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Demographic traits of the invasive species *Tetranychus evansi* (Acari: Tetranychidae) on different Solanaceous crops

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Abstract
Key biological parameters of a Tunisian strain of *Tetranychus evansi* (Acari: Tetranychidae) reared on four solanaceous plants (*Solanum tuberosum*, *Lycopersicon esculentum*, *Capsicum annuum* and *Solanum nigrum*) were determined under laboratory conditions (30°C, 60% RH and 16:8 L:D). Significant differences in longevity, fecundity, fertility were noticed between *T. evansi* reared on *Solanum nigrum* and on the other *Solanum* crops. The calculated values of the intrinsic rate of natural increase (r_m) were 0.254, 0.236, 0.232 and 0.260 days^{-1}, respectively, on potato, tomato, pepper and black nightshade.

Keywords: *Tetranychus evansi*, *Solanum tuberosum*, *Lycopersicon esculentum*, *Capsicum annuum*

Introduction

Tetranychus evansi Baker and Pritchard (Acari: Tetranychidae) is a serious pest of solanaceous crops such as tomato (*Lycopersicon esculentum*), aubergine (*Solanum melongena)*, potato (*Solanum tuberosum*) and tobacco (*Nicotiana tabacum*), but is also found on several other vegetables (e.g., beans, citrus, cotton, castor bean) and ornamental crops (e.g., *Rosa* spp.), as well as on many weeds (e.g., *Amaranthus* sp., *Chenopodium* sp., *Convolvus* sp., *Conyza* sp., *Diplotaxis* sp., *Hordeum murinum*, *Lavatera* sp., *Sonchus* sp., *Solanum nigrum*) [1]. *T. evansi* originates from South America [2], but has recently invaded many other parts of the world and emerged as a major invasive agricultural pest [1, 3].

It presently occurs in many countries of the African continent: Mozambique, Zimbabwe [4], Morocco [5], Tunisia [6, 7], Zambia [6], Congo [8], Kenya [9], Niger, Senegal [10], South Africa, Tanzania and Somalia. The tomato red spider mite is also spreading within many European countries including France, Greece, Italy, Portugal and Spain), Asia (Taiwan) and North America (e.g., Arizona, California, Florida of the USA). As it is considered an invasive species and a damaging pest of tomatoes and other solanaceous crops, it was added to the EPPO Alert List [11]. *T. evansi* is morphologically similar to *Tetranychus urticae* Koch, with which it can easily be confused, and therefore can remain undetected on crops. After invading a crop, *T. evansi* can became the most abundant species, representing up to 60% of the total spider mites recorded [12].

Chemical control is possible, although there is always the potential of *T. evansi* developing resistance as well as harmful effects on beneficial arthropods. Many efforts were dedicated to find effective natural enemies of *T. evansi*, the large majority of the predatory mites tested have not been able to control this pest. The webbing produced by *T. evansi* may be one of the possible factors interfering with its suitability as prey [1]. Very few natural enemies such as the phytoseiid species *Phytoseiulus longipes* Evans [13] and the fungus species *Neozygites floridana* Weiser & Muma [14] seem to be promising candidates to control *T. evansi*. Further efforts are needed to evaluate these promising control agents and to detect new candidates. For instance, Wekesa *et al.* [14] collected several *T. evansi* from tomato (*L. esculentum* var. Santa Cruz) and maintained them on tomato (*L. esculentum* var. Santa Cruz), cherry tomato (*L. esculentum* var. cerasiforme), eggplant (*S. melongena* L. var. 'Natu Nobilis'), nightshade (*S. americanum* Mill a wild variety) and pepper (*C. annuum* var. Black pearl) for several generations and concluded that *T. evansi* reared on eggplant, tomato and nightshade had a high oviposition but not on cherry tomato and pepper. The same authors reported that *T. urticae* had a high oviposition on jack bean but not on strawberry, cotton and Gerbera [14].

This corresponds with other studies with *T. urticae* maintained on coton and cucumber suggesting that local adaptation to host plants may be genetically correlated with reduced performance on other hosts [15].

Improved knowledge on the biology of the pest is necessary for the design of pest management strategies. In the present study, we assessed the developmental biology of *T. evansi* on the solanaceous plants: potato, tomato, pepper and black nightshade.

Material and Methods

Tetranychus evansi specimens were collected from infested plants in citrus orchards in Tunisia (Cap Bon region) and transferred to a climate-controlled room (30 °C, 50-60% RH, 16:18 L:D) in a laboratory at the National Institute of Agronomy of Tunisia. The strain was reared on different leaves of potato, tomato, pepper and black nightshade placed on moistened cotton in Petri dishes [16]. Only young adult (24 h old) females and males were chosen for the bioassay.

Biological parameters of the females (fecundity, fertility, longevity, oviposition and sex-ratio) as well as some demographic parameters of the strain; finite rate of increase (r_m), generation time (T), doubling time of the population size (T2) and net reproduction rate (R0); were studied on leaf discs in each host plant.

Statistics

The tests were performed using Graph Pad Prism version 7 for windows (Graph Pad Software, San Diego, CA, http:// www.graphPad.com). All tests were applied under the two-tailed hypotheses, and the level of statistical significance level, *P*, was set at 0.05.

The intrinsic rate of natural increase (r_m) is mainly used to compare the potential growth rates of populations belonging to the same or different species. The intrinsic rate of increase (r_m), generation time (T), and net reproduction (R0) were calculated according to Birch (1948). The following equation was used for r_m estimation: $\sum \exp^{(-rmx)} lxmx = 1$ where lx was the survivorship of the original cohort at age x and mx was the number of female offspring produced per surviving female in each age interval.

Results

Developmental time

The study revealed that *T. evansi* performed differently on the four solanaceous plants tested. The mean female developmental time of *T. evansi*, is 10.6±0.9 days on potato, 10.7±1.0 days on tomato, 10.8±1.0 days on pepper and 11.4±1.2 days on *S. nigrum* at 30 °C. The mean male developmental period was 9.7±0.9; 9.9±1.0; 9.9±1.0 and 10.5±1.2 days, respectively, on potato, tomato, pepper and black nightshade at 30 °C (figure 1). ANOVA revealed significant differences between the development of males and females ($F_{7.354}$ = 13.74; P<0.005). Both, females and males developed faster on potato, tomato and pepper than on black nightshade.

Longevity, pre-oviposition, oviposition, post-oviposition

The maximum longevity of *T. evansi* was 13 days on black nightshade and 12 days on tomato, potato and pepper at 30 °C. The mean female longevity, pre-oviposition, oviposition and post-oviposition times of *T. evansi* are reported in Fig- 2.

The pre-oviposition and post-oviposition of *T. evansi* were high with a value of 1.2 on tomato compared with potato, pepper and black nightshade (P<0.005). However, *T. evansi* had a high oviposition on black nightshade with a value of 10.1) compared with other solanaceous plants (P<0.05 (Figure 2).

Fecundity and sex-ratio

Fecundity of female *T. evansi* differed even between host plants. Females were more fecund on black nightshade than females on potato, tomato or pepper at 30°C. The overall mean fecundities were 69 eggs per female on potato, 66 on tomato, 59 on pepper and 93 on black nightshade. The daily fecundities were 12.8, 14.4, 17.4 and 21.2 eggs/female/day on pepper, tomato, potato and black nightshade at 30 °C (figure 3). Fertility was similar on the four host plants, respectively 84.6, 84.8, 83.6 and 85.4% on potato, tomato, pepper and black nightshade. The sex-ratio was 0.71% of females for the four host plants (P<0.005).

Survival and fecundity

As shown in figures 4, 5, 6 and 7 the survival rate (lx) and fecundity rates (mx) of *T. evansi* females were influenced by the host plants.

The survival rates (lx) were 0.93, 0.85, 0.87 and 0.94 on potato, tomato, pepper and black nightshade respectively. The mx value reached a peak on 17th day (12 eggs), 18th day (10 eggs), 18th day (14.5 eggs) and 17th day (9 eggs) respectively on potato, tomato, pepper and black nightshade at 30 °C of the female emergence. The first death of the adult female occurred on days 11, 13, 13, and 13 respectively (P<0.005).

Life table parameters of T. evansi reared at different solanaceous plants

The values of the intrinsic rate of natural increase (r_m) of *T. evansi* were 0.254, 0.236, 0.232 and 0.260 days^{-1}, respectively, on potato, tomato, pepper and black nightshade at 30 °C. The finite rates of increase (λ) were 1.289, 1.266, 1.261 and 1.297 (ind/ind/day) respectively on potato, tomato, pepper and black nightshade. The doubling time of the population (T2) was 2.7, 2.7, 2.9 and 3, respectively, on potato, black nightshade, tomato and pepper (P<0.005) (Table 1).

Discussion

Biological parameters

The study revealed that *T. evansi* performed differently on the four solanaceous plants tested. Significant differences in longevity, fecundity, fertility and development time were found between *T. evansi* reared on *S. nigrum* and on the other three *Solanum* plants. Our results are in agreement with other reports. The effect of host plant on life parameters of Tetranychidae species was confirmed by many authors [14, 15].

In this study, *T. evansi* reared on *S. nigrum* had the longer longevity (11.9 days) compared to the other host plants, potato, tomato and pepper (P<0.005).

The developmental time from egg to adult of *T. evansi* at 25 °C was investigated by Murungi *et al.* [17] on different African nightshade species and results showed that the development time of *T. evansi* was affected by the different nightshade species, *S. sarrachoides* was less favorable for *T. evansi* development than the other species tested. The longevity of *T. evansi* on tomato calculated by Bonato [8] was 13.2 days at 31 °C.

In Tunisia, Grissa [18] and Grissa and Saharoui [19] studied the life table parameters of *T. urticae* on apple and tomato crops and found a mean female development time of *T. urticae* is

13.2 and 9.2 days on apple at 25 and 30 °C respectively. On tomato, the mean female developmental time of *T. urticae* was 12.8±0.9 days at 25 °C and 7.2±1.0 days at 30 °C. For males, it was 11.7±1.5 and 6.2±1.4 days respectively at 25 and 30 °C [19].

In comparison, the longevity of *T. urticae* on tomato is 23 days at 25 °C and 16 days at 30°C. On apple, the longevity of the yellow spider mite *Panonychus ulmi* was lower at 30 °C than at 25 °C, respectively 18 and 32 days [18, 19]. Grissa reported that *T. urticae* longevities on tomato at 25 and 30 °C were, respectively, 12.8 and 9.8 days, while on apple, they were, respectively, 12.7 and 13 days [18]. The different host plants may explain the difference found.

Our results showed that the host plant could play an important role in the oviposition. *T. evansi* had a high oviposition on black nightshade and a high preoviposition and post-oviposition on tomato compared with other solanaceous plants suggesting that local adaptation to host plants may be genetically correlated with reduced performance on other hosts. Gotoh *et al.* [20] found that the pre-oviposition periods for *T. evansi* decreased with increasing temperatures from 15 to 25 °C reared on different solanaceous plants. Our results corroborate previous studies that demonstrate difference in phytophagous mites species efficiency on different host plants tested [14, 15], and that they have higher oviposition rate on appropriate host plants [14, 21].

Fecundity of female *T. evansi* differed even between host plants. Females were more fecund on black nightshade than females on potato, tomato or pepper at 30 °C. Quershi *et al.* [22] showed that the pubescence of the host plant can play an important role in the fecundity of *T. evansi*. Wekesa *et al.* [14] reported that *T. evansi* reared on eggplant, tomato and nightshade resulted in the highest production of eggs while cherry tomato and pepper both resulted in significantly less eggs. Gotoh *et al.* [20] found that the total fecundity (eggs/female) of *T. evansi* varied from 100.7 to 140.3 at 30 °C on *S. nigrum.* On tomato, it is 123.3 eggs/female at 31 °C [8]. Decreases in female fecundity have been shown to occur in *T. urticae* following temperature and host plants [23]. On apple, *T. urticae* had a higher fecundity at 30 than at 25 °C, with the total numbers of eggs being, respectively, 39.7 and 21.4 [18]. The fertility of *T. urticae* was 93.8% at 25 °C and 83.4% at 30 °C on tomato and 87.7% and 92.9% on apple at 30 °C respectively [19].

The sex-ratio was 0.71% of females for the four host plants. The survival rate (lx) and fecundity rates (mx) of *T. evansi* females were influenced by the host plants. The fecundity and the survival rate of *T. evansi* proved to be vital parameters, graphically demonstrating the critical role that host plants play in the population dynamics of the species.

Demographic parameters

The values of the intrinsic rate of natural increase (r_m) and the finite rates of increase (λ) for *T. evansi* seem to be influenced by the host plant. Gotoh *et al.* [20] reported that the (r_m) and (**λ**) for *T. evansi* grew from 0.059–0.070 and 1.060–1.072 at 15 °C to 0.354-0.398 and 1.424–1.491 at 35°C, respectively. The same authors demonstrated that the doubling time (T2) decreased with increasing temperature: T2 ranged from 11.84 at 15 °C for the strain collected from France to 1.75 at 35 °C for the strain originated from Spain [20]. The study of Murungi *et al.* [17] revealed that *T. evansi* performed differently on the five African nightshade species tested. They demonstrated that fecundity and life table parameters of *T. evansi* were similar on four plant tested (*S. americanum*, *S. villosum*, *S. tarderemotum* and *S. scabrum*) but significantly different on *S. sarrachoides*. The negative r_m and T2 show that the *T. evansi* population will decrease on *S. sarrachoides.* So, this plant was the most unsuitable host for the development of *T. evansi* [17].

Furthermore, the chemical content of the host plant trichomes might be important for their suitability to tetranychidae. Wekesa *et al.* [14] showed that trichomes found on tomato, cherry tomato and eggplant varied in size and intensity which results in behavior variation on spider mites. Our results support the well-known opportunistic adaptive strategies of phytophagous mites, in which they rapidly build up populations to very high densities. A high fecundity of young females, a sex-ratio of offspring with a pronounced dominance of females and a short development time, lead to a rapid increase in the population. The r_m values of *T. evansi* obtained in this study are high, ranging from 0.220 to 0.340, especially compared with the values commonly reported by authors [24]. Differences in rm values between different host plants were also reported in *T. evansi.* Bonato [8] reported that the temperature could have influence on the population growth and he demonstrated that the highest r_m of *T. evansi* was estimated at 34 °C and has a value of 0.4. This value is greater than our results (See above) and greater than the maximum of 0.330 for *T. urticae* [25]. The value of r_m can help us to manage the risk of this species by evaluating the probability of the mite spreading to new areas [1]. Thus, it can be assumed that *T. evansi* has a very high potential for population growth with regard to the variety of host plant.

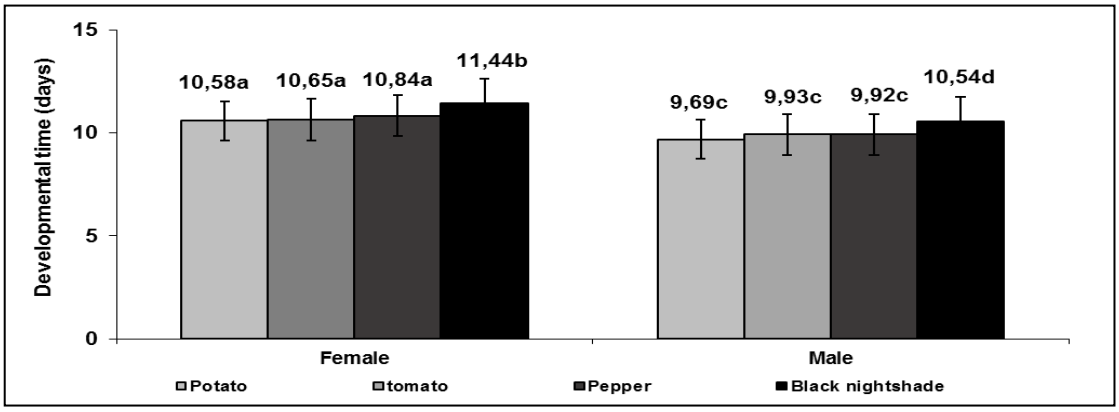

Fig 1: Developmental time of females and males of *T. evansi* (mean ± SE). Values with different letters are significantly different from each other (ANOVA test).

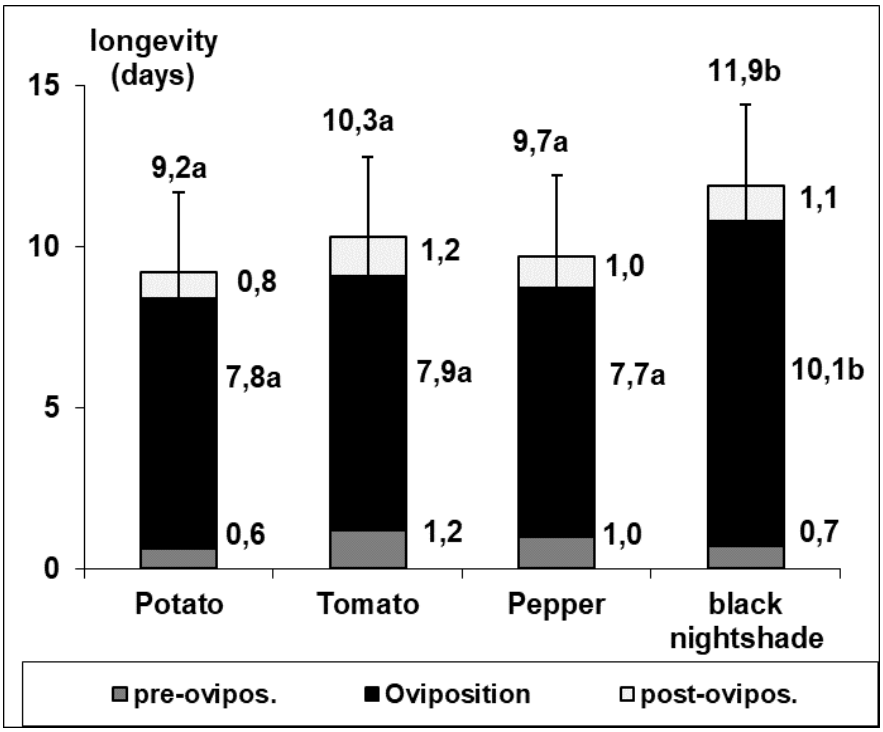

Fig 2: Longevity (days) of females of *T. evansi* (mean ± SE) at 30 °C. Values with different letters are significantly different from each other (ANOVA test).

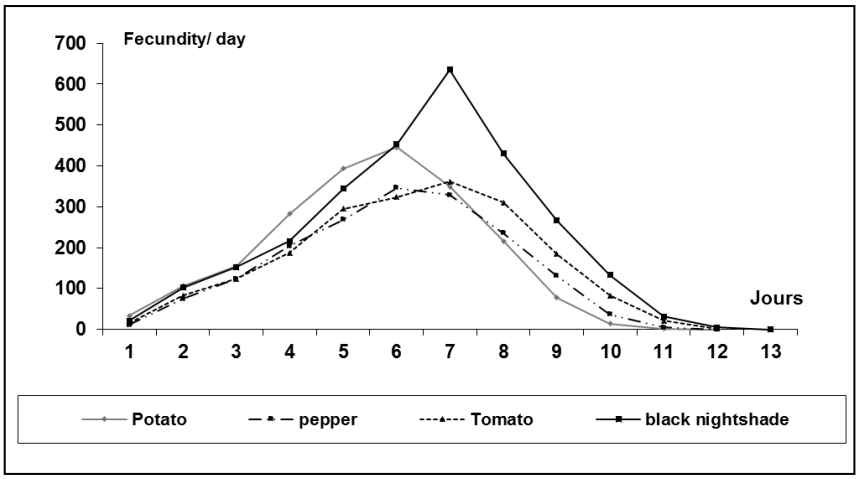

Fig 3: Fecundity of *T. evansi* female reared on four solanaceous plants at 30 °C

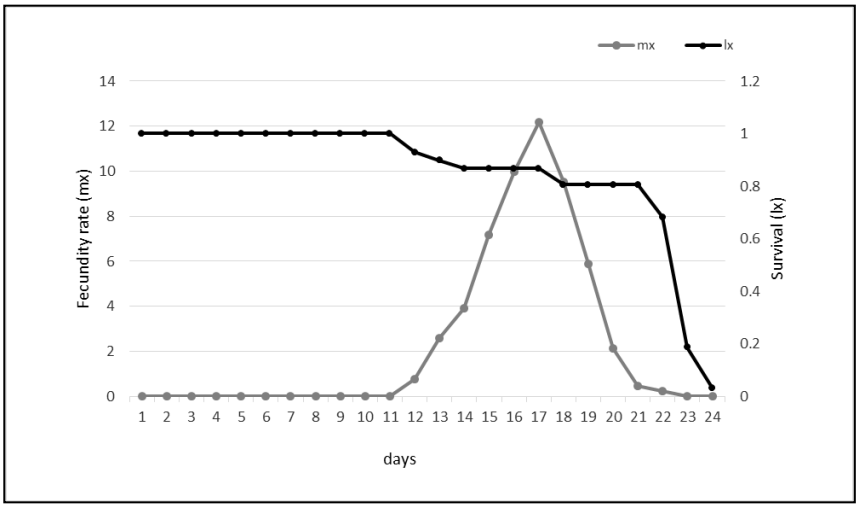

Fig 4: The survival rate (lx) and fecundity rates (mx) of *T. evansi* females reared on potato at 30 °C

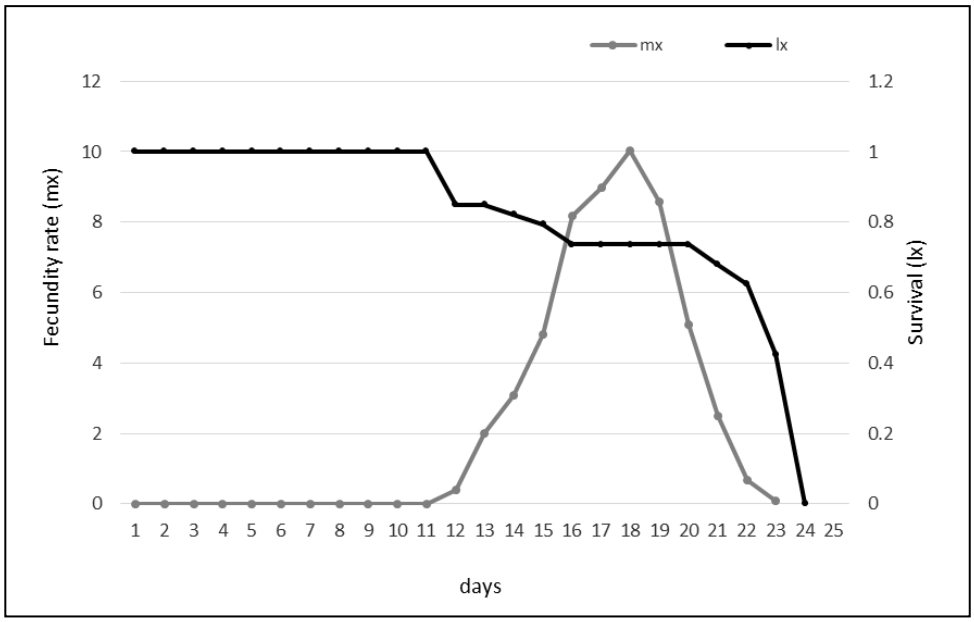

Fig 5: The survival rate (lx) and fecundity rates (mx) of *T. evansi* females reared on tomato at 30 °C

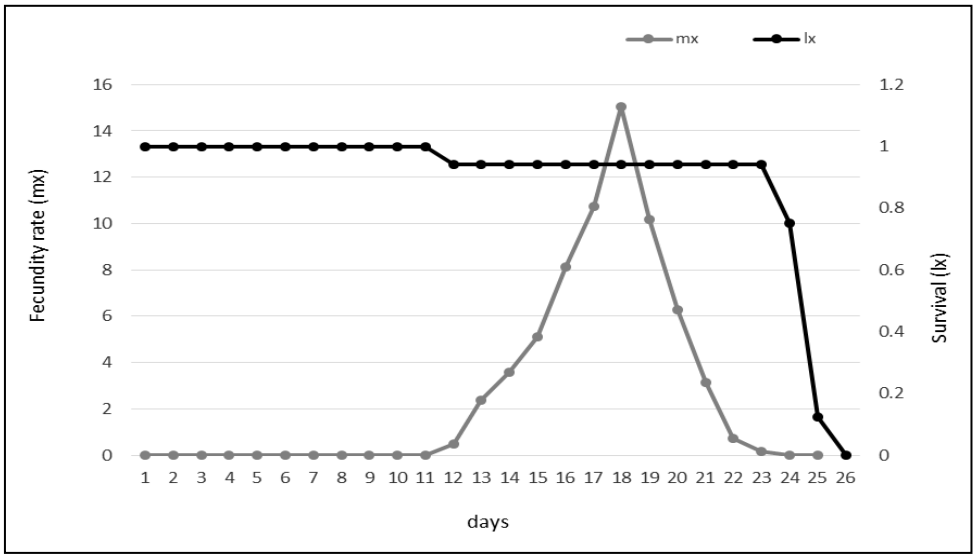

Fig 6: The survival rate (lx) and fecundity rates (mx) of *T. evansi* females reared on black nightshade at 30 °C

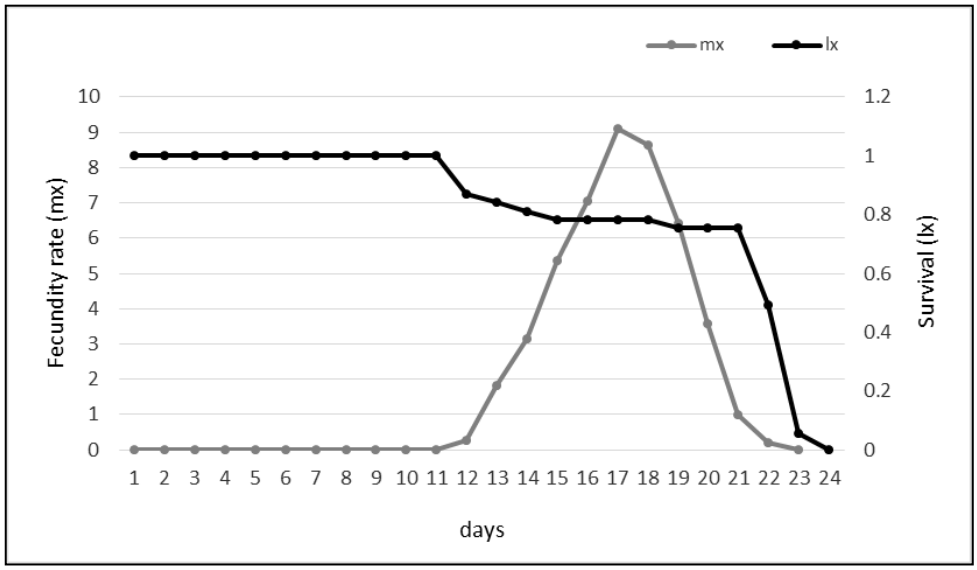

Fig 7: The survival rate (lx) and fecundity rates (mx) of *T. evansi* females reared on pepper at 30 °C

Table 1: Life table parameters of *T. evansi* reared on different solanaceous crops (potato, tomato, pepper) and black nightshade.

	rm	λ	T2 (days)	GRR	R0	T (days)
Potato	0.254	1.2891718	2.72892591	54.8491628	46.5772644	15.1224903
Tomato	0.236	1.26617431	2.93706432	54.3826187	40.6164	15.6956438
Pepper	0.232	1.26111973	2.98770336	46.5920186	36.32076	15.4844374
Black nightshade	0.26	1.29693009	2.66595069	65.9885833	62.0292683	15.875409

(The finite rate of increase (λ= e-rm) indicates the number of females witch replace each female each day. The doubling time (T2 = ln2/rm) represents the time needed to double the size of the population. GRR represents the gross reproductive rate, r: intrinsic rate of increase, T: mean generation time and R0 the net reproductive rate)

Conclusion

As reported by different authors, *T. evansi* is a highly destructive pest. While performing statistical analysis, detectability of differences in longevity, fecundity, fertility and development time of *T. evansi* were found between different host plants.

The results obtained in this study allow a better understanding of the effect of host plants on developmental parameters of *T. evansi*. The differential suitability of different solanoceaous plants to *T. evansi* could be an important factor to consider while exploring IPM solutions for this mite. They also allow some proposals to improve agricultural practices and promote a better biological control of mite pests.

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