips are commonly pale yellow to pale tan. Phytoseiid mites have five life stages in life cycle like egg, larva, protonymph, deutonymph and adult. Most mites of this family are free-living predators in the deutonymphal and adult stages on a variety of arthropods in plants or crops. This chapter presents broad-spectrum ideas of the findings in research focusing on rhetorical aspects of biology and ecology of some predacious as well as harmful mites with particular reference to their possible role in biological control [33, 34].

2. Beneficial mites

Beneficial mites are excellent biological control agents and have been used in controlling of tiny mite pests and insect pests that cause a serious damage to many economically important crops.

2.1 *Neoseiulus (Amblyseius) cucumeris* (Oudemans)

Cucumeris predatory mite *Neoseiulus* (= *Amblyseius*) *cucumeris* (Oudemans) has a worldwide distribution because of its natural occurrence and commercial use in various parts of the ecosphere. Cucumeris is soft-bodied and translucent pale brown to sometimes tan-colored depending on the food consumed. These can be distinguished from most pest mites by their shape and mobility (**Figure 1**). Cucumeris moves rapidly along the underside of leaves and in flowers of plants. Adult mite is pear-shaped and may range between 0.5 and 1.0 mm in length with long legs. Gnathosoma corniculi is slightly convergent distally, dorsal shield strongly reticulate with 17 pairs of setae, and sternal shield smooth with few lateral striae, three pairs of setae and two pairs of lyrifissures. Eggs are laid on the leaf surface, on domatia or on hairs (trichomes) along the midrib on the underside of leaves and occasionally on petiole hairs. The eggs are round, translucent white and measure 0.14 mm in diameter. Females lay 1–3 eggs per day for an average of 35 eggs over their lifetime. The eggs hatch in about 3 days later [35].



Figure 1.
Neoseiulus cucumeris.

Cucumeris populations have somewhat more females than males (64% females). Mite develops through one larval stage and two nymphal stages (protonymph and deutonymph) before becoming adults. The non-feeding larvae emerge from eggs in about 3 days and molt into protonymphs 2 days later. The two nymphal stages last for 7–10 days before developing into adults. Adults live for up to 30 days and eat an average of 1 thrips/day. Cucumeris has a life cycle of 10–12 days at 20°C, while development time at 75°F is 6–9 days and development takes from 8 to 11 days (at 20–25°C). Cucumeris prefers environment with >65% relative humidity (R. H.), but eggs can survive at as low as 40% R. H. Greenhouse *N. cucumeris* is not susceptible to diapause, however, less effective above 28°C. Optimum temperature range for Cucumeris mites is 66–80°F with humidity between 65 and 75%. The lowest developmental time of the predator from neonate larva to adult emergence (7.50 days), the highest immature survivorship (99%), higher fecundity (3.85 eggs/female/day), long oviposition period (26.57 days), and the highest adult female's life span (39 days) have been observed when offered maize pollens along with *Tyrophagus putrescentiae* (Schrank) as prey [36].

For studying food habits of predatory mite *N. cucumeris*, well known pests, stored food mite *T. putrescentiae*, red spider mite *Tetranychus urticae* Koch and western flower thrips *Frankliniella occidentalis* (Pergande), have been used as prey. Significant differences have been observed for the types of prey diet used, *T. putrescentiae* proved the most suitable prey closely followed by *T. urticae* and then *F. occidentalis* diet, wherein, duration of the developmental stages of the predatory mites noted 7.6, 7.7 and 8.5 days, respectively [37].

Cucumeris is an aggressive predator of several soft-bodied pests and generally microclimates inside the greenhouse crop seem to be significant for their existence. Cucumeris feeds on little (first and second instar) thrips on foliage and flowers, and does not nourish on big larvae or adult thrips. The prime targets of Cucumeris are thrips species including western flower thrips (*F. occidentalis*), onion thrips (*Thrips tabaci* Lind.), plague thrips (*Thrips imaginis* Bagnall), melon thrips (*Thrips palmi* Karny), common blossom thrips (*Frankliniella schultzei* Trybom) and chilli thrips (*Scirtothrips dorsalis* Hood) [38]. These are known to feed on the immature stages of a variety of plant damaging mites, for instance, broad mite (*Polyphagotarsonemus latus* Banks), cyclamen or strawberry mite (*Phytonemus pallidus* Banks), spider mites, tomato russet mite and mites of the genus *Schizotetranychus* in ornamental, fruit and market garden crops. Cucumeris is also used effectively for control of thrips in stored red salad onions [39, 40].

Cucumeris is an appropriate enemy for many tiny pests of greenhouse crops, and both outdoor and indoor strawberry crop. This is able to live on pollen in the absence of pest and as a result might be used precautionary in crops such as strawberries or capsicums that produce pollen. Cucumeris has been efficaciously used for thrips control in capsicums, cucumbers, berry fruits and eggplants as well as in ornamental crops such as rose and gerbera, and other potted plants. In circumstances having very huge thrips pressure, Cucumeris ought to be always used in combination with the predatory pirate bug *Orius tantillus* (Motschulsky). Cucumeris is not efficient control agent on geraniums or tomatoes owing to leaf structure and toxic plant exudates [41].

In recent years, various delivery systems (formulations) of *N. cucumeris*, such as buckets (100,000 mites) or bottle (50,000 mites) containers are offered for direct release in greenhouse, field and nursery operations. Both systems comprise of predatory mites and bran mites *T. putrescentiae* (a temporary food source of the predatory mite) mixed with bran or vermiculite. Cucumeris is supplied from the insectary at approximately 100,000 predators per liter of substrate. Each liter of insectary material should cover 600–2500 m² of greenhouse area (4–16 L/ha). For strawberries, release is done at the rate of 2 L/10,000 plants at initial flowering in

spring and yet again 4–6 weeks later. Wherever thrips are high, a third release of predator can be desirable. In greenhouse crops, Cucumeris must be released at a rate of 50–200 predators/m² of cropping area (4–16 L/ha) subjected to thrips density. In crops with little thrips density and which have enough pollen, for instance, capsicums (once flowering has started), the lesser amount can be used, however must be used in two doses about 14 days apart to make certain even dispersal through the crop. Sprinkle 200 mL of mixture per ton of onions over the top of the onions once stored into bins prior to storage [42].

2.2 *Neoseiulus* (= *Amblyseius*) *fallacis* (Garman)

Mite *Neoseiulus* (= *Amblyseius*) *fallacis* (Garman) is an excellent general predator for control of many different types of mites in warm and moderately humid environments. Particularly, it targets two-spotted spider mite (*T. urticae*), broad mite, hemp russet mite, European red mite (*Panonychus ulmi* Koch), spruce spider mite (*Oligonychus ununguis* Jacobi), southern red mite (*Oligonychus ilicis* McGregor), bamboo mite (*Schizotetranychus celarius* Banks), cyclamen mite, other small arthropods and is also able to feed on an array of pests, especially their eggs on roses and vegetable crops. *Fallacis* can also be effective in orchards as it tolerates higher temperatures and lower humidities. For the reason that *N. fallacis* is a hungry user of mites and owing to its density rises rapidly relatively to its prey, it is able to surpass an intensifying pest populations. Additionally, it progresses into the mature stage in nearly one third the time needed by other mite predators. Moreover, this may also feed on pollen and can survive for periods having pollen alone, which makes it an excellent preventative natural enemy [43].

Adults of *N. fallacis* are about 0.5 mm long, with pear-shaped bodies. These can vary in color from cream to orange-beige, shiny and semi-transparent, with long legs (**Figure 2**). The immature stages are generally a semi-transparent cream color and difficult to see without a microscope. The eggs are oval, almost transparent, and 0.33 mm in diameter (double than size of a two-spotted spider mite egg). Adult females lay 1–5 eggs per day along the ribs on the undersides of leaves and a total of 26–60 eggs over their lifetime (which could be between 14 and 62 days) are laid. The eggs hatch in 2–3 days and newly hatched predators do not eat, but later stages and adults feed on all stages of prey. Generally, female *A. fallacis* can eat 2–16 spider mites per day. Of the five *N. fallacis* life stages, only the first nymphal stage is six legged, while all other post-egg stages have eight legs [44, 45].



Figure 2.
Neoseiulus fallacis.

Growth from egg to adult takes place in 7–9 days at 70°F, 3 days at 85°F and at 78°F a fourfold rise in numbers can occur within 4 days. Under optimum conditions in the field, densities may increase from 10 predators per 100 leaves to 200–500 predators per 100 leaves in just 2 weeks. Adult mated females enter diapause in response to the short days in the fall (<14 hours of daylight) in plant crevices or other protected areas. As a result, these stop reproducing and move into sheltered areas, such as under bark or ground cover. But, these do not enter diapause in greenhouses or interior plantscapes if the temperature is 64°F (18°C) or above. These emerge as early as bloom, but in reduced numbers due to heavy winter mortality. Fallacis increases in number rapidly and adults become numerous by July or August, and on an average 40–60 eggs are laid. Warmer or cooler conditions accelerate or slow down reproduction/feeding, respectively, and these live about 20 days [46, 47].

Mite predator *N. fallacis* works extremely well to control mite infestations in greenhouses, so, it is suggested for use in tomatoes, roses and other vegetable crops. On field crops, before introducing *N. fallacis*, monitoring and counting should be done to determine numbers of spider mites and existing predators. Inoculate only those fields having spider mite populations of 0.3 mites per leaf and higher [48]. Spread *N. fallacis* evenly throughout the field using 150–200 release points per hectare (60–80 per acre), concentrating extra predators near to higher mite counts. For new strawberries and mint or raspberries and currants plantings, release 25,000 predators per hectare (10,000 per acre) as soon as possible after planting or 10 days after applying insecticides to control aphids, and on producing fields, release 17,000 per hectare (7000 per acre).

2.3 *Phytoseiulus persimilis* Athias-Henriot

Predator mite *Phytoseiulus persimilis* Athias-Henriot, is a specific predator of web-spinning spider mites like two spotted spider mite. Indeed, *P. persimilis* nourishes, breeds, and completes growth merely on mites in the subfamily Tetranychinae, even though it too feeds on young thrips and may be cannibalistic at what time spider mite prey is absent [49]. This species is approximately 0.5 mm long, fast moving, orange to bright reddish orange in color, has a teardrop-shaped body, long legs and is slightly larger than its prey (**Figure 3**). Adult females are reddish, pear-shaped and active at room temperature. Immatures and males are smaller and lighter in color. The life cycle of *P. persimilis* has been determined under a diurnal temperature cycle of 58–83°F. Eggs are oval, oblong and approximately twice as large as the pest mite eggs and hatch in 2–3 days. The adult female may lay up to 60 eggs during its 50 day-long lifetime at 17–27°C. The adult female, after a pre-ovipositional (the time between emergence from the egg to the deposition of the first egg) period of 3.0 days, laid an average of 2–4 eggs per day for 22.3 days. The average duration of incubation for both males and females is 3.1 ± 0.2 days [50].



Figure 3.
Phytoseiulus persimilis.

Larvae do not attempt to feed and remain inactive near the old egg shell. Although the larval stage does not feed, yet the subsequent nymphs and adults feed on all stages of prey. Both males and females remained in the larval stage for an average of 1.0 ± 0.1 days. Immatures are normally pale salmon in color. The male and female protonymphal stages lasted 1.7 and 1.6 days, respectively. During this time both males and females ate an average of 4–4 eggs of *T. urticae*. The eight-legged final nymphal stage (deutonymphal stage) remained active throughout the period. Both males and females remained an average of 1.7 ± 0.1 days in this stage, and during that time the deutonymphs ate 6.0 eggs. Both males and females start to forage just about instantaneously afterward these have molted. Afterwards nourishing, the females become very active and spend plentiful of its time running around the cell enclosure. Simply, when a male is faced and mating has taken place then the female settles down. Usually 6–12 hours is elapsed between the time of molting and the time of mating. The duration of mating is erratic, taking from 5 minutes to several hours. The duration of the ovipositional period (period during which eggs are deposited) ranged from 6 to 39 days, with an average of 22.3 days. The maximum number of eggs laid by any female in a day is six. During the pre-ovipositional and ovipositional periods, the females consumed 7.3 and 14.3 eggs of *T. urticae*, respectively. After ceasing to oviposit, the females lived an average of 7.1 days during which each individual consumed 3.9 eggs per day. Each sex ate an average of 10.5 eggs during entire development. Total developmental time for males is 7.5 days and for females 7 days. However, total generation time from egg to adult ranges from 25.2 days at 15°C (59°F) to 5.0 days at 30°C (86°F) [51–53].

Due to its tropical origin, *P. persimilis* does not have a diapause stage and is active year-round in enclosed habitats such as interior plantscapes and greenhouses. Because this mite is much efficient hunter and disperser, it can cause effective extinction of its spider mite prey. *Persimilis* predaceous mite, is one of the pillars of greenhouse integrated pest management programs for control of spider mites on vegetables and ornamentals [54, 55].

2.4 *Neoseiulus* (= *Amblyseius*) *californicus* (McGregor)

Predaceous mite *Neoseiulus californicus* (McGregor) is a predator, which primarily attacks spider mites, but also feeds more generally on many leaf inhabiting mites or other small insects and pollen. It is tolerant and active at both high and low temperatures, and low humidity, but prefers warm to hot conditions where it can reproduce very quickly.

Mite *N. californicus* is pear-shaped, buff to tan in color and <1 mm long. It is nearly related in look to *N. cucumeris*. Males are greatly smaller and darker brown than females, with females commonly more abundant (**Figure 4**). The female lays ovate, pure white eggs singly or in clusters on underside of leaf, frequently on leaf hairs or else at the junction of veins. The laid eggs are bigger than those of spider mites. These hatch 1–2 days afterward and pass through a 6-legged larval and two 8-legged nymphal stages to become mature. The life-cycle from egg to adult is temperature reliant, however under greenhouse situations it varies from 4 to 10 days. The adult females live about 20 days and lay three eggs per day, commencing after 2–3 days. Pollen is its maintenance food only, however this can helpful for establishment and persistence in the crop at what time pests are short. In the deficiency of food, predator scatters over the crop and on the ground examining for new prey, however a lot of will halt in crop and wait for the appearance of new prey [56, 57].

Predator *N. californicus* is a promising agent for successful *T. urticae* (two-spotted spider mite, red spider mite) control through conservation techniques in strawberry; *Panonychus citri* McGregor (citrus red mite); *Tarsonemus pallidus* Banks



Figure 4.
Neoseiulus californicus.

(cyclamen mite, strawberry mite); *P. latus* (broad mite, yellow tea mite, citrus silver mite); *Raoiella indica* Hirst (red palm mite); *Brevipalpus* spp.; *Panonychus ulmi* (European red mite, fruit tree red spider mite); *Tetranychus cinnabarinus* (Boisduval) (carmine spider mite, cotton red spider mite) in flowering crops; fruit-bearing vegetables; ornamentals (protected); spice crops; berries; and grapes. Promoting preservation of *N. californicus* can furthermore be done on an extensive range of crops. Appropriate crops comprise ornamentals (gerbera, chrysanthemum, rose), vegetables (capsicum, eggplant, cucumber) and herbs. It is frequently used in greenhouse crops production, however, can as well be used in the field, mostly fruit crops like as pome, melons and stone fruits [58].

Californicus works in the superlative form while used preventatively, or else when spider mites are initially observed in the crop. It establishes the best early in the crop and when is permitted to build up prior to spider mites found. Predator *P. persimilis* ought to be used for quicker knockdown of spider mites for the period of modest temperature and high humidity circumstances, however wherever situations are identified to be hot or dry later in the year, it is recommended to discharge and settle the species early in the crop cycle. If spider mite numbers are already high, it is desirable the usage of a non-disruptive miticide to lower the population prior to release or after establishment for helping in pest control. Residual broad spectrum insecticides should not be used for at least 4 weeks prior to predator release. Use *N. cucumeris* preferentially for broad and cyclamen mites, though *N. californicus* will assist in pest control and may be more effective at higher temperatures [59, 60].

Californicus are primarily sent in a loose, vermiculite-based medium and the predator should be distributed evenly through the crop on foliage, with additional material at ends of rows and in hotter areas prone to spider mites. Rates will vary depending on the crop and infestation level, however, the subsequent rates have been determined as preventative @ 25/m² (2.5 L/ha) releasing 2 weeks apart for 2–3 releases, and after spider mite detection 100–200/m² (10 L/ha) weekly for at least three applications.

2.5 Swirski mite *Amblyseius swirskii* (Athias-Henriot)

The species *Amblyseius* (*Typhlodromips*) *swirskii* (Athias-Henriot) is considered a generalist predator and readily consumes small soft-bodied arthropod pest species as well as pollen or plant exudates. It can be found on various crops including apples, apricot, citrus, vegetables and cotton. It has attracted substantial interest as a biological control agent of mites, thrips and whiteflies in greenhouses and nursery

crops. This species is documented to feed and reproduce on a wide range of prey from several orders, including thrips (western flower, onion, melon and chili), whiteflies (greenhouse and silverleaf) [61], and plant feeding mites (spider, broad and eriophyoid) [62, 63]. It mainly feeds on the immature stages of thrips and whitefly, although it also attacks the adult stages of smaller pest species. A recent study documented *A. swirskii* feeding and probably reproducing on immature Asian citrus psyllids. Adult predatory mites search for their prey or wait for it to pass by and then suck it dry [64].

Adults are pear-shaped, 0.5 mm in length with an unsegmented body and four pairs of long legs, and males may be slightly smaller than females (**Figure 5**). The eggs are round and transparent white and measure approximately 0.15 mm in diameter. These mites lay their eggs on leaf hairs (trichomes) and along the veins on the inner surface of leaves mainly at the intersection of main and lateral ribs. Females prefer to lay eggs on leaf hairs on the underside of plant leaves near plant domatia (small hairy tufts or pockets found on the lower surface of some leaves), which may be an adaptation to avoid egg from predators. The eggs hatch in about 3 days later. Larvae are pale white to nearly transparent in color and only have three pairs of legs. Mobile stages are beige-pink, droplet shaped and 'pushed down' position on short legs. The protonymph (second stage) and deutonymph (third stage) have four pairs of legs and are darker than the larvae. All stages can be found in the corner of main vein and lateral veins, and in the flowers [65, 66].

In addition to arthropod prey, *A. swirskii* can survive and reproduce on various pollens and gain nutrition from plant nectars, which may allow them to persist during periods of low pest density and improve their effectiveness as biological control agents. Development of *A. swirskii* is influenced by type of food (prey, pollen and plant exudates) as well as availability of food and environmental conditions. Mites develop between 18 and 36°C and at 60% relative humidity [67]. By feeding on prey, the egg to adult development period at 25°C is around 5 days [68]. Mite *A. swirskii* feeding on live prey develops faster and lays more eggs when compared with pollen-feeding *A. swirskii*, for example, females laid 26 and 38 eggs on pollen and mite diets, respectively. When not actively hunting, *A. swirskii* is typically found on the underside of leaves along the midrib or in other protected locations such as domatia [69].

Species *A. swirskii* is commonly used to control whitefly and thrips in greenhouse vegetables (especially cucumber, pepper and eggplant) and some ornamental crops, and other pests on citrus and other subtropical crops. The mites are released directly in the crops in bran or vermiculite carriers sprinkled on the leaves or substrates, or may be broadcasted via air blast or other automated distribution technique. The recommended release rates are typically between 25 and 100 mites per m² depending on pest species, pest density and type of crop [70, 71].



Figure 5.
Amblyseius swirskii.

2.6 *Amblyseius (Neoseiulus) barkeri* (Hughes)

The predatory mite *Amblyseius barkeri* (Hughes) [= *A. mckenziei* Schuster and Pritchard] has played important roles in biological controls of thrips in glasshouses with cucumber and cabbage, and also feeds on tetranychid, tarsonemid and eriophyid mites, and pollen of various plants. In appearance, adults species of predaceous mites *A. barkeri* are small and reddish-brown in color (**Figure 6**). Mobile stages are pale-pink, droplet shaped and have 'pushed down position' on short legs. Mite *A. barkeri* in the field is indistinguishable from *N. cucumeris* and *N. californicus*. It is smaller than *N. cucumeris* and is therefore better suited as a predator for broad mites, which often live in tight and small crevices [72].

The eggs are oval, transparent white and around 0.15 mm in diameter. All stages can be mainly found in the corner of main vein and lateral veins, and in the flowers. When fed on *T. tabaci*, at 25°C, *A. barkeri* exhibited a mean time of 2.2, 0.8 and 3.2 days for the egg, larval and nymphal phases, with mortalities at 1.0, 1.0 and 3.1%, correspondingly. Females denoted 63% of the total population and needed several copulations for optimum fecundity. The oviposition time is 20.3 days and the mean oviposition rate 2.3 eggs per day, while the intrinsic rate of increase is 0.22 per day. The estimated life span is 29.6 days for male and 27.4 days for female. Both male and female *A. barkeri* devoured 3.3 nymphs of thrips per day (average value for the feeding stages), whereas the larva does not consume diet. Without thrips diet, *A. barkeri* is capable of consuming adults broad mite *P. latus*, two-spotted spider mite *T. urticae* and their eggs, and pollen of many plants. Cannibalism has been detected within *A. barkeri* at what time food is deficient [73, 74].

The predacious mite *A. barkeri* as well accomplished its life cycle when fed on eriophyid mite *Eriophyes dioscoridis* Soliman and Abou-Awad and tetranychid mite *T. urticae*. The growth is not accomplished while the phytoseiid mite fed on pollen grains of *Phoenix dactylifera* (L.), and *Ricinus communis* (L.), as an alternative food material. The adult female everyday devoured 17 and 102 individuals of *T. urticae* and *E. dioscoridis*, respectively. The day-to-day reproduction rate is 1.3 eggs per day after nourished on eriophyid mites, whereas the number of eggs laid improved (1.9 eggs per day) while fed on tetranychid mites [75].

It is used against various thrips species and broad mite as well as other tarsonemid mites in greenhouses and indoor plantscapes. It works well on *P. pallidus* (cyclamen mite) and *P. latus* mites (broad mite, yellow tea mite and citrus silver mite). Mites pierce the instars of their prey and suck out the internal organs to eat, but do not eat adults. It is found as wild populations on cut flowers (orchids,



Figure 6.
Amblyseius barkeri.

bromeliads and roses), on vegetable crops (capsicum) and strawberry. Adult predatory mites and nymphs suck young thrips larvae and multiple stages of broad mite. Predator can also eat pollen of peppers and eggplant and thus build its population in these crops [34].

2.7 *Amblyseius andersoni* (Chant)

Mite species *Amblyseius* (*Typhlodromips*) *andersoni* (Chant), is a polyphage, and the predator is able to consume alternative food sources such as young larvae of thrips, flower pollen, fungi and the sugary excretions of other pests. This predatory mite is ideal for vegetables, hardy ornamentals and fruit crops, for controlling red or two-spotted spider mite, fruit-tree red spider mite, and russet mites. An adult predatory mite has light beige color and a size of 0.5–1 mm long (**Figure 7**). The female of the mite lays several eggs every day on the underside of a leaf near its veins. Adult female mites lay eggs singly onto leaf hairs and approximately 30–35 eggs are laid during the whole life cycle, and these hatch after 2–3 days to give rise larvae. Young larvae have six legs, while the next two nymph stages have eight legs (like an adult). The complete transformation from an egg to an adult ordinarily takes 8–11 days at 68–77°F (20–25°C). Entirely, the mobile stages are predatory in nature, and these will forage on adults, juveniles and eggs of spider mites. As per temperatures decline, and days turn out to be smaller, in initial autumn, mites will come into a diapause so these can magnificently persist winter situations. Mites are described to become active once more as early as January, however this is influenced by food and temperatures accessibility. The healthy adult of *A. andersoni* lives for about 3 weeks and consumes various food sources [76, 77].

Predatory mite *A. andersoni* is a predator that forages on several kinds of tiny arthropods prey and pollen. It is broadly described as a predator of spider mites on fruit crops such as grapes, raspberries, peaches and apples, and many conifers. This predatory mite feeds on numerous diverse pest mites such as gall mite, russet mite and spider mite. Its foremost target pests are spider mites *Tetranychus* spp., (*T. urticae* and *T. cinnabarinus*), broad mite and cyclamen mite (*P. latus* and *P. pallidus*), European (or citrus) red mite (*Panonychus* spp.), broad mites and Eriophyid mites including the tomato rust (or russet) mite *Aculops lycopersici* Masee (Eriophyidae). These mites can also survive on young larvae of thrips, flower pollen, sugary excretions from pests and fungi, and gall midges, so, these can be introduced before the prey is present. These feed on and control all stages of phytophagous mites with all mobile life stages of *A. andersoni* to forage on prey. It is an excellent choice for pre-emergent control of pest infestations because of their varied diet and ability



Figure 7.
Amblyseius andersoni.

to survive in cooler temperatures. These have a wide temperature tolerance of 43–104°F that makes *A. andersoni* an easy choice for preventative mite control in commercial garden [78, 79].

This predator works well on both inside protected crops and outside in ornamental crops, fruit trees, horticulture, nurseries and seedbeds. The invasion of the predator is realized under the low mass and the average density of 0.25–1 individual per 1 m² of pest population in amounts. Based on the focuses of pest populations, the rate of predator application is increased. This predatory mite is suitable for biologically controlling of some mites. For scouting, if some agile-looking mites are seen running quickly across the leaf's undersurface, these are probably predators. One predatory mite per every 6 feet of crop row or 2–3 mites per 10–11 square feet are used. For best results, apply the *A. andersoni* when pest mite numbers are low or use before pest populations have reached high levels. The predatory mites will then be able to feed on small colonies of pest mites and prevent these from growing and causing major damage. Predatory mite is intended as a preventative treatment @ 1 per m² (curative, light @ 2–3 per m² at 5–7 days interval with three frequencies and curative, heavy @ 3–5 per m² at 5–7 days interval with three frequencies). Apply as a preventative treatment or to active mite infestations in vegetable crops, strawberries, raspberries and fruit trees, and it might be a stronger competitor under low humidity conditions [80, 81]. High numbers of this mite overwinter in the ground litter in apple orchards and by transferring such ground litter to young orchards, the population density has been found to be significantly increased in the released compared to control fields [82].

2.8 *Neoseiulus* (= *Amblyseius*) *pseudolongispinosus* (Xin, Liang and Ke)

Mite *Neoseiulus* (= *Amblyseius*) *pseudolongispinosus* (Xin, Liang and Ke) [synonym *Amblyseius* (*Neoseiulus*) *womersleyi* Schicha], is considered as the best native predator of spider mites in China. Among the stages of predator, a high predation rate has been observed in adult that showed more preference towards the eggs and nymphs of *T. urticae* [83] as well as *T. cinnabarinus* [84]. It is very similar to *Neoseiulus longispinosus* (Evans), but dorsal seta S-5 is long (as long as S-4) and barbed in *N. pseudolongispinosus* (Figure 8), while short (much shorter than S-4) and smooth in *N. longispinosus*. The pattern of mating behavior of *N. pseudolongispinosus* summaries that there is a period of male's climbing on the dorsum of the female. A sex attractant produced by female deutonymphs probably played a role only when the sexes physically encounter one another. The average time of a full mating lasted for 183 minutes. Most male *A. pseudolongispinosus* inseminated females with only one endospermatophore transferred to only one of the female spermathecae in single mating. The egg production and oviposition period increased with the duration of copulation. The egg production in single mating that lasted for the whole duration is only half of that in natural mating condition. The ratio of female offspring increased with the duration of copulation and then decreased slightly after 120 minutes [85–87].

Research on the biology of predator *N. pseudolongispinosus* has been carried out by usage of *T. putrescentiae*, reared on flour of soybean (*Glycine max* L.), wheat (*Triticum aestivum* L.), and maize (*Zea mays* L.), as hosts. When *N. pseudolongispinosus* nourished on *T. putrescentiae* reared on diverse foods, it could breed ordinarily and accomplished its growth as magnificently as *T. putrescentiae*. Mean period of egg and nymph development of *N. pseudolongispinosus* continued fastest statistically by means of *T. aestivum* fed *T. putrescentiae* in comparisons with *G. max* and *Z. mays* diets. Average overall longevities of male (20.8, 16.8, and 13.1 days) and the female (29.4, 25.8 and 17.7 days) have been considerably lengthier on *T. aestivum* than on *G. max* and *Z. mays* diets, correspondingly. Average fecundity of female adults



Figure 8.
Neoseiulus pseudolongispinosus.

amplified too on *T. aestivum* daily (3.5 per day), but reduced (2.8 and 1.2 per day) with *Z. mays* and *G. max*, whereas, the total growing time observed 10.1, 11.8 and 12.9 days, correspondingly. A calculation of macronutrients in wheat, soybean and maize flours displayed that wheat has additional ash and carbohydrate, and on the other hand decreased fat and protein contents, as a result, it evidenced as a prominent compound to support greater mite densities [88].

The effectiveness of hunter *N. pseudolongispinosus* as a possible biocontrol means of webworm *Loxostege sticticalis* L., has been investigated. When eggs food offered, total life cycle of predator has been accomplished on an average of 12.75 days for female or male. An average pre-oviposition time of 4.28 days noted in female, oviposition time lasted for 8.71 days, and the mean number of 1.42 eggs day⁻¹ female⁻¹ have been observed [89].

A fenvalerate-resistant strain of *N. pseudolongispinosus* has been selected and evaluated for level of resistance. After 18 selection cycles, the LC₅₀ value is 65 times higher than in wild-type strain. Genomic task showed that the resistance aspect is organized by a distinct and partly prevailing gene. The resistant strain that has an identical intrinsic rate of upsurge as the wild-type strain, might be a valuable biological control mediator of spider mites in the system of an integrated pest management (IPM) [90].

Among the effects of different developmental stages of two spider mite species, for instance, *T. urticae* and *T. cinnabarinus*, predatory mite *A. pseudolongispinosus* preferred for egg followed by nymph, while larva observed the least preferred stage. Fecundity of female fed on egg, nymph or all developmental stages has been noted significantly higher than that on larva [91]. Experiments have been carried out to observe fitness and effectiveness of Phytoseiid mites as predators of carmine spider mite *T. cinnabarinus*, greenhouse whitefly *Trialeurodes vaporariorum* (Westwood) and western flower thrips *F. occidentalis*, under greenhouse conditions in cucumber (*Cucumis sativus* L.), crop. For this trial, predatory mites *Euseius utilis* (Liang and Ke), *Euseius finlandicus* (Oudemans), *Euseius castaneae* (Wang and Xu) and *N. pseudolongispinosus* have been examined for their possibility as biological control agents in treated as well as untreated control. Among all predators, *N. pseudolongispinosus* has proved 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 [92].

2.9 *Cheyletus eruditus* (Schrank)

Predatory mite *Cheyletus eruditus* (Schrank) (Acari: Cheyletidae), generally exists in bulk foodstuff storages, for instance, within warehouses. It is likewise frequently establishes in animal feedstuff, mammal and bird nests, house dust and poultry litter. The food of *C. eruditus* includes a diversity of mites and insects. Altogether, its active life stages in the absence of other prey, are cannibalistic, thus it is a predatory mite that may be used to control storage mites. It is a translucent, pale yellow in color and the male mite is slightly smaller than the female. Its characters state to categorize it as a member of the family Cheyletidae, are the occurrence of a claw on the palp tibia (forming a thumb-claw process with the tarsus) and a big gnathosoma that links the body anteriorly (rather than in the more usual slightly anteroventral position) (**Figure 9**). The two smooth curved setae and two comb-like setae on the palp tarsus are analytical characteristics of the genus *Cheyletus* [93].

The average adult's body length of *C. eruditus* (not including the mouthparts) is approximately 500 micrometers (0.5 mm) for the female (range 440–630 micrometers). The homeomorphic male is smaller, with a range of 280–320 micrometers. The heteromorphic form is about 400 micrometers long. Specific male characters are, the posterior margin of the body is more narrowly rounded than in the female, propodosomal shield is wider than in female, and gnathosoma is proportionally broader and more heavily sclerotized than in females [94].

Eggs are laid in clusters and the eggs have a gluey surface, even though these are not very definitely fixed down, but are lightly bound together with silky strands. Development and fecundity are affected by prey type and environmental situations. Per female, the total number of eggs laid ranges from about 19 to 317. The time taken for an egg to develop to an adult within the temperature range of 12–30°C, decreased with an increasing in temperature. It took 33.8 days at 18.5°C, and at 25°C acquired 15.4 days. At 76% relative humidity and with *Lepidoglyphus destructor* Schrank (grocers' itch mite) as prey, maximum longevity is 107, 67 and 56 days at 18.5, 22 and 25°C, respectively [95].

It is widespread and abundant in grain stores especially those that have significant storage mite problems. Maximum accounts of *C. eruditus* are from stored foods (commonly whole grains and flour) intended for domesticated animal and human feeding. Left over densities frequently persist in storing basins and premises afterward the substances have been removed. It as well establishes in animal bedding, nests of mammals and birds, house dust, poultry litter, and occasionally in field habitats, e.g., soil, haystacks and plant debris. For commercial use, it is reared on storage mites particularly *Acarus siro* (Linnaeus), and is the only biological control agent used to control pest mites in food storage systems, for example, in grain and



Figure 9.
Cheyletus eruditus.

seed stores. Its target pests are mainly various storage mites including the flour mite (*A. siro*)—Astigmata: Acaridae, fodder mite or grocers itch mite (*L. destructor*)—Astigmata: Glycyphagidae, and various spider mites [96].

The maximum frequently faced ectoparasite in captive snakes is the hematophagous snake mite (*Ophionyssus natricis* Gervais). Infested snakes frequently show laziness, behavioral changes (increased bathing time, rubbing against objects), pruritus, dysecdysis, crusting dermatitis (sometimes progressing to abscesses), and anemia and septicemia are special difficulties. In a study to identify the ability of the predatory mite *C. eruditus* to control *O. natricis*, 125 *O. natricis* mites have been placed in separate plastic tubes together with the same number of *C. eruditus* mites. After 48 hours, the survival rate of snake mites noted 6% compared with 92% in the control group. With another experiment, 11 infested ball pythons, with an average of 13 *O. trnaicis* per snake, have been positioned in isolated cages with 1000 *C. eruditus* mites + vermiculite. Only an average of two mites per snake persisted in comparison with 48 per snake in the control group after 15 days [97].

It can be reared in large numbers and this makes it useful in the biocontrol of pest mites that infest harvested cereal and cereal products. For bulk rearing of the predator *C. eruditus* to utilize in an extensive scale biological control of stored food mites, among several resources confirmed, lettuce seeds performed to be the best substrates for this purpose. The suggested process of bulk rearing elaborated that mite batches are retained at 25°C and R. H. 75% in paper bags on 100 g of lettuce seeds. Within 28–35 days, each batch yielded an average of 2100 ± 600 predatory mites without any additional procedures, if the initial predator-prey ratio is 1:100–1:200. The batches can either be used directly in infected stores otherwise retained at low temperature for later use [98]. The results revealed that *C. eruditus* is a mite predator with the highest natural performance in the field, indicating that it is the most pre-adapted species for biocontrol of stored-pest arthropods in grain stores [99].

3. Harmful mites

Although mites are tiny creatures, these could be extremely harmful to cause great trouble for peoples or in other ways inflicting a variety of problems associated to plants.

3.1 Spider mites (Order: Acari, Family: Tetranychidae)

Spider mites (Acari: Tetranychidae), belong to the superfamily Tetranychoida that comprises five families, of which Tetranychidae is the largest. The common name 'spider mites' is so-called because of their ability to produce silken strands as do spiders, which is used to spin webs under that to reproduce and feed. Conversely, the silk glands in mites are situated close to mouth and allied with the mouthparts. From an applied opinion, the silk-producing habit has two vital uses for mites, firstly, falling from foliage and being adjourned from the host on a silk strand permits easy spread by wind and convection currents. Secondly, mats or tents of webbing around the mite colonies provide some degree of protection from natural enemies and treatments with pesticides.

Spider mites appear as tiny moving dots on their hosts by the naked eye. Spider mites are established on a wide variety of vascular plants, comprising shrubs, trees and herbaceous plants, from entirely all over the biosphere. Several horticultural and agricultural crops are affected by these pests, together with greenhouses and field crops, extending from low-growing bushes to fruit trees. Generally, spider mites forage on the lower side of foliage, however will cover the whole leaf surface

while their densities are extraordinary. These puncture the plant cells and extract the cell contents. Their nourishing results in tiny clumps of dead cells and a spotted look of infested foliage. Wilting, leaf distortion, dryness and abscission take place with extended and high population invasions. Disturbance of photosynthesis results in plant growth checking and decrease in produce [100, 101]. Two widely distributed spider mites found on a broad range of plants are mention in the ensuing section.

3.1.1 Two-spotted spider mite *Tetranychus urticae* Koch

Two-spotted spider mite *Tetranychus urticae* Koch, feeds on an enormous variety of plants, including fruit trees, ornamental trees, vegetables, small fruits, shrubs and many species of weeds. The adults are typically pale green in color and adult females <0.4 mm lengthy, and in color greenish yellow having two conspicuous dark spots on either side of the back. As the mite feeds, these spots may become large enough to cover the body (**Figure 10**). Coloring and spots can be variable and may lead to misunderstanding with other mite species. Pest mite *T. urticae* reproduces through arrhenotoky, that is, a form of parthenogenesis in which unfertilized eggs develop into males. Mite overwinters as spotless, orange diapausing female beneath bark at the bottoms of trees or else in rubbish on the plantation floor. Shortly prior to bloom, these transfer to renewed shrubbery (particularly vetch and other legumes) and start nourishing on new green matter. As the climate warms and these hosts shrivel up, mites will transfer into trees, generally invading the middle portion initially. Through this time, these will have return to their characteristic green and spotted summer form and start laying eggs on the underneath of foliage [102, 103].

If a female has mated, the fertilized eggs develop into both male and female mites, if not mated, the unfertilized eggs develop into males. Eggs are shiny spheres, clear to pale green in color, pearl-like and about 0.14 mm in diameter. Eggs are laid singularly, with females depositing 5–6 eggs per day, with a total of 60–100 eggs per female. Eggs hatch in 3–6 days depending on temperature. Eggs hatch into six-legged larvae, then progress through protonymph and deutonymph stages before becoming to adults. Larvae are about the same size as eggs and the only life stage with six legs (protonymphs, deutonymphs and adults are all eight-legged). The octopods deutonymph is generally larger than the protonymph, although similar in color pattern. Larvae and nymphs complete development in 4–9 days depending on temperature and the females have a pre-oviposition period of 1–2 days. Since generations overlap, all life stages can usually be found simultaneously. There can be nine or more generations per year and adults live about 30 days [104–106].

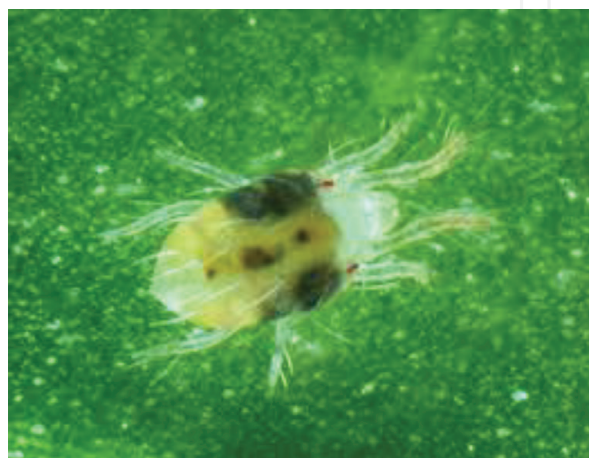


Figure 10.
Tetranychus urticae.

Generally, the earlier a foliage is injured by mites, the more detrimental the damage will be to tree health. Midseason injury is less significant, but can combine with other stresses to cause fruit drop, poor fruit color, or reduced effectiveness of growth regulating chemicals. Some steps for spider mites controlling are scouting for the presence of pest, and noting damage and other signs of growing populations, looking for direct damage and other signs of pest, deciding if and when to take control action, choosing the best tool or tools to treat spider mites in growing situation, making spider mite treatments, and applications of biocontrol agents following the label and producer's instructions [107, 108].

One of the studies investigated the development, fecundity and population density of *T. urticae* on three different species of bean, accordingly, *Lablab purpureus* L., [Papilionaceae: Leguminosae] has been found to be a superior host plant for prey species to further culture predator *N. pseudolongispinosus* [109]. Another study examined the efficacy of four mite predators such as *E. castaneae*, *E. finlandicus*, *E. utilis* and *N. pseudolongispinosus* released for the suppression of spider mite *T. urticae* infesting sweet pepper (*C. annuum*) in greenhouse. When the predatory mites have been released, their establishment remained successful to control the population of spider mite [110].

3.1.2 Carmine spider mite *Tetranychus cinnabarinus* (Boisduval)

The carmine spider mite *Tetranychus cinnabarinus* (Boisduval) has the largest host range of all Tetranychidae species and is undoubtedly of greatest economic importance. The carmine spider mite has a worldwide distribution and invades approximately 100 cultured crops and weeds. It is a severe pest on eggplant, beans, pepper, cucurbits, tomatoes and various other vegetables. It is as well a pest of papaya, passion fruit and numerous further fruits. This mite also invades several flowers and ornamental plants such as chrysanthemum, carnation, cymbidium, marigold, gladiolus, rose and pikake. Nymphs and adults forage mainly on the undersides of the foliage. The upper surface of the foliage converts to stipple having the tiny dots, which are the nourishing ruptures. This pest have a habit of feeding in 'pockets' frequently adjacent to midrib and veins. Silk webbing formed by this mite is typically noticeable on host. The attacked foliage ultimately turn out to be bleached and discolored, and may drop off. The heaviest damage has been noted on glasshouse tomatoes, but the species is also frequent on other host plants such as cucumber, capsicum, aubergine and gerbera [111, 112].

The carmine spider mite is closely related to two-spotted spider mite *T. urticae* and it is difficult to distinguish both from each other in their immature stages, but its adult stage is bright red in color and more commonly found on vegetable crops than in ornamentals. Adult females are about 0.4–0.5 mm long, reddish and more or less elliptical (**Figure 11**). The males are slightly smaller than females and wedge shaped. These have a black spot on either side of their relatively colorless bodies. All stages of this mite are present throughout the year and their reproduction is most favorable when the weather is hot and dry. The adult female may live for up to 24 days and lays about 200 eggs. These eggs are laid singly on the underside of the leaf surface or attached to the silken webs spun by the adults. Eggs are spherical, shiny, straw colored and hatch in 3 days. Young larvae are a little bigger than the egg, pinkish in color and bear three pairs of legs. This stage lasts for a small period and the duration may be 1 day. There are two nymphal stages such as the protonymph and deutonymph. The nymphal stage varies from the larval stage by being somewhat bigger, having reddish or greenish color with four pairs of leg and lasts about 4 days. The carmine spider mite normally completes a life cycle from egg to adult in about 1 week [113].



Figure 11.
Tetranychus cinnabarinus.

Development times of the carmine spider mite *T. cinnabarinus* have been evaluated in the laboratory on excised leaf disc of lablab bean *Dolichos lablab* L., at $30 \pm 2^\circ\text{C}$ and $70 \pm 5\%$ relative humidity. Total development times from egg to adult stage have been noted 7.33 ± 0.13 days. The pre-oviposition period, oviposition period and post-oviposition period noted 0.5 ± 0 , 8.05 ± 0.14 and 0.65 ± 0.07 days, respectively. Fecundity averaged 42.5 ± 1.7 eggs and longevity lasted for 9.2 ± 0.13 days [114].

The major natural predator of the carmine spider mite is a ladybird beetle *Stethorus vagans* (Blackburn) (Coccinellidae: Coleoptera), which feeds on all stages of these mites and in laboratory conditions each individual beetle consumed an average of 2400 mites [115, 116]. There are a number of predaceous mites, such as *Phytoseiulus macropilis* (Banks) and several species of predatory thrips that are also effective on many crops in controlling of carmine spider mites. In orchards, it may be possible to maintain natural enemy's populations and use of sulfur to control mites in the field [117, 118].

In a study, the populations of *T. cinnabarinus* persisted greater (1.77 and 1.40 per leaf) in Bt than non-Bt varieties subsequent to insecticides usage for the control of cotton pest complex. The useful mite *N. cucumeris* persisted as vigorous in both Bt and non-Bt varieties, however Bt cotton has somewhat greater sums of the predator than non-Bt cotton (0.58 per leaf and 0.40 per leaf, respectively) to be used in creating new resistant cotton varieties as a component of an IPM strategy [119]. Biological control of the mite *T. cinnabarinus* in an open-field cotton crop (*Gossypium hirsutum* L.), by releasing the predatory mite *N. pseudolongispinosus* (Phytoseiidae) has been investigated. 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 [120].

3.2 Mould mite *Tyrophagus putrescentiae* (Schrank)

Mould mite or cheese mite *Tyrophagus putrescentiae* (Schrank) in the family Acaridae, is a cosmopolitan species occurring throughout the world in a wide range of habitats, including foodstuffs, plant and animal materials, grasslands, old hay,

mushrooms, and the nest of bees and ducks. It is a common pest of stored products, especially those with a high protein and fat contents including grains, nuts and seeds, and feeds on the fungi that grow on the foodstuffs [121]. The research found that *T. putrescentiae* is a fungivorous storage mite that can grow and flourish well on dog food. The study demonstrated that the presence of mould positively influences mites viability and low relative humidity can result in detrimental consequences for *T. putrescentiae* [122]. Storage mite colonizes different human-related environments and feeds on various post-harvest foods. This mite is a pest of many foods and has been found, in wheat flour, wheat germ, soy flour, inter alia, rye bread, cheese, white bread, mixtures of wheat, barley and oats, straw stacks in the field, various fruits (including dried bananas), dried milk, ham, and decaying animal and vegetable matters [123]. Mites directly endanger human health due to allergenic contamination of food, are vectors of toxicogenic fungi and thus indirectly contribute to contaminate food and feed with mycotoxins. These also cause significant grain weight losses and decrease of germination ability [124].

This mite is 0.2–0.5 mm in length and has a minute translucent body with nearly colorless legs and mouthparts. These besides have a scale on the last terminating segment of the legs. To a certain degree, their slim bodies endure a sequence of hairs, which are more frequent and lengthier than those on *A. siro*. On the underneath of the male's body, there are two dome-shaped suckers arranged on either side of the anus (**Figure 12**). The study conducted to throw some lights on the effect of some food stuffs on the main biological aspects of the Acarid mite *T. putrescentiae* at 25°C and 75% R. H., indicated that there is a slightly significant difference between the incubation period of female and food types. The females reached to maturity (life cycle) in 11.1, 12.5, 13.3 and 14.0 days when fed on wheat flour, milk powder, fish powder and granular chicken feed, respectively. Female longevity is the longest on wheat flour (39.0 days), while recorded the shortest time on fish powder (25.1 days). The female needed 34.6, 30.4, 22.8 and 21.0 days for egg deposition, respectively. The highest number of deposited eggs is recorded on wheat flour (39.0 eggs), while the lowest with fish powder (27.8 eggs) as feeding source. However, the male life cycle duration is significantly affected by the food type, as it averaged 9.8, 10.3, 12.4 and 13.2 days on the aforementioned diets, respectively. Male adulthood is the longest on wheat flour (28.7 days), while decreased to 17.0 days on fish powder. The male life span lasted for 38.5, 34.2, 31.2 and 30.2 days, when fed on the above mentioned diets, respectively [125].

Under optimum conditions, a generation can be completed in 8–21 days. As the temperature falls, the length of the life cycle increases greatly. This mite will tolerate high temperatures, and the larval stage is particularly susceptible to low and high



Figure 12.
Tyrophagus putrescentiae.

temperatures with 93.6 and 54% mortality at 10 and 34°C, respectively. Unlike *A. siro*, it does not produce a hypopus stage. Under ideal conditions, with temperatures above 30°C (86°F) and humidity above 85%, it can complete its life cycle in under 3 weeks [126].

Laboratory investigations on the biology of *T. putrescentiae* have been conducted using the flour of soybean (*G. max*), wheat (*T. aestivum*) and maize (*Z. mays*) as hosts. Life stages of *T. putrescentiae* (egg, larval, protonymphal and deutonymphal) have faster development rate that fed on *T. aestivum* compared to those nourished on *Z. mays* and *G. max*. Higher fecundity of *T. putrescentiae* has been observed (23.8 eggs) on *T. aestivum*, in comparison to the other diets experienced (17.1 eggs on *Z. mays* and 11.4 with *G. max*), longevity of female averaged 34.1, 27.0 and 40.8 days, whereas male longevity distinguished as 23.5, 18.7 and 28.7 days when reared on *Z. mays*, *G. max* and *T. aestivum*, respectively. On a food of *T. aestivum*, the average generation period of *T. putrescentiae* from egg to adult lasted for 11.7 days corresponding to 15.2 and 18.8 days after served with *Z. mays* and *G. max*, and net population growth known as 119.0, 61.0 and 32.0 mites per gm of substrate, respectively [88].

An IPM strategy has been developed to manage infestations of mould mite in stored animal feed, due to the increasing importance as pest of storage facilities and feed processing. This approach includes some features such as adopting striking hygiene practice in and around the processing and storage facility, controlling the moistness content of the processed feed to 12%, rejection of infested grain at the receiving point, and admixing vegetable oil to some feed (2% w/w). Moreover, seven contact insecticides and phosphine fumigant for their effectiveness against the mould mite have been evaluated to measure their potential integration into the IPM tactic. Amongst these, pyrethrin synergized with a newly developed bacterium-based material spinosad, piperonyl butoxide and insect growth regulator s-methoprene controlled the mites. Moreover, the fumigant phosphine at 1 mg/L over a 6 days exposure period also controlled these mites. Until now, the IPM tactic, has resulted in a complete eradication of the mite population in this particular case of stored animal feed [127].

Even though, the predatory mites aggressively feed on many pest species, their reproduction and dispersion to cover the affected area and time spent in prey searching can slow the mites management. Because of this limitation, *N. cucumeris* is commonly used as a precautionary controller device and can deliver a competent control of pest in its initial stage of invasion. This predator can be combined with some of the chemical insecticides (flonicamid, buprofezin, fenoxycarb, pymetrozine) for the ecologically managing of several pests. Conversely, chemical like bifenthrin, abamectin, cyfluthrin, acephate, esfenvalerate, chlorfenapyr, spinosad, fipronil, thiamethoxam and imidacloprid can be lethal to life stages of *N. cucumeris*. Within a production system, a planned rotation of *N. cucumeris* by benign insecticides can decrease the general usage of severe chemistries and interrupt the insecticide resistance selection in a pest population [128].

In the case of multiple pests inhabiting different plant parts, a higher rate or multiple predator releases may be required to achieve the desired level of control. In some natural pest control programs, various predator species are released to manage a single prey species. Whereas, in some circumstances, release of multiple species may offer a well control, while in other cases species may interact with each other for a possible negative outcome on biological control package. In a study, intraguild predation has been evaluated between three phytoseiid species, *P. persimilis*, *A. swirskii* and *N. barkeri* in laboratory situations in either presence or absence of *T. urticae* and/or pollen. Adult females of entire three predator species revealed higher predation rates on larvae than on the other immature stages. Mite predator *P. persimilis* did not forage on the nymphal stages of the other two phytoseiid species, whereas *A. swirskii* and *N. barkeri* fed on all juvenile stages of the two

others. Females of *A. swirskii* devoured more phytoseiid larvae than did the other two species. On the other hand, the predation of the three female species on immature stages reduced considerably when prey/food has been added to experimental units. Results advocate that three species, *P. persimilis*, *A. swirskii* and *N. barkeri* are possibly prone to intraguild interactions with each other, and *A. swirskii* is the durable intraguild predator. The outcomes of this study may be supportive in choosing of effective biological control approaches against spider mites [129].

Predator mites are most effective when applied at the first sign of a mites or insect pests infestations. These will typically turn out to be established in the crop afterward one introduction, wherever there persist either mites or pollen for diet. When prey become infrequent, for example, *N. fallacis*, transfers to the upper portion of the plant and commonly scatters all over the crop by the wind or on air currents. Once predators are set up on some infested foliage, it is generally meaning that the biological control package will be fruitful. It may take another 2–6 weeks for new plant growth to display improvement, reliant on growth degrees. For best results in field crops, placing higher numbers of predators on the prevailing upwind side of the crop will increase their dispersal throughout the crop via wind. In greenhouses, natural enemy *Persimilis* should always be applied along with *Fallacis* predator [130].

4. Conclusion

Ongoing studies include the biology and ecology of some mite predators along with pest mites and how biotic and abiotic factors affect pests and their natural enemies. To cut a long story into short, from lookout of biological control of pest mites or insect pests, the knowledge on biology and ecology of some predacious as well as harmful mites is undoubtedly important. A successful management plan requires information about a species biology including its diet, lifecycle and mass releases of predator, how it interacts with the environment and with other species as well as species behavior and how the behavior of both pests and beneficial enemies can be manipulated to reduce or prevent yield losses. Information of the biology and ecology of mite pests and their natural enemies contained in the chapter is a prerequisite to keep a minimum economic impact of pests, eliminate pest menaces by organic pest controlling and implement efficient plantation protection practices with modern thinking on environmental problems.

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