J. Appl. Entomol. **130(1)**, 32–36 (2006) doi: 10.1111/j.1439-0418.2005.01018.x

Host-plant acceptance and performance of *Tetranychus urticae* (Acari, Tetranychidae)

N. M. Greco, P. C. Pereyra and A. Guillade
Centro de Estudios Parasitológicos y de Vectores (CONICET-UNLP), La Plata, Argentina

Ms. received: March 14, 2005; accepted: October 6, 2005

Abstract: *Tetranychus urticae* is a serious pest of several crops worldwide. It performs differentially on diverse host-plant species. Because dispersion is mainly passive, the process of host-plant selection should be viewed in terms of host-plant acceptance and not in terms of host finding. The objectives of this study were to investigate: (1) the acceptance of strawberry (S) in comparison with onion (O), leek (L) and parsley (P) by *T. urticae*; and (2) the suitability of these host plants for the performance of *T. urticae*, in terms of fecundity and survival. Host-plant acceptance was measured through females that settled on a test plant or females that left for another host plant. In another experiment, for a duration of 5 days, individual newly mated females were assigned to discs of each host plant and the fecundity, the maximum number of offspring obtained from one female that settled on the disc, the survival and the percentage of females that oviposited at least one egg were analysed. A choice test to measure the preference of females for different host plants was performed. Movements took place towards (S) from the three plants: (O), (L) and (P). Mites significantly moved to other places in the Petri dishes from leek-origin discs. Dispersal of *T. urticae* from (S) to other host-plant discs was similar for all plants. Mean fecundity was higher on (S) than on the other plants. The maximum number of offspring per female was highest on (S), lowest on (L) and (O), and intermediate on (P). Survival of females and percentage of females that laid at least one egg were independent of the host plant. The choice test showed that oviposition was higher on (S) and (P) and very poor on (L) and (O) and that more females settled on (S) and (P). Although mites migrated from parsley to strawberry, the first host plant has a higher acceptance of *T. urticae* in terms of maximum number of offspring per female than onion and leek, and a lower performance in terms of fecundity than strawberry. Parsley could be a good candidate for an associate plant in a strawberry crop; however, it needs more research under field conditions.

Key words: fecundity, host-plant range, preference, survival, two-spotted spider mite

1 Introduction

The phytophagous spider mite, *Tetranychus urticae* Koch, has a broad host-plant range and is a serious pest of several crops worldwide. Strawberry, one of the most preferred host plants, is heavily infested by spider mites, suffering severe damage (Dabrowski et al., 1971; Sances et al., 1982; Raworth, 1986; Walsh et al., 1998; Greco et al., 1999). Although spider mites are highly polyphagous (Rodriguez and Rodriguez, 1987; Yano et al., 1998), they are known to accept and perform differentially on diverse host-plant species.

Two components of the ecology and evolution of host-plant range for spider mites are preference and performance in terms of survival and fecundity (Agrawal, 2000). Ovipositing females should lay eggs on the best possible host plant for larval survival and subsequent reproduction. However, preference and oviposition of *T. urticae* on a broad range of host plants do not seem to be positively correlated (Yano et al., 1998).

Once settled, females of *T. urticae* feed or attempt to move away from the encountered host plant (Brandenburg and Kennedy, 1982; Kennedy and Smitley, 1985; Sabelis, 1985). Therefore, under natural conditions, the host-plant range is partly determined by the repeated escape of females from unfavourable plants. An initial piercing before ovipositing allows the assessment of the host-plant quality; nevertheless, females might settle on unfavourable host plants and have low fecundity (Yano et al., 1998).

As dispersion mechanisms are mainly passive, the process of host-plant selection should be viewed in terms of host-plant acceptance and not in terms of host finding (Sabelis, 1985). Host-plant range of *T. urticae* related to host-plant acceptance is expressed by Yano et al. (1998) and van den Boom et al. (2003) as the proportion of adult females settling on those host plants where they have been placed. Adult females reach potential host plants either by random walking or by passive dispersal by wind; hence, once in the air, the probability of finding and colonizing new resources, depends in part on the host-plant range and the layout of the crop.

Integrated pest management for vegetable production considers the creation of possible spatial designs (i.e. intercropping) in order to reduce herbivore attacks (Kennedy and Smitley, 1985; Vandermeer, 1989; Theunissen, 1997), and this requires the knowledge of host-plant range of pests. Different plants associated with a main crop could lead to reduction in herbivore pressure in two possible ways: changing the patterns of trivial movements and increasing emigration rates of the pest (Kareiva, 1986; Andow, 1991) or through associational resistance as a synergic effect of host and non-host plants, decreasing the density of the pest by physical and chemical protection among plants (Altieri, 1992). In the case of *T. urticae*, with an extremely broad host-plant range, it becomes necessary to assess which plants could be appropriate for this purpose in different crops. In this sense, a host plant with high acceptance and low performance could be a candidate for an associate plant.

The objective of this study was to investigate: (1) the acceptance of strawberry (S) in comparison with onion (O), leek (L) and parsley (P), measured through females that settled on a host plant or left for other host plants; and (2) the suitability of these host plants for the performance of the spider mite, *T. urticae*, in terms of fecundity and survival.

Onion, parsley and leek are not as heavily infested by spider mites as strawberry, and hence their acceptance and suitability as host plants are supposed to be lower than those of strawberry. Nevertheless, they were selected on the basis of their economical importance among horticultural crops, the possible association to strawberry crops in greenhouses and their expected level of defences against *T. urticae* – all traits making them good candidates for intercropping with strawberry.

2 Materials and Methods

Strawberry plants *Fragaria × ananassa* var. Selva, onion *Allium cepa*, parsley *Petroselinum sativum* and leek *Allium porrum* were cultivated and maintained in a greenhouse until the experiments were performed. The experiments were conducted under controlled conditions in the laboratory: 24 ± 1°C, 75% relative humidity (RH), photoperiod 16 : 8 h (light : dark). Individuals of *T. urticae* used in the experiments were reared in an experimental greenhouse of 16 m^2 with no supplement of heat or light.

2.1 Host-plant acceptance

Host-plant acceptance was measured through females that settled on a test plant or females that left for other host plants (Yano et al., 1998). We used the same experimental units with two discs of leaves: one as 'origin' (test plant) and the other as 'fate'. In each origin disc, we placed five females and recorded their position (on the fate disc or on any other place in the Petri dish) after 24 h. We performed two assays in order to measure the following types of movements: (1) from onion (O), parsley (P) and leek (L) discs to strawberry (S) discs. We used the treatments O-S, P-S and L-S, and the control S-S to test the null hypothesis that spider mites settled as much on test plants as on strawberry; (2) from strawberry discs to onion, parsley and leek discs. The treatments were S/O, S/P, and S/L; and the control: S/S. In both experiments, 20 replicates were performed for each treatment, hence a total of 675 females were used. Percentages of mites that moved to the fate disc and to any other place of the Petri dish were analysed by one-way anova on arcsine-transformed data or by Kruskal–Wallis test when variances were heteroscedastic.

2.2 Suitability of different host plants

To know whether all four host plants were equally suitable for the performance (fecundity and survival) of *T. urticae*, two experiments were conducted using discs of leaves (1.8 cm diam) individually placed in Petri dishes (10 cm diam.) with moistened filter paper in the bottom.

In the first trial, individual newly mated females were assigned to discs of each host plant: strawberry (S), onion (O), parsley (P) and leek (L). To evaluate the performance of the females on different host plants, we registered the fecundity (number of eggs per female per 5 days), the maximum number of offspring obtained from one female that settled on the disc, the survival of 5-day-old females, and the percentage of females that oviposited at least one egg. Fecundity was analysed using anova and Tukey test; the maximum number of individuals per female was analysed by non-parametric tests (Kruskal–Wallis and Mann–Whitney tests), while survival of females and percentage of ovipositing females, by a chi-squared test.

The second experiment consisted of a choice test to measure the preference of females for different host plants. Ten females were put in the centre of the Petri dish, and four discs, one of each plant, were put in the angles of a square. Six replicates were performed, with a total number of 60 mites. The fate of each female and the number and position of the eggs were computed after 24 h. Data were analysed by Kruskal–Wallis and Mann–Whitney *U*-tests.

3 Results

3.1 Host-plant acceptance

Movements took place to strawberry from the three test plants: onion, leek and parsley. Movements of *T. urticae* were significantly higher from onion to strawberry (Kruskal–Wallis O-S vs. S-S: $H_{(1,n=35)} = 7.282$; $P = 0.007$) (fig. 1a), from leek to strawberry (Kruskal–Wallis L-S vs. S-S: $H_{(1,n=35)} = 5.545$; $P = 0.018$) (fig. 1b) and from parsley to strawberry (Kruskal–Wallis P-S vs. S-S: $H_{(1,n=35)} = 4.73$; $P = 0.029$) (fig. 1c) than to discs of strawberry to strawberry.

Some mites moved away from the discs to other places of the Petri dish. When leek was tested, *T. urticae* tended to move to other place in the Petri dish (L-S vs. S-S, anova: $F = 5.24$; d.f. $= 1, 33$; $P = 0.028$). Instead, when the test plants were onion and parsley, spider mites did not move significantly to other place in the Petri dish (O-S vs. S-S, anova: $F = 0.022$; d.f. $= 1, 33$; $P = 0.883$; P-S vs. S-S, anova: $F = 3.60$; d.f. $= 1, 33$; $P = 0.066$).

Dispersal of *T. urticae* from strawberry to other host-plant discs were similar for all plants ($F = 1.34$;

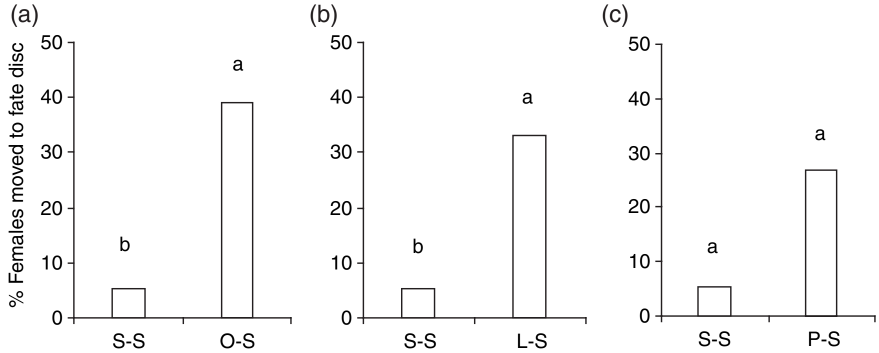

Fig. 1. *Percentage of* T. urticae *females moving from onion (O), leek (L) and parsley (P) to strawberry (S) discs (a, b and c respectively) after 24 h. Different letters in each figure indicate statistical difference (P < 0.05) between treatments and controls*

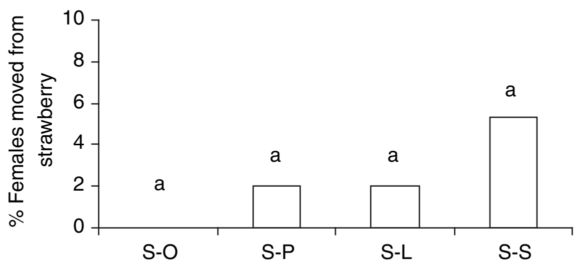

Fig. 2. *Percentage of* T. urticae *females that moved from strawberry (S) discs to discs of onion (O), parsley (P), leek (L) and strawberry after 24 h. Same letters indicate no significantly differences (P > 0.05)*

d.f. = 3, 41; P = 0.272) (fig. 2). The same was observed when mites moved to any other place of the Petri dish (ANOVA: F = 2.05; d.f. = 3, 41; P = 0.079).

3.2 Suitability of different host plants

Mean fecundity (eggs per female per 5 days) was higher on strawberry than on the other plants (ANOVA: F = 43.55; d.f. = 3, 46; P = 0.001) (table 1). The maximum number of individuals of all developmental stages per female was different between host plants (Kruskal–Wallis test: $H_{(3,n=25)} = 15.00$; $P = 0.0018$) (table 1); it was highest on strawberry, lowest on leek and onion, and intermediate on parsley.

Survival of 5-day-old females was independent of the host plant, and no differences were found between them ($\chi^2 = 4.38$; d.f. = 3; P = 0.223) (table 1). The percentage of females that laid at least one egg did not depend on the host plant either ($\chi^2 = 6.89$; d.f. = 3; P = 0.075) (table 1).

The choice test showed that the oviposition (number of eggs laid after 24 h) was higher on strawberry and parsley and very poor on leek and onion (Kruskal–Wallis test: $H_{(3,n=24)} = 14.01$; $P = 0.003$) (table 2).

In the choice test, host-plant preference was measured as the acceptance of the females on different host plants. Considering that some mites were found outside the discs, we included the Petri dish in the analysis as another place where the females settled on after 24 h. More females settled on strawberry and less on leek and onion (Kruskal–Wallis test: $H_{(4,n=30)} = 22.82$; P = 0.0001) (table 2).

Table 1 *Performance of the two-spotted spider mite,* T. urticae *on strawberry, parsley, onion and leek*

Host plant	Fecundity (eggs per female per 5 days)	Maximum number of offspring per female	Percentage of survival at fifth day	Percentage of females that laid at least one egg
Strawberry	50.61 ± 15.28 a(18)	33.14 ± 24.47 a(14)	57.89 (38)	71.05 (38)
Parsley	7.42 ± 7.98 b(12)	10.66 ± 7.77 ab(3)	48 (25)	47.83 (25)
Onion	9.91 ± 9.85 b(12)	1.00 ± 0 b(2)	42.31 (26)	42.31 (26)
Leek	9.87 ± 13.69 b(8)	2.00 ± 0.89 b(6)	32 (25)	56 (25)

Values are mean ± SD, sample sizes in parentheses. Different letters in columns mean statistical difference (P < 0.05).

Host plant	Choice test (number of eggs per disc)	Choice test (number of females per disc)
Strawberry	17.5 ± 7.7 a(6)	1.83 ± 0.7 a(6)
Parsley	7.00 ± 3.83 a(6)	0.33 ± 0.33 ab(6)
Onion	0.33 ± 0.33 b(6)	0.17 ± 0.17 b(6)
Leek	0.0 ± 0.0 b(6)	0.0 ± 0.0 b(6)

Sample sizes in parentheses. Different letters in columns mean statistical difference (P < 0.05).

Table 2 *Mean ± SD number of eggs laid on the four plants and acceptance of* T. urticae *females in the choice test*

4 Discussion

The lack of migration from the strawberry discs to other host plants demonstrated the preference for this host plant; when spider mites settled on strawberry they did not leave under the conditions of this experiment. In contrast, the spider mites did migrate from onion, leek and parsley origin discs to strawberry discs. From leek discs they also moved significantly to other places in the Petri dishes.

As expected, this experimental manipulation showed a high preference and a better performance of *T. urticae* on strawberry leaves than on any other host plant. This was shown not only in the fecundity (number of eggs laid in the choice and non-choice tests) but in the maximum number of offspring settled, as well. Differences in fecundity between host plants, probably because of different leaf nutrients and chemicals, had been previously demonstrated for *T. urticae* (van de Vrie et al., 1972; Dabrowski and Bielak, 1978). Nevertheless, survival at fifth day was not greater on strawberry than on the other host plants. Parsley is more suitable than onion and leek for the two-spotted spider mite, indicating that populations of this pest could be maintained on this host plant. Although parsley could support the development of more individuals than onion and leek, the fecundity on this host plant was lower than that on strawberry. In the choice test for oviposition, *T. urticae* laid more eggs on parsley than on onion and leek.

When the test plant was not a good host plant (like onion and leek) for *T. urticae*, the spider mites started wandering around in search of another food source. This suggests that onion and leek should be neglected as associate host plants, as there were escapes from these test plants, probably as a consequence of chemical resistance of host plants. Onion and leek could neither be considered crop traps, as a strategy to reduce the density of spider mites on strawberry, as they are not more attractive than the main crop. Onion and leek seem to be unsuitable for the development of the two-spotted spider mite, where they had a poor performance: low fecundity, poor development of the offspring and low survival rate. In addition, when choice tests were done, females did not select these two host plants for oviposition and acceptance preferentially. Spider mites did not start the oviposition process on onion until the second or third day, which suggests the presence of some chemical trait that generates rejection (P. C. Pereyra, pers. obs.).

There is a positive correlation between acceptance and performance for onion and leek: spider mites tended to leave these host plants and fecundity and survival was very low, and also for strawberry, where acceptance and performance were high and positive. Spider mites placed on parsley migrated to strawberry but the values of the number of eggs and females in the choice tests, and the maximum number of offspring/female were intermediate between the best host plant (strawberry) and the poorest ones (onion and leek).

Although mites migrated from parsley to strawberry, the first host plant has a higher acceptance of *T. urticae* in terms of maximum number of offspring/female than onion and leek, and a lower performance in terms of fecundity than on strawberry. Among the three plants tested, parsley could be the better candidate for an associate plant in a strawberry crop; however, it needs more careful research under field conditions.

Although a positive correlation between plant acceptance and high fecundity would be a desirable trait from the herbivore's view point, negative or null correlations have been found (Thompson, 1988; Mayhew, 1997) for the two-spotted spider mite.

The potential of intercropping for contributing to sustainable field vegetable growing is clear, but its technical, agronomic and economic aspects need more attention (Theunissen, 1997). One general effect of intercropping in vegetable production, defined as the cultivation of two or more species of crop in such a way that they interact agronomically (Vandermeer, 1989), is a significant reduction of most pest populations and sometimes diseases. Assays of this kind are useful for an early evaluation of possible associate host-plants to a main crop, as not every host plant seems to be suitable for associations for an alternative agriculture.

The results of this study provide a better understanding of the host range of *T. urticae* and the patterns of movements of spider mites between host plants, which may suggest ways of modifying the habitat or agroecosystem to reduce spider mite populations on specific crops.

References

Agrawal, A. A., 2000: Host-range evolution: adaptation and trade-offs in fitness of mites on alternative hosts. Ecology **81,** 500–508.

Altieri, M. A., 1992: Biodiversidad, Agroecología y Manejo de Plagas. Valparaíso, Chile: Cetal Ediciones.

Andow, D. A., 1991: Vegetational diversity and arthropod population response. Annu. Rev. Entomol. **35,** 561–586.

van den Boom, C. E. M.; van Beek, T. A.; Dicke, M., 2003: Differences among plant species in acceptance by the spider mite *Tetranychus urticae* Koch. J. Appl. Ent. **127,** 177–183.

Brandenburg, R. L.; Kennedy, G. G., 1982: Intercrop relationships and spider mite dispersal in a corn/peanut agroecosystem. Entomol. Exp. Appl. **32,** 269–276.

Dabrowski, Z. T.; Bielak, B., 1978: Effect of some plant chemical compounds on the behaviour and reproduction of spider mites (Acarina: Tetranychidae). Entomol. Exp. Appl. **24,** 117–126.

Dabrowski, Z. T.; Rodriguez, J. G.; Chaplin, C. E., 1971: Studies in the resistance of strawberries to mites. IV. Effect of season on the preference or non preference of strawberries to *Tetranychus urticae*. J. Econ. Entomol. **64,** 806–809.

Greco, N. M.; Liljesthröm, G. G.; Sánchez, N. E., 1999: Spatial distribution and coincidence of *Neoseiulus californicus* and *Tetranychus urticae* (Acari: Phytoseiidae, Tetranychidae) on strawberry. Exp. Appl. Acarol. **23,** 567–580.

Kareiva, P., 1986: Trivial movements and foraging by crop colonizers. In: Ecological Theory and Integrated Pest Management Practice. Ed. by Kogan, M.. New York: Willey & Sons, 59–82.

Kennedy, G. G.; Smitley, D. R., 1985: Dispersal. In: Spider Mites. Their Biology, Natural Enemies and Control, 1A. Ed. by Helle, W.; Sabelis, M.. Amsterdam: Elsevier, 233–242.

Mayhew, P. J., 1997: Adaptive patterns of host-plant selection by phytophagous insects. Oikos **79,** 417–428.

Raworth, D. A., 1986: An economic threshold function for the two-spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae) on strawberries. Can. Entomol. **118,** 9–16.

Rodriguez, J. G.; Rodriguez, L. D., 1987: Nutritional ecology of phytophagous mites. In: Nutritional Ecology of Insects, Mites, Spiders and Related Invertebrates Ed. by Slansky, F., Rodriguez, J.. New York: Wiley-Interscience, 177–208.

Sabelis, M. W., 1985: Reproductive strategies. In: Spider Mites. Their Biology, Natural Enemies and Control, 1A. Ed. by Helle, W. and Sabelis, M.. Amsterdam: Elsevier, 265–278.

Sances, F. V.; Toscano, N. C.; Oatman, E. R.; Lapre, L. F.; Johnson, M. W.; Voth, V., 1982: Reductions in plant processes by *Tetranychus urticae* (Acari: Tetranychidae) feeding on strawberry. Environ. Entomol. **11,** 733–737.

Theunissen, J., 1997: Application of intercropping in organic agriculture. Entomol. Res. Organ. Agric. **12,** 251–259.

Thompson, J. N., 1988: Evolutionary ecology of the relationship between oviposition preference and performance of offspring in phytophagous insects. Entomol. Exp. Appl. **47,** 3–14.

Vandermeer, J., 1989: The Ecology of Intercropping. Cambridge: University Press.

van de Vrie, M.; McMurtry, J. A.; Huffaker, C. B., 1972: Biology, ecology and pest status, and host-plant relationships of Tetranychids. Hilgardia **41,** 343–432.

Walsh, D. B.; Zalom, F. G.; Shaw, D. V., 1998: Interactions of the twospotted spider mite (Acari: Tetranychidae) with yield of day-neutral strawberries in California. J. Econ. Entomol. **91,** 678–685.

Yano, S.; Wakabayashi, M.; Takabayashi, J.; Takafuji, A., 1998: Factors determining the host plant range of the phytophagous mite, *Tetranychus urticae*, (Acari: Tetranychidae) a method for quantifying host plant acceptance. Exp. Appl. Acarol. **22,** 595–601.

Author's address: Nancy M. Greco, (corresponding author), Centro de Estudios Parasitológicos y de Vectores, 2 No 584 (1900) La Plata, Argentina. E-mail: ngreco@fcnym.unlp.edu.ar