The Searching Behavior of *Scolothrips longicornis* (Priesner) in Relation to Plant Surface Topography

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Abstract

The searching behaviour of the predaceous thrips, *Scolothrips longicornis* Priesner, was studied to evaluate the predator orientation toward its prey related to host plant features specially plant surface trichomes. We estimated walking speed, number of turns and orientation degree and time needed to get the first prey under laboratory condition on the undersurface of four plant species (eggplant, cucumber, tomato and sweet pepper). Eggplant with rational dense trichomes on the undersurface provided the most favorable substance for predator searching behaviour with significant difference; walking speed (6.27 ± 0.32 seconds), covered distance (20.41 ± 1.11 mm), 5.58 ± 0.76 turns and 176.66 ± 13.96 seconds. So, the predator´s searching efficiency was not similar among plant species. Thus the combined effect of plant directly on the predator walking behavior influenced the predator´s searching efficiency and it may lead to significantly different predation rate.

Keywords- plant topography, *Scolothrips longicornis,* walking, orientation, host plant

Introduction

Plant-natural enemies' interactions include the reaction of natural enemies to chemical and physical features of host plants which would arise in natural enemies' preference. Although major attention has been concentrated on the host plant volatiles induced by herbivores affecting the natural enemies' reaction toward host plants, in some cases it has been seen that plant physical structures such as color, trichomes, architecture of the plants, etc. could have major effect, too (Coll *et al.,* 1997; Agelopoulos *et al.,* 1999; Roda *et al.,* 2001). A significant interaction between behaviour of natural enemies and plant architecture would be evident for the tritrophic interaction (Kareiva & Sahakian, 1990). Previous investigations of the interplay between host plant morphology and biological control agents have involved different host plants and predator species. The success of ladybird larvae *Coccinella septempuntata* L. in suppressing aphid population is largely related to the host plant surface structures (Bottrell *et al.,* 1998). Trichomes are shown to be the major factors which would play opposite roles for the predator; they can alter their route toward prey and increase their handling time, or evenly prevent their oviposition as it has been seen in *Anthocoris confuses* Reuter (Evans, 1976). On the other hand, they can make great shelter to hide in and find more preys or provide more efficient path to catch prey (Dicke & Sabelis, 1988). Agrawal (1997) reported the effect of avocado plant trichomes on the searching time of the phytoseiids. *Neoseiulus cucumeris* Oudemans is affected by the *Eucalyptus* leaf trichomes (Beard & Walter, 2001). Some other studies showed the effect of wax layer of the leaf surface on the predators' efficiency parameters such as predator's walking speed (Clark & Messina, 1998a; Clark & Messina, 1998b; Krips *et al.,* 1999), handling time (Chang & Eigenbrode, 2004), functional response (Skirvin & Fenlon, 2001; Shiojiri *et al.,* 2000), oviposition (Lundgren & Fenlon, 2006) and consumption rates (Kareiva & Sahakian, 1990; Grevstad & Klepetka, 1992; Heinz & Zalom, 1996; Eigenbrode *et al.,* 1996; Agrawal *et al.,* 2000; White & Eigenbrode, 2000; Norton *et al.,* 2001). In a study, Clark and Messina (1998a) showed that *Propylea quatuordecimpunctata* L. larvae were affected by host plant species in some behavioral sequences like contacting and capturing aphids.

Spider mites (Acari: Tetranychidae) are widespread pests which often cause several damage to various crops (Gerlach & Sengonca, 1985). Biological control would be a good alternative to the other control methods especially chemical control. Among the natural enemies of spider mites are predacious thrips include acarophagous species with various degree of specialization on mites. All species in the genus *Scolothrips* appear to be the specialized predators of spider mites (Priesner, 1950). Minute thrips of *Scolothrips longicornis* Priesner (Thysanoptera:

Thripidae), are native specialist predators in Iran in many cropping system such as cucumber, bean, tomato and sugar cane (Pakyari *et al.,* 2008).

The success of a biological control agent to locate the prey can be influenced by the presence of trichomes on the host plant. Although physical features of host plants is considered to influence *S. longicornis* (Kheradpir *et al.,* 2009b), it has not been received any attention in the literature. So, the aim of this study was to find out the effect of the physical surface factors of host plant on the walking, orientation and foraging behavior of predacious thrips, *S. longicornis,* under laboratory condition on the undersurface of four experimental host plant species with high cultivated area in greenhouses of Iran.

Material and methods

Prey rearing. Two-spotted spider mites collected from bean (var. Varamin) in a research field near Tehran, 2007, were reared on 2-3 weeks old of the same bean plant variety in a climate room (26±1ºC, RH=65±5% and 16L**:**8D). After 3-4 days, heavily infested plants were used for predatory thrips culture. Mites belong to the third generation were used for the experiment.

Predator culture. Adult females of *S. longicornis* were obtained from the colony that was started with specimens from cucumber greenhouse in the IPPR and kept in the same climate room on cow pea plants infested by spider mites of different developmental stages. Newly infested cow pea plants were provided weekly as food. The colony was kept for more than one year.

Experimental plants. Four species of greenhouse vegetables such as cucumber *Cucumis sativum* var. Sultan, tomato *Solanum lycopersicum* var. Cantander, eggplant *Solanum melongena* var. Valencia and sweet pepper *Capsicum annum* var. local were planted as experimental plants in small pots in the same climate room. Four to five leaf seedlings were used for the experiment. The second uppermost leaf was cut and used up-side down as leaf disk on water soaked cotton for the tests. Ten leaves per plant species (10 replications) were included in the test.

Predator movement analysis. Predator movements and actions in response to physical features of host plant leaf surface were studies through manipulating walking behaviour of the predator on the undersurface of four experimental plants (cucumber, tomato, eggplant and sweet pepper) (Van Baalen & Sabelis, 1995). The evaluated parameters were predator walking speed (mm/sec) (Chang & Eigenbrode, 2004), orientation behavior such as applying direct or indirect path to reach the prey source (Eigenbrode *et al.,* 1996; Coll *et al.,* 1997; Van Loon *et al.,* 2000; White & Eigenbrode, 2000; Nachappa *et al.,* 2006) and time needed to catch the first prey (Nakamuta, 1984; Dicke, 1986; Grevstad & Klepetka, 1992; Heinz & Zalom, 1996; van Laerhoven *et al.,* 2000). Predator walking speed was determined as the time needed for passing 10 mm on the plant leaf surface and every turn which was more than 90 degrees was taken as tendency (Clark & Messina, 1998a). The predator pathway was banned by tow glasses (10×50 mm) on the undersurface of the plant leaves, containing some part of the main vein. At the end of the pathway, a group of twenty five spider mite eggs were put as the prey source and infochemical signals. The pathway was considered on the underside of leaf surface containing some part of the main vein. Length of the way was considered 50 mm within the releasing point and mite eggs (Krips *et al.,* 1999). The behavior of each individual predator was observed till the first contact with prey. In addition, the direction of predator behavior affected by leaf surface was also determined; as sixty seconds were given to each predator to pass the way toward the prey source, then the length of direct way toward the prey source was recorded. Time needed to catch the first prey was also recorded for individual predator on each plant species surface. Predators which could not reach their first prey or visit it within 120 seconds were removed from the test. Twenty individual predators at the age of 4-5 days were used for each plant species. Each predator entered the test once and if it could not reach the first prey within 600 seconds, jumped or did not moved, were removed from the records. Data was subjected to ANOVA test under complete random blocks and mean comparison method of Duncan in SPSS 14.0 software.

Trichome density analysis. Trichomes in 25 mm^2 of mid-blade on lower surface of each plant species (in 14 replications) were counted and recorded via binocular 40x (Agrawal, 1997; Norton *et al.,* 2001; Skirvin & Fenlon, 2001). The data were analyzed under complete random test in ANOVA and mean comparison method of Duncan in SPSS 14.0 software.

Results

Predator movement analysis. Walking speed of the predaceous thrips - time needed to pass 10 mm toward spider mite eggs- showed significant difference among four experimental plants (F= 194.14, sig. <0.0001). From all the individual predators used in this test, 76% (18 individual predators for eggplant, 17 for tomato, 14 for cucumber and 12 for sweet pepper) revealed the final result and passed the pathway. As Table 1 shows the mean time needed to pass the way on eggplant (6.27±0.32 sec.) and sweet pepper (6.43±0.39 sec.) leaf surfaces had no significant difference and in comparison with other two host plants were considerably lower and thus more favorable for the predator. Tomato showed the longest time required to pass the way.

The covered direct distance in 60 seconds by *S. longicornis* showed significant difference among four experimental plants (F= 69.334, sig <0.001), as long as 71% of the predators (18 individual predators for eggplant, 13 for tomato, 15 for cucumber and 11 for sweet pepper) stayed on the plant surfaces and walked on to search the prey till 60 seconds. The highest distance covered by predator individuals was recorded for eggplant (20.41 ± 1.11 mm), thus eggplant leaf surface would be more favorable for adult *S. longicornis* to forage preys. Table 1 shows Duncan classification of the results regarding plant species. The shortest distance covered in 60 seconds was recorded for sweet pepper (3.58 ± 0.55 mm) in direct way.

The data belonged to observation on the 71% of the predator individuals participated in the previous test showed that the number of turnings that walking predators made on the undersurface of the four plant leaves undersurfaces revealed significant difference (F=0.84, sig<0.001). As the Table 1 shows, the most turnings were recorded on tomato (31.58 ± 2.19), respectively on sweet pepper (19.58 ± 1.83), cucumber (15.58 ± 1.20) and the lowest number for eggplant (5.58 ± 0.76).

Time needed to obtain the first prey had no significant difference among four experimental plants. Only 35% of the predators could obtain their prey and were not removed from the test, among the observed predators, 14 individuals were observed on eggplant and 10 on cucumber. None of the predators could reach its prey within our experimental time on tomato and sweet pepper. Mean time needed for visiting the first prey were recorded as 176.66 ± 13.96 seconds for eggplant and 323.58 ± 15.37 seconds for cucumber. The predators could not obtain any prey within 600 seconds on sweet pepper and tomato, so they were removed from the test.

Trichome density analysis. The results revealed significant difference in trichomes density and quality among the plants. Qualitatively, trichomes were designed in solitary and group structures. As on both, cucumber and tomato leaf surfaces, trichomes were distributed individually (unilobular) but in other two plants, trichomes were accumulated in groups (multi-lobular). Eggplant had group trichomes in the number of six and sweet pepper had seven ones in each trichome group. This type of trichome decoration made an umbrella-shaped structure on the undersurfaces of the leaves that could be used as shelters to hide tiny preys or predators. In addition, quantitative analysis of trichome density showed significant difference in main blade (F= 166.342, sig< 0.001, respectively). The highest trichome density in 25 mm^2 of main blade was recorded on cucumber leaf surface (503.57 ± 24.38 individual trichomes), and respectively on eggplant (226.28 ± 3.89 trichome in group), tomato (52.21 ± 1.5 individual trichomes) and finally on sweet pepper (12 ± 1.54 trichomes in group). According to Duncan mean comparison test, tomato and sweet pepper were put in one group with significant difference from two others (cucumber and eggplant; Table 1).

Discussion

These experiments showed that predaceous thrips adults are affected by the physical features of host plant surface. Predator movement speed based on the time needed for covering 10 mm on the leaf surface of four experimental plants showed significant difference. As eggplant with the lowest amount of the required time to pass were selected as the most suitable surface of host plant for *S. longicornis.* Apparently the features of eggplant leaf surface such as trichome quality and quantity are in favor of predator movement. The least number of turnings of *S. longicornis* on eggplant leaf surface revealed the easy pathway provided by the plant for preying. In addition, the longest route passed by the predators on eggplant revealed the positive interaction between *S. longicornis* and eggplant leaf topography. The high number of turnings and the lowest distance covered in 60 seconds on sweet pepper are factors which represent this host plant as the less suitable for the predaceous thrips foraging behavior.

Predator movement is determined by two factors**:** prey distribution and host plant topography (Evans, 1976). As the prey eggs were accumulated in one area of the undersurface of plant leaves, the main factor affecting predator movement and searching behavior is host plant surface in this test. The predaceous bugs, *Orius tristicolor* White, waste more time in searching the environment in accumulated prey condition (van Laerhoven *et al.*, 2000). The searching behavior of the predator may be due to their visual ability or olfactory response; *Coccinella septempunctata* cannot find its prey in distance more than 2 mm (Nakamuta, 1984). Dick (1986) mentioned both infochemicals and host plant surface topography are important in the final success of predator foraging behavior. He noted the densest leaves are more favorable for *Phytoseiulus persimilis* Mathias-Henriot. Trichome density was shown to be effective on *P. persimilis* on gerbera leaf surface (Krips *et al.*, 1999a). Several examples of the required time for catching the first prey have been shown to affect parasitoid wasps (Shiojiri *et al.*, 2000). Predatory preference of *Hippodamia convergens* Guerrin-Menneville is dependent on host plant topography and plant with more trichome density and less wax on their surface is more suitable for predator searching (White & Eigenbrode, 2000). Plant surface feature in rice cultivars, especially trichome density has been shown to affect *Chrysoperla carnea* Stephens larvae searching efficiency; as the required time for the first prey catching and the number of turnings are the main factors determining predator direction toward prey which can be dependent on plant topography (Clark & Messina, 1998b). Bean leaf surface had altered foraging behavior of *Orius insidiosus* Say parameters such as walking speed, required time for the first preying and number of turnings (Coll *et al.,* 1997). Trichomes on the leaf surface have great effect on movement of lady beetle *Delphastus pusillus* (Heinz & Zalom, 1996). Walking speed of *P. persimilis* was reported as affected by the density of trichomes on the undersurface of gerbera leaves (Krips *et al.*, 1999)

The results in study provide additional evidence that plant surface trichome can affect the effectiveness of the predator. Under certain condition we showed that in *S. longicornis,* patterns of searching and foraging behavior are influenced by the topography of the plant, particularly the blade and main vein which are favored searching areas for the hungry predaceous thrips. These area support the best sites for oviposition and best pathways toward prey colonies, specially spider mite eggs. Similar results has been shown in parallel studies (Kheradpir *et al.,* 2009b); it was shown that *S. longicornis* could not make its decision to select the most favorable host plant among four experimental plants and it is needed to pass on and also the predator could choose between host plant within a family with similar leaf structure rather than different families that confirms the effect of host plant structure on predator

Table 1: parameters relating to walking behavior of *S. longicornis* on the lower surface of four experimental plants (Mean ± SE mean)

Host plants	cucumber	eggplant	tomato	Sweet pepper
parameterspecies				
Speed (sec.)	12.13 ± 0.4^b	6.27 ± 0.32^c	17.22 ± 036^a	6.43 ± 0.39^c
Distance covered (mm)	12.75 ± 1.15^b	20.41 ± 1.11^a	6.08 ± 0.62^c	3.58 ± 1.92^c
Turns number	15.58 ± 1.20^b	5.58 ± 0.76^c	31.58 ± 2.19 ^{a}	19.58 ± 1.84^b
First preying time (sec.)	323.58 ± 15.37	176.66 ± 13.96	n.a.	n.a.
Mid-blade trichom density	503.57 ± 24.38^a	226.28 ± 3.89^b	52.21 ± 1.5^c	12 ± 1.54^c

foraging behaviour. Any change in foraging behavior of *S. longicornis* would lead to higher predation efficiency and higher survival, so host plant can indirectly affect predator success. Eggplant with semi-dense trichome profile on its leaf surface can be considered as the most suitable host plant to be combined with foraging behavior of the natural enemy, *S. longicornis* among our experimental plants.

The four host plants in this study differed in specifics as a host plant for the predator locomotion. In enclosure, *S. longicornis* located and attacked spider mites more rapidly on eggplant leaves than other three plants. Mobility of the predator was reduced on sweet pepper, trichome-less leaves reinforcing link between mobility and predation. Plant trichomes can reduce adhesion by herbivores as well as predators (Eigenbrode *et al.,* 1996) and it should provide against herbivory. Our study showed that we may not detect the importance of plant morphological effect on the final output of biological control, unless studying predator locomotion on different plant surfaces. However, it is unclear if short-time differences in predator behaviour in laboratorial condition can be used to predict predator-prey interaction under field condition. Our observations on the predator behaviour can be confirmed by other results obtained of feeding and oviposition rates and also release-recapture test under greenhouse condition (unpublished data; Kheradpir *et al.,* 2009a).

References

1. Agelopoulos, N., Birkett M.A., Hick, A.J., Hooper, A.M., Picket, J.A., Pow, E.M., Smart, L.E., Smiley, D.W.M., Wadhams, L.J. and Woodcock, C.M. 1999. Exploiting semiochemials in insect control. *Pesticide Science* **55:**225-235.
2. Agrawal, A.A. 1997. Do leaf domatia mediate a plant-mite mutualism? An experimental test of the effects on predators and herbivores. *Ecological Entomology* **I22:**371-376.
3. Agrawal, A.A., Karban, R. and Colfer, R.G. 2000. How leaf domatia and induced plant resistance affect herbivores, natural enemies and plant performance. *OIKOS* **89:**70-80.
4. Beard, J.J. and Walter, G.H. 2001. Host plant specificity in several species of generalist mite predators. *Ecological Entomology* **26:**562-570.
5. Bottrell, D.G., Barbosa, P. and Gould, F. 1998. Manipulating natural enemies by plant variety selection and modification**:** A realistic strategy? *Annul Review of Entomology* **43:**347-367.
6. Chang, G.C. and Eigenbrode, S.D. 2004. Delineating the effects of a plant trait on interactions among associated insects. *Oecologia* **139:**123-130.
7. Clark, T.L. and Messina, F.J. 1998a. Foraging behavior of lacewing larvae (Neuroptera**:** Chrysopidae) on plants with divergent architecture. *Journal of Insect Behavior* **11(3):**303-316.
8. Clark, T.L. and Messina, F.J. 1998b. Plant architecture and the foraging success of ladybird beetles attacking the Russian wheat aphid. *Entomologia Experimentalis et Applicata* **86:**153-161.
9. Coll, M., Smith, L.A. and Ridgway, R.L. 1997. Effect of plants on the searching efficiency of a generalist predator**:** the importance of predator-prey spatial association. *Entomologia Experimentalis et Applicata* **83:**1-10.
10. Dicke, M. 1986. Volatile spider-mite pheromone and host-plant kairomone, involved in spaced-out gregariousness in the spider mite, *Tetranychus urticae. Physiological Entomology* **11:**251-62.
11. Dicke, M. and Sabelis, M.W. 1988. How plants obtain predatory mites as bodyguards. *Netherlands Journal of Zoology* **38(2-4):**148-165.
12. Eigenbrode, S.D., Castagnola, T., Roux, M.B. and Steljes, L. 1996. Mobility of three generalist predators is greater on cabbage with glossy leaf wax than on cabbage with a wax bloom. *Entomologia Experimentalis et Applicata* **81:**335-343.
13. Evans, H.F. 1976. The searching behaviour of *Anthocoris confusus* (Reuter) in relation to prey density and plant surface topography. *Ecological Entomology* **1:**163-169.
14. Gerlach, S. and Sengonca, C. 1985. Comparative studies on the effectiveness of the predatory mite *Phytoseiulus persimilis* and the predatory thrips *Scolothrips longicornis. Zeitschrift f. Pflanzenkrankheiten Pflanzenshutz* **92:**138-146.
15. Grevstad, F.S. and Klepetka, B.W. 1992. The influence of plant architecture on the foraging efficiencies of a suite of ladybird beetle feeding on aphids. *Oecologia* **92:**399-404.
16. Heinz, K.M. and Zalom, F.G. 1996. Performance of the predator *Delphastus pusillus on Bemisia* resistant and susceptible tomato lines. *Entomologia Experimentalis et Applicata* **81:**345-352.
17. Kareiva, P. and Sahakian, R. 1990. Tritrophis effects of a simple architectural mutation in pea plants. *Nature* **345:**433-434.
18. Kheradpir, N., Rezapanah, M., Kamali, K. and Fathipour, Y. 2009a. Effect of physiochemical features of host plants in different species or cultivars on foraging behavior of *Scolothrips longicornis. Bulletin IOBC/WPRS* (under publication)
19. Kheradpir, N., Rezapanah, M., Kamali, K., and Fathipour, Y. 2009b. Physical Structures of Host Plants Affect Predaceous Thrips, *Scolothrips longicornis* (Thysanoptera**:** Thripidae) Preference Behaviour. *Journal of Biological Control* **23(2):** under publication.
20. Krips, O.E., Kelijn, P.W., Willems, P.E.L., Gols, G.J.Z. and Dicke, M. 1999. Leaf hairs influence searching efficiency and predation rate of the predatory mite *Phytoseiulus persimilis* (Acari**:** Phytoseiidae). *Experimental and Applied Acarology* **23:**119-131.
21. Lundgren, J.G. and Fergen, J.K. 2006. The oviposition behavior of the predator *Orius insidiosus***:** acceptability and preference for different plants. *Biocontrol* **51:**217-227.
22. Nachappa, P., Margolies, D.C. and Nechols, J.R. 2006. Resource-dependent giving-up time of the predatory mite, *Phytoseiulus persimilis. Journal of Insect Behavior* **19(6):**741-752.
23. Nakamuta, K. 1984. Visual orientation of a ladybeetle, *Coccinella septempunctata* (Coleoptera**:** Coccinellidae), toward its prey. *Applied Entomology and Zoology* **19(1):**82-86.
24. Norton, A.P., English-Loeb, G. and Belden, E. 2001. Host plant manipulation of natural enemies**:** leaf domatia protect beneficial mites from insect predators. *Oecologia* **126:**353-542.

25. Pakyari, H., Fathipour, Y., Rezapanah, M. and Kamali, K. 2008. Prey-stage preference in *Scolothrips longicornis* Priesner (Thysanoptera**:** Thripidae) on *Tetranychus urticae* Koch (Acari**:** Ttraanychidae). *IOBC/WPRS Bulletin* **32:**167-169.

26. Priesner, H. 1950. Studies on the genus *Scolothrips. Bulletin of Society Fouadler Entomology* **34:**39-68.

27. Roda, A., Nyrop, J., English-Loeb, G. and Dicke, M. 2001. Leaf pubescence and two-spotted spider mite webbing influence phytoseiid behavior and population density. *Oecologia* **129:**551-560.

28. Shiojiri, K., Takabayashi, J., Yano, S. and Takafuji, A. 2000. Herbivore-species-specific interactions between crucifer plants and parasitic wasps (Hymenoptera**:** Braconidae) that are mediated by infochemicals present in areas damaged by herbivores. *Applied Entomology and Zoology* **35(4):**519-524.

29. Skirvin, D.J. and Fenlon, J.S. 2001. Plant species modifies the functional response of *Phytoseiulus persimilis* (Acari**:** Phytoseiidae) to *Tetranychus urticae* (Acari**:** Tetranychidae)**:** implication for biological control. *Bulletin of Entomological Research* **91:**61-67.

30. Van Baalen, M. and Sabelis, M.W. 1995. The milker-killer dilemma in spatially structured predator-prey interactions. *OIKOS* **74:** 391-400.

31. Van Laerhoven, S., Gillespie, D.R. and McGregor, R.R. 2000. Leaf damage and prey type determine search effort in *Orius tristicolor. Entomologia Experimentalis et Applicata* **97:**167-174.

32. Van Loon, J.J.A., De Vos, E.W. and Dicke, M. 2000. Orientation behavior of the predatory hemipteran *Perilus bioculatus* to plant and prey odours. *Entomologia Experimentalis et Applicata* **96:**51-58.

33. White, C. and Eigenbrode, S.D. 2000. Leaf surface waxbloom in *Pisum sativum* influences predation and intra-guild interactions involving two predator species. *Oecologia* **124:**252-259.