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Fitness of *Tetranychus urticae* Koch (Acari: Tetranychidae) on Three Strawberry Varieties: Biology and Fertility Life-Tables

A.K.M. Azad Hossain, Md. Nizam Uddin*, Sharmin Afroj Ruba, Alina Rabbi, Rumana Akhter Basunia and Md. Adnan Al Bachchu
Department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh

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Abstract: The two-spotted spider mite, *Tetranychus urticae* Koch, is one of the most important pests of strawberry crops. The use of comparatively resistant crop cultivars or varieties may limit the negative effects of this pest; we tend to thus compared population growth parameters of *T. urticae* reared on three strawberry varieties: RU-1, RU-2 and RU-3. The life table parameters were estimated at 25 ± 1 °C, 60 ± 10 % RH, and a photoperiod of 16:8 h (L: D). The average developmental time from egg to female adult on the varieties was 11.70 ± 1.23, 12.60 ± 0.91 and 12.77 ± 0.92, respectively. The lifetime fecundities were 57.38 ± 3.67, 56.57 ± 4.42 and 63.90 ± 4.33 eggs/female for RU-1, RU-2 and RU-3, respectively. RU-2 was the most suitable host for *T. urticae* with r_m = 0.172 (offspring/female/day), followed by RU-3 (0.170). The slowest population growth was observed on the RU-1 variety with r_m = 0.167. These findings indicate that the selection of strawberry variety will affect how fast spider mite populations reach destructive levels during a culture.

Key words: Strawberry, Two-spotted spider mite, Life table, Resistance

Introduction

Strawberry is a small fruit crop of great importance throughout the world. The strawberry belongs to the family Rosaceae in the genus Fragaria, containing 23 species [1,2]. It is native to the Americas and also found in several other regions of the world. Several diseases and pests can significantly compromise strawberry production, among them *Tetranychus urticae* Koch (Acari: Tetranychidae) is one of them. The two-spotted spider mite (TSSM) is one of the most important polyphagous pest species that can cause losses of up to 80% in strawberry crop [3,4]. Both nymphs and adults suck cell sap on the ventral surface of the older leaves [5]. Severe infestation of strawberry leaves by TSSM reduces plant growth and yield which ultimately affects the quality and quantity of berries produced [6,7]. The short lifespan and high reproductive rate permits *T. urticae* to achieve damaging population levels very quickly once growing conditions are favourable, leading to a uniformly fast decline within the quality of host plants. The growth parameters of *T. urticae* like survival, fecundity, developmental rate and stability might vary in response to changes in temperature, different plant species and their nutritional status, totally different varieties, humidity, phenological stage, exposer to pesticides, physico-chemical properties of the host plant or cultivar, etc. [8,9,10,11].

As *T. urticae* is an important pest of fruits, including berries, it is necessary to control its populations. The present mite management tactis solely depends upon the use of acricides [12]. The over dependence on acaricides is a risky scheme that results in resistance development of the mites

*Corresponding author (Md. Nizam Uddin)
E-mail: <nizam_hstu@yahoo.com>

only after a few applications [13,14]. Two spotted spider mite, *T. urticae* showing resistance to more than 80 pesticides belonging to different chemical groups has been reported by Vassiliou and Kitsis [15]. In addition, chemical pesticides are often not friendly with natural enemies, causing the resurgence of pest and various ecological hazards [16]. Therefore, considering the increasing difficulty to control mites by pesticides, it would be important to identify host plant cultivars or varieties that are not dainty to *T. urticae* and can suppress or at least delay outbreaks. This would reduce the dependency of agrochemicals and has no additional cost to the farmer. On the other hand, it serves as auxiliary tools in integrated management, which can be associated with other pest management practices [17].

Life table parameters are an important tool in the study of population growth under a given set of conditions. Many scientists use life-table parameters of the mite as an appropriate endpoint to express the effect of different host plants or cultivars on the mite [18,19]. Relative susceptibility of the host plants can be determined by considering the fertility life-table parameters of the mite [20,21]. Little information is available on the host plant resistance to strawberry mites. So, the present study was undertaken to investigate the life history parameters of two spotted spider mites, *T. urticae* in selected three varieties of strawberries that are commercially grown in Bangladesh.

Material and methods

The present study was carried out in the laboratory of the Entomology Department, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh, during 2016 - 2017. All experiments were carried out in a growth chamber maintained at 25 ± 2 °C, 65 ± 5 % relative humidity (RH) and a photoperiod of 16L: 8D.

Mite colony

Two-spotted spider mites were collected from a bean field of Mahabolipur village, Dinajpur, Bagladesh, in November 2016. Collected mites were reared on country bean (*Lablab purpureus* L.) leaves grown in plastic pots (20 cm D × 20 cm H) and maintained at the above-mentioned conditions.

Strawberry varieties

The developmental time and fecundity of *T. urticae* were evaluated on three strawberry varieties namely RU-1, RU-2 and RU-3. Seedlings were collected from the Rana Nursery, Rangpur, Bangladesh. The seedling were planted in earthen pots (25 cm D × 25 cm H), filled with fertilized field soil and kept in a screenhouse. After 30 days, fresh strawberry leaves were collected and used for leaf disc preparation. All plants were irrigated at a similar time (3-day interval). No fertilizers or pesticides were applied throughout the study periods.

Immature development and performance of adults

To perform the study, 3 cm diameter discs were cut from the centre of the fresh strawberry leaves of each variety. The leaf discs were placed upside down on water saturated cotton pads in 9-cm Petri dishes, and two to three gravid females were placed on each leaf disc. After 5 h the females and extra eggs were removed and maintained as one egg per disc. Observations were made twice daily (12-h interval) and duration of the development from egg to adult, adult longevity and fecundity were recorded for each group reared on leaves of three strawberry varieties. The number of replications was 31, 35 and 33 on RU-1, RU-2 and RU-3 varieties, respectively. To evaluate mite fecundity, one newly emerged female was paired with the opposite sex from the cohort on every leaf disc in a Petri dish. Eggs laid by a female were recorded daily until the death of each individual. The leaf discs were replaced every 7 days. In this way the fecundity of 21 *T. urticae* females per strawberry variety were evaluated [22]. The whole experiment was conducted in a completely randomized design (CRD). To determine the sex ratio, the females were allowed to deposit eggs for 5 days after the pre-oviposition period. The eggs were permitted to develop to adulthood and then their sex was determined according to Gotoh and Nagata [23].

Life table

Life table parameters of females were estimated according to the equation suggested by Birch [24]: $\Sigma e^{-r_m x} l_x m_x = 1$, where x is the age class, lx is the probability of survival at age x, and m_x is the mean number of female progeny at age x. The net reproductive rate ($R_o = \Sigma l_x m_x$), the mean generation time ($T = \ln R_o/r_m$) and the finite rate of increase ($\lambda = e^{rm}$) were calculated by associated formulae. Doubling time ($DT = \ln 2/r_m$) was calculated according to Mackauer [25].

Data analyses

Statistical analyses were carried out using the SPSS version 20.0. Means were compared using the Tukey HSD test ($P<0.05$). Chi-square test was used to analyses sex ratio. Life table parameters and their standard error were estimated using the Jackknife method [26].

Results

Developmental time of immature stages of T. urticae

No significant difference among strawberries varieties was observed for the development period of two-spotted spider mite eggs, of mite larvae, of mite nymphs or of mite quiescent periods. The means of these periods are listed in Table 1. When the total development time, i.e., egg to adult, is compared among varieties, the variation is significant. Two-spotted spider mites developed fastest on RU-1, followed by RU-2 and RU-3 (Table 1).

Female longevity and sex ratio

The average female longevity and sex ratio of two spotted spider did not differ significantly among the three strawberry varieties. In all varieties, sex ratio of offspring was male biased in the first 2 - 3 days after oviposition period. However, for the rest of the oviposition period, the sex ratio was female biased (Table 3).

Fecundity of female

Pre-oviposition, oviposition and post-oviposition period ranged from 1.86 to 2.10, 11.12 to 11.71 and 1.61 to 2.61 days, respectively. Pre-oviposition and post-oviposition period differ significantly among *T. urticae* fed on RU-1, RU-2and RU-3 (Table 2). Total fecundity and daily fecundity of *T. urticae* females reared on the three strawberry varieties did not differ either (Table 3). The daily fecundity of cohort, expressed as the total number of eggs laid by the surviving females, is presented in Fig. 2.

Life table

Demographic parameters of *T. urticae* clearly differed among strawberry varieties (Table 4). Mites reared on RU-1 had a significantly lower intrinsic rate of increase (r_m) than those reared on the two other varieties. The net reproductive rate

Table 1. Development time in days (mean ± S.E.) of female of *T. urticae* reared on three varieties of strawberry

Sex	Stages	Strawberry varieties		
		RU-1	RU-2	RU-3
Female	Egg	3.83 ± 0.41a	4.33 ± 0.31a	4.53 ± 0.33a
	Larva	1.83 ± 0.20a	1.90 ± 0.10a	1.96 ± 0.15a
	Protochrysalis	0.80 ± 0.10a	0.86 ± 0.08a	0.63 ± 0.08a
	Protonymph	1.60 ± 0.18a	1.80 ± 0.14a	1.80 ± 0.14a
	Deutochrysalis	0.73 ± 0.10a	0.73 ± 0.08a	0.76 ± 0.08a
	Deutonymph	1.76 ± 0.20a	1.83 ± 0.14a	2.10 ± 0.17a
	Teliochrysalis	1.13 ± 0.13a	1.13 ± 0.10a	0.96 ± 0.10a
	Egg-adult	11.70 ± 1.23b	12.60 ± 0.91a	12.77 ± 0.92a

Different letters indicate significant differences among strawberry varieties, (within rows; P < 0.05)

Table 2. Mean in days (± S.E.) of female longevity and preoviposition, oviposition and post oviposition periods (days) of *T. urticae* on three strawberry varieties

	RU-1	RU-2	RU-3
Pre-Oviposition	1.98 ± 0.02ab	1.86 ± 0.05b	2.10 ± 0.06a
Oviposition	11.71 ± 0.70a	11.12 ± 0.78a	11.71 ± 0.59a
Post-oviposition	1.61 ± 0.18b	2.38 ± 0.33ab	2.61 ± 0.30a
Longevity	15.33 ± 0.81a	15.35 ± 0.97a	16.42 ± 0.84a

Different letters indicate significant differences among strawberry varieties, (within rows; $P < 0.05$)

Table 3. Mean (± S.E.) total fecundity (eggs/female), daily fecundity (eggs/female/day) and sex ratio of the three strawberry varieties

	RU-1	RU-2	RU-3
Total fecundity	57.38 ± 3.67	56.57 ± 4.42	63.90 ± 4.33
Daily fecundity	4.93 ± 0.19	5.06 ± 0.20	5.42 ± 0.22
Sex ratio	0.71 ± 0.65	0.71 ± 0.53	0.67 ± 0.62

No significant differences were observed among strawberry varieties

Table 4. Life table parameters of *T. urticae* reared on three strawberry varieties at 25 ± 1°C

Parameter	Varieties		
	RU-1	RU-2	RU-3
r_m	0.167 ± 0.000c	0.172 ± 0.000a	0.170 ± 0.000b
R_o	38.985 ± 0.147b	38.921 ± 0.169b	40.992 ± 0.163a
T	21.877 ± 0.012a	21.252 ± 0.014c	21.816 ± 0.013b
λ	1.182 ± 0.000c	1.188 ± 0.000a	1.185 ± 0.000b
DT	4.139 ± 0.004a	4.023 ± 0.004c	4.072 ± 0.004b
GRR	47.498 ± 0.115b	48.262 ± 0.134a	47.497 ± 0.148b

Within row different letters indicate significance differences among strawberry varieties (Tukey HSD test: $P < 0.05$)

r_m= Intrinsic rate of natural increase per day

R_o = Net reproductive rate

T= Mean generation time in days

DT= Population doubling time in days

λ = Finite rate of increase

GRR= Gross reproductive rate

(R_0) for mites reared on RU-3 variety was the highest than for those reared on RU-1 and RU-2 varieties. Mean generation time (21.877 ± 0.012 days) and population doubling time (4.139 ± 0.004 days) was clearly the highest; the finite rate of increase (1.182 ± 0.000) was lowest for *T. urticae* reared on RU-1 variety (Table 4).

The age-specific survival rate (l_x) of *T. urticae* for different strawberry varieties is presented in Fig. 2. The curves indicate that *T. urticae* completed its development on all strawberry varieties. Almost similar survival curves were

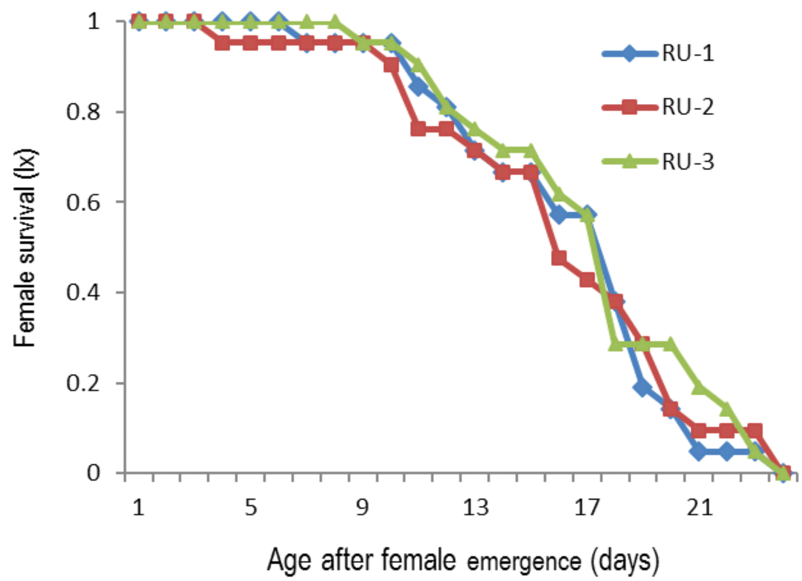

Fig. 1. Age-specific survival (lx) curves of female of *T. urticae* in adulthood on three strawberry varieties

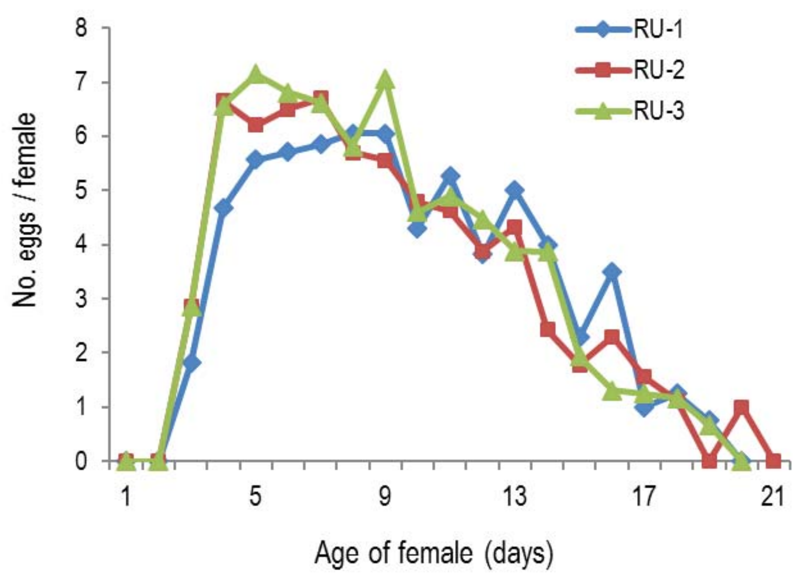

Fig. 2. Daily fecundity curves (eggs/female/day) of *T. urticae* on three strawberry varieties

observed among the *T. urticae* fed on three strawberry varieties. No live mite was observed after 23 days for all varieties. Female started to die at the ages of 7, 4 and 9 days for RU-1, RU-2 and RU-3, respectively (Fig. 1).

Discussion

The use of plant-resistant cultivars is one of the fundamental strategies of integrated management of pests and secondary metabolites of plants or allelochemicals play an important role in the resistance of plants to pests [27]. Understanding the reproductive parameters of a pest is one of the key components in the development of an integrated pest management strategy [28]. The shorter development time and higher total fecundity of a pest on a host crop determine a greater suitability of those crops [29]. Studies of host plant resistance and determination of the resistance mechanism has been the subject of many works. Aina *et al.*[30] revealed the mechanism of resistance viz: antibiosis, antixenosis and tolerance of different tomato lines against the *T. urticae*. MacDonalds *et al.*[31] used a leaf disc assay to determine the resistance and susceptibility of different *Solanum* clones to two-spotted spider mite. They considered the total number of deposited eggs as resistance criterion, but the fertility and sex ratio of the deposited eggs were ignored in their studies. In present study, when fecundity alone was considered as the resistance index, the variety RU-3 was believed to be susceptible among the other varieties, respectively, whereas results for immature developmental time revealed resistance in the varieties RU-2 and RU-3.

Intrinsic rate of natural increase (r_m) is a good indicator for assessing the growth potential of a population under certain climatic and food conditions, as it reflects the overall effects of temperature and food on the development, reproduction and survival of pests [32]. Krips *et al.*[33] investigated the effect of eight different varieties of *Gerbera jamesonii* Adlam on *T. urticae* considering r_m as the main indicator of resistance. They have shown that the r_m value of the mite differs on various varieties from 0.088 to 0.242 females/female/day. The current study also showed the discrepancy in r_m values of *T. urticae* among different strawberry varieties from 0.167 to 0.172 females/female/day. Castagnoli *et al.*[34] used fertility life-tables on the resistance of several lines of tomato to *T. urticae*. They showed that the r_m value reflects the suitability and unsuitability of the host plants for mite development. According to the r_m value comparisons, the varieties RU-1 was determined to be the most unsuitable strawberry varieties for the development of the *T. urticae* among the tested varieties. Taking into account the effect of host variability on the other life-table parameters confirms the unsuitability of the variety RU-1 as host plants for *T. urticae*. This may be related to the effect of the antibiotic resistance mechanism of this variety on the mite. Such a difference in strawberry variety suitability has been reflected in the other fertility life-table parameters; T, DT, and λ.

Conclusion

The quality of host plant influence the fertility life table parameters of the two-spotted spider mite and are factors to consider when planning integrated pest management programs for the mite. An important element of IPM is the use of crop cultivars or varieties that support only low pest population growth or even resistant varieties. The goal of future research will be to compare the varieties susceptibility to two-spotted spider mite with other economically relevant traits. The strawberry producer will only use varieties that reduce mite infestations if these varieties do not possess exhibit other undesirable attributes such as yield reduction or increased susceptibility to various pests or pathogens.

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Conflict of interest

The authors declare no conflict of interest.

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