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Biological Control Methods for Agricultural Mites: A Review

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ABSTRACT

Agriculture is the most important economic activity around the world with its contributions reflected by its share in the gross domestic product of countries. It ensures food security, provides raw materials for many industries and employment opportunities. Today, pest and diseases are among the main challenges plaguing the agricultural sector. More specifically, phytophagous mites are devastating many economically important crops worldwide. *Tetranychus urticae* Koch (Two-spotted spider mites), *Raoiella indica* Hirst, (red palm mites), *Polyphagotarsonemus latus* Banks (broad mites) and *Panonychus ulmi* Koch (European red mites) are widely known for their extensive damage to crops. To control these mites, farmers have incorporated the use of pesticides into their farming systems. However, chemical control comes with many problems such as insect resistance, detrimental environmental effects and various human health implications. As such biological control is an environmentally friendly alternative that uses bio-control agents such as predators, pathogens and parasitoids to control pests. In this review, it was found that predators and pathogens were the most widely used biocontrol agents, specifically, the *Amblyseius spp*. Berlese were most effective and widely documented. The available literature also suggests that for successful control of agricultural mites *via* biological control, there needs to be a clear understanding of the behaviors of these mites and the bio-control agents used.

Key words: *Amblyseius spp,* Biological control, Phytophagous mites, *Raoiella indica, Tetranychus urticae.*

Agriculture is the backbone of many economies given its major contributions to many sectors that cater to the basic needs of humans (Praburaj, 2018). The global value of agriculture is estimated to be 2.4 trillion US dollars, with employment provision for approximately 1.3 billion people worldwide (Alston and Pardey, 2014). Developing and underdeveloped nations dominate this sector which in turn provides their economies with much-needed GDP (Freire, 2014). Despite the widespread modernization of agricultural development, the industry is still faced with issues such as urban development, irrigation, natural disaster, pest, diseases, *etc*. (Makal *et al*., 2017). Pests and diseases pose a serious threat to food security as they damage crops and increase the demand for produce. Changes in climate compound this threat because pests are constantly migrating to new environments with favorable conditions (FAO, 2017).

Mites are a diverse group of insects that have been destroying and devastating the agricultural industry for many decades. They are categorized in the class Arachnida, subclass Acari and families Tenuipalpidae, Tarsonemidae, Tetranychidae and Eriophyidae (Baker and Wharton, 1958). They also occupy a wide range of habitats and a wide range of hosts including vegetable and ornamental crops (Al-Atawi, 2011; Boczek and Kropczynska, 1964). Mites cause damage by piercing plant cells with their mouthparts and sucking the plant juices (Bensoussan *et al*., 2016). Common symptoms of mite infection include yellow/ whitish spots on the leaf tissues and the formation of small webs (Jeppson *et al*.,1975).

Effects of these pests can be seen in industries such as soybean, which was devastated between 2005-2006 in the state Rio Grande do Sul, Brazil, by spider mites that attacked areas with and without chemical control and resulted in losses of 270 kg ha on average in soybean production (Arnemann *et al*., 2006). Symptoms of this infestation included white and yellow spots on the leaf surface while severe effects included premature leaflets, accelerated maturation and reduced grain yield (Dehghan *et al*., 2009). In 2009, the coconut industry in Brazil also suffered more than 70% losses in production due to the effects of the red palm mite (RPM) which were already dispersed in Martinique, Antilles islands and Trinidad (Rodrigues *et al*., 2020). Further studies on eggplant and tomato crops by Maina *et al.* (2014) on spider mites around the Lake Chad Shore Area of Nigeria showed that farmers experienced more than 50% yield losses (Maina *et al*., 2014). Renkema *et al*. (2017) reported the grievances of strawberry growers due to the attack of Broad mites during the 2015-2016 growing season and its increase in 2016-2017. Symptoms of the mite infestation include stunted plants, curling of young leaves, darkening of leaf petioles, yellowing, *etc*. Plants showing such symptoms were recorded in five

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strawberry fields with <1% of each field area affected. Yong-Heon (2002) investigated the control of two-spotted spider mites (TSSM) destroying strawberry crops in Korea. The excessive use of pesticides to control these mites resulted in the death of untargeted species (*e.g*., pollinating bees) and the development of strains of TSSM that were highly resistant to all forms of pesticides. Furthermore, these studies found that the control of the pests was almost impossible because of their high fecundity rate, rapid development and rate of development of resistance to miticide (Yong-Heon, 2002).

Pest management is dominated by the use of pesticides which in the long term can cause severe environmental effects, public health concerns and insecticide resistance; hence the need for biological control (Tudi *et al*., 2021; Gangwar, 2017). These chemicals are detrimental to the environment as they pollute the air, water and soils, diminish biodiversity, reduce nitrogen fixation, *etc.* (Mahmood, 2016). Over 98% of sprayed insecticides and 95% of herbicides reach non-target species (Miller, 2004; Follet and Duan, 2000; Robinson *et al*., 1999). Toxic residues from these pesticides may remain in the environment for long periods; continued exposure is associated with immune system dysfunction, neurological dysfunction, reproductive system defects and blood disorders (Miraglia *et al*., 2009; Baker and Wilkinson, 1990). Bio-accumulation and bio-magnification may cause severe effects on human health as organisms at the top of the food chain are most affected (Ali *et al*., 2021; Lee *et al*., 2000).

Biological control is an environmentally friendly, sustainable and effective method of managing pests (Routray *et al.,* 2016; Bale *et al*., 2008). This method is inexpensive, does not affect non-target species, environmentally friendly and involves a safe application and bio-control agents that can enhance root and plant growth by encouraging beneficial soil microflora (Sharma, 2013; Waage and Greathead, 1988). Bio-control agents include predators, parasitoids, pathogens and competitors (Kamal *et al.,* 2015). It typically involves active human management. The history of biological control is divided into 3 periods; (1) preliminary efforts when living agents were released haphazardly with no scientific approach (2) the intermediate period (3) the modern period where there is now careful planning and evaluation of natural enemies (Polanczyk and Pratissoli, 2009; Van Driesche *et al*., 2008). In this paper, we analyze and synthesize results from previous studies on the biological control of mites in the agricultural field. We specifically examine different methods of biological control and their effectiveness in regulating agricultural mite populations.

The broad survey of the literature indicates that biological control can be successful in eradicating agricultural mite populations. Over the years, there have been major developments in biological control as scientists work to find a balance between food production and conserving biodiversity within the environment for present and future generations (Ghosh, 2011). The excessive use of agrochemicals/ pesticides can have serious implications on human health and the environment (Mahmood, 2016; Baker and Wilkinson, 1990); hence most published articles emphasized the need for biological control as it is a step toward a 'greener' world (Sheppard *et al*., 2019; Bale *et al*., 2008). Successful bio-control programs require adequate knowledge of population dynamics of pest/predators, endemic species, seasonality of species, generation time and the ability to be mass-reared, among other areas of knowledge surrounding pest biology and ecology. Analysis of the publications identified the following key concepts: (i) predators, (ii) pathogens and (iii) parasitoids as biological control agents. Further, Hoy (1986) outlined the criteria for successful predator release as the potential of the agent to manifest after release, survive spray routines and manipulate target pest populations. Al-Atawi (2011) identified the four families of phytophagous mites that cause economic damage to crops: Tetranychidae Tenuipalpidae, Tarsonemidae and Eriophyidae as shown in Table 1.

Pathogens

In Mexico, the citrus rust mite, *Phyllocoptruta oleivora* Ashmead was a major pest of citrus fruits and caused decreased production in the industry (Vanoye-Eligio *et al*., 2017). Acosta-Robles *et al.* (2019) evaluated the effect of concentrations of *Beauveria bassiana, Metarhizium anisopliae* and *Isaria fumosorosea* on mortality and growth rate of *P. oleivora* populations under greenhouse conditions. The results indicated that *B. bassiana* and *M. anisopliae* were efficient in controlling the citrus rust mite populations under greenhouse conditions as the growth rate of the mites under these pathogen treatments was lower than that of the control. In both treatments, the higher concentrations were

Table 1: Phytophagous mites and crops affected.

Family	Species	Common name	Crops affected	Author
Tenuipalpidae	*Raoiella indica*	Red palm mites	Coconut, Banana	Carillo *et al*., (2012)
Tarsonemidae	*Polyphagotarsonemus latus*	Broad mites	Tomato, Cucumber, Peppers	Montasser *et al*., (2010)
Tetranychidae	*Tetranychus urticae*	Two-spotted spider mites	Squash, Eggplant, Cucumber	Fasulo and Denmark, (2003)
Eriophyidae	*Vasates quadripedes* *Phyllocoptruta oleivora*	Gall mites Citrus rust mite	Maple, Cherry, Goji berry, Citrus fruits	Xu *et al*., (2014); Vanoye-Eligio *et al*., (2017)

inversely proportional to the mortality of the mites. However, it was evident that *I. fumosorosea* controlled the population at moderate levels as the growth rate of the citrus mites were still below that of the control but higher than that of *B. bassiana* and *M. anisopliae.* In other words, *I. fumosorosea* was not as effective as *B. bassiana* and *M.anisopliae* (Acosta-Robles *et al*., 2019). Parveen *et al.* (2021) in an investigation to screen fungal isolates of *B. bassiana, M. anisopliae* and *Lecanicillium lecanii* against TSSM and broad mites found that both agricultural mites were susceptible to all fungal isolates tested. However, isolates of *B. bassiana* showed the highest mortality in TSSM and *M. anisopliae* showed the same in broad mites. Despite the varying degree of virulence, it was evident that with increased concentrations of fungal isolates there was an increase in the mortality rates of both mites (Acosta-Robles *et al*., 2019). Table 2 further highlights various fungi reported to control agricultural mites.

Locusts and grasshoppers are the most dominant insect pest in dry grasslands and desert areas; often forming large swarms while feeding on crops resulting in massive economic losses and are therefore treated as a national priority (Lecoq and Cease, 2022; Lomer *et al*., 2001; Bullen, 1966). They attack plants such as cotton, corn, wheat and barley (Wright, 1986). Locust outbreaks were recorded in Ethiopia in 1958 amounting to £4 million in losses; later in 1962, Khuzistan also recorded £150,000 in losses and India and Pakistan suffered up to £600,000 in economic damage (Bullen, 1966). To rapidly eradicate these devastating pests chemical control techniques were implemented in areas prone to locusts and grasshopper infestation, as their control is critical to ensuring food security (Zhang *et al*., 2019; Lomer *et al*., 2001). However, with increasing awareness of public health and the negative environmental impacts caused by the excessive use of pesticides, there has been an active effort to implement bio-control techniques. Bio-pesticides from plants and micro-organisms proved to be an excellent alternative as it has high specificity, non-toxic to humans and animals and have little to no negative impact on the environment (Kooyman, 2003). *Metarhizium flavoviride* in water-based formulations was among the first pathogen to be tested against desert locusts in both laboratory and field conditions (Githae andKhuria, 2021). To improve its efficiency, treatments were made in oil formulations. Under laboratory conditions, daily food consumption and flight activity were reduced (Seyoum 1994; Moore 1992).

On the other hand, in field experiments, Langewald *et al.* (1997) saw reduced numbers in swarms and mortality within 10-11 days in open fields and 6-10 days in cages. However, *M. flavoviride* in oil formulations displayed negative impacts on non-target organisms such as bees leading to the use of another entomopathogenic fungus, *M. anisopliae* (Ball *et al*., 1994; Zimmerman, 1993). This fungus kills approximately 70-90% of locusts in about 14-20 days with little to no effect on non-target organisms (Lomer *et al*.,2001). Mohamed *et al*., 2011 conducted a study to investigate the combined effects of Phenylacetonitrile (PAN) and Teflubenzuron with *M. anisopliae* on desert locusts. The results indicated that applying each component at half doses aided in speeding up the rate of fungal infection. This supports reports by Hassan and Charnley (1989) and Joshi and colleagues (1992) who demonstrated that a combination of Metarhizium and insect growth regulator *e.g*., Teflubenzuron can weaken the insect body wall increasing its susceptibility to fungal infection. Furthermore, PAN induces stress upon the insects also increasing their susceptibility to fungal infection (Lecoq, 2001). Therefore, implementing integrated management programs with the use of *M. anisopliae* can be ideal for effectively eradicating locust infection while protecting the environment and ensuring human safety.

Thuringiensin which is a bacterial pathogen was also proven to be successful in controlling agricultural mites (Vargas *et al*., 2001; Royalty *et al*., 1990). During vegetative growth, thuringiensin is secreted externally from *Bacillus thuringiensis* berliner cells into the culture medium (Farkas *et al*., 1969). It acts by hindering the ribosomal DNA-dependent RNA polymerase and competing with ATP for enzymatic binding sites (Mohd-Salleh *et al*., 1980). Toxicity is an expressed process that requires high rates of RNA synthesis *i.e*., high growth rates and physiological processes that occur in immature insects (Sebesta *et al*., 1981). Perring and Farrar (1986) investigated the use of thuringiens in the bio-control of TSSM on melons which resulted in no control of the pest population. Later, Royalty *et al*., (1991, 1990) discovered low mortality after three days in the immature stages of TSSM and European red mite (ERM) which were more susceptible than adults. Vargas *et al.* (2001) conducted an experiment that involved the comparison of the direct

Table 2: Bio-control for agricultural mites using fungi.

Host	Fungi	Method of application	Results	Author
Tetranychus urticae	*Beauveria bassiana*	Dust formulation	71% mortality	Dresner, 1949
Tetranychus urticae	*Beauveria bassiana*	Sprays	95% reduction	Chandler *et al*., (2005)
	Metarhizium anisopliae			
	Hirsutella thompsonii			
	Lecanicillium lecanii			
Tetranychus evansi	*Beauveria. bassiana*	Oil formulation	91% reduction	Wekesa *et al*., (2006)
	Metarhizium anisopliae	Aqueous formulation	94% reduction	
Tetranychus urticae	*Beauveria bassiana*	Sprays	94% reduction	Tamai *et al*., (2002)

and residual toxicity of thuringiensin on immature and adult stages of TSSM and ERM, also to determine the effects of the bacteria on the reproduction and population development of TSSM. The results indicated that direct toxicity was higher than residual toxicity to TSSM (Vargas *et al*., 2001). Also, the immature stages for both mites were more susceptible than adults. After adult females of TSSM were exposed to thuringiensin residues for varying periods, fecundity was significantly reduced. Tehri *et al.* (2014) stated that due to the high reproduction rates of TSSM, it is crucial to apply control measures as soon as mite infestation is detected.

Natural enemies

There are several natural predators of agricultural mites including the green lacewings and mites such as the *Amblyseius spp.*, *Stethorus punctillum* Weise and *Phytoseilus persimilis* Athias-Henriot.

Raoiella indica (Red Palm Mite)

Raoiella indica (RPM) was first discovered in Martinique in 2004 (Flechtmann and Etienne, 2004), after which it was rapidly dispersed in the Caribbean Regions: Saint Lucia (2005), Dominica (2005), Trinidad (2006) and Guyana (2013) (Van Lenteren, 2019; Kane *et al*., 2005). In almost all the affected countries, RPMs were prominent on palm trees of the family, Arecaceae, with the coconut palms being more severely affected (Pena *et al*., 2012). The leaves at the base of the coconut tree were the most targeted as they turned pale and yellow and some died completely after the attack of RPMs (Pena *et al*., 2012; Kane and Ochoa, 2006). The immature stages of lacewings of the genus Ceraeochrysa have actively shown to prey on RPMs on coconut palms, hence its potential as a biocontrol agent (Carrillo *et al*., 2012). Afzal and Khan (1978) discovered that one *Chrysoperla carnea* Stephens larvae can consume up to 487 aphids and 511 whitefly pupae before pupation and has excellent searching capacity. Viteri Jumbo and colleagues (2019) assessed the potential of *Ceraeochrysa caligata* Banks, as a biological control agent of RPMs by conducting functional response bioassays. Three stages of RPMs (eggs, immature stages and adult females) were provided to less than 24 hrs old *C. caligata* in coconut leaf arenas. The amount of prey consumed was recorded six hours after releasing the lacewings. They found that the ability of the lacewings to feed on the RPMs increased with larval development (Viteri Jumbo *et al.,* 2019).

Higher feeding levels were recorded for the first and second instars of *C. caligata* when preying upon the eggs and immature stages of *R. indica*. Viteri Jumbo *et al.* (2019) stated that *C. caligata* of different stages exhibited differential functional responses, for example, *C. caligata* second instar individuals exhibited an increase in consumption rate with increasing prey availability (type III functional response) when preying upon immature stages of *R. indica*. However, when preying on the adult females, *C. caligata* second instar individuals exhibited a type II functional response (*i.e*., an increase in consumption rate with increasing prey availability, before reaching a plateau). Predator individuals of the first and third instar stages exhibited a type II functional response for all prey types. As the prey density increased, predatory consumption also increased eventually leading to a decline in the prey population. Therefore, green lacewings can be considered excellent predators/natural enemies of RPM. Hassanpour *et al.* (2009) also evaluated green lacewings as a potential predator against the two-spotted spider mites and found similar results. As the prey density increased, predatory consumption also increased leading to a decline in the prey population. The first and second instar showed a type II functional response *i.e*., as prey density increases, predator consumption increases. However, the third larval instar showed type III functional response *i.e*., responding to high levels of prey density in a density-dependent manner (Hassanpour *et al*., 2009). According to these studies, we can conclude that green lacewings are excellent predators/ natural enemies of RPMs and TSSM.

Amblyseius spp

The phytophagous mites of the *Amblyseius* species were the most effective predators against Red Palm mites, Broad mites, European red mites and Two Spotted Spider Mites. They occupy a wide range of habitats and are generalists feeding on several prey, pollen and plant exudates (McMurtry *et al*., 2015; Carillo *et al*., 2014). Numerous overlapping observations of *Amblyseius* spp. attribute these characteristics to its successes.

Carillo *et al.* (2014) assessed the effects of *Amblyseius largoensis* Muma on *R. indica* using exclusion and release strategies to obtain coconut palms with varying levels of the natural enemy. Four treatments consisting of four rates of release of *A. largoensis* females (0= control, 1:10, 1:20 and 1:30 *A. largoensis*: *R. indica*) were tested. The results showed that the highest reduction of *R. indica* (92%) was observed at the highest predator release rate (1:10 *A. largoensis*: *R. indica*). Meanwhile, the other release rates (1:20 and 1:30 *A. largoensis*: *R. indica*) caused 55% and 43% reductions, respectively in the pest populations. In another study, Carillo and Pena (2011) assessed the potential of *A. largoensis* to control *R. indica* populations by evaluating the predator preferences among *R. indica* developmental stages and estimating predator functional and numerical responses to varying densities of its most preferred prey stage. The results indicated that *A. largoensis* consumed significantly more eggs than in other stages, therefore it was the most preferred stage. Moreover, *A. largoensis* displayed a type II functional response which demonstrated that with increased prey population density there was increased mortality. Hence, the results of these assessments support the hypothesis that *A. largoensis* is an important biological control agent of *R. indica* and should be implemented in Integrated Pest Management programs (Carillo *et al*., 2014).

Furthermore, Van Maanen *et al.* (2010) analyzed the ability of *Amblyseius swirskii* Athias-Henriot to control broad mites on pepper plants in a greenhouse by measuring oviposition and predation. Plants infested with adult female broad mites were used in the experiment. Pollen was used as food by *A. swirskii,* hence, young plants without flowers (without food) and pollen-producing plants were used as a control. The oviposition rate of *A. swirskii,* on a diet of broad mites, was lower than the oviposition rate on a diet of pollen, but higher than oviposition in the absence of food. On average, the predators consumed 8.6 and 10.2 adult female broad mites during the first and second day respectively (Van Maanen *et al*., 2010).

To control ERM and TSSM at peach orchards in Ontario in 1995, Lester *et al.* (1999) released a pyrethroid-resistant strain phytoseiid mite known as *Amblyseius fallacis* Garman. The predator was mass-produced on kidney bean plants and approximately three bean leaves were wrapped in a 'twist tie' around one peach leaf which was infected with two-spotted spider mites. Overall, approximately 1000-2000 predatory mites were released per tree. Throughout 1995, the peach orchard received deltamethrin on seven occasions and additional fungicides as part of a spray program. The initial release of 2,000 *A. fallacis* per tree in June and July 1995 showed an increased density of the predator species than those observed in control trees where no predatory mite was released. However, the release of 1,000 *A. fallacis* per tree in August, did not result in increased abundance. The following year displayed low densities of *A. fallacis* throughout the growing season with increased densities of TSSM (Lester *et al*., 1999). In 1995, *A. fallacis* was established and its abundance increased, however, in 1996 the organisms overwintered and arrived too late to be used as a biological control agent in peach orchards (Lester *et al*., 1999). This study involved spray programs that may have affected the re-emergence of the predatory mite. Hence, the importance of gathering substantial information before conducting such research. Penman *et al.* (1979) recognized a similar trend where *A. fallacis* was introduced in Australia and significantly controlled TSSM and ERM populations affecting apple orchards. Unfortunately, in the following season, Penman *et al.* (1979) observed a decline in predator populations. *A. fallacis* typically overwinters at the base of plants or beneath the ground; after winter they recolonize their way up to the canopy, feeding on prey species present (Johnson and Croft, 1976). This shows that the nourishment of ground cover is important for the survival and renewal of predators (Croft and McGroarty, 1978). Climatic elements, spray routines, low humidity, the presence of other species acting together in a complex food web, *etc.* are all factors that may influence the ability of *A. fallacis* to establish, survive and accomplish biological control (Janssen *et al*., 1998; Berry *et al*., 1991; Boyn and Hain, 1983). The success of *Amblyseius spp.* as a biological control agent is due to varying characteristics as shown in Fig 1.

Sthetorus

Stethorus spp., Weise, commonly known as the lady beetles and belonging to the family Coccinellidae; are well known for being natural predators (Biddinger *et al*., 2009). Chazeau (1985) reported Stethorus beetles present in various regions and ecosystems (tropical rainforests to dry savannahs) with differing climates. The adults and larvae of *S. punctillum* were identified as a potential biological control agent of spider mites in various crops (Roy *et al*., 1999; Hull 1977; Hull *et al*., 1976). Parvin and Haque (2008) investigated the ability of three predators (*Scolothrips sexmaculatus* Pergande, *P. persimilis, S. punctillum*) to control TSSM affecting bean plants in Bangladesh (Takafuzi *et al*., 2000; Herron *et al*., 1993; Helle and Sabelis 1985). The experiment was carried out during three different periods. The bean plants were cultivated in pots and infected with TSSM eight weeks after cultivation. The predators were later released on the plants of group B after one week of mite infestation and on the plants of group C after three weeks of mite infestation; hence plants of group A were considered the control and went untreated (Parvin and Haque, 2008). The results indicated that TSSM populations increased

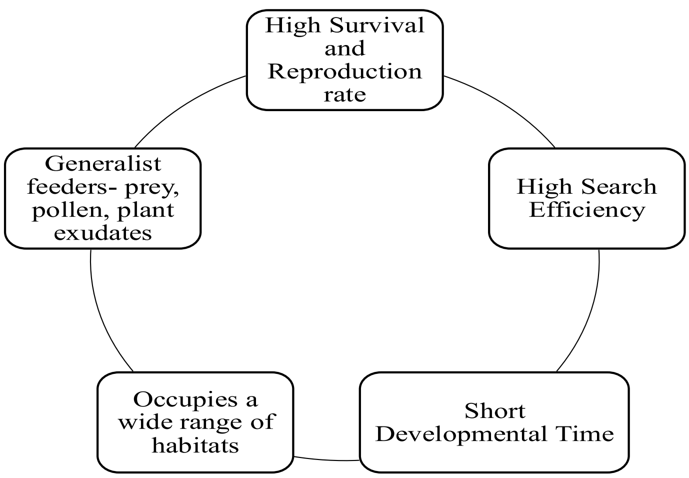

Fig 1: Characteristics that attribute to the success of the *Amblyseius spp*. (Janssen *et al*., 1998; Berry *et al*., 1991; Boyn and Hain, 1983).

Table 3: Bio-control for agricultural mites using predators.

Family	Scientific name	Common name	Vegetable crop/s affected	Predator	Author
Tenuipalpidae	*Raoiella indica*	Red palm mites	Coconut, Banana	*Amblyseius largoensis, Chrysopidae sp.*	Zannou *et al.*, (2010); de Moura *et al.*, (2015)
Tetranychidae	*Tetranychus urticae*	Two-spotted spider mite/ spider mites	Strawberries, Tomatoes, Lemons, Bean	*Amblyseius californicus, Phytoseiulus persimilis Stethorus punctillum*	Rhodes and Liburd, 2006; Roy *et al.*, 1999; Hull, 1977; Hull *et al.*, 1976
Tarsonemidae	*Polyphagotarsonemus latus*	Broad mite	Pepper, Cucumber, Eggplants	*Amblyseius swirskii*	Van Maanen *et al.*, 2010

exponentially up to the sixth week on plants of group A. However, in plants of Group B and C, where the predators were released, the mite population was reduced significantly due to predation. Parvin and Haque (2008) concluded that the early release of the predators reduced the TSSM population earlier in all the cases. Table 3 shows predators of agricultural mites and crops that are mostly affected by the infestation of these mites.

Parasitoids

Despite several studies on parasitoids' ecology and evolution, (Calatayud, 2020; Colmenarez, 2018) no study documented parasitoids' potential to minimize agricultural mite populations. Key gaps lie in the availability of adequate data to understand and resolve challenges for current and future potential biological control programs. Further field investigations will enable more precise attempts at developing control plans since several environmental elements cannot manifest under laboratory conditions. Information on population dynamics throughout a season, dispersion levels and patterns can aid in unpredicted setbacks such as predator species affecting untargeted organisms. In addition, for parasitoids to successfully develop and infect insect hosts, they must be adapted to the physiology, life cycle and defenses of the host (Stoner, 1998). Consequently, increased accuracy of informed control plans leads to less application of chemicals which overall achieves environmental sustenance and improved health and wellness.

Conclusion

Overall, the phytophagous mites causing economic damage to crops were among four families: Tetranychidae, Tenuipalpidae, Tarsonemidae and Eriophyidae. Predators/ Natural enemies were the most successful biological control agent. Predacious mites (*Amblyseius sp.*), green lacewings (Chrysopidae and *Ceraeochyrsa sp.*) and lady beetles (*Stethorus sp.*) can effectively reduce mite populations due to their specificity to the target pest, ability to manifest after release and survive spray regimes. Despite a few challenges experienced with affecting non-target and beneficial organisms, pathogens still proved to be good bio-control agents. Due to a lack of sufficient data, parasitoids' potential to minimize agricultural mites is still unknown. Adequate data on pest/predator population dynamics, generation time, ability to be mass-reared and interaction/relationship with other organisms are essential to fill the gaps and promote biological control as it is an alternative method to promote ecological sustainability.

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