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Host preference and life table parameters of two-spotted red spider mite, *Tetranychus urticae* Koch (Acari: Tetranycidae) on some solanaceous and cucurbitaceous vegetable crops

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Abstract
Comparative biological studies based on development, survival, fecundity and life tables' parameters of *Tetranychus urticae* were conducted to assay host suitability of some solanaceous and cucurbitaceous vegetable crops. Survival rates of *T. urticae* were significantly different on the tested hosts that varied from 42.86 on pepper to 100% on watermelon. Development periods of larvae, deutonymph and total immature stages were significantly affected by kind of host plants that the longest times were observed on pepper. Furthermore, long longevity (13.2-13.9 days) and oviposition periods (11.5-12.3 days) of females on the cucurbitaceous, stimulate females to deposit large numbers of eggs. The mite populations could double in 0.423-1.055 days on cucurbitaceous and faster than solanaceous. Highest values for finite rate of increase (λ) (7.82 individual/day), net productive rate (Ro) (72.95 egg/female), and intrinsic rate of natural increase (rm) (2.055 offspring/female/day) were observed on watermelon. So cucurbitaceous, especially watermelon have high host suitability to *T. urticae*.

Keywords: *Tetranychus urticae*, host preference, life table, solanaceae, cucurbitaceae

Introduction
Vegetable crops are considered as essential food resources for human consumption that belong to more than thirteen botanical families. Families of Solanaceae and Cucurbitaceae are the most important families that ranks among the highest of plant families for number and percentage of species used as human food such as eggplant (*Solanum melongena*), peppers (*Capsicum* sp.), Cucumber (*Cucumis sativus*) Watermelon (*Citrullus lanatus*) [1-3].
Vegetable plants are attacked by several pests [4], among those obstacle arthropod pests is phytophagous mite (Arachnida: Acari) that is causing various types of remarkably injuries and consequently affect the crop production [5- 8]. Mites of Family: Tetranychidae are considered as common plant feeder of Actinedida that exists in fields and greenhouses of vegetable crops throughout the world [9- 11].
Two-spotted spider mite (TSSM), *Tetranychus urticae* Koch (Acarina: Tetranychidae) is worldwide polyphagous and economically important agricultural pest that feed on more than 900 host plants [12] in greenhouses and open field [13]. Moreover it was described as a serious pest on 150 economically important host plants, most of them are vegetable crops [14, 15, 16]. The TSSM feeding causes significant damage for cells and tissues of plants that destroy mesophyll tissue and chloroplasts. Then photosynthesis declines, stomata close, and transpiration decreases, leading to reduced crop production [17]. Unless controlled, this mite may cause severe damage to yield quantity and quality [18]. To establish successful management tactics against the spider mite, biological traits related to growth, fertility, reproduction and mortality of population should be achieved [19].
On the other side, each nutritive and toxic constituents and morphology of host plants are considered as limiting factors for accepting the two-spotted spider mite by host plants [20, 21, 22], which varied among host plant species and varieties [23]. These characteristics depend on plant genotype, pest species, and the interactions between both [24]. Relative susceptibility or preference of the host plants can be determined by considering developmental duration and survival of immature stages of the pest, and oviposition and longevity of its mature stages [25-27].

However, preferences, development and reproduction of the mite differ not only among plant species but also on different cultivars of the same plant species [28-30]. Although the TSSM has a short lifespan, very rapid population growth, high fecundity and long adult survival [31], The quality of the host plant affects the life-history traits of TSSM such as intrinsic rate of natural increase, generation time, doubling time, and finite rate of increase [32, 33].

Life table parameters of the mite were considered as an appropriate endpoint to reveal the effect of different host plants or varieties on the mite [34, 35]. The host suitability for the mite were concerned on strawberry cultivars [36-38]; different bean varieties [39]; okra [40]; soybean cultivars [33], *Phaseolus vulgaris; Capsicum annuum; Cucumis sativus* [41]; watermelon cultivars [19]; eggplant; pepper and tomato [42]. Although, the biology of the two-spotted spider mite affected by resistant solanaceous plants [43], the biology and life table of *T. urticae* on the pepper and eggplant plants has been rarely investigated [44, 45]. Furthermore, each of Cucumber and watermelon hasn't received adequate attention like other host plants. Thus, current study aimed through same lights on biological aspects of *T. urticae* on most common solanaceous and cucurbitaceous plants, to determine most suitable host plant for the mite populations' development.

Materials and Methods

Comparative biological study based on fertility and survival life tables' parameters of the two-spotted red spider mite, *Tetranychus urticae* Koch was conducted under laboratory conditions of Plant Protection Department, Faulty of Agriculture, Damanhour University, during summer season of 2020.

Cloning initial mite culture

To establish the initial mite culture, adult females of two spotted spider mite were collected from cultivated fields with eggplant, pepper, cucumber and watermelon, that located in Borg-Rashid village, El-Beheira governorate, Egypt (31º25'20"N and 30º23'53"E). The infested leaves were sampled and transmitted to the laboratory that were investigated later by a stereo microscope to pick the adult female of the two spotted spider mite by using fine brush and deposited it on lower surface of clean leaves for same host. The leaves with maintained mites were placed in petri dish that was furnished with a wet cotton piece and coated with filter paper. The maintained mites preserved in controlled growth chamber (25±2° C, 65±5 RH and 10:14h). The incubated leaves were replaced day after day with fresh one, for three sequenced generations.

Mite maintain on the tested hosts and investigations

To study host preference of the two spotted spider mite toward solanaceous and cucurbitaceous plants, life table parameters were estimated on middle leaves of four host plants i.e., eggplant *Solanum melongena* (Black Baladi cultivar), peppers *Capsicum annuum* (Baladi cultivar), Cucumber *Cucumis sativus* (Salim cultivar) and Watermelon *Citrullus lanatus* (Skata cultivar). Thus, leaf discs with diminution 2x2cm were cut from middle region of tested host leaves. Leaf discs of same host (3-4 leaf discs) were also placed in the furnished petri dish as previously mentioned for stock culture, that their upper surfaces down on water saturated cotton and tissue paper. Four petri dishes were prepared for every tested host plant. Only one new emerged adult female was picked from the reared colony and maintained on the lower surface of leaf disc to allow the mite to deposit only one egg on every disc. After egg laying, the adult female was disposed and the rest of the eggs was discarded. The discs were investigated every 12h to monitor egg hatchability, and record the duration and survival of developmental stages like egg, larvae, protonymph and deutonymph. Furthermore, survivor and daily egg laying of adult females were also recorded from the adults' emergence untill death.

Life-Tables Parameters Estimation

Apparent and real mortality (%AM and %RM), and survivor rates (Sx) of each developmental stage (I_x) could be estimated as follow:

$\%\ A.M. = d_{xn} / I_{xn}$
$\%R.M. = d_{xn} / I_{x1}$ d_x : Number of dead individual in specific stage $d_x = I_{x1} - I_{x2}$
$S_x = (I_{x1} / I_{x2}) * 100$

Fertility and survival life tables' parameters of the two-spotted red spider mite were estimated on the tested host plants. Life table parameters were including age-specific survival rates (lx) and average number of female offspring (fecundity) (mx), net productive rate (R_o), intrinsic rate of natural increase (rm), finite rate of increase (λ), mean generation time (Gt) and doubling time of population (Dt). Those parameters were calculated as follow:

mx = number of offspring / number of females
$R_o = \Sigma\ Ix\ mx$
$Gt = \Sigma x.\ Ix\ mx / Ro$
$r_m = (Log.e^{Ro}) / Gt$
$\lambda = e^{rm}$
$Dt = (Log\ e^2) / r_m$

Statistical analysis

The obtained biological data (developmental stage periods and number of deposited eggs) were subjected to statistical analysis of variance and least significant difference at level of probability $p \leq 0.05$, by using COSTAT (2008) [46] statistical software.

Results

Survival and morality in immature stages

Although physical rearing conditions of *Tetranychus urticae* were convenient for developing the immature stages on the foliage of the tested host plants, species of host plant had not only obvious effect on survival but also development time of the mite. Obtained data in Table (1) and illustrated data in Figure (1) declared that the survival rates of *T. urticae* were significantly different on the tested hosts that varied from 42.86 on pepper to 100% on watermelon. Those variations may be due to larval stages where larvae survival rates were also varied 57.14 on pepper to 100% on watermelon. Thus it was considered as only developmental stage that was affected by host plant species than others. On contrary, deutonymphs most survivor stages that could successfully survive on the all tested host with lowest morality. The morality of all immature stages of *T. urticae* was completely non-existent on watermelon, to indicate that watermelon was the most favorable host for surviving and development of all immature.

Developmental durations of immature stages

The tested solanaceous and cucurbitaceous host plants affected developmental period of some immature stages as well as generation time of *T. urticae*, Table (2). The development times of larvae and deutonymph stages of the mite were significantly affected by host plants that hadn't any significant effects on egg incubation period as well as development time of protonymph stages. Thus, host effect extend to total duration of immature stage and then generation time. The egg incubation periods were nearly similar (3 days) on the investigated hosts and under laboratory temperature. On other hand, fastest total development time of immature stages was observed on cucumber and watermelon host plants that total immature duration ranged between 9.50 and 10.50 days. Thus, shortest generation time (9.8 days) was also observed on watermelon while the longest was on solanaceous host plants (12.6-12.7 days). Variation of total immature durations were due to effect of host plant kind on development times of larvae and deutonymph where shortest durations was noticed on watermelon, while the longest was on pepper. Thus, cucurbitaceous host plants may save fast development factors for immature stages of the mite, especially watermelon.

Adult longevity and oviposition

The investigated host plants were differed in their effect on life span and adult longevity of *T. urticae*, Table (3). Longer life span and adult longevity were observed on leaves of cucurbitaceous. The life spans were 23.4 and 23.7 days on watermelon and cucumber, respectively. Unlike the post-oviposition period, the pre-oviposition (F= 6.151**) and oviposition (F = 31.515***) durations of *T. urticae* adults differed significantly among the four tested host plants. Furthermore, wide adult longevity (13.9 and 13.2 days respectively) with long oviposition period (11.5 and 12.3 days, respectively) on cucurbitaceous host plants gave a big chance to adult females to deposit large number of egg on them (81.1 and 70.30 egg/female, respectively). Those obtained results are in contrast to that was observed on the solanaceous host plants. Thus, tested watermelon and cucumber leaves was more suitable for surviving and egg production of the mite adult females. Finally, daily egg numbers, deposited by female, didn't differ significantly among the four tested host plants.\

Fertility life table parameters

The calculated values of fertility life table parameters of *T. urticae* on the four investigated host plants are shown in Table 4., in addition records of daily survival rates and fecundity of the mite are graphically illustrated in Figure 2. It is clear that population of the mite with 15-16 individuals could survive from 26-27 days on the cucurbitaceous host plants, and less (21 -22 days) on the solanaceous host plants. Wherever, mains daily egg deposit (mx) of each female along its life span were higher on the cucurbitaceous than solanaceous host plants. Wherever daily egg deposit rates were picked earlier on the cucurbitaceous than solanaceous host plants. Highest survival rates were not noticed only in immature staged but also in most adult duration of *T. urticae* on watermelon. Furthermore, there were significant differences among values of net productive rate (R_o) and Finite rate of increase (λ) that highest values were observed on watermelon then cucumber. Wherever, each female of *T. urticae* may produce nearly 72 and 30 new individuals on those hosts, respectively that added to the mite population. Thus values of finite rate of increase (λ) were 7.82 and 2.28 individuals/female /day, respectively to harbor highest value of intrinsic rate of natural increase (rm) 2.055 on watermelon leaves. Populations of *T. urticae* could double in 0.423 days on watermelon and less than cucumber (1.055 days) and other solanaceous host plants. So we can conclude that cucurbitaceous host plants, especially watermelon are more preferred to *T. urticae* and suitable for their surviving and reproduction than solanaceous host plants.

Table 1: Egg hatchability and survival rate of *Tetranychus urticae* immature stages on different solanaceous and cucurbitaceous host plants.

Host Plant	% Egg Hatchability	% Survivor of Immature Stages			
		Larvae	Protonymph	Deutonymph	Egg To Adult
Eggplant	86.67	76.92	90.00	88.89	53.33
Pepper	100.00	57.14	75.00	100.00	42.86
Cucumber	81.25	61.54	87.50	100.00	43.75
Watermelon	100.00	100.00	100.00	100.00	100.00
$\chi^2_{(df=3)}$	2.96	15.21	3.60	0.95	36.71
P	0.398	0.002	0.308	0.813	5.3^{-8}

Table 2: Developmental durations (days) of immature stages and associated generation time of the two-spotted red spider mites as host preferences indicators.

Biological parameters	Host plant				F	$LSD_{0.05}$
	Eggplant	Pepper	Cucumber	Watermelon		
Egg duration	3.10±0.10	3.10±0.10	3.00±0.00	3.00±.0.00	0.667^{ns}	0.203
Larvae duration	$2.80±0.20^{b}$	$3.40±0.22^{a}$	$2.70±0.15^{b}$	$2.10±0.10^{c}$	9.273***	0.501
Protonymph duration	2.80±0.29	3.10±0.18	2.60±0.16	2.40±0.16	2.098^{ns}	0.591
Deutonymph duration	$2.60±0.16^{a}$	$2.30±0.15^{ab}$	$2.20±0.13^{b}$	$2.00±0.00^{b}$	3.689*	0.373
Total Immature duration	$11.30±0.40^{ab}$	$11.90±0.41^{a}$	$10.50±0.27^{bc}$	$9.50±0.22^{c}$	9.720***	0.956
Generation Time	$12.60±0.54^{a}$	$12.70±0.42^{a}$	$11.20±0.33^{b}$	$9.80±0.20^{b}$	2.081***	1.128
Each value is mean of 10 replicate ± Standard Error (SE)						
Column values followed by different letter(s) are significantly different at 0.05 levels. *						

Table 3: Longevities of two-spotted red spider mites and associated egg production on different host plants.

Biological parameters	Host plant				F	$LSD_{0.05}$
	Eggplant	Pepper	Cucumber	Watermelon		
Female life span	19.30±0.42^{b}	19.00±0.76^{b}	23.70±0.65^{a}	23.40±1.04^{a}	11.520***	2.152
Adult Longevity	8.00±0.54^{b}	7.10±0.73^{b}	13.20±0.53^{a}	13.90±0.97^{a}	23.722***	2.058
Pre-oviposition duration	1.30±0.21^{a}	0.80±0.13^{b}	0.70±0.15^{bc}	0.30±0.15^{c}	6.151**	0.476
Oviposition duration	5.90±0.61^{b}	5.10±0.71^{b}	11.50±0.50^{a}	12.30±0.80^{a}	31.515***	1.903
Post-oviposition duration	0.80±0.13	1.20±0.13	1.00±0.26	1.30±0.34	0.917^{ns}	0.664
Total Egg Deposit/female	21.10±3.44^{b}	17.90±3.66^{b}	70.30±7.04^{a}	81.10±5.92^{a}	39.113***	15.029
Daily Egg Deposit/female	3.90±0.79	4.58±1.69	6.21±0.66	6.83±0.62	1.751^{ns}	2.974
Each value is mean of 10 replicate ± Standard Error (SE)						
* Column values followed by different letter(s) are significantly different at 0.05 levels.						

Table 4: Life table parameters of the two-spotted red spider mites as host preferences indicators.

Life-table parameters	Host plant				$\chi^2_{(df=3)}$	*P*
	Eggplant	Pepper	Cucumber	Watermelon		
Initial population size (No. of Individuals)	15	14	16	15	-	-
Population life span (days)	21	22	26	27	1.08	0.782
Mean Fecundity (mx) (egg/female/day)	2.61	2.19	5.10	5.40	2.158	0.540
Net productive rate (R_o) offspring / female	13.280	7.786	30.098	72.948	84.23	3.796^{-18}
Intrinsic rate of natural increase (rm) (offspring/female/day)	0.398	0.218	0.824	2.055	2.35	0.503
Finite rate of increase (λ) (individual / day)	1.489	1.244	2.281	7.816	9.01	0.029
Doubling time of population (Dt) (days)	2.184	3.990	1.055	0.423	3.50	0.321

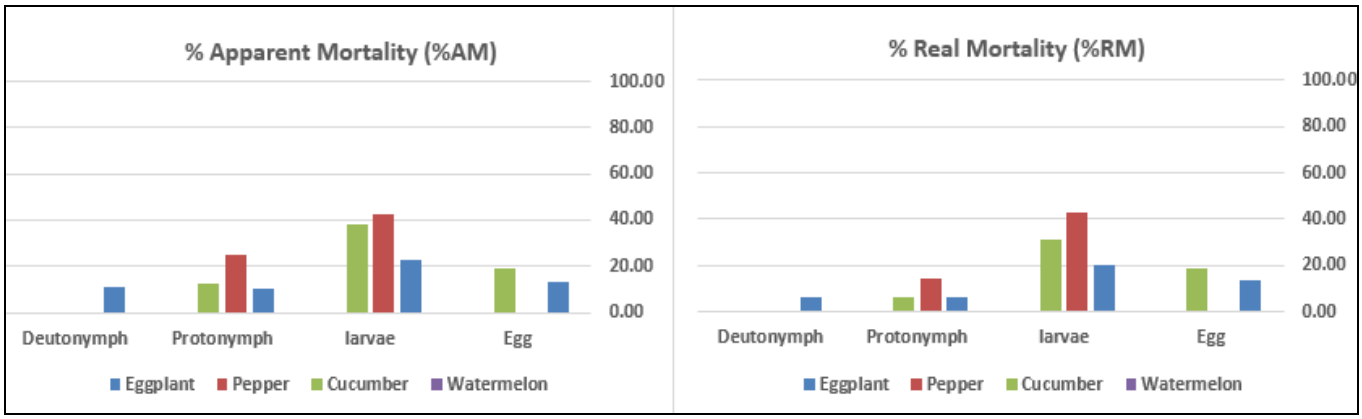

Fig 1: Apparent and real mortality of *Tetranychus urticae* immature stages on different solanaceous and cucurbitaceous host plants.

Discussion

The current study concluded that cucurbitaceous crops, especially watermelon are suitable for ideal development of *T. urticae* depending on biological parameters such as survival and development of immature stages. Although the survival rates of *T. urticae* were varied insignificantly from 55.51 to 83.52% on seven cultivars of eggplant [47], it was significantly different on the tested hosts. On contrary, survival rates of egg, larva and egg-adult stages of *T. urticae* were significantly different on sixteen strawberry cultivars that larval stage was also the most sensitive to the resistance effects of plants so highest mortality occurred in this stage [37]. The sensitivity of larval stage in current and other studies may due to the presence of components that may have toxic or anti-digestive effects in the initial stages of herbivores [48]. Some defensive compounds (i.e., capsaicin and dihydrocapsaicin) in pepper plants can cause mortality in some immature stages of *T. urticae* [49] in addition, hot cultivars of pepper can cause high mortality in the larval, nymph and adult stages [50].

The host plant species has significant effect on developmental time of the immature stages except egg and protonymph phases which agree with results of Karlec *et al*. (2016) [37]. A faster developmental time of an arthropod species on its host indicates higher susceptibility of the host plant [51]. Although total development times of immature stages were higher on solanaceous host (11.30-11.90 days), closed or lower values were recorded on eggplant cultivars in India (9.1-11.2 day) [44], sweet pepper (11.7 days) [52], tomato (11.6 days) [28, 45], persimmon (11.92 days) and pecan (12.98 days) [53]. Lowest value of total immature stages (6.31, 6.06, 6.27, 6.59 and 6.49 days) were also noticed on beans, cucumber, eggplant, tomato and pepper, respectively by Osman *et al*. (2019) [54]. The development rate of *T. urticae* immature stages are slightly influenced by host plants [55-57].

Generation time was also influenced by solanaceous host species [42] and soybean varieties [20] and it could reach to 13.64 and 13.94 days on soy bean and cowpea leaves, respectively [58]. Thus, life span of the mite is probably longer on host plants such as soy bean (25.69 days) and common bean (27.06 days) [58].

Although the egg incubation period was nearly stable on the tested host plants (3 days), it is lasted to 3.93, 3.92 and 3.86 days on eggplant, tomato and pepper, respectively [42]. It was also influenced significantly by eggplant cultivars (3.09 - 4.39 days) [47] or even higher on lower temperature (25±1 ºC) (4.00±0.63 days) [59]. Larval duration was also influenced by host plants of *Lycopersicon hirsuturn f. glabratum* and (tomato) *L. esculentum* while there was no significant difference in duration of protonymphal stage [39]. Observed

deutonymph durations were also close to obtained values by Sandeepa *et al*. [60] on cranation (2.11 ± 0.76 days for male and 2.80 ± 0.63 days for female), and Kasap [61] (2.5 ± 0.11 days for male 2.8 ± 0.10 days for female) on apple.

The pre-oviposition period was less than 1.3 days on eggplant which was related to estimated value by Awad *et al*. [42] while it was lower than other solanaceous hosts such as tomato (1.5 days), or pepper (1.08-2.50days) [42, 47] and cranation (2.0-5.0 days) [60]. Observed oviposition period on the tested solanaceous hosts (5.1-5.9 days) was lower than estimated values on different host plants in other studies such as eggplant (11.13), tomato (9.93), pepper (8.61) [42] soybean (9.83), peanut (8.88) and common bean (11.63) [58]. The oviposition period was 6.9-12.6 days and the number of eggs/female was 21.5-55.8 on pepper cultivars [47]. Numbers of deposit egg per female were 27.5 eggs on sweet pepper, 85-276 eggs on tomato, 231 eggs on bean, 124 eggs on soybean and 172 eggs on cucumber [62, 33, 28]. Post-oviposition period of adult females of *T. urticae* on tomato, pepper and eggplants leaves were 2.61, 2.30 and 2.36 days, respectively [42] and on cranation was 1-7 days [60] while *T. Viennensis* died within 1-2 days after the end of oviposition [63].

Fertility parameters are used to determine the resistance of several tomato lines to *T. urticae* [64]. They showed that the *rm* value reflects the suitability and unsuitability of the host plants for mite development. The intrinsic rate of natural increase (r_m) and finite rate of increase (λ) were highest for the mites reared on beans compared with cucumber, eggplant, tomato and pepper. Both beans and cucumber produced the highest net reproductive rate, that each female produced 55.65 and 55.45 offspring/female/generation, respectively [54]. The rm value of *T. urticae* varies between 0.22 and 0.34 in the optimum conditions and host plants conditions [65]. *T. urticae*, fed on the seven eggplant cultivars, had rm values ranged between 0.218–0.269 [47] that were close to the obtained results on solanaceous host plants, while Ro values (26.47–45.5, respectively) of same author were greater than the obtained values. While, these values were close to the findings of Khanamani *et al*. [44] (0.031–0.157 and 1.5–11.6) when *T. urticae* females reared on Indian eggplant cultivars. No significant differences were observed among the R_o values of the mite on various soybean cultivars [33]. According life table parameters, eggplants can be regarded as a less suitable host plant to *T. urticae* compared to beans and soybeans [56, 49].

Conclusion

Cucurbitaceous host plants, especially watermelon are more preferred to *T. urticae* and suitable for their surviving and reproduction than solanaceous host plants.

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