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RESEARCH ARTICLE

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Influence of host plant species on the development and reproduction of hawthorn spider mites

Abstract A leaf disc bioassay was employed to investigate the influence of host species of deciduous fruit trees, like apple, peach, plum, cherry and apricot, on the development and reproduction of the hawthorn spider mite *Tetranychus viennensis* Zacher in the laboratory under conditions of 25±1℃, 60±10% RH and a photoperiod of 16 h: 8 h light: dark. This was done by determining the duration of each life stage of the mites, the intrinsic rate of population increase (r_m), mean generation time (T) and net reproductive rate (R_0) of the spider mites on each of the host plant species. Differences in life table parameters of the spider mite among host plants were analyzed with the jack-knife method. The results indicated that plum might be the best suitable plant for the spider mite among the plants tested due to shorter developmental period and higher intrinsic rate of increase, whereas cherry and apricot were least suitable due to their long developmental duration and low intrinsic rates of increase. When the spider mites were transferred from apple to other fruit trees, negative effects on developmental duration, fecundity and life table parameters were found in the first generation, but the effects faded out in succeeding generations. When transferred onto plum and peach, the spider mite adapted to the new hosts in the second generation; however, on cherry and apricot, it adapted in the third generation.

Keywords hawthorn spider mite, intrinsic rate of increase, host plants; apple, apricot, cherry, peach, plum

1 Introduction

The hawthorn spider mite, *Tetranychus viennensis* Zacher, is an important and damaging pest in apple orchards worldwide (Liu and Wang, 1965; Li et al., 1998). In Northern China, this pest regularly causes economic damage to most fruit trees of the family Rosaceae, such as apple, peach, pear, cherry and apricot (Liu and Wang, 1965; Li, 2002) and has become a very serious phytophagous spider mite since the early 1990s. *T. viennensis* causes yellow spots on the leaves by sucking. Besides, it also causes indirect damage by laying eggs on the leaf surface and covering them individually with silky thread. At high population levels, the mite may cause defoliation and result in second germination and second bloom, which weaken the vigor of host plants and thereby sharply reduce the quality and yield of apple production in the current season and most likely in the next or even in more growing seasons (Cai et al., 1992; Qin, 1994; Li, 2002).

In the development of structural adjustment in deciduous fruit tree production, apple production in all growing areas of China has decreased since the beginning of this century, whereas the production of other fruit trees of Rosaceae family, such as peach, pear, cherry and apricot has increased (Li, 2003). In most growing areas, these fruit trees are usually inter-cultivated/ mixed-cultivated with apple or cultivated on the borders of apple orchards. This facilitates emigration of the mite among different host plants. Investigations of the interaction between pest and its host plant are needed to improve our understanding of the dynamics of pest populations and thereby develop effective IPM programs to contain pest populations in deciduous tree orchards under various situations. Several studies on the interaction between spider mites and their host plants have been published thus far (Gotoh, 1986; Gotoh, 1987; Cai et al., 1992; Gotoh and Takayama, 1992; Qin, 1994; Skorupska, 1998; Li, 2002; Kasap, 2003); however, detailed studies of the effects of shifting host plants in the family Rosaceae and of the host on the development and reproduction of *T. viennensis* remain in limbo. In this study, plant species were selected on the basis of their economical

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relevance and their current status in deciduous tree production in China.

2 Materials and methods

2.1 Plant materials

The investigated test plants were apple (*Malus pumila* Mill cv Golden Delicious), peach (*Amygdalus persica* L. cv Baifeng, a local variety), cherry (*Prunus avium* L. cv Napoleon Bigarreau × Governer Wood), apricot (*Prunus armeniaca* L. cv Yangshao, a local variety) and plum (*Prunus domestica* L. cv Blue Diamond).

2.2 Mite colonies

Colonies of *T. viennensis* used in host plant experiment were initiated by individuals of the wild spider mite collected from apple, apricot, cherry, peach and plum orchard in Luoyang city, Henan Province, P. R. China. These were separately maintained in climatic chambers (LRH-250-GSⅡ, Guangzhou Medical Instrument Co Ltd) at 25±1℃, 60±10% RH and a photoperiod of 16 h: 8 h light: dark on detached leaves of their original hosts for a full life cycle before their use in the experiment. The colony of *T. viennensis* used in the host-shift experiment was initiated by individuals collected from an apple orchard and reared on detached apple leaves in climatic chambers under the same conditions for at least four generations before their trials. Bioassays were performed under the same conditions.

2.3 Rearing units

Each rearing unit consisted of five leaf discs of 20 mm diameter (with major veins, 3.14 cm^2), placed upside down on a 3 mm layer of agar (1.5% w/v) inside a 90 mm diameter Petri dish. The height of the dish lid was increased by 2 mm for air circulation and prevention of excess humidity. Dishes were kept in a climatic chamber with conditions as described above. During the experiments, the leaf discs were replaced every three days and the agar at six-day intervals.

2.4 Bioassay

Fully stretched leaves of each plant species were used in the experiments. They were checked carefully under a binocular microscope to remove traces of mite, if any, and to ensure cleanliness of leaves and then the leaf discs were cut. To obtain synchronized eggs, two *T. viennensis* producing females were placed on the 20 mm diameter leaf disc and allowed to lay eggs over a period not more than 24 h and removed afterwards. The number of eggs laid was adjusted to two eggs per disc. The discs containing the eggs were placed inside the Petri dish and kept in climatic chambers to allow the eggs to develop. Observations were made twice daily at 12-h intervals; larvae were individually transferred to a new leaf disc after hatching to ensure one larva per disc. The presence of exuvium was used as the criterion for successful molting to the next developmental stage. Incubation periods of the egg stage, duration of larval, protonymphal and deutonymphal stages, preoviposition and oviposition periods during the adult stage and sex ratios were recorded for each treatment. The sex ratio was calculated as the proportion of females in the same cohort. Females in their quiescent stage prior to adulthood (teleiochrysalis) were provided with a newly emerged male isolated from the stock culture of each host plant. The male was removed 24 h after the female emerged. At the onset of reproduction, females were transferred daily to fresh leaf discs; eggs laid per female were counted and collected daily, pooled per host plant and kept under the same conditions for hatching to determine hatchability.

To investigate the effects of host-shifting, *T. viennensis* producing females, collected from stock culture maintained on apple (reared host) leaves, were transferred onto cherry, peach, apricot and plum leaf (transferred host) discs to obtain synchronized eggs. Individual mites were reared on transferred host plants for three consecutive generations. The experimental procedures have been described above. For comparative purpose and convenience, when we referred to data obtained in the former host plant experiment, host plants such as apricot, cherry, peach and plum were assigned as original host plants.

2.5 Statistical analyses

Data on developmental time, longevity and fecundity were analyzed with one-way ANOVA followed by Fisher's LSD test ($p<0.05$). Differences in sex ratios were analyzed by a chi-square test ($p=0.05$). We used an arcsine square root transformation for the hatch rate data, prior to performing an ANOVA. Population growth rates in each treatment and generation were calculated by constructing life tables (Birch, 1948; Ding, 1994; Southwood, 2000).

Age-specific survival rates (l_x) and number of female offspring (m_x) for each age interval (x) day were used for the data of life tables. From these data, the net reproductive rate (R_0=female offspring/female/generation), the intrinsic rate of natural increase (r_m=female offspring/female/day) and the mean generation times ($T=\ln(R_0)/r$, in days) were calculated. After r_m was computed from the original data (r_{all}), the differences in r_m-values were tested for significance by estimating the variance using the jack-knife method, which facilitated calculation of the standard errors of r_m estimates. The jack-knife pseudo-value r_j was calculated for the n samples using the following equation:

$$r_j = nr_{all} - (n-1)\, r_i$$

After calculating the mean values of (n-1) jack-knife pseudo-values for r_m, T, and R_0 in each treatment were calculated and confidence limits for R_0, r_m, and λ determined (Meyer et al., 1986; Krebs, 1998; Maia aline De et al., 2000). Non-overlap of 95% confidence limits was the criterion for significance of differences in both treated and untreated females for each parameter. Every phase of the experiment was considered separately.

3 Results

3.1 Development on different host plants

Table 1 shows the durations of various stages of *T. viennensis* fed on various host plants. ANOVA indicated that there were significant differences in the incubation periods of the egg stage (F=9.72; df=4,348; p<0.000,1) among various host plants. The longest duration of egg was found on cherry, followed by apple. The shortest durations were recorded on peach and plum. Similarly, significant differences were observed among the durations of larvae (F=18.17; df=4,268; p<0.000,1), deutonymphs (F=4.66; df=4,233; p=0.001,3), and pre-imaginal (egg to adult, F=11.83; df=4.162; p<0.000,1 for females; F=11.83, df=4.162, p<0.000,1 for males). The longest durations of larvae, deutonymphs and pre-imaginal were all confirmed on cherry and the shortest ones on peach. The durations of pre-imaginal stages in both males and females fed on apricot and plum were significantly longer than those fed on peach. No significant difference was detected between the durations of protonymphs (F=1.76; df=4,244; p=0.083) and pre-oviposition (F=1.93; df=4,162; p=0.108), although Fisher's LSD tests indicated that the duration of protonymphs fed on peach was significantly shorter than that fed on apricot.

3.2 Fecundity, longevity, hatchability

No significant difference was detected in hatchability (F=0.96; df=4; p=0.543), longevity (F=0.744; df=4; p=0.735), oviposition period (F=0.665; df=4; p=0.722) and sex ratio (Chi =0.335; p=0.705) among various host plants. Survivorships of *T. viennensis* were 73.85%, 57.33%, 55.35%, 61.96%, and 72.75% for apple, apricot, cherry, peach, and plum respectively. Significant differences were found in fecundity (F=9.52; df=4; p<0.000,1), the highest being in those fed on plum, followed by those fed on apple and peach. These values were significantly higher than those fed on apricot and cherry, which showed the lowest fecundity (Table 2).

Table 1 Duration in days of different stages of hawthorn spider mite on various host plants at 25℃

Stage	Host plant				
	Apple	Peach	Cherry	Apricot	Plum
Eggs	4.536±0.604b	4.285±0.663c	4.936±0.688a	4.411±0.509bc	4.275±0.636c
Larvae	2.468±0.414b	2.598±0.512b	3.194±0.706a	2.706±0.634b	2.538±0.566b
Protonymphs	2.132±0.447ab	2.026±0.519b	2.146±0565ab	2.314±0.478a	2.261±0.456ab
Deutonymphs	2.476±0.563a	2.212±0.331b	2.679±0.504a	2.629±0.475a	2.538±0.566a
Preoviposition	1.683±0.559a	1.882±0.452a	1.635±0.776a	1.660±0.428a	1.897±0.626a
Pre-imaginal duration♀	12.403+1.075b	10.912±0.476c	13.279±1.315a	12.354±1.026b	12.230±1.234b
Pre-imaginal duration♂	11.35±0.668b	10.583±0.404c	12.367±0.915a	11.45±0.956b	11.556±0.950b

Data are means ± SD; the duration of protochrysalis, deutochrysalis and teleiochrysalis are included in larvae, protonymphs and deutonymphs respectively. Means followed by same letter in a row are not statistically different (Fisher's LSD test, p>0.05).

Table 2 Comparison of Survivorship fecundity and longevity of hawthorn spider mite on various host plants

Host plants	Hatchability/ %	Fecund eggs /per female	Longevity/days	Oviposition period /days	Sex ratio/%
Apple	87.23±1.67a	24.26±10.34b	24.58±5.76	10.72±4.08	78.59
Apricot	89.74±1.73a	17.44±10.45c	22.61±7.43	9.12±4.49	75.67
Cherry	83.33±2.03a	19.67±9.89c	24.09±5.39	11.17±4.45	76.19
Peach	87.95±2.31a	23.12±10.33b	22.68±6.01	9.96±4.13	72.22
Plum	91.89±2.44a	30.43±12.11a	25.64±4.65	13.54±4.53	77.78

Means in a column followed by same letter are not statistically different (Fisher's LSD, P>0.05).

3.3 Life table parameters

The effects of host plants on the population growth can be demonstrated by simply comparing the life table parameters (Table 3). Mean generation time of the mites fed on peach was the shortest and significantly shorter than of those fed on cherry and plum. This is due to the absence of overlap among their associated 95% CL of jack-knife estimates. The jack-knife procedures showed that there was no significant difference in the mean generation time of those fed on apple, apricot, cherry and plum. Net reproductive rates (R_0) differed significantly among various host plants; the poorest R_0 were confirmed on apricot (13.589♀/♀) and cherry (13.718♀/♀), as evidenced by the absence of overlap among their associated 95% CL of the jack-knife estimates.

The highest R_0 was confirmed on plum (34.359♀/♀), followed by apple (23.951♀/♀). It was higher on apple than on peach, apricot and cherry. Consequently, *T. viennensis* fed on plum had the largest (0.173) intrinsic rate of increase and that on cherry the lowest (0.129). On apple, the intrinsic rate of increase was significantly higher than those on peach, apricot and cherry, whereas on peach, the intrinsic rate of increase was significantly higher than those on apricot and cherry. This variation contributed to notable differences among the values of Dt and λ.

Table 3 Comparisons of life table parameters of hawthorn spider mites on various host plants.

Parameters	Apple	Apricot	Cherry	Peach	Plum
Mean generation time (T)	19.326 18.653–20.153	19.146 18.423–19.863	20.902 19.649–22.155	18.143 17.519–18.767	20.395 19.697–20.981
Intrinsic rate of increase (r_m)	0.164 0.158–0.170	0.131 0.128–0.135	0.130 0.126–0.132	0.152 0.148–0.156	0.173 0.169–0.177
Net reproductive rate (R_0)	23.951 21.724–26.148	13.589 11.723–14.972	13.7175 11.951–15.065	15.750 14.187–17.602	34.359 33.502–38.548
Doubling time (Dt)	4.21 4.006–4.227	5.086 4.536–4.987	5.251 5.01–5.484	4.562 4.088–4.368	3.997 3.820–4.046
Finite rate of increase (λ)	1.179 1.17–1.186	1.140 1.136–1.145	1.138 1.134–1.141	1.164 1.159–1.169	1.189 1.184–1.194

Values in the same cells consist of original parameters and associated 95% CL of jack-knife estimates.

Daily age-specific fecundity and age-specific female survivorship for *T. viennensis* fed on five species of host plants are shown in Fig. 1. Oviposition rates increased rapidly from the beginning of the reproductive period to its peak and then leveled off gradually. Daily egg production on apple, apricot, cherry, peach and plum reached the peak on day 17 (4.44 eggs/♀/day), day 17 (4.44 eggs/♀/day), day 20 (3.07 eggs/♀/day), day 17 (3.57 eggs/♀/day), and day 18 (4.14 eggs/♀/day) respectively. Most eggs were laid within about 10 days on each host plant. *T. viennensis* showed similar survival curves for the five species of plants tested, although a slightly lower survivorship was found on peach.

3.4 Effects of host-shifting

3.4.1 Development

Figure 2 shows the pre-imaginal duration of *T. viennensis* reared separately on transferred host plants for three consecutive generations (F_1–F_3 represent three generations of those on transferred host plants, F_0 represent those reared on their original host plants). The durations of pre-imaginal stages in the mites reared on apple were stable

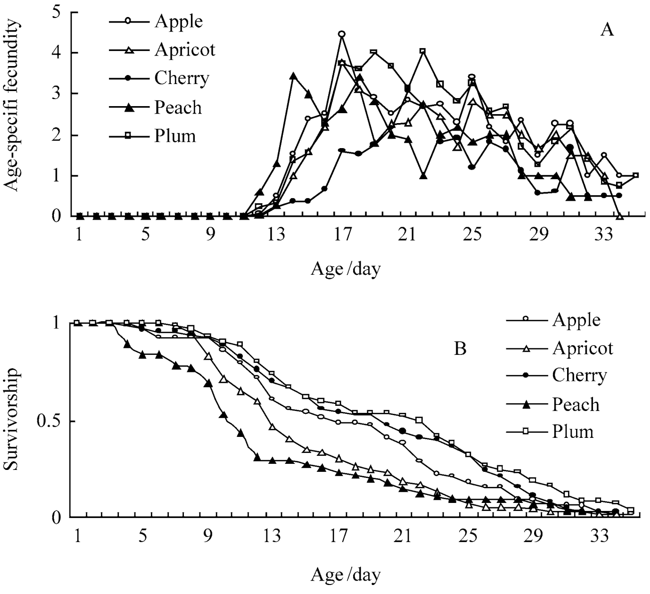

Fig. 1 Age-specific fecundity (A) and age-specific female survivorship (B) for *T. viennensis* on various host plants

during three consecutive generations, whereas significant differences were recorded among transferred host plants. However, the durations approached those of their original host plants in subsequent generations.

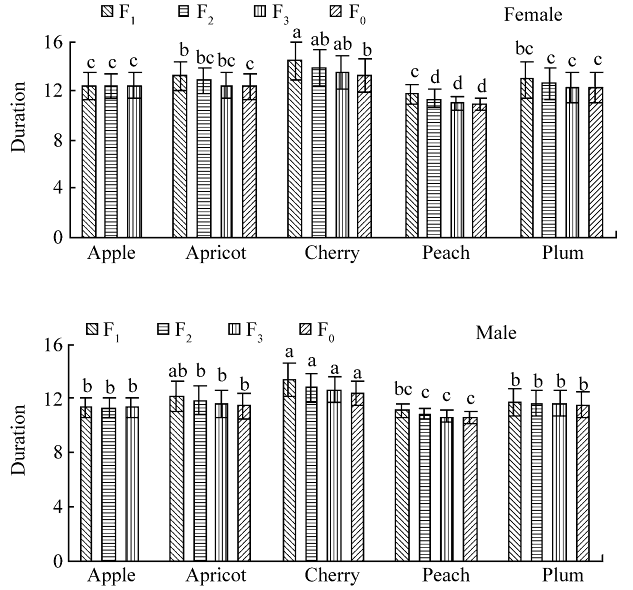

Fig. 2 Effects of host plants shifting on pre-imaginal duration of hawthorn spider mites. F_1–F_3 represent three generations of those on transferred host plants, F_0 represent those reared on their original host plants. Bars in the figure indicate SD; histograms with the same letter are not statistically different (p>0.05)

In the first generation after host-shifting, the duration of eggs exhibited no significant difference among various transferred host plants as compared to those fed on apple. This can be attributed to the fact that all their mothers were reared on apple; however, significant differences were observed among the durations of larvae (F=9.86; df=4,334; p<0.000,1), protonymphs (F=7.78; df=4,282; p=0.004,3), deutonymphs (F=7.45; df=4,236; P=0.001,6) and pre-imaginal (F=2.16; df=4,69; p=0.017,1 for males; F=4.94; df=4,168; p=0.002,2 for females). The longest duration of larvae on transferred plants was found on cherry, followed by apricot, which was significantly longer than that on plum but was not statistically different from their original host plants. The durations of protonymphs on transferred apricot and cherry were significantly longer than those on peach and plum. No significant differences were found among cherry, plum and peach. The differences found in the duration of deutonymphs were similar to those found in the duration of protonymphs. No significant difference was detected in the duration of pre-imaginal stage, including both males and females, between cherry and apricot, but on their original host plants they differed significantly. These results indicated that transferred apricot and cherry imposed stronger adverse effects on the development of spider mites than what peach and plum imposed.

The durations of pre-imaginal stages on transferred cherry and apricot were significantly longer than those on their original hosts. The durations on transferred peach and plum were also prolonged but not statistically different from those on their original hosts, thereby suggesting that stronger adverse effects were imposed on the development of *T. viennensis* by the shift from apple to apricot and cherry than the shift from apple to peach and plum.

In the second generation after host-shifting, significant differences were detected in the duration of eggs (F=11.53; df=13, 924; p<0.000,1). The durations of eggs on cherry and apricot were prolonged as compared to those of their parents, but were shorter on peach and plum; however, they were not statistically different from those of their parents. Similarly, significant differences were detected in the duration of larvae (F=8.72; df=13,876; p=0.004,6), protonymphs (F=6.94; df=13,768; p=0.003,4) and deutonymphs (F=6.29; df=13,696; p=0.004,3). The longest duration was confirmed on cherry in larvae, protonymphs and deutonymphs. The duration of pre-imaginal stages on transferred host plants differed significantly (F = 8,135; df = 13,562; p =0.000,5 for females, F = 6,122; df = 13,134; p = 0.000,7 for males), the longest being on cherry for both males and females. After comparing the durations of various life stages, it was found that the durations on peach and plum were almost identical to those on their original host, whereas those on apricot and cherry were mediated between those of their parent and those on their original hosts.

In the third generation, the duration of various life stages in *T. viennensis* exhibited a further contraction. This was consistent with that obtained in host plants experiment in this study (Table 1), indicating that mites adapted to these new host plants.

3.4.2 Population growth

Effects of host-shift on the populations' growth of *T. viennensis* in successive generations can be illustrated by comparing their life table parameters and their jack-knife estimated 95% confidence limits (Table 4).

The life table parameters of *T. viennensis* females fed on apple were stable in three consecutive generations. When shifted onto the transferred host plants, *T. viennensis* on apricot and cherry exhibited a significantly longer mean generation time than those on reared hosts and original hosts, whereas those on transferred peach displayed a mean generation time similar to those on reared hosts and original hosts. On transferred plum, the mites exhibited a significantly longer mean generation time than that on reared hosts but similar to that on original host plants. The values of Ro decreased significantly in the first generation on transferred host plants except plum and were similar to those on its original host plant. The values of Ro on apricot, cherry and peach were significantly lower than those fed on reared host plants and original host plants. Consequently, the values of r_m decreased significantly in the first generation on transferred host plants, including plum, thus suggesting that population growth of *T. viennensis* on transferred host plants was impaired. However, this impairment decreased gradually in subsequent generations, as evidenced by the fact that the life table parameters of *T. viennensis* on peach and plum in the second generation were similar to those on their original host plants. Those fed on apricot and cherry were in the third generation, thus indicating that the mites adapted well to peach and plum in the second generation and to apricot and cherry in the third generation.

Table 4 Effects of host plants shifting on the life table parameters of hawthorn spider mite (mean ± SD)

Parameters	Generation	Apple	Apricot	Cherry	Peach	Plum
T	F1	19.326±2.063c	21.564±2.417ab	22.679±4.023a	18.48±2.414c	21.216±2.096b
	F2	18.978±1.932c	20.643±1.968b	21.712±3.04ab	18.277±1.865c	20.576±1.912b
	F3	19.026±1.810c	19.263±2.027c	20.996±2.493b	18.253±1.627c	20.488±1.736b
r_m	F1	0.164,2±0.019b	0.101,1±0.017g	0.099,3±0.018g	0.136,6±0.020d	0.167,1±0.019b
	F2	0.165,1±0.026ab	0.118,8±0.018f	0.114,4±0.016f	0.151,4±0.016c	0.172,1±0.016ab
	F3	0.167,2±0.022ab	0.129,7±0.012e	0.128,8±0.013e	0.152,1±0.012c	0.173,8±0.017a
R_0	F1	23.951±6.274b	11.833±6.132e	10.382±3.402e	13.844±3.776d	33.753±7.328a
	F2	22.750±5.503b	11.849±5.406d	12.016±4.21de	15.377±5.147c	34.369±7.197a
	F3	24.128±5.638b	13.464±4.307d	13.512±4.276d	15.68±4.441c	34.454±6.287a

Means in a column followed by same letter are not statistically different (P>0.05). See Table 3 for data of F_0.

No significant difference was detected in longevity, sex ratio and oviposition period of females between transferred host plants and original host plants. Survivorship of pre-imaginal stages showed a slight reduction on transferred host in the first generation, i.e., 44.68%, 41.46%, 61.38% and 70.22% for apricot, cherry, peach and plum respectively, but the reduction faded out in subsequent generations. Lifetime fecundities of *T. viennensis* on transferred host plants were 12.35±6.45, 13.25±6.89, 20.86±9.47 and 29.54±10.11 eggs for apricot, cherry, peach and plum respectively in the first generation. They decreased by 29.19%, 32.64%, 9.78% and 2.92% as compared to those of the original hosts, thus suggesting that host-shifting imposed adverse effects on the reproduction of mites. However, the reduction in fecundities on transferred host plants dwindled from 12.46%, 15.13%, 1.06% and 0.41% in the second generation to 3.16%, 6.44%, 0.87%, and 1.22% in the third generation. This implies that mites adapt to peach and plum in two generations and to apricot and cherry in three generations.

4 Discussion

The adaptability of fruit tree industry to changing market depends largely on timely adjustment of fruit trees to structural changes and periodic updating of varieties (Li, 2003), which together change the ecological environment inhabited by *T. viennensis*. Therefore, for designing IPM programs of the mite, it is necessary to investigate the effects of such change in the environment on the population dynamics of *T. viennensis*.

The present study has shown that development and reproduction of *T. viennensis* differ among various host plants, the longest developmental period being on cherry and the shortest being on peach. The duration of pre-imaginal stage of the mites on apple is 12.403 days, which compares well with the observation of Gotoh (1986) (12.367 days). The intrinsic rate of natural increase (r_m) is an important parameter for describing the growth potential of a population under specific climatic and food conditions, because it reflects the overall effects of temperature and food on development, reproduction and survival (Southwood, 2000). In the present study, the r_m value obtained on apple (0.168) is lower than the r_m value obtained by Gotoh and Takayama (1992) (0.195) and Kasap (2003) (0.247). The r_m value obtained on cherry also is lower than that obtained by Gotoh and Takayama (1992). This discrepancy can be ascribed to the difference in the quality of host plants used. In the present study, host leaves have been collected from abandoned orchards and their poor quality in nutrition could be responsible for the lower r_m. The lower r_m on cherry could be explained by the fact that different varieties were used, because it was illustrated that the population performance of *T. viennensis* differed significantly among different varieties (Gotoh and Takayama, 1992; Li, 2002; Kasap, 2003; van den Boom et al., 2003). On the subject of different host plants, Gotoh and Takayama (1992) reported that the r_m of *T. viennensis* fed on apple (0.195) was lower than that on cherry (0.222). The results reported by Kasap (2003) contradict this observation. Our results are consistent with those reported by Kasap (2003).

The present study demonstrates that *T. viennensis* has the best performance on plum. This is mainly due to short development time (12.23 days), high daily egg production (4.13 eggs) and an early peak in reproduction. *T. viennensis* on peach also exhibits a short development time, high daily egg production and an early peak in reproduction, but its r_m value is lower than that on plum due to high mortality of mites on peach. Although high reproduction rates and short developmental times contribute to a high intrinsic rate of increase, their contributions are not equal (Southwood, 2000).

It is common for many pests to disperse among plants or emigrate among different host plants and thus result in host shifting. Our present study illustrates that development and reproduction of *T. viennensis* would be adversely affected in a few generations after the mites were transferred from apple onto apricot, cherry, peach and plum; however, mites can adapt to these transferred host plants gradually. From comparisons of the development and demographic parameters of the hawthorn spider mite on such transferred host plants as apricot, cherry, peach and plum, it has been found that mites adapted to peach and plum in two generations and to apricot and cherry in three generations. It has also been noticed that the index of net reproduction rate (R_0) on transferred plum has been the same as that on the original plum and, on average, two times higher than that on transferred apricot, cherry, and peach, indicating that no adverse effect has been imposed on the reproduction of the mites by such a host shift. This implies that serious damage would be imposed by *T. viennensis* when plum is inter-cultivated/ mixed-cultivated with apple.

The morphology of the leaf surface, such as a thick cuticle and glandular or non-glandular hairs, can have significant effect on the population performance of pests (Kasap, 2003; van den Boom et al., 2003). Besides, the plant's nutritional value can also play important role in determining the increased rate of pest populations (van den Boom, 2003). Perhaps, the less hairy leaf surface has been responsible for the low r_m of *T. viennensis* on apricot and cherry, because an increase in oviposition of *T. urticae* has been shown for hop cultivars with a higher density of glandular hairs (Peters and Berry, 1980). On strawberry, however, *T. urticae* survival and oviposition were negatively correlated with the density of glandular hairs (Luczynski et al., 1990). Skorupska (1998) reported that the density of hairs on the bottom leaf side of different apple varieties was not correlated with the demographic parameters of *T. viennensis* or *T. urticae*. Therefore, further investigations on the effect of other factors, such as density of glandular hairs, on the biology of *T. viennensis* should be conducted to characterize the main factors responsible for changes in population dynamics.

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