Egypt. J. Plant Prot. Res. Inst. (2019), 2 (2): 417 - 427

وزارة الزراعة واستصلاح الأراضي
Ministry of Agriculture and Land Reclamation
ARC
مركز البحوث الزراعية
Agricultural Research Center

Egyptian Journal of Plant Protection Research Institute

www.ejppri.eg.net

Efficacy of the predatory mites and entomopathogenic fungi against *Thrips tabaci* (Thysanoptera: Thripidae) infesting strawberry in Egypt

Ahmed, M. E. Abd El-Salam [1]; Amna, M. H. Maklad [2] and El-Sayed, M. A. El Saiedy[1]

[1]*Pests and Plant Protection Department ,National Research Centre , 33 El- Buhose Street, Dokki, Giza, Egypt.*

[2]*Plant Protection Research Institute, Agricultural Research Centre, Dokki, Giza, Egypt.*

ARTICLE INFO

Article History

Received: 5 / 5 / 2019

Accepted: 27 / 6 /2019

Keywords

Strawberry , *Thrips tabaci* , predator mites, entomopathogenic fungi, *Beauveria bassiana* and biocontrol.

Abstract:

The strawberry is one of the most popular berry fruits of the world. Strawberries are an excellent source of vitamins C and K as well as providing a good dose of fiber, folic acid, manganese and potassium. *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) is a serious insect pests affecting strawberries in all stages of growth. The aim of the present work is to study the efficacy of the predatory mites and entomopathogenic fungi (*Beauveria bassiana*) against *T.tabaci* infesting strawberry in El-Behera Governorate (Bader centre). The results indicated that the two predator mites, *Typhlodromus swirskii* Denmark and *Neoseiulus cucumeris* (Qudemans) (Acari: Phytoseiidae) used to control strawberry T.tabaci by releasing two times at a rate of 5-10 /m^2 during the season of productivity. Four varieties; winterstar, florida, fortuna and markez were used. The efficiency of the predatory mites was different according to the strawberry variety. The predator *T.swirskii* proved to be more efficient than the predator *N. cucumeris*. The use of entomopathogenic fungi, *B. bassiana* was less efficient than the predatory mites and the effect was varied according to the strawberry variety in control *T.tabaci*. The study affirmed that the use of the predatory mites is very important in the integrated control program for strawberry *T.tabaci*.

Introduction

In Egypt, strawberry (*Fragaria* x *ananassa*) is grown as a semi protected crop in open-sided polythene tunnels. *Thrips tabaci* Lindeman (Thysanoptera: Thripidae) is one of the mainly significant insect pests affecting strawberries in each stages of growth (Shakya *et al*., 2010). It generated significant yield loss globally (Lewis, 1997). Thrips are polyphagous nature, transmitted plant pathogens, tiny life cycle and insecticides resistance (Morse and Hoddle, 2006 and Diaz-Montano *et al*., 2011). *T.tabaci* is caused to delay growth of plant and attributed to decrease yield as resulting for extensive feeding.

At the present time, traditional pesticides use is not feasible, especially with successful of some the predator mites against *T.tabaci*. Many insecticides were efficiency against this species, although not all were agreed for use on strawberry in all countries. However, all options use in pest management control for reducing pest numbers with precedence to the non-chemical control [International Organisation for Biological and Integrated Control (IOBC), 2008]. Accordingly, chemical applications should not be made on a standard protection program, except only when critical. Supremely, crop protection agents should be slight toxicity to non target insects because of used in control program (Cuthbertson, 2004 and Rosell *et al*., 2008). The predatory mites *Typhlodromus swirskii* Denmark and *Neoseiulus cucumeris* (Qudemans) (Acari: Phytoseiidae) are effective in controlling *T. tabaci* (Croft *et al*., 1998; Fitzgerald *et al*., 2007 and Khaliq *et al*., 2018). However, biological control is only effective when pest populations were low to moderate (Croft *et al.,* 1998) whereas slow acting its (Fitzgerald *et al*., 2007). The main goal of biological control is to maintain environmental balance (Pedigo and Rice, 2015). In this context, the performance cost of natural enemies are cheap and safe (Buitenhuis *et al*., 2007). Also, use of entomopathogenic fungi for example, *Beauveria bassiana* had become very important in controlling *T.tabaci* (Abd El-Salam *et al*., 2013).

The main focus of these studies were measured the efficacy of the predators, *T. swirskii* and *N. cucumeris* against *T.tabaci*. Also, the resistance of strawberry varieties for *T.tabaci* was studied. *B. bassiana* fungi was used as comparison with the predatory mites in integrated pest management.

Materials and methods

1. Experimental design:

Tests were conducted on an area of 1400 m^2 at El-Behera Governorate (Bader centre) from 17th October 2015 to 6th March 2016. Four strawberry varieties were used winterstar, florida, fortuna, markez, each 350m^2 specialized to each variety. Each 350m^2 divided into 4 blocks, the treatment blocks were 100 m^2 for each block while the untreated block was 50 m^2 area and each block is divided into 5 pieces as replicates. Shit plastic separator placed between each treatment and other. The strawberry was cultivated on terraces (15x5m^2 terrace area).

2. Rearing and mass rearing the predator mites:

Two predator mites were used, *T. swirskii* and *N. cucumeris*. The predator mites were reared in Laboratory of Pests and Plant Protection Department in National Research Centre (El-Saeidy and Romeih, 2007). The predator mites were maintained and rearing on mulberry leaves highly infested with *Tetranychus urticae* Koch (Acari: Tetranychidae) previously and transmitting in large plastic boxes 26x15x10 cm inside car refrigerator under 20.0 C^o to the experimental region.

3. Compound used:

Bio-Power is a biological insecticide based on a selective strain of naturally-occurring entomopathogenic fungus *Beauveria bassiana*. The product contains spores and mycelial fragments of *B. bassiana* and is available in liquid (1x109 CFU's/ml). The compound is produced by T. Stanes Company limited.

4. Samples collection:

Thirty strawberry leaves were inspected from each area and the numbers of adult *T.tabaci* per leaf were counted by eye in the field using a x7 head lens (optimizer, Light Craft, London, UK). We used counts of adult *T.tabaci* rather than nymphs because this is more practical for growers and the assessment of nymphs by eye in the field is unreliable (Gonzalez-Zamora and Garcia-Mari, 2003).The number of *T. swirskii* and *N. cucumeris* predatory per leaf was also counted. Leaves pooled and placed in 70 % alcohol so that *T.tabaci* could be extracted and identified to species. The predatory mites, *T. swirskii* and *N. cucumeris* were released by the growers in all the fields sampled, but with varying amounts and frequencies. The count of the *T.tabaci* individuals was carried out before and after the treated either the predators or bio-compound.

5.Release of the predatory mites :

Discs of mulberry leaves with predatory mite, *T. swirskii* and/or *N.cucumeris* contained 5-10 individuals put on one strawberry plant in 2.0 m^2 area containing 10 strawberry plants approximately. This process carried out 1-2 hours before sunset and 3-4 hours after crop irrigation to warrant suitable air temperature and relative humidity for introduction of predatory mites. The process of release carried out twice during the experimental when *T. tabaci* density reached to 2-3 individuals / leaf.

6. Application of bio-power formulation:

Three applications were carried out by bio-power (*Beauveria bassiana*) at rate of 5.0 ml /l.

7. Statistical analysis

The experimental data were analyzed by one-way Anova analysis of variance. Statistical analysis was carried out with Spss,11.

Results and discussion

1. Efficacy of predators of *Typhlodromus swirskii* and *Neoseiulus cucumeris* compared with *Beauveria bassiana* against *Thrips tabaci* in strawberry:

The results showed in Figure (1) the most susceptible varieties of *T.tabaci* were florida, fortuna and winterstar and markez was the least sensitive. In the first week, the *T.tabaci* numbers began to attack the leaves recording 5.2, 5.0, 4.8 and 4.0 individuals / leaf in florida, fortuna, markez and winterstar, respectively.

The populations fluctuated between rise and little decrease until reached 11.2, 10.2, 9.8 and 8.8 individuals /leaf with winterstar, florida, fortuna and markez, respectively, with the end of the twenty-first week. The results clarified that the highly peak of *T.tabaci* population was 12.4 , 10.6 ,9.6,9.4 individuals /leaf for florida, frotona, winterstar and markez varieties, respectively, during the seventeen and eighteen weeks .The mean number of *T.tabaci* during 21st week was recorded 9.2, 8.0, 7.8, 7.0 individuals / leaf in florida, fortuna, winterstar and markez, respectively. The results manifested that the varieties have different sensitivity for *T.tabaci* infestation.

The results in Table (1) indicated that a difference in the efficiency of both predators against *T.tabaci* individuals with different strawberry variety. The *T. swirskii* predator achieved more efficient with the winterstar variety to reduced the number of *T.tabaci* to 85.5%. Other varieties, the predatory achieved 77.14, 76.59 and 76.52% reduction in the *T.tabaci* numbers with markez, florida and fortuna, respectively. *N. cucumeris* predator achieved to reduce of the *T.tabaci* numbers reached 79.5, 75.3, 74.74 and 72.5% with winterstar, markez, florida and fortuna, respectively. This may refer to the physical of the strawberry leaves varieties.

Predator release for two times at a rate of 5-10 individuals/ m^2 during the twenty one weeks led to decline in the number of *T.tabaci* / leaf to 85.5 and 79.5% by *T. swirskii* and *N. cucumeris* ,respectively, in the winterstar variety. While the blocks which was treated twice time with *B. bassiana* fungi, led to achieved 71.8% reduction in T.tabaci numbers. This indicated that the process of using predator mites is more efficient than the entomopathogenic fungi. Also, the *T. swirskii* predator was more efficient than *N. cucumeris*. The efficiency of *B. bassiana* was varied with variety difference; the *T.tabaci* numbers was decline to reaching 74.46, 72.5, 71.8 and 69.88% reduction in florida, fortuna, winterstar and markez varieties, respectively.

The population of *T.tabaci* after the predators release and spraying with entomopathogenic fungi illustrated in Figures (2, 3, 4 and 5). Radically differences were detected between the control and the three different treatments. The predators related with *T.tabaci* were phytoseiid mites (*Amblyseius* spp.). The findings suggest that feed more on little instars of *T. tabaci* and if these predators were free during early pest epidemic it would be success in controlling the *T.tabaci* population.

The surface of a host plant had a physical block such as waxy cuticles and/or epidermal structures including trichomes. Thrips damage were harmfully with the amount of epicuticular wax on gladiolus leaves (Zeier and Wright, 1995). Other studies did not recognize any connection between *T.tabaci* feeding harm and morphological constitution such as hairiness, age and area of leaf (Leiss *et al*., 2009 and Mirnezhad *et al*., 2009). Instead, the resistance of plant was mainly affected by chemical constitution in host plant. Plant chemical guard can to be high from both primary and secondary metabolites. Primary metabolites, as dietetic chemicals, are generally favorable for thrips . However, at low concentrations of perfumed amino acids in host plant were connected with reduced T.tabaci feeding damage (Mollema and Cole, 1996). Therefore, the common of studies focus on the plant defense by secondary metabolites. In the mean time, few studies had examined the chemical host resistance to *T.tabaci*. In a study on different chrysanthemum varieties, is obutylamide was recommended to be associated with thrips host plant resistance (Tsao *et al*., 2005). Leiss *et al*. (2011) was developed an ecometabolomic technique to identified resistant and sensitivity plants for thrips. Some compounds were identified for example, jacobine, jaconine and kaempferol glucoside in the wild plant species *Jacobaea vulgaris*, chlorogenic and feroluylquinic acid in chrysanthemum, acylsugars in tomato and sinapic acid, luteolin and β-alanine in carrot (Leiss *et al*.,2009 ; Mirnezhad *et al*.,2009; Tsao *et al*.,2005 and Leiss *et al*., 2011). In a review of Francisco *et al*. (2011) that dissection and discussed the strawberry plant defense mechanism. The authors confirmed that physiological responses of plants at a molecular level will provide valuable information to improve future breeding strategies for new strawberry varieties and to engineer strawberry plants for durable and broad-spectrum disease resistance. In turn, this will lead to a reduction in use of chemicals and in environmental risks. Mouden *et al*. (2017) stated that some metabolites of plants had shown harmful effect on thrips and also had attention for prevention of human health by their antioxidant functions. In strawberry, a downbeat relationship between the oviposition and survival of the two-spotted spider mite *T. urticae*, the number and density of glandular and non-glandular trichomes in leaves has been reported (Luczynski *et al.*, 1990b). However, Kishaba *et al.* (1972) proposed that foliar character might be related to spider mite susceptibility. The resistance of strawberry cultivars and other plant attributed the density of non-glandular trichomes and pre-formed glandular trichomes that containing oxidative enzymes. Also, cultivars that had yellow-green, glossy to semi-glossy leaf surfaces were less attractive to onion *T.tabaci* compared with other cultivars that had blue green and waxy. Thus, semiglossy onion cultivars with low levels of epicuticular waxes to glossy should be important in onion thrips control strategies (Steinite and Levinsh , 2003; Diaz-Montano *et al.*, 2012 and Damon *et al.*, 2014).

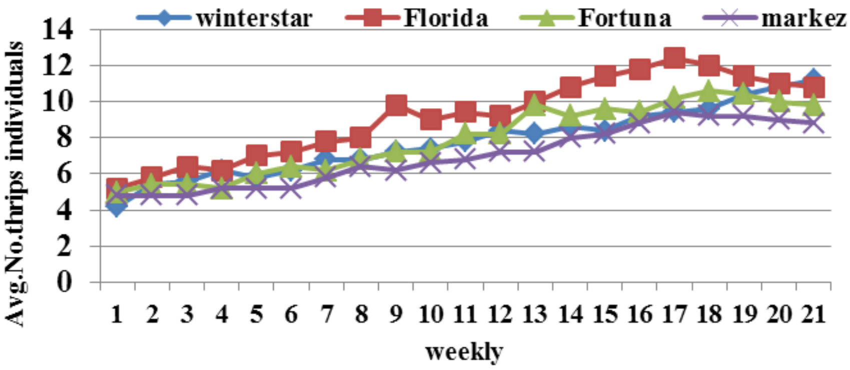
Brown *et al.* (1999) reported that the predation efficacy of predatory mites, *N. cucumeris* against *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) was different on different plant species. The variation in predation efficacy might be due to differences in plant style, surface structure of leaves (Kareiva and Sahakian, 1990) and plant chemistry (Price *et al.*, 1980). The susceptibility of herbivores to predators is often related to the nutritional quality and quantity of plants in orders to attractive the herbivores for feeding (Price *et al.*, 1980).

Several species of *Amblyseius* Berlese have been found as predators of *T.tabaci*. The first greedy mites used for *T.tabaci* control were *Amblyseius barkeri* Hughes (Acari: Phytoseiidae) and *N. cucumeris* which mainly eat upon larval first instar. Result to the insufficient control, a number of other mites had been deliberated to find a greater *T. tabaci* predator. A pair of *N. cucumeris* can feed on more than five *T.tabaci* /day and prefer tiny individuals (Riudavets, 1995 and Sabelis and van Rijn, 1997). *N. cucumeris* reduced *T. tabaci* numbers to more than 80.0 % on cucumber plants (Hassan *et al.*, 2008), while *A. swirskii* favorite to eat on thrips larvae (Xu and Enkegaard, 2010 and Kutuk *et al.*, 2011). An adult female of *Amblyseius fallacies* Garman (Acari: Phytoseiidae) devoured an average of 21.43 and 26.86 thrips at temperatures of 20 °C and 30 °C, respectively, during its life cycle (Abdel-Karim and Abd El-Wareth ,2012). *A. barkeri* is an oligophagous predatory mite against *T. urticae* and *T. tabaci* infestations (initial instars) on cucumber and pepper plants (Karg *et al.*, 1987; Hansen, 1988; Bakker and Sabelis, 1989 and Fan and Petit, 1994). Metwally *et al.* (2008) found that *N. barkeri* females produce 1.9, 2.1, 2.3 eggs per day feeding on *T. urticae*, *T. tabaci* nymphs and eriophyid mites, respectively. Species such as *Amblydromalus limonicus* (Garman and McGregor) (Acari: Phytoseiidae), *A. swirskii*, *Amblyseius degenerans* (Berlese, 1889) and *Amblyseius montdorensis* (Schicha) confirm successful predators of thrips in sweet pepper and chrysanthemum (Messelink *et al.*, 2008; Wimmer *et al.*, 2008; Arthurs *et al.*, 2009; Knapp *et al.*,2013; Buitenhuis *et al.*,2015; and Hewitt *et al.*,2015). Efficiency of *A. swirskii* against thrips in biocontrol agent is also influenced by increased trichomes densities hinder in host plant species (Buitenhuis *et al.*,2014). *T. tabaci* could devour *A. swirskii* eggs and female predators were observed preferentially to oviposit at sites in absence *T.tabaci*, or to kill more T.tabaci at oviposition sites to protect their young (De Almeida and Jansen, 2013). Thrips are not the best food source for mites. Therefore, the addition of supplemental food to *A. swirskii* has recently been investigated. Supplying pollen improved the performance of *A. swirskii* in thrips control on chrysanthemum (Vangansbeke *et al.*, 2016). Efficient predator of T.tabaci, *A. swirskii* was easily reared that allowed economic mass production. Since , 2005, *A. swirskii* had become used for biological control program of *T.tabaci* and whiteflies in crops worldwide. Khaliq *et al.* (2018) found that predatory mites, *N. barkeri* eat more on larval first instar than second larval instar and adults of *T.tabaci*. However, consumption rate of *N. barkeri* was rather higher during the initial 12 hours of feeding then slowed down later (24 h); this may be result to aggressive predation initially.

Table (1): Efficacy of predator mites and entomopathogenic fungi against *Thrips tabaci*.

Varieties	Winterstar			Florida			Fortuna			Markez		
Predatory & Fungus	Mean No. *Thrips tabaci* individuals/leaf±SE		% Reduction	Mean No. *Thrips tabaci* individuals/leaf±SE		% Reduction	Mean No. *Thrips tabaci* individuals/leaf±SE		% Reduction	Mean No. *Thrips tabaci* individuals/leaf±SE		% Reduction
	Before treatment	After treatment by 21 week		Before treatment	After treatment by 21 week		Before treatment	After treatment by 21 week		Before treatment	After treatment by 21 week	
T. swirskii	3.6±0.5a	1.2±0.2b	85.5	4.2±0.58a	2.2±0.8b	76.59	4.6±0.6a	1.8±0.5b	76.52	4.6±0.5a	1.6±0.5b	77.14
N. cucumeris	3.4±0.8a	1.6±0.24b	79.5	4.6±1.2a	2.6±0.5b	74.74	4.8±0.9a	2.2±0.3b	72.5	4.8±0.01a	1. 8±0.4b	75.35
B. bassiana	3.4±0.51a	2.2±0.58b	71.8	4.2±1.1a	2.4±0.6b	74.46	4.8±1.2a	2.2±0.5b	72.5	4.8±0.9a	2.2±0.5b	69.88
Cont.	3.4±0.7a	7.8±2.1a	------	4.2±1.59a	9.2±0.7a	------	4.8±0.7a	8.0±2.0a	------	4.6±0.7a	7.0±1.3a	------
F	0.02UN	7.5UN	------	0.02UN	20.04*	------	0.01UN	7.18UN	------	0.01UN	10.9UN	------
LSD $_{0.5}$	2.03	3.37	------	3.57	2.06	------	2.67	3.32	------	3.3	2.34	------

Means within columns followed by the same letter are not significantly different.
(UN means unsignificant)



Figure(1): Senstivity of differrent strawberry varities for *Thrips tabaci* infestation

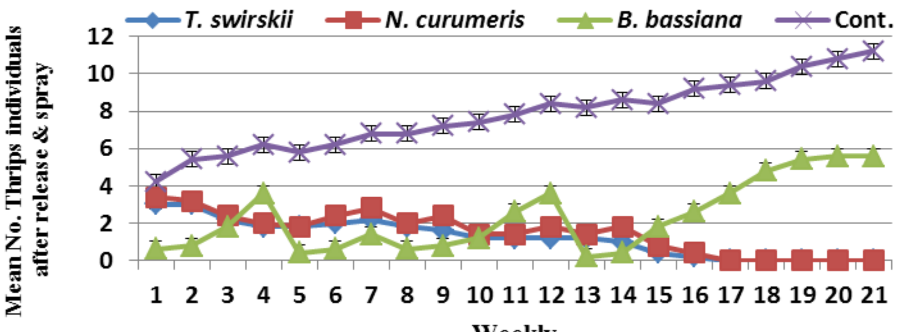
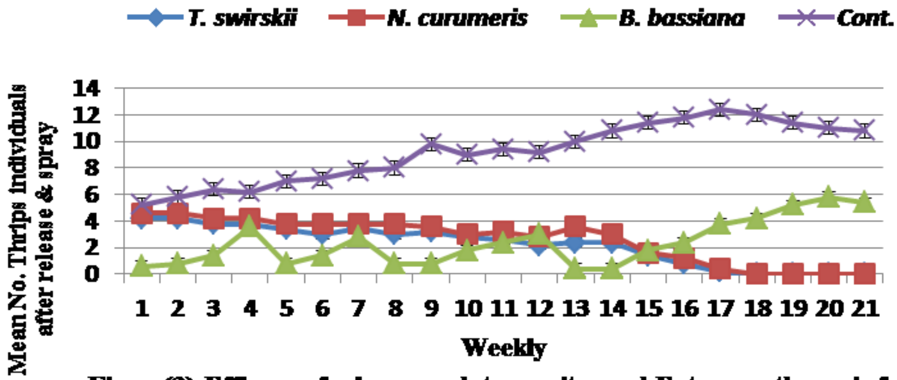
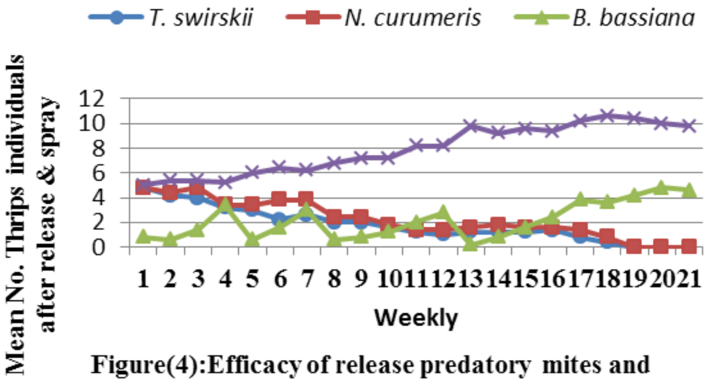


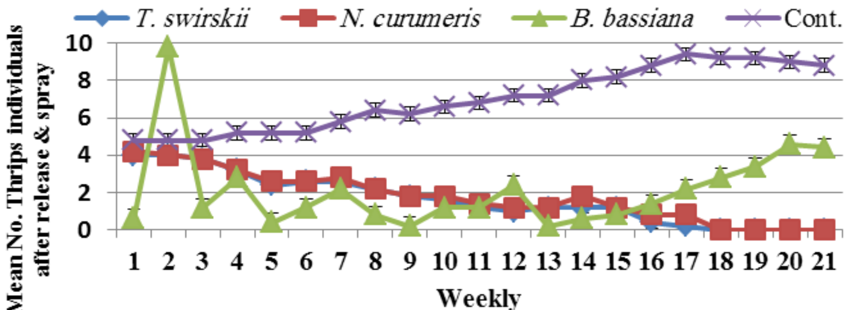
Figure (2):Efficacy of release predatory mites and Entomopathogenic fungi against *Thrips tabaci* individuals on strawberry (Winterstar variety)



Figure(3):Efficacy of release predatory mites and Entomopathogenic fungi against *Thrips tabaci* individuals on strawberry (Florida variety)



Figure(4):Efficacy of release predatory mites and Entomopathogenic fungi against *Thrips tabaci* individuals on strawberry (Fronta variety)



Figure(5):Efficacy of release predatory mites and Entomopathogenic fungi against *Thrips tabaci* individuals on strawberry (Markez variety)

References

Abd El-Salam, A.M.E.; Salem, H.A. and Salem, S.A. (2013): Biocontrol agents against the leafminer, *Liriomyza trifolii* in faba bean fields. Archives of Phytopathology and Plant Protection, 46(9):1054-1060.

Abdel-Karim, H.S. and Abd El-Wareth, H.M. (2012): Biological aspects of the predatory mite, *Amblyseius fallacies* Garman (Phytoseiidae) feeding on thrips nymphs under laboratory condition. Egyptian Academic Journal of Biological Sciences, 5(2): 197–204.

Arthurs, S.; Cindy, L.M.; Jianjun, C.; Dogramaci, M.; Brennan, M.; Houben, K. and Osborne, L. (2009): Evaluation of *Neoseiulus cucumeris* and *Amblyseius swirskii*

(Acari: Phytoseiidae) as biological control agents of chilli thrips, *Scirto dorsalis* (Thysanoptera: Thripidae) on pepper. Biological Control, 49: 91–96.

Bakker, F.M. and Sabelis, M.W. (1989): How larvae of *Thrips tabaci* reduce the attack success of phytoseiid predators. Entomologia Experimentalis et Applicata, 50: 47–51.

Brown, A.S.S.; Simmonds, M.S.J. and Blaney, W.M. (1999): Influence of species of host plants on the predation of T.tabaci by *Neoseiulus cucumeris*, *Iphiseius degenerans* and *Orius laevigatus*. Entomologia Experimentalis et Applicata, 92: 283–288.

Buitenhuis, R.; Murphy, G.; Shipp, L. and Scott Dupree, C. (2015): *Amblyseius swirskii* in greenhouse production systems: a floriculture perspective. Exp. Appl. Acarol., 65:451–464.

Buitenhuis, R.; Shipp, J.; Jandricic, S.; Murphy, G. and Short, M. (2007): Effectiveness of insecticide treated and non-treated trap plants for the management of *Frankliniella occidentalis* (Thysanoptera: Thripidae) in greenhouse ornamentals. Pest Management Science, 63: 910–917.

Buitenhuis, R.; Shipp, L.; Scott-Dupree, C.; Brommit, A. and Lee, W. (2014): Host plant effects on the behavior and performance of *Amblyseius swirskii* (Acari: Phytoseiidae). Exp. Appl. Acarol., 62:171–180.

Croft, B.A.; Pratt, P.D.; Koskela, G. and Kaufman, D. (1998): Predation, reproduction and impact of phytoseiid mites (Acari: Phytoseiidae) on cyclamen mite (Acari: Tarsonemidae) on strawberry. J. Econ. Entom., 91 (6): 1307-1314.

Cuthbertson, A.G.S. (2004): Unnecessary pesticide applications in Northern Ireland apple orchards due to mis-identification of a beneficial mite species. Res. J. Chem. Environ., 8: 77-78.

Damon, S. J.; Groves, R.L. and Havey, M.J. (2014): Variation for epicuticular waxes on onion foliage and impacts on numbers of onion T.tabaci. J. Am. Soc. Hortic. Sci., 139: 495–501.

DeAlmeida, A.A . and Jansen, A. (2013): Juvenile prey induce antipredator behavior in predators. Exp. Appl. Acarol., 59:275–282.

Diaz-Montano, J.; Fuchs, M.; Nault, B.A. and Shelton, A.M. (2012): Resistance to onion thrips (Thysanoptera: Thripidae) in onion cultivars does not prevent infection by Iris yellow spot virus following vector-mediated transmission. Fla. Entomol., 95: 156–161.

Diaz-Montano, J.; Fuchs, M.; Nault, B.A.; Fail, J. and Shelton, A.M. (2011): Onion thrips (Thysanoptera: Thripidae): a global pest of increasing concern in onion. J. Econ. Entomol., 104: 1–13.

El-Saeidy, E.M.A. and Romeih, H.M. (2007): Comparative studies between predatory mites and pecticides in controlling *Tetranychus urticae* Koch on strawberry plants at Qualubyia Governorate. J. Agric. Sci., Mansoura Univ.,32(4):2601-2608.

Fan, Y.Q. and Petit, F.L. (1994): Biological control of broad mite, *Polyphagotarsonemus latus* (Banks), by *Neoseiulus barkeri* Hugues on pepper. Biological Control, 4: 390–395.

Fitzgerald, J.; Pepper, N.; Easterbrook, M.; Pope, T. and Solomon, M. (2007): Interactions among phytophagous mites, and introduced and naturally occurring predatory mites, on strawberry in the UK. Exp. Appl. Acarol., l43 (1): 33-47.

Francisco, Amil-Ruiz; Rosario Blanco-Portales; Juan, Munoz-Blanco and Jose´,L. Caballero. (2011): The strawberry plant defense mechanism: A Molecular Review. Plant Cell Physiol., 52(11): 1873–1903.

Gonzalez-Zamora, J.E. and Garcia-Mari, F. (2003): The efficiency of several sampling methods for *Frankliniella occidentalis* (Thysan., Thripidae) in strawberry flowers. J. Appl. Entomol., 127:516–521.

Hansen, L.S. (1988): Control of *T.tabaci tabaci* (Thysanoptera: Thripidae) on glasshouse cucumber using large introductions of predatory mites *Amblyseius barkeri* (Acarina: Phytoseiidae). Entomophaga, 33: 33-42.

Hassan, M.F.; Ali, F.S.; Hussein, A.M. and Mahgoub, M.H. (2008): Biological and chemical control of three plant piercing-sucking insect pests on cucumber in plastic houses. Egyptian Journal of Biological Pest Control ,18(1): 167–170.

Hewitt, L.C.; Shipp, L.; Buitenhuis, R . and Scott Dupree, C. (2015): Seasonal climatic variations influence the efficacy of predatory mites used for control of western flower thrips in greenhouse ornamental crops. Exp. Appl. Acarol., 65:435–450.

International Organisation for Biological and Integrated Control (IOBC) (2008): IOBC Global Newsletter. http://www.unipa.it/iobc/ view.php. Status: 09.2008.

Kareiva, P. and Sahakian, R. (1990) : Tritrophic effects of a simple architectural mutation in pea plants. Nature, 345: 433–434.

Karg, W.; Mack, S. and Baier, A. (1987): Advantages of oligophagous predatory mites for biological control. Bulletin SROP-WPRS, 10: 66–73.

Khaliq, A.; Afzal, M.; Raza, A.M.; Kamran, M.; Khan, A.A.; Aqeel ,M.A.; Ullah, M.I. ; Khan, B.S. and Kanwal, H. (2018): Suitability of *Thrips tabaci* L. (Thysonaptera: Thripidae) as prey for the phytoseiid mite, *Neoseiulus barkeri* Hughes (Acari: Phytoseiidae). African Entomology, 26(1): 131–135.

Kishaba, A.N.; Voth, V.; Howland, A.F.; Bringhurst, R.S. and Toba, H.H. (1972): Two spotted spider mite resistance in California strawberries. J. Econ. Entomol., 65: 117–119.

Knapp, M.; van Houten, Y.; Hoggerbrugge, H. and Bolckmans, K. (2013): *Amblydromalus limonicus* (Acari: Phytoseiidae) as a biocontrol agent: review and new findings. Acaralogia ,53:102–202.

Kutuk, H.; Yigit, A.; Canhilal, R. and Karacaoglui, M. (2011): Control of western flower thrips (*Frankliniella occidentalis*) with *Amblyseius swirskii* on greenhouse pepper in heated and unheated plastic tunnels in the Mediterranean region of Turkey. African Journal of Agricultural Research, 6(24): 5428–5433.

Leiss, K.A.; Choi, Y.H.; Abdel-Farid, I.B.; Verpoorte, R. and Klinkhamer, P.G. (2009): NMR metabolomics of thrips (*Frankliniella occidentalis*) resistance in Senecio hybrids. J. Chem. Ecol., 35:219–229.

Leiss, K.A.; Choi, Y.H.; Verpoorte, R. and Klinkhamer, P.G. (2011): An overview of NMR-based metabolomics to identify secondary plant compounds involved in host plant resistance. Phytochem. Rev ., 10:205–216.

Lewis, T. (1997): T.tabaci as crop pests. CAB International, New York, NY.

Luczynski, A.; Isman, M.B.; Raworth, D.A. and Chan, C.K. (1990b): Chemical and morphological factors of resistance against the two spotted spider mite in beach strawberry. J. Econ. Entomol., 83:564–569.

Messelink, G.J.; Van Maanen, R.; Sebastiaan, E.F. and Van-Steenpaal, J.A. (2008): Biological control of thrips and whiteflies by a shared predator: two pests are better than one. Biological Control, 44: 372–379.

Metwally, M.A.S.; EL-Naggar, M.E.; EL-Khateeb, H.M. and Abou-Zaid, A.M.M. (2008): Effect of intercropping of some aromatic plants on the infestation levels of *Tetranychus urticae* Koch to cucumber plants and its resulted yield in both open and greenhouse conditions. Egyptian Journal of Agricultural Research , 86(1): 259–268.

Mirnezhad, M.; Romero-Gonzalez, R.R.; Leiss, K.A.; Choi, Y.H.; Verpoorte, R. and Klinkhamer, P.G. (2009): Metabolomics analysis of host plant resistance to thrips in wild and cultivated tomatoes. Phytochem Anal ., 21:110–117.

Mollema, C. and Cole, R.A. (1996): Low aromatic amino acid concentrations in leaf proteins determine resistance to *Frankliniella occidentalis* in four vegetable crops. Entomol. Exp. Applic., 78:325–333.

Morse, J. G. and Hoddle, M. S. (2006): Invasion biology of T.tabaci. Ann. Rev. Entomol., 51: 67–89.

Mouden, S.; Kryss, F.S.; Peter, G.K. and Leiss, K.A . (2017): Integrated pest management in western flower thrips: past, present and future. Pest Manag. Sci., 73: 813–822.

Pedigo, Larry and Rice Marlin, E. (2015): Entomology and pest management. Book 6th edition,249 p.

Price, P.W.; Bouton, C.E.; Gross, P.; McPheron, B.A.; Thompson, J.N. and Weis, A.E. (1980) : Interactions among three trophic levels: influence of plants on the interaction between insect herbivores and natural enemies. Annual Review of Ecology and Systematics, 11: 41–65.

Riudavets, J. (1995): Predators of *Frankliniella occidentalis* (Perg.) and *Thrips tabaci* Lind.: a review. Wageningen Agricultural University Papers, 95(1): 43–87.

Rosell, G.; Quero, C.; Coll, J. and Guerrero A. (2008): Biorational insecticides in pest management. J. Pestic. Sci., 33:103-121.

Sabelis, M.W. and Van-Rijn, P.C.J. (1997): Predation by insects and mites. 259–354. In: Lewis, T. (Ed.) Thrips as Crop Pests. CAB International, Wallingford, U.K.

Shakya, S.; Coll, M. and Weintraub, P.G. (2010): Incorporation of intraguild predation into a pest management decision-making tool: The case of thrips and two pollen-feeding predators in strawberry. J. Econ. Entomol. ,103:1086–1093.

Steinite, I. and Levinsh, G. (2003): Possible role of trichomes in resistance of strawberry cultivars against spider mite. Acta Univ. Latviensis, 662: 59–65.

Tsao, R.; Marvin, C.H.; Broadbent, A.B.; Friesen, M.; Allen, W.R. and McGarvey, B.D. (2005): Evidence for an isobutylamide associated with host-plant resistance to western flower thrips, *Frankliniella occidentalis*, in chrysanthemum. J. Chem.Ecol ., 31:103–110.

Van Houten, Y.M.; Ostilie, M.L.; Hoogerbrugge, H. and Bolckmans, K. (2005): Biological control of western flower T.tabaci on sweet pepper using the predatory mites *Amblyseius cucumeris*, *Iphiseius degenerans, A. andersoni* and *A. swirskii*. IOBC/WPRS Bull**.,** 28:283–286.

Vangansbeke, D.; Nguyen, D.T.; Audenaert, J.; Verhoeven, R.; Gobin, B. and Tirry, L . (2016): Supplemental food for *Amblyseius swirskii* in the control of thrips : friend or foe?. Pest Manag. Sci., 72:466–473.

Wimmer, D.; Hoffmann, D. and Schausberger, P. (2008): Prey suitability of western flower T.tabaci, *Frankliniella occidentalis*, and onion *Thrips tabaci*, for the predatory mite *Amblyseius swirskii*. Biocontrol Science and Technology, 18(6): 541–550.

Xu, X. and Enkegaard, A. (2010): Prey preference of the predatory mite, *Amblyseius swirskii* between first instar western flower thrips *Frankliniella occidentalis* and nymphs of the two spotted spider mite *Tetranychus urticae*. Journal of Insect Science, 10: 149.

Zeier, P. and Wright, M.G. (1995): Thrips resistance in *Gladiolus* spp.: potential for IPM and breeding, in thrips Biology and Management, ed. By Parker BL, Skinner M and Lewis T. Plenum Press, New York, NY, 411–416.