Predatory mites, a green pesticide, and an Entomopathogenic compound: A proposed IPM tactic based on pest species diversity indices and population dynamics

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ABSTRACT

The study was aimed to conduct the population dynamics and diversity indices for three major pest species in order to design an IPM protocol in two experimental sites (Om Saber, Beheira Governorate 30°29'50.6"N, 30°46'18.8"E), and (Kom Oshim, Fayoum Governorate 29°34'40.9"N, 30°55'38.3"E). The resulted data showed statistically significant fluctuation, population dynamics, abundance, distribution, and diversity indices of the two-spotted spider mite (TSSM) *Tetranychus urticae* Koch (Acari: Tetranychidae), the silver leaf whitefly *Bemisia tabaci* Genn. (Hemiptera: Aleyrodidae), and the onion thrips *Thrips tabaci* Lindman (Thysanoptera: Thripidae) which recorded on four plant species belonging to Brassicaceae (Siberian (Russian) kale *Brassica napus* var. *pabularia* L. and Italian (Tuscan) kale *Brassica oleracea* var. *palmifolia*), and Lamiaceae (Spearment *Mentha spicata* L. and Saudi Mint *Mentha longifolia* L.). The proposed IPM program consisted of predatory mites; *Phytoseiulus persimilis* Athias-Henriot, *Amblyseius swirskii* Athias-Henriot, and *Cydnoseius negevi* (Swirski & Amitai) (Acari: Phytoseiidae), a green pesticide, and an entomopathogenic compound. It was concluded that abiotic and biotic factors together help in explaining why various pest species build their communities rapidly and increase their parameters that become above the EIL. Such factors are hypothesized to affect the plant-arthropod, predator-herbivore, predator-predator, and tri-trophic interactions. And it recommends the application of such protocol should consider the timing of tacking an action and merging tactics together to get the maximum efficiency.

KEYWORDS

Plant-Arthropod interactions, Biological Control, Phytoseiidae, Brassicaceae, Lamiaceae, Weed management.

INTRODUCTION

Different kinds of relations between plants and various taxa of arthropods in the Agro-ecosystem, whether plant taxa are, either economic crop, or spontaneous plant. Plant-herbivore interaction is one of the possible forms. It depends on diversified chemical and morphological relations (Frago *et al.*, 2022). Another relation is the Predator-herbivore relation, which is considered a second level of trophic interactions occurring in an ecosystem (Alba *et al.*, 2012; Gardarin *et al.*, 2018). Connecting these interactions together forms a tri-trophic relation, that consisted of Plant-Herbivore-Predator interaction (Verkerk, 2004; Kavitha and Reddy, 2014), and this one we do hypothetically suggest, is the main method of the biological control applications and Integrated Pest Management (IPM) tactics which used to suppress pest infestations.

IPM is a complex of agricultural, chemical, biological, and ecological procedures, as well as, good knowledge about biodiversity and distribution of living organisms within the habitat (El-Shafie, 2019). The most IPM strategy's goal is to prevent pests from reaching economically damaging levels without causing a risk to the environment (Koul *et al.*, 2004; Smagghe and Diaz, 2012). Successful IPM program may have some components such; monitoring crops for pests, pest identifying accuracy, detecting economic thresholds, implementing integrated pest control tactics, and evaluation. The factors that render crop habitats unsuitable for pests and diseases include limitation of resources, competition, parasitism, and predation (Drinkwater *et al.*, 1995; Edwards-Johnes, 2001; Ehi-Eromosele *et al.*, 2013).

The first use of biological control backs to the ancient Chinese at the 3rd - 4th centuries A.D. (Shijiang, 1983). Till now, very large number of predatory and/or parasite taxa been used to control pest infestations that caused massive economic losses (Smagghe and Diaz, 2012). Predatory phytoseiid mites have reported to be successful control means for spider mites (Negm *et al.*, 2014; Alatawi *et al.*, 2018), eriophyids (Momen *et al.*, 2004, 2014; Momen and Abdel-Khalek, 2008; Abou-Ellella *et al.*, 2014; Melo *et al.*, 2015; Abdel-Khalek and Momen, 2022; Ferreira *et al.*, 2022), whiteflies (Teich, 1966; Nomikou *et al.*, 2001, 2002, 2003), thrips (Messelink *et al.*, 2006; Arthurs *et al.*, 2009; Sanad and Hassan, 2019), aphids (Messelink *et al.*, 2013), and they were proven to feed alternative sources as pollen (van Rijn and Tanigoshi, 1999; Abou-Ellella *et al.*, 2014; Delisle *et al.*, 2015 b; Rahmani *et al.*, 2021; Xin and Zhang, 2021), fungi (Zemek and Prenerová, 1997; Momen and Abdelkhader, 2010), or other factitious food/artificial diet to be mass produced (Janssen and Sabelis, 2015; Delisle *et al.*, 2015 a, b; Momen *et al.*, 2020; Xin and Zhang, 2021).

New trends of bio-agents which been used are the Entomopathogenic fungal species, e.g., *Beauveria bassiana* (Bals.) Vuill. and *Metarhizium anisopliae* (Metschn.) Sorokin to control insect and mite pests (Akmal *et al.*, 2013; Wraight *et al.*, 2016). These fungi can inhabit the plant/crop ecosystem; on leaves (Garrido-Jurado *et al.*, 2015), soil (Evans, 1982), or endophytically (Greenfield *et al.*, 2016). These fungi were highly recommended on IPM protocols due to their wide distribution and diversity of hosts in different localities and conditions (Lacey *et al.*, 2015; McGuire and Northfield, 2020).

Another new trend of IPM is using the eco-friendly or green-pesticides, which consisting mainly of natural resources, such plant essential oils and extracts (Isman, 2006; Isman and Machial, 2006; Koul *et al.*, 2008). Plant essential oils were reported to suppress pest infestations on different climatic zones (Regnault-Roger *et al.*, 1993; de Melo *et al.*, 2019; Allam *et al.*, 2020; Ebadollahi *et al.*, 2020).

Some studies have proposed using the mixture of phytosidees, entomopathogenic, and biopesticides to control different pest infestations (El-Saiedy *et al.*, 2008, 2015; Abou-Awad *et al.*, 2017; El-Saiedy and Fahim, 2021). On other side, the climate change factors are affecting different kinds of agricultural pests and beneficial arthropods (Shrestha *et al.*, 2019; Skendžić *et al.*, 2021), these changes affected the biological aspects, prey preferences, distribution, population dynamics, and threaten the IPM applications (Halsch *et al.*, 2021; Karthik *et al.*, 2021). Therefore, this study was aimed to conduct the population

dynamics and diversity indices for three major pest species infested four Brassicaceae and Lamiaceae plants, in order to design a successful IPM protocol.

MATERIAL AND METHODS

1. Experimental sites

Two locations were selected to perform the field experiments; Om Saber, Kom Hamada, El Beheira Governorate ($30^{\circ}29'50.6''\text{N}$ $30^{\circ}46'18.8''\text{E}$), and Kom Oshim, Fayoum Governorate ($29^{\circ}34'40.9''\text{N}$ $30^{\circ}55'38.3''\text{E}$) (Fig. 1). The data of population dynamics were recorded for two seasons; Mar to Aug 2016, and Feb to Jul 2017. The proposed IPM procedures were taken place from Apr to Aug 2017, and replicated from Feb to Jun 2018.

Fig. 1. Google Earth map photography of the experimental locations (pointed with pin), i) Om Saber, Kom Hamada, El Beheira Governorate ($30^{\circ}29'50.6''\text{N}$ $30^{\circ}46'18.8''\text{E}$), and ii) Kom Oshim, Fayoum Governorate ($29^{\circ}34'40.9''\text{N}$ $30^{\circ}55'38.3''\text{E}$).

2. Plant sources

Four plant species belonging to two families; Brassicaceae, Siberian (Russian) kale *Brassica napus* var. *pabularia* L., Italian (Tuscan) kale *Brassica oleracea* var. *palmifolia*, and Lamiaceae, Spearmint *Mentha spicata* L. and Saudi Mint *Mentha longifolia* L. Brassicaceae plants were introduced from Egyptian Hydrofarms farm (KM 53 Cairo-Alex Desert Road, inside Al-Azzazy Village, $30^{\circ}09'07.0''\text{N}$

30°51'00.2"E). While Lamiaceae plants were introduced from a private farm of herbal and medicinal plants in Fayoum Governorate (Ibshway, 29°21'07.4"N 30°44'17.8"E).

3. Planting

The design of the experiment is showed in Fig. 2. Mixture of compost and organic manure added in the soil before planting. Seedlings transferred into fertilized soil and covered with sand layer, then irrigated. Also, in each plot, there were five rows; for treatments. About 0.50 m between plant plots (in each treatment), and 1 m between treatment plots to easily handling, maintaining, recording, sampling, and to prevent predatory species movement to the other plots.

Fig. 2. Schematic diagram of the experiment's plantation

4. Sampling

Samples collected for the pest population dynamics weekly from each site, and were investigated in the Acarology lab, NRC. Active stages were counted and recorded. Besides, weeds that checked for arthropod occurrence to figure out the possible interactions. Ten leaves of each plant were checked for pest dynamics randomly. While, another ten leaves were checked randomly to record pest population before/after each treatment when control application been taken place.

5. Used control strategies

5.1. Predatory mite species

Three phytoseiid species, *Phytoseiulus persimilis* Athias-Henriot, *Amblyseius swirskii* Athias-Henriot, and *Cydnoseius negevi* (Swirski & Amitai), were introduced as bio-agents to control pests existed in the experimental locations. Predatory mites were commercially available from private companies in Qaha, Al-

Qalioubia Governorate, Badr City, Al Beheira Governorate, and Al-Ayat, Giza Governorate. A single mite package was containing about 1000 individuals. Releasing ratio was 1:5 predator to pest, based on sampled pest density in preliminary investigations.

5.2. Plant extracts

Egyxide[®] is a commercial compound recommended in organic farming systems protocols and clean farming in open and semi-field conditions. Egyxide is a water-soluble natural oils mixture, that used for mite and insect pests, also to prevent plant diseases. It is containing natural emulsified plant oils 10% and Glue 2%. Recommended as foliar application with dosage 5 ml/Liter, and was available at Royal for Agricultural Development, Cairo, Egypt. <http://royalagri.com>.

5.3. Pest pathogens

Bio-Magic[®] is a biological insecticide based on a selective strain of naturally-occurring entomopathogenic fungus *M. anisopliae*. It was available in liquid package contains spores and mycelial fragments (1x10⁹ CFU's/ml) that used as foliar spray 6 ml/Liter, and was available at Gaara Establishment for Import and Export, Cairo (www.gaara.com.eg).

6. Control experimental procedure

Pest infestations were recorded weekly. Ten leaves of each plant (of both locations) were sampled randomly, to check the pest population density/leaf/plant to detect the Economic injury level (EIL) and the Economic Threshold Level (ETL). When population reached the EIL we started applying the proposed strategy. Predators releasing ratio was 1:5 depending on pest density/plant. *Phytoseiulus persimilis* was introduced for TSSM infestations; while *A. swirskii* and *C. negevi* were planned for controlling the TSSM, whiteflies, and thrips. Pest population before and after treatments were counted and calculated due to Henderson and Tilton (1955) module as follow: Reduction percentage = $(1 - \frac{n \text{ in } Co \text{ before treatment} * n \text{ in } T \text{ after treatment}}{n \text{ in } Co \text{ after treatment} * n \text{ in } T \text{ before treatment}}) * 100$
Where *n* is the pest population, *T* treated, *Co* control.

7. Statistical analysis

Hypothesis was tested by the Kruskal-Wallis test using SPSS computer program ver. 20.0. The null hypothesis *H*₀ suggested that distribution of pests would be the same across the host plants and locations during the experimental time. While the alternative hypothesis *H*₁ was designed as there were significant differences among pest populations in both tested plants and experimental locations. The test has conducted to determine either *H*₀ or *H*₁ is accepted. The test results rejected the *H*₀ due to significant differences within the three major pest populations recorded; *T. urticae*, *B. tabaci*, and *T. tabaci* (Suppl. 2; Figs. 9-12).

Results among two locations tested by Student's test (T-test) using SPSS v. 20.0. Differences in the mean number of species before/after treatments were analysed by one-way analysis of variance ANOVA and were tested with Tukey's test at 95% confidence level using SPSS v. 20.0. Biodiversity indices were; Shannon-Wiener index (*H'*), Simpson's index (dominance *D* and species richness 1/*D*), and the similarity

index between locations (Jaccard's index), which calculated using the BioDiversity Pro. ver. 2.0 software (McAleece *et al.*, 1997) and PAST ver. 4.08 software (Hammer *et al.*, 2001).

RESULTS

1. Population dynamics and diversity indices of three major pest species

a. Om Saber location

The population dynamics of *T. urticae*, *B. tabaci* and *T. tabaci* were detected for the two seasons, 2016 and 2017. The highest mean population of *T. urticae* was found on *B. napus var pabularia* (63.22 ± 6.10 immatures/10 leaves, and 57.11 ± 5.68 adults/ 10 leaves, $F= 20.762$, $P= 0.000$); while the lowest mean recorded in case of *M. spicata* (3.34 ± 0.21 immatures/10 leaves and 2.78 ± 0.18 immatures/10 leaves; $F= 19.289$, $P= 0.000$). *Thrips tabaci* was the lowest population that been recorded in both Lamiaceae plants. Similar results were detected on the second season, 2017, when all pest populations have recorded the highest levels of occurrence on *B. napus var pabularia* ($F= 22.688$, $P= 0.001$), and the lowest was recorded in case of *M. spicata* ($F= 3.117$, $P= 0.001$), and *B. tabaci* has the highest population recorded on the Brassicaceae in both seasons (Table 1).

Diversity indices have reflected the three pest species populations preferences. The dominance (D) was the highest in case of *B. oleracea var palmifolia* leaves ($D= 0.423$ in 2016 and 2017), the highest species richness ($1/D= 2.362$ in 2016 and 2017), and the highest Shannon-Winner diversity index ($H'= 0.933$ in 2016, and 0.935 in 2017) in both seasons (Table 2). Despite the occurrence of pest populations; species distribution was varied for each population. When *B. tabaci* has recorded the highest density distribution on the four tested plants ($\chi^2= 734.223$, $P= 0.000$) in 2016, *T. tabaci* ($\chi^2= 3730.706$, $P= 0.000$) in 2017, and *T. urticae* has a fluctuated significant distribution among plants in both seasons (2016: $\chi^2= 5370.34$, $P= 0.000$; 2017: $\chi^2= 805.3225$, $P= 0.000$) (Table 3).

b. Kom Oshim location

The population dynamics of *T. urticae*, *B. tabaci* and *T. tabaci* have resulted significant differentiations among tested plants. The highest mean population recorded in Brassicaceae was in *B. napus var pabularia* ($F= 80.963$, $P= 0.000$), when *T. urticae* recorded 35.17 ± 2.91 adults/10 leaves, and *B. tabaci* 67.54 ± 7.60 individuals/10 leaves in 2016. While, *T. tabaci* highest mean population was recorded in *B. aleracea var. plamifolia* (11.04 ± 2.62 individuals/10 leaves) (Table 4). The second season showed a similarity in population density dynamics, and the recorded results were statistically significant on probability level of 95% (*B. napus var pabularia* $F= 50.413$; *B. aleracea var. plamifolia* $F= 43.405$; *M. spicata* $F= 5.410$; *M. longifolia* $F= 7.462$) (Table 4).

Diversity indices have not been changed too much between two seasons, when the sampled individuals were significantly differed. Although they have given a real indication of pest species abundance, richness and preference due to their significant values of dominance (D), species richness ($1/D$), diversity (H'), similarities (J') and evenness (e^H/S) (Table 5). Besides, the species distribution of each species has statistically significant differences, when *B. tabaci* (2016 $\chi^2= 257.95$; 2017 $\chi^2= 299.50$, $P= 0.000$) and *T. tabaci* (2016 $\chi^2= 1968.09$; 2017 $\chi^2= 1971.23$, $P= 0.000$) were the most distributed species on the four tested plants in two experimental seasons, and *T. urticae* has recorded a moderate distribution on Brassicaceae and *M. spicata*, and heavy occurrence on *M. longifolia* in 2016 ($\chi^2= 1575.60$, $P= 0.000$), and heavily distribution on Lamiaceae plants only in the second season ($\chi^2= 219.82$, $P= 0.000$) (Table 6).

2. The proposed IPM tactic for resulted pests

Using the predatory phytoseiid species was efficient to reduce the *T. urticae*, *B. tabaci*, and *T. tabaci* populations on *B. napus* var. *pabularia*, *B. oleracea* var. *palmifolia*, *M. spicata* and *M. longifolia*. Releasing *P. persimilis* and *A. swirskii* were effectively reduced the mean number of *T. urticae* in both Brassicaceae and Lamiaceae tested plants comparing with the control. *Amblyseius swirskii* was effective not only towards TSSM infestations, but also to reduce *T. tabaci* and *B. tabaci*. While *C. negevi* was less effective comparing with the two other phytoseiids, the average reduction percentage of releasing *C. negevi* against *T. urticae*, *T. tabaci*, and *B. tabaci* on the four tested plant species was 50% in Om Saber and 55% in Kom Oshim (Tables 7-10) (Suppl. 1).

Weather data were recorded during the experimental duration period; the average temperature was 28° C in Om Saber and Kom Oshim, and the relative humidity was 54% in Om Saber and 52% in Kom Oshim. The least reduction percentage was recorded in Bio-Magic and Egyxide applications. These two means were replicated (spray application) three times every three weeks due to their low performance. The least reduction percentage recorded in case of using Bio-Magic was 34% in Om Saber, and 40% in Kom Oshim, and in case of Egyxide it was recorded 40% in Om Saber and 45% in Kom Oshim (Tables 11) (Suppl. 1).

A Kruskal-Wallis test was carried out to determin which hypothesis to accept; either the null hypothesis (H_0) (which suggested that there were no significant differences between seasons 2017 and 2018), or the alternative hypothesis (H_1) (which suggested that there were significant differences), at confidence level = 95%. Kruskal-Wallis resulted was to reject the alternative hypothesis H_1 and accept the null hypothesis H_0 . Results obtained in 2018 of the two experimental locations were not significantly different, when compared with those gathered in 2017 using Student's test and ANOVA. Bio-Magic and Egyxide have the least reduction percentage resulted, when *A. swirskii* was the most effective for control targeted pests, then *C. negevi* which success in suppression *B. tabaci* and *T. urticae* populations. The specialist *P. persimilis* showed a successful application toward TSSM populations in both experimental locations in the two seasons (Table 11).

DISCUSSION

Four principles of integrated pest management in an Agro-ecosystem; prevention, monitoring, avoidance, and suppression (EPA, 2021). According to these tactics, the current study was designed. The prevention phase was occurred by managing weeds which were found in each location, by mechanical removal. However, diverse weed species have been recorded in both locations; e.g., the slender amaranth *Amaranthus viridis* L. (Amaranthaceae), the Cheese weed *Malva parviflora* L. (Malvaceae), the burning nettle *Urtica urens* L. (Urticaceae), and the common cocklebur *Xanthium strumarium* L. (Asteraceae). These shared weeds have been employed as shelters for the recorded pests, besides, other secondary lepidopterans, aphids, and other phytophagous tydied, tarsonemid, and tenuipalpid mite species. Despite, some studies considered weeds not much harm as prospected and they might do another ecological role in an ecosystem; as being shelter/banker plants for predatory species (Parolin *et al.*, 2012; 2013), and/or trap plants for herbivore species as applied in commercial applications in Europe (Shelton and Badenes-Pérez, 2006) which had been vital for the entire process (Soloneski and Larramendy, 2013).

Monitoring, as a second tactic, was taking place alongside during the experiment. Detecting climatic factors was very essential for most of the phytophagous species such as spider mites (Praslička and Huszár, 2004; White and Liburd, 2005; Zou *et al.*, 2018), whiteflies (Jha and Kumar, 2017; Khan, 2019; Gamarra *et al.*, 2020; Chandi *et al.*, 2021), thrips (McDonald *et al.*, 1998; Bergant *et al.*, 2005; Cao *et al.*, 2018; Garrick and Liburd, 2018), also for predacious mite (Tixier, 2018; Urbaneja-Bernat and Jaques, 2022), as

in the current study. As well, for predatory insect (Schuldiner-Harpaz and Coll, 2013), or spider (Blamires and Sellers, 2019; Napiórkowska *et al.*, 2021) species, and even for the stored product and public health pests (Beckett, 2011; Mahakittikun *et al.*, 2011) life table parameters, population dynamics, and behaviours which affected due to climate changes.

The present study recorded the mean numbers of *T. urticae*, *T. tabaci*, and *B. tabaci* populations, which were significantly varied, increased, and changed (Tables 1 and 4). However, *T. urticae* population growth was not significantly changed in the two experimental seasons, where the fluctuation of pest distribution was affected (*T. urticae* immatures $T=0.719$, $P=0.474$; *T. urticae* adults $T=1.011$, $P=0.314$). While *T. tabaci*, and *B. tabaci* populations growth were highly significant increased (*T. tabaci* $T=3.999$, $P=0.000$; *B. tabaci* $T=6.086$, $P=0.000$) (Supplementary).

Abou-Elella *et al.*, (2021) have concluded that organic fertilization could affect the life table parameters of the TSSM positively. That helps in explaining why these pest species built their populations rapidly and increase their fluctuations that became higher than the EIL, which needed to be controlled. Climatic factors, also, affect the tri-trophic interactions, by changing the chemical responses of herbivore-plant and predator-prey interactions (Laws, 2017), which reflects on the ecosystem and any possible IPM program may applied.

Despite, climatic factors were not only the reason that causes pest populations to increase; variations could be occurred due to different abiotic (e.g., plant nutritional contents, soil fertilization plant, and climatic factors), and biotic factors (e.g., plant morphological characters, herbivore physiological characters, plant-herbivore relation, and herbivore-herbivore relation) (Laws, 2017; Skendžić *et al.*, 2021; Zidan, 2021).

Together, these factors are sustainable for the agroecosystem balance and suppression of harmful pests. As faunal and floral diversities, which have substantial roles in pest and disease management in the Agroecosystems (Westerman *et al.*, 2003; Hajjar *et al.*, 2008).

Another example to understand the increasing of pest fluctuations and abundance, the presence of primary and secondary pests on the weed species in both sites; as the monitoring has helped in indicating the most abundance and dominant pest species for control applications (secondary pest species have been statistically neglected due to not causing significant damages). As the mathematical modulation of diversity indices have measured the community species diversity, and diversity differences in populations within the ecosystem (Magurran, 2004).

Avoidance, as the third protocol, was carried for maintaining the predatory species, keeping the pest populations under the EIL/ETL, and to reduce/prevent the need for chemical application. Some arthropods (e.g., *T. urticae*) could build resistant generations toward chemical compound (Ramasubramanian *et al.*, 2005), as a specialist predator; *P. persimilis* was very efficient towards *T. urticae* (reduction percentage average= 90% in the whole study), and useless for other pests, due to its diet specialty (McMurtry and Croft, 1997; McMurtry *et al.*, 2013). To keep other pest species under the EIL, therefore, we used the predatory species; *A. swirskii* and *C. negevi* which were the best candidates, as an indigenous species in the Mediterranean basin, and have a wide range of feeding preferences (e.g., whiteflies, thrips, eriophyid and tetranychid pests) in both open fields and greenhouses (Nomikou *et al.*, 2001; Wimmer *et al.*, 2008; Arthurs *et al.*, 2009; Stansly and Castillo, 2010; Calvo *et al.*, 2011; Doğramaci *et al.*, 2011; Onzo *et al.*, 2012; Xiao *et al.*, 2012; Negm *et al.*, 2014; Alatawi *et al.*, 2018; Sanad and Hassan, 2019).

Interactions such as competition, intraguild predation (IGP), extraguild predation, and cannibalism would affect the plant-prey-predator relations in the IPM procedure, thus using multiple predatory species different in their dietary preferences and predatory behaviour is better than using single ones (Schausberger and Walzer, 2001; Momen, 2010; Momen and El-Borolossy, 2010; Momen *et al.*, 2013; Guo *et al.*, 2016; Knapp *et al.*, 2018; Döker *et al.*, 2021; Momen and Abdel-Khalek, 2009 a, b, 2021).

Otherwise, the reduction percentages of Bio-Magic and Egyxide compounds in both locations were negative (especially in July and August) (Supplementary file). This indicated that using these methods in that time was not useful, despite, their active ingredients are natural origin (*M. anisopliue* fungi and plant essential oils). It was stated that 28 °C and a photoperiod of 16 hours were the most suitable conditions for *M. anisopliue* (Alves *et al.*, 1984). Although, the UV-A and UV-B of solar waves radiation extremely reduce *M. anisopliue* capability to form conidia which cause targeted pest mortality (Francisco *et al.*, 2008). Besides, storage, transportation, and field application are also limitation factors (Parra, 2014; Sinha *et al.*, 2016).

The suppression, the final tactic in the present study; represented by *A. swirskii* and *C. negevi* results in reducing whitefly and thrips populations in both Brassicaceae and Lamiaceae plantations. Also, the role of *P. persimilis* as a specialist for *T. urticae*, and hypothetically, therefore, getting a large loss if this specialist is used as a “solo” tool.

The combination of using these three phytoseiid species is successful in the Agro-ecosystem, but we should take in consideration the release timing and capacity (Knapp *et al.*, 2018; Fonseca *et al.*, 2020). The combination may include Egyxide and/or Bio-Magic means to suppress targeted pest populations below the EIL and ETL, however, they might be failure methods if used individually; due to degradation by weather conditions such as temperature, humidity, daylight UV waves, and wind speed (Allam *et al.*, 2020).

CONCLUSION

Within an Agro-ecosystem, abiotic and biotic factors together help in explaining why various pest species build their communities rapidly and increase their parameters that become above the EIL. Such factors are hypothesized to affect the plant-arthropod, predator-herbivore, predator-predator, and tri-trophic interactions. We proposed such IPM tactic aimed to help in the suppression of pest infestations. The study is recommending that application of such protocol should consider the timing of tacking an action and merging tactics together to get the maximum efficiency.

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DECLARATION OF INTEREST

The authors declare that there is no conflict of interest regarding this manuscript publication.

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DATA AVAILABILITY

The data that support the findings of this study are available and attached in the supplementary file.

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TABLES

Table 1. Pest species populations on four medicinal plant species (mean/10 leaves $\pm$ SE) in Om Saber location (2016 & 2017)

2016					
	<i>T. urticae</i>		<i>T. tabaci</i>	<i>B. tabaci</i>	<i>F</i> -test
	Nymphs	Adults			
	25 ^z	25	22	22	df = (3, 89)
<i>B. napus</i>	63.22 $\pm$ 6.10 ^b	57.11 $\pm$ 5.68 ^c	17.89 $\pm$ 3.49 ^d	143.86 $\pm$ 20.02 ^a	20.762 [*]
<i>B. oleracea</i>	45.75 $\pm$ 2.78 ^b	38.79 $\pm$ 2.88 ^c	19.62 $\pm$ 3.96 ^d	111.30 $\pm$ 15.38 ^a	21.839 [*]
<i>M. spicata</i>	3.43 $\pm$ 0.2 ^a	2.78 $\pm$ 0.18 ^b	0.66 $\pm$ 0.13 ^c	3.77 $\pm$ 0.51 ^a	3.289 [*]
<i>M. longifolia</i>	4.81 $\pm$ 0.40 ^a	4.29 $\pm$ 0.33 ^a	1.00 $\pm$ 0.21 ^c	2.71 $\pm$ 0.38 ^b	9.423 [*]
2017					
	<i>T. urticae</i>		<i>T. tabaci</i>	<i>B. tabaci</i>	<i>F</i> -test
	25	25	21	21	
<i>B. napus</i>	62.50 $\pm$ 4.78 ^b	50.96 $\pm$ 4.93 ^b	22.36 $\pm$ 3.71 ^c	149.86 $\pm$ 21.42 ^a	22.688 [*]
<i>B. oleracea</i>	44.81 $\pm$ 2.54 ^b	39.54 $\pm$ 2.52 ^b	22.14 $\pm$ 4.10 ^c	116.52 $\pm$ 17.25 ^a	20.904 [*]
<i>M. spicata</i>	4.68 $\pm$ 0.21 ^a	4.28 $\pm$ 0.18 ^a	0.91 $\pm$ 0.13 ^b	4.41 $\pm$ 0.24 ^a	3.117 [*]
<i>M. longifolia</i>	6.60 $\pm$ 0.40 ^a	6.10 $\pm$ 0.33 ^a	1.39 $\pm$ 0.24 ^c	3.69 $\pm$ 0.55 ^b	5.991 [*]

Means within rows, followed by the same letter are not significantly different (Tukey, $P \leq 0.05$).

(*) significant at $P \leq 0.05$

^z Number of samples during experimental duration

Table 2. Diversity indices of pest species infesting Brassicaceae and Lamiaceae in Om Saber experimental site 2016 - 2017

	2016				2017			
	<i>B. napus</i>	<i>B. oleracea</i>	<i>M. spicata</i>	<i>M. longifolia</i>	<i>B. napus</i>	<i>B. oleracea</i>	<i>M. spicata</i>	<i>M. longifolia</i>
Individuals	6547	4974	251	306	6458	5019	335	423
Simpson (D)	0.448	0.423	0.488	0.586	0.436	0.423	0.525	0.600
Simpson (1/D)	2.233	2.362	2.050	1.706	2.296	2.367	1.911	1.671
Shannon-Wiener (H')	0.873	0.933	0.833	0.730	0.904	0.935	0.788	0.711
Evenness (e [^] H/S)	0.798	0.847	0.767	0.692	0.823	0.849	0.733	0.679
Brillouin	0.869	0.930	0.790	0.677	0.901	0.930	0.760	0.683
Menhinick	0.037	0.043	0.189	0.171	0.037	0.042	0.164	0.146
Margalef	0.228	0.235	0.362	0.349	0.228	0.235	0.344	0.331
Jaccard's index (J')	0.794	0.849	0.758	0.665	0.823	0.851	0.717	0.648
Fisher alpha	0.300	0.34	0.479	0.461	0.301	0.309	0.454	0.436
Berger-Parker	0.483	0.484	0.615	0.737	0.487	0.487	0.667	0.748

Diversity indices were tested at $P \leq 0.05$

Table 3. Pest Species distribution in Om Saber location 2016 - 2017

	<i>B. napus</i>	<i>B. oleracea</i>	<i>M. spicata</i>	<i>M. longifolia</i>			
Pest Species	2016				Variance	χ^2	<i>P</i>
	Species distribution						
<i>T. tabaci</i>	++	+	+++	+++	2005760	4372.649	0.000
<i>T. urticae</i>	+++	+++	+	++	2557160	5370.342	0.000
<i>B. tabaci</i>	+++	+++	+++	+++	52963.15	734.223	0.000
Pest Species	2017				Variance	χ^2	<i>P</i>
	Species distribution						
<i>T. tabaci</i>	+++	+++	+++	+++	1705812	3730.706	0.000
<i>T. urticae</i>	+++	+++	++	++	66332.41	805.3225	0.000
<i>B. tabaci</i>	++	++	+++	+++	2533514	5274.391	0.000

Distribution variance and χ^2 were tested at $P \leq 0.05$

Table 4. Pest species populations on four medicinal plant species (mean/10 leaves $\pm$ SE) in Kom Oshim experimental site (2016 - 2017)

2016							
	<i>T. urticae</i> (18) ^z		<i>T. tabaci</i>		<i>B. tabaci</i>		<i>F</i> -test
	Nymphs	Adults	N	Mean $\pm$ SE	N	Mean $\pm$ SE	
<i>B. napus</i>	37.90 $\pm$ 2.52 ^b	35.17 $\pm$ 2.91 ^c	16	8.16 $\pm$ 1.90 ^d	18	67.54 $\pm$ 7.60 ^a	80.963 [*]
<i>B. oleracea</i>	35.12 $\pm$ 2.59 ^b	30.82 $\pm$ 2.51 ^c	16	11.04 $\pm$ 2.62 ^d	18	48.94 $\pm$ 6.42 ^a	82.651 [*]
<i>M. spicata</i>	5.75 $\pm$ 0.31 ^a	2.32 $\pm$ 0.26 ^b	10	1.05 $\pm$ 0.17 ^c	14	1.92 $\pm$ 0.25 ^{bc}	6.021 [*]
<i>M. longifolia</i>	9.92 $\pm$ 0.76 ^a	3.24 $\pm$ 0.23 ^b	10	1.23 $\pm$ 0.15 ^c	14	1.27 $\pm$ 0.25 ^c	9.736 [*]
2017							
	<i>T. urticae</i> (18) ^z		<i>T. tabaci</i>		<i>B. tabaci</i>		<i>F</i> -test
	Nymphs	Adults	N	Mean $\pm$ SE	N	Mean $\pm$ SE	
<i>B. napus</i>	40.26 $\pm$ 3.14 b	36.38 $\pm$ 2.77 c	16	15.16 $\pm$ 1.90 d	18	62.54 $\pm$ 7.60 a	50.413 [*]
<i>B. oleracea</i>	38.14 $\pm$ 3.23 b	35.39 $\pm$ 2.50 c	16	13.04 $\pm$ 2.62 d	18	52.94 $\pm$ 6.42 a	43.405 [*]
<i>M. spicata</i>	8.24 $\pm$ 0.36 a	5.31 $\pm$ 0.26 c	10	4.33 $\pm$ 0.17 d	14	7.98 $\pm$ 0.25 b	5.410 [*]
<i>M. longifolia</i>	11.14 $\pm$ 0.86 a	6.53 $\pm$ 0.23 b	10	3.44 $\pm$ 0.15 c	14	6.44 $\pm$ 0.25 b	7.462 [*]

Means within rows, followed by the same letter, are not significantly different (Tukey, $P \leq 0.05$).

(*) significant at $P \leq 0.05$

^z Number of samples during experimental duration

Table 5. Diversity indices of pest species infesting Brassicaceae and Lamiaceae in Kom Oshim (2016 - 2017)

	2016				2017			
	<i>B. napus</i>	<i>B. oleracea</i>	<i>M. spicata</i>	<i>M. longifolia</i>	<i>B. napus</i>	<i>B. oleracea</i>	<i>M. spicata</i>	<i>M. longifolia</i>
Individuals	2593	2243	181	265	3503	3147	1560	1516
Simpson (D)	0.455	0.440	0.656	0.793	0.499	0.515	0.949	0.955
Simpson (1/D)	2.196	2.274	1.524	1.261	2.005	1.942	1.054	1.047
Shannon-Wiener (H')	0.856	0.904	0.627	0.429	0.805	0.807	0.138	0.124
Evenness (e^{H/S})	0.784	0.8232	0.624	0.512	0.745	0.747	0.383	0.378
Brillouin	0.780	0.823	0.571	0.39	0.798	0.802	0.13	0.115
Menhinick	0.850	0.895	0.558	0.372	0.051	0.053	0.076	0.077
Margalef	0.059	0.063	0.222	0.184	0.245	0.248	0.272	0.273
Jaccard's index (J')	0.254	0.259	0.385	0.358	0.733	0.735	0.126	0.113
Fisher alpha	0.335	0.341	0.51	0.473	0.323	0.327	0.358	0.359
Berger-Parker	0.507	0.529	0.794	0.884	0.622	0.659	0.974	0.977

Diversity indices were tested at $P \leq 0.05$

Table 6. Pest Species distribution in Kom Oshim location 2016 - 2017

Pest Species	<i>B. napus</i>	<i>B. oleracea</i>	<i>M. spicata</i>	<i>M. longifolia</i>	Variance	χ^2	<i>P</i>
	2016						
	Species distribution						
<i>T. urticae</i>	++	++	++	+++	378705	1575.60	0.000
<i>B. tabaci</i>	+++	+++	+++	+++	7091.29	257.95	0.000
<i>T. tabaci</i>	+++	+++	+++	+++	340108.5	1968.09	0.000
Pest Species	2017				Variance	χ^2	<i>P</i>
	Species distribution						
<i>T. urticae</i>	++	++	+++	+++	132967.08	219.82	0.000
<i>B. tabaci</i>	+++	+++	+++	+++	9860.65	299.50	0.000
<i>T. tabaci</i>	+++	+++	+++	+++	341292.63	1971.23	0.000

Distribution variance and χ^2 were tested at $P \leq 0.05$

Table 7. Mean number ($\pm$ SE) of Brassicaceae pests after proposed application, Om Saber experimental site 2017

<i>Brassica napus</i> var. <i>pabularia</i>				
	<i>T. urticae</i> nymphs	<i>T. urticae</i> adults	<i>T. tabaci</i>	<i>B. tabaci</i>
N	21	21	19	16
<i>Phytoseiulus persimilis</i>	4.90 $\pm$ 1.51 ^c	7.18 $\pm$ 2.05 ^c	19.85 $\pm$ 3.62 ^a	112.91 $\pm$ 17.00 ^a
<i>Amblyseius swirskii</i>	11.65 $\pm$ 1.94 ^{bc}	14.34 $\pm$ 1.48 ^{bc}	0.82 $\pm$ 0.21 ^c	3.32 $\pm$ 0.81 ^c
<i>Cydnoseius negevi</i>	19.37 $\pm$ 1.41 ^b	21.35 $\pm$ 0.80 ^b	19.56 $\pm$ 3.60 ^a	5.20 $\pm$ 0.60 ^c
Bio-Magic	20.27 $\pm$ 1.30 ^b	23.11 $\pm$ 1.53 ^b	5.96 $\pm$ 0.79 ^b	19.85 $\pm$ 3.50 ^b
Egyxide	20.34 $\pm$ 1.33 ^b	23.73 $\pm$ 1.33 ^b	9.60 $\pm$ 1.81 ^a	16.58 $\pm$ 2.25 ^b
Control	71.31 $\pm$ 5.66 ^a	65.00 $\pm$ 5.12 ^a	19.70 $\pm$ 3.61 ^a	113.68 $\pm$ 16.81 ^a
<i>F</i> -test	77.310*	65.615*	9.587*	28.665*

<i>Brassica oleracea</i> var <i>palmifolia</i>				
	<i>T. urticae</i> nymphs	<i>T. urticae</i> adults	<i>T. tabaci</i>	<i>B. tabaci</i>
N	21	21	19	21
<i>Phytoseiulus persimilis</i>	7.48 ± 2.33 ^c	7.94 ± 2.10 ^d	24.08 ± 4.04 ^a	114.64 ± 15.70 ^a
<i>Amblyseius swirskii</i>	8.09 ± 2.36 ^c	16.66 ± 1.14 ^c	0.96 ± 0.25 ^c	2.38 ± 0.65 ^c
<i>Cydnoseius negevi</i>	8.93 ± 2.11 ^c	19.70 ± 1.22 ^c	22.91 ± 3.71 ^a	4.80 ± 0.75 ^c
Bio-Magic	26.28 ± 1.84 ^b	22.00 ± 0.91 ^b	5.96 ± 0.79 ^b	27.86 ± 5.00 ^b
Egyxide	20.42 ± 1.50 ^b	22.92 ± 1.17 ^b	9.60 ± 1.81 ^b	38.27 ± 8.11 ^b
Control	50.19 ± 2.07 ^a	43.55 ± 2.06 ^a	23.65 ± 4.00 ^a	114.74 ± 15.72 ^a
F-test	64.816[*]	61.471[*]	12.631[*]	27.281[*]

N= the number of application weeks/samples

Within column, means followed by similar letters are not significantly different (Tukey HSD), (*) significant at $P \leq 0.05$

Table 8. Mean number ($\pm$ SE) of Lamiaceae pests after proposed application, Om Saber experimental site 2017

<i>Mentha spicata</i>				
	<i>T. urticae</i> nymphs	<i>T. urticae</i> adults	<i>T. tabaci</i>	<i>B. tabaci</i>
N	21	21	21	21
<i>Phytoseiulus persimilis</i>	0.29 $\pm$ 0.13 ^c	0.40 $\pm$ 0.14 ^d	1.10 $\pm$ 0.11 ^a	5.48 $\pm$ 0.40 ^a
<i>Amblyseius swirskii</i>	0.46 $\pm$ 0.16 ^c	0.68 $\pm$ 0.14 ^{cd}	0.04 $\pm$ 0.02 ^c	0.95 $\pm$ 0.31 ^c
<i>Cydnoseius negevi</i>	0.52 $\pm$ 0.15 ^c	1.52 $\pm$ 0.05 ^b	1.05 $\pm$ 0.10 ^a	0.87 $\pm$ 0.22 ^c
Bio-Magic	1.43 $\pm$ 0.20 ^b	0.97 $\pm$ 0.06 ^c	0.52 $\pm$ 0.10 ^b	2.53 $\pm$ 0.27 ^b
Egyxide	1.29 $\pm$ 0.19 ^b	0.95 $\pm$ 0.07 ^c	0.70 $\pm$ 0.12 ^b	3.23 $\pm$ 0.37 ^b
Control	3.74 $\pm$ 0.20 ^a	3.06 $\pm$ 0.14 ^a	1.08 $\pm$ 0.11 ^a	5.27 $\pm$ 0.34 ^a
F-test	56.907*	77.717*	17.946*	38.640*
<i>Mentha longifolia</i>				
	<i>T. urticae</i> nymphs	<i>T. urticae</i> adults	<i>T. tabaci</i>	<i>B. tabaci</i>
N	14	14	14	14
<i>Phytoseiulus persimilis</i>	0.32 $\pm$ 0.15 ^c	0.41 $\pm$ 0.16 ^d	1.63 $\pm$ 0.19 ^a	4.75 $\pm$ 0.43 ^a
<i>Amblyseius swirskii</i>	0.58 $\pm$ 0.17 ^c	1.20 $\pm$ 0.15 ^c	0.01 $\pm$ 0.01 ^c	0.62 $\pm$ 0.21 ^c
<i>Cydnoseius negevi</i>	0.91 $\pm$ 0.18 ^c	2.06 $\pm$ 0.07 ^b	1.60 $\pm$ 0.18 ^a	1.14 $\pm$ 0.21 ^c
Bio-Magic	2.10 $\pm$ 0.15 ^b	2.44 $\pm$ 0.20 ^b	0.01 $\pm$ 0.00 ^b	1.66 $\pm$ 0.15 ^b
Egyxide	2.27 $\pm$ 0.16 ^b	1.97 $\pm$ 0.12 ^b	0.60 $\pm$ 0.15 ^c	1.96 $\pm$ 0.24 ^b
Control	5.33 $\pm$ 0.38 ^a	4.70 $\pm$ 0.33 ^a	1.62 $\pm$ 0.18 ^a	3.88 $\pm$ 0.25 ^a
F-test	72.997*	59.199*	30.995*	37.860*

N= the number of application weeks

The means followed by similar letters in the column are not significantly different (Tukey HSD), (*) significant at $P \leq 0.05$

Table 9. Mean number ($\pm$ SE) of Brassicaceae pests after proposed application in Kom Oshim experimental site 2017

<i>Brassica napus</i> var. <i>pabularia</i>				
	<i>T. urticae</i> nymph	<i>T. urticae</i> adult	<i>Thrips tabaci</i>	<i>Bemisia tabaci</i>
N	18	18	13	10
<i>Phytoseiulus persimilis</i>	6.86 $\pm$ 2.30 ^c	7.72 $\pm$ 1.78 ^d	10.67 $\pm$ 2.17 ^a	125.13 $\pm$ 13.17 ^a
<i>Amblyseius swirskii</i>	8.93 $\pm$ 1.02 ^c	8.95 $\pm$ 0.87 ^d	0.55 $\pm$ 0.14 ^b	20.70 $\pm$ 5.75 ^b
<i>Cydnoseius negevi</i>	11.26 $\pm$ 0.97 ^c	13.08 $\pm$ 0.47 ^{cd}	10.43 $\pm$ 2.10 ^a	21.38 $\pm$ 5.90 ^b
Bio-Magic	26.60 $\pm$ 2.61 ^b	19.78 $\pm$ 1.75 ^b	3.85 $\pm$ 0.71 ^{ab}	35.11 $\pm$ 3.70 ^b
Eggyxide	24.50 $\pm$ 2.48 ^b	24.68 $\pm$ 2.32 ^{bc}	4.23 $\pm$.080 ^b	39.49 $\pm$ 3.88 ^b
Control	37.89 $\pm$ 2.52 ^a	35.17 $\pm$ 2.91 ^a	9.88 $\pm$ 2.05 ^a	122.44 $\pm$ 13.16 ^a
F-test	31.980*	29.448*	5.250*	32.522*
<i>Brassica oleracea</i> var. <i>palmifolia</i>				
	<i>T. urticae</i> nymph	<i>T. urticae</i> adult	<i>Thrips tabaci</i>	<i>Bemisia tabaci</i>
N	18	18	13	10
<i>Phytoseiulus persimilis</i>	7.92 $\pm$ 2.01 ^c	6.82 $\pm$ 1.15 ^c	13.78 $\pm$ 2.84 ^a	85.90 $\pm$ 11.28 ^a
<i>Amblyseius swirskii</i>	10.84 $\pm$ 0.86 ^b	18.31 $\pm$ 2.04 ^{bc}	0.68 $\pm$ 0.20 ^c	11.76 $\pm$ 3.51 ^c
<i>Cydnoseius negevi</i>	18.10 $\pm$ 1.97 ^b	26.06 $\pm$ 1.75 ^b	13.62 $\pm$ 2.84 ^a	12.60 $\pm$ 2.43 ^c
Bio-Magic	18.05 $\pm$ 1.86 ^b	22.27 $\pm$ 2.00 ^b	5.81 $\pm$ 1.15 ^b	32.90 $\pm$ 4.67 ^b
Eggyxide	20.89 $\pm$ 2.72 ^b	27.93 $\pm$ 2.26 ^b	5.57 $\pm$ 1.21 ^b	33.01 $\pm$ 5.86 ^b
Control	84.96 $\pm$ 12.70 ^a	57.62 $\pm$ 6.90 ^a	13.40 $\pm$ 2.85 ^a	84.44 $\pm$ 11.20 ^a
F-test	24.144*	24.773*	4.623*	19.545*

N= the number of application weeks

The means followed by similar letters in the column are not significantly different (Tukey HSD), (*) significant at $P \leq 0.05$

Table 10. Mean number ($\pm$ SE) of Lamiaceae pests after proposed application in Kom Oshim experimental site 2017

<i>Mentha spicata</i>				
	<i>T. urticae</i> nymphs	<i>T. urticae</i> adult	<i>T. tabaci</i>	<i>B. tabaci</i>
N	18	18	13	10
<i>Phytoseiulus persimilis</i>	1.01 $\pm$ 0.32 ^c	1.43 $\pm$ 0.30 ^d	1.71 $\pm$ 0.20 ^a	4.17 $\pm$ 0.31 ^a
<i>Amblyseius swirskii</i>	1.13 $\pm$ 0.24 ^b	2.15 $\pm$ 0.24 ^d	0.25 $\pm$ 0.12 ^b	0.54 $\pm$ 0.20 ^d
<i>Cydnoseius negevi</i>	0.96 $\pm$ 0.20 ^b	2.32 $\pm$ 0.30 ^c	1.30 $\pm$ 0.14 ^a	0.57 $\pm$ 0.15 ^d
Bio-Magic	1.23 $\pm$ 0.13 ^b	3.55 $\pm$ 0.10 ^b	0.60 $\pm$ 0.10 ^b	1.78 $\pm$ 0.10 ^c
Egyxide	1.06 $\pm$ 0.16 ^b	3.13 $\pm$ 0.12 ^{bc}	0.63 $\pm$ 0.07 ^b	1.80 $\pm$ 0.07 ^c
Control	3.77 $\pm$ 0.22 ^a	5.75 $\pm$ 0.34 ^a	1.27 $\pm$ 0.14 ^a	2.42 $\pm$ 0.11 ^b
F-test	36.327*	40.602*	13.811*	63.012*
<i>Mentha longifolia</i>				
	<i>T. urticae</i> nymphs	<i>T. urticae</i> adult	<i>T. tabaci</i>	<i>B. tabaci</i>
N	18	18	13	10
<i>Phytoseiulus persimilis</i>	0.64 $\pm$ 0.30 ^d	0.98 $\pm$ 0.27 ^d	1.75 $\pm$ 0.11 ^a	3.69 $\pm$ 0.25 ^a
<i>Amblyseius swirskii</i>	0.77 $\pm$ 0.25 ^c	1.42 $\pm$ 0.24 ^c	0.32 $\pm$ 0.12 ^c	0.11 $\pm$ 0.03 ^b
<i>Cydnoseius negevi</i>	1.63 $\pm$ 0.10 ^{bc}	2.31 $\pm$ 0.10 ^{bc}	1.41 $\pm$ 0.11 ^a	0.11 $\pm$ 0.02 ^b
Bio-Magic	3.47 $\pm$ 0.31 ^b	2.46 $\pm$ 0.30 ^b	0.75 $\pm$ 0.10 ^b	0.22 $\pm$ 0.07 ^b
Egyxide	3.15 $\pm$ 0.30 ^{bc}	2.15 $\pm$ 0.29 ^{bc}	0.81 $\pm$ 0.08 ^b	0.22 $\pm$ 0.06 ^b
Control	5.03 $\pm$ 0.20 ^a	3.43 $\pm$ 0.20 ^a	1.43 $\pm$ 0.11 ^a	3.92 $\pm$ 0.21 ^a
F-test	25.858*	19.857*	21.880*	37.201*

Within column, means followed by similar letters are not significantly different (Tukey HSD), (*) significant at $P \leq 0.05$

Table 11. Reduction percentages of control applications. An evaluation between 2017 and 2018 results using Student's test and ANOVA

	Om Saber			Kom Oshim		
	2017	2018	T-test	2017	2018	T-test
<i>Phytoseiulus persimilis</i>	88%	85%	1.50^{ns}	90%	88%	1.042^{ns}
<i>Amblyseius swirskii</i>	75%	73%	1.000^{ns}	80%	80%	-
<i>Cydnoseius negevi</i>	50%	51%	0.561^{ns}	55%	57%	1.035^{ns}
Bio-Magic	34%	35%	0.675^{ns}	40%	40%	-
Egyxide	40%	42%	1.860^{ns}	45%	44%	0.809^{ns}
ANOVA	40.667*	41.025*		46.145*	45.004*	

T-test df= 18; $P \leq 0.05$