

# THE INFLUENCE OF FOUR PLANTS ON THE BIOLOGICAL PARAMETERS OF THE TOMATO RED SPIDER MITE, *TETRANYCHUS EVANSI* BAKER AND PRITCHARD, 1960 (ACARI: TETRANYCHIDAE)

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**ABSTRACT:** The tomato red spider mite, *Tetranychus evansi*, causes damage to cultivated Solanaceae plants (specifically tomato), resulting in a highly negative economic impact. In the current study, some biological parameters of *T. evansi* were evaluated using four plants as nutritive substrates (*Solanum lycopersicum* L., *S. melongena* L., *S. macrocarpum* L. and *Amaranthus hybridus* L.). The aforementioned parameters were recorded in laboratory conditions (28°C, 60–70% RH and 12:12 L:D). Twelve leaf discs of each plant species were used to assess *T. evansi*'s reproductive parameters. Each leaf disc was separately placed in a Petri dish, covered with moist cotton. Each dish was considered a replicate. The results have indicated a significant effect that the choice of plants had on several biological parameters of *T. evansi*. In particular, the performance of *T. evansi* was significantly related to host plants ( $p = 0.01$ ), as revealed by the duration of their development stages. No larvae reached the protonymph stage on amaranths. Significant differences of fecundity and oviposition ( $p = 0.01$ ) were observed between females reared on tomatoes and the females reared on other substrates. However, no significant difference was found in female longevity. The offspring's sex ratio was, in general, biased in favor of females. The differential effect of host plants on *T. evansi* may be a key factor for exploring integrated management strategies.

**KEY WORDS:** *Tetranychus evansi*, biological parameters, host plants, pest management, tomato red spider mite

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## INTRODUCTION

Solanaceae crops are regularly consumed worldwide (Naika *et al.* 2005; Blancard *et al.* 2009). However, these crops are subject to numerous pest attacks, resulting in losses that range from 50 to 100% of the crop (IFDC 2007). *Tetranychus evansi* is among these pests, causing damage to cultivated Solanaceae, including tomato (*Solanum lycopersicum* L.), eggplant (*S. melongena* L.), potato (*S. tuberosum* L.) and tobacco (*Nicotiana tabacum* L.) (Attia *et al.* 2019). Such damage is associated with a highly negative economic impact. In addition to cultivated Solanaceae, previous observations have reported the presence of this species on other cultivated plants, such as beans, cowpea, cotton, amaranth (Navajas *et al.* 2012), black nightshade and datura (Azandémè-Hounmalon 2015). The above plants are reservoir hosts, serving as sources of contamination for cultivated Solanaceae. Wherever this species is found, it has been considered a threat to agriculture (Moraes *et al.* 1987; Furtado *et al.* 2006; Ferrero *et al.* 2011). It has a very high reproductive capacity and can quickly reach high population densities on host plants (Ferrero 2009). Considered an invasive species, *T. evansi* is the most abundant species, ac-

counting for up to 60% of the total spider mites recorded worldwide (Attia *et al.* 2019).

Native to South America (Boubou *et al.* 2012), *T. evansi* has become an invasive pest in Africa, where environmental conditions seem favorable for its development and distribution (Saunyama and Knapp 2003; Navajas *et al.* 2012). First reported in 1979 on tobacco in Zimbabwe (Blair 1983; Gutierrez and Etienne 1986), *T. evansi* causes yield losses of up to 90% (Sibanda *et al.* 2000). In the Republic of Benin, it has been estimated that damage caused by this species accounts for up to 90% of the yield losses in tomato crops (Azandémè-Hounmalon *et al.* 2016).

Recently, in Burkina Faso, *T. evansi* has been reported as an emerging pest, leading growers to either intensify spraying or, in some cases, to abandon Solanaceae cultivation altogether (Drabo *et al.* 2020). The infestations of *T. evansi* are mainly controlled by pesticides, which are applied up to 12 times per month (Drabo *et al.* 2020). However, the use of chemicals is not always effective; in addition, it leads to environmental risks and pesticide resistance (Azandémè-Hounmalon *et al.* 2016). In response to these risks, great efforts have been

devoted to the search for promising biological control agents such as insects, mites, and entomopathogenic fungi (Ferrero 2009; Savi *et al.* 2019). Although dozens of species of predatory mites and insects have been identified, only one mite (*Phytoseiulus longipes* Evans, Phytoseiidae) and one entomopathogenic fungus (*Neozygites floridana* Weiser and Muma, Entomophthorales) have demonstrated real potential (Humber *et al.* 1981; Furtado *et al.* 2007; Silva *et al.* 2010; Navajas *et al.* 2012). Another potentially interesting alternative is the use of biopesticides. Indeed, Drabo *et al.* (2022) showed that a combination of overhead irrigation with a natural acaricide not only reduced the population of *T. evansi*, but have also resulted in better yields.

Nevertheless, it is necessary to know some biological parameters of this pest on different substrates to contribute to the implementation of an integrated management strategy. Factors, such as plant species or variety can affect the biological, physiological, and behavioral characteristics of *T. evansi* (Maluf *et al.* 2007; Silva *et al.* 2008). Therefore, host plants would be a key factor to consider when exploring integrated pest management solutions (Attia *et al.* 2019). Several studies have already shown the invasive effect of *T. evansi* on Solanaceae. The particularity of the present study lies in the comparison of the biological parameters obtained on tomatoes and purple-fruited eggplants with those obtained on the African eggplants and local amaranths.

## MATERIALS AND METHODS

### Mites rearing technic

The strain of *T. evansi* used in this study was collected in November 2020 from a tomato field in Ouagadougou, Burkina Faso (12°27'15.0"N and 1°33'17.7"W). These mites were kept in a jar during their transportation to the laboratory. They were then maintained in the laboratory on tomato leaves placed on layers of damp cotton, inside a rearing box with a diameter of 14 cm and a height of 2 cm. The wild individuals that were initially transferred to the rearing leaves constituted the starting generation ( $G_0$ ). Three days after the transfer of the  $G_0$  individuals, the leaves containing the eggs were removed and incubated, in order to obtain a new generation ( $G_1$ ). This new generation was reared on tomato plants (*S. lycopersicum*) in a mini greenhouse, at the Central Laboratory of Agricultural Entomology in

Kamboinsé. The tomato plants were grown in small plastic pots. Individuals were collected from these plants to study different biological parameters.

### Experimental conditions

The study was conducted using *Solanum lycopersicum*, *Solanum melongena*, *Solanum macrocarpum* L. and *Amaranthus hybridus* L. leaf discs. The choice of *A. hybridus* (local amaranth) is based on the fact that it is widely produced in the same market gardens as Solanaceae plants. The tests were carried out under laboratory ambient climatic conditions, with a photoperiod of 12 hours of light and 12 hours of darkness (12 h: 12 h LD). The temperature and relative humidity varied between 27.6–28.2°C and 60–70%, respectively. Based on Djossou *et al.*'s (2020) methodology, for each parameter studied, twelve leaf discs from each plant were individually distributed into Petri dishes, lined with a layer of moist cotton, for the mite biological parameter determination. The cotton was soaked with water daily to keep the leaf discs fresh. Each dish was considered a replicate. In total, twelve replicates per food substrate were performed.

### The substrates' effects on the duration of the developmental stages of *T. evansi*

Five fertilized females were placed on a leaf disc that was maintained on wet cotton in a Petri dish for 24 hours. The females were allowed to lay eggs before being removed. A single egg was kept in each Petri dish, while others were carefully crushed. These eggs were observed daily in order to determine the duration of their development and the survival rate of immature stages (egg, larvae, protonymph, deutonymph) and adults. Each individual was observed once a day, and the evolution between stages was noted. To prevent the development of saprophytic fungi, the leaf discs were renewed every 96 hours.

### Longevity, oviposition, fertility and sex ratio

One newly emerged female and two males were placed in each Petri dish, containing a leaf disc (Bonato 1999). Females of the same age were used. The males were removed after the first oviposition. The number of eggs laid by each female was counted daily. The leaf discs were renewed every day until the female died. At the same time, the average duration of pre-oviposition, oviposition and post-oviposition was determined. The collected eggs were then observed under the same laboratory conditions until the adults emerged.

**Statistical analysis**

Statistical analyses were carried out according to a scheme proposed by Hervé (2021). When the normality and homogeneity of the variables were verified, a parametric ANOVA (F) test was performed. Otherwise, the non-parametric Kruskal-Wallis ( $\chi^2$ ) test was performed. The post-hoc test was performed using the Student Newman Keuls test and the Dunn’s test (for ANOVA (F) and Kruskal-Wallis ( $\chi^2$ ), respectively). These analyses were performed using R (v. 4.0.2 (2020-06-22)) at the 5% significance level, using the FSA (Ogle *et al.* 2023) and the RVAide Memoire (Hervé 2020) packages.

**RESULTS**

Here, we describe the effects of the tested plants on the studied biological parameters of *T. evansi*.

**Duration of *T. evansi*'s development stages**

The duration of *T. evansi*'s development stages varied depending on the tested plants (Table 1).

Indeed, the development time from an egg to an adult was 10.16 days on tomatoes, compared to 9 and 9.5 days on the African eggplants and the purple fruit eggplants, respectively ( $p = 0.01$ ). However, no larvae reached the nymphal stage on the amaranths. The development times of the embryonic and larval stages significantly differed among food substrates tested ( $p < 0.05$ ). Only the deutonymph stage showed a significant difference ( $p = 0.01$ ) between the tomato and the two eggplant varieties.

**Oviposition and the longevity period of females**

Tested plants significantly affected pre-oviposition ( $p = 0.03$ ), oviposition ( $p = 0.01$ ) and post-oviposition ( $p = 0.001$ ) periods (Table 2). The longest egg laying period was observed on the tomato ( $6.41 \pm 0.19$  days). However, no significant difference was noted for female lifespan, ranging between 11 and 11.75 days.

Table 1. The mean duration of *T. evansi* developmental stages on four tested plants.

Tested plants	Duration of developmental stages (days)				
	Egg	Larvae	Protonymph	Deutonymph	Egg-Adult
Tomato ( <i>S. lycopersicum</i> )	4.75±0.13 <sup>B</sup>	1.83±0.11 <sup>B</sup>	1.75±0.17 <sup>A</sup>	1.83±0.11 <sup>A</sup>	10.16±0.27 <sup>A</sup>
African eggplant ( <i>S. macrocarpum</i> )	4.16±0.16 <sup>C</sup>	1.91±0.28 <sup>B</sup>	1.66±0.25 <sup>A</sup>	1.25±0.13 <sup>B</sup>	9.00±0.21 <sup>B</sup>
Purple fruit eggplant ( <i>S. melongena</i> )	4.5±0.23 <sup>BC</sup>	2.00±0.00 <sup>B</sup>	1.75±0.13 <sup>A</sup>	1.25±0.13 <sup>B</sup>	9.50±0.23 <sup>AB</sup>
Amaranth ( <i>A. hybridus</i> )	5.83±0.11 <sup>A</sup>	3.00±0.00 <sup>A</sup>	—	—	—
Probabilities	$\chi^2 = 28.16$ , n = 4; N = 48; $p < 0.001$	$\chi^2 = 23.72$ , n = 4; N = 48; $p < 0.001$	$\chi^2 = 0.51$ , n = 3; N = 36; $p = 0.7749$	F = 7.28, n = 3; N = 36; $p = 0.011$	F = 5.98, n = 3; N = 36; $p = 0.011$

n—number of treatments; N—total of replicates.

Table 2. The mean duration of the pre-oviposition, oviposition and post-oviposition periods, as well as the longevity of *T. evansi* females.

Tested plants	Pre-oviposition	Oviposition	Post-oviposition	Longevity
Tomato ( <i>S. lycopersicum</i> )	2.41±0.14 <sup>AB</sup>	6.41±0.19 <sup>A</sup>	2.33±0.18 <sup>A</sup>	11.75±0.27 <sup>A</sup>
African eggplant ( <i>S. macrocarpum</i> )	2.16±0.11 <sup>B</sup>	5.41±0.28 <sup>B</sup>	2.00±0.12 <sup>A</sup>	11.16±0.16 <sup>A</sup>
Purple fruit eggplant ( <i>S. melongena</i> )	2.58±0.14 <sup>AB</sup>	5.33±0.18 <sup>B</sup>	1.83±0.16 <sup>A</sup>	11.41±0.22 <sup>A</sup>
Amaranth ( <i>A. hybridus</i> )	2.75±0.13 <sup>A</sup>	5.58±0.28 <sup>B</sup>	1.25±0.13 <sup>B</sup>	11.00±0.21 <sup>A</sup>
Probabilities	$\chi^2 = 8.74$ ; n = 4; N = 48; $p = 0.03$	F = 4.15; n = 4; N = 48; $p = 0.01$	F = 8.62; n = 4; N = 48; $p = 0.001$	F = 2.09, n = 4; N = 48; $p = 0.117$

n—number of treatments; N—Total of replicates

**Average number of eggs laid, hatching, emergence and survival rates for the plants tested**

Compared to other food substrates, the average number of eggs laid on the tomato leaf discs was significantly higher ( $p < 0.001$ ). The lowest number of eggs was recorded on the amaranth (Table 3).

The oviposition activity of *T. evansi* females was spread over 6–7 days (Fig. 1). The oviposition period of *T. evansi* females was 6 days on the purple fruit eggplant and the amaranth, and 7 days on the

tomato and the African eggplant. In all tested plants, more eggs were laid on the third day (Fig. 1).

The egg hatching rates (Table 3) were similar for all Solanaceae substrates. These rates were significantly higher than the rate recorded for the amaranth ( $p = 0.008$ ). It was also noticed that the adult emergence and the larval survival rates were higher on the tomato and the African eggplant than on the purple fruit eggplant ( $p < 0.001$ ). No mites were able to develop into adults on the amaranth (Table 3).

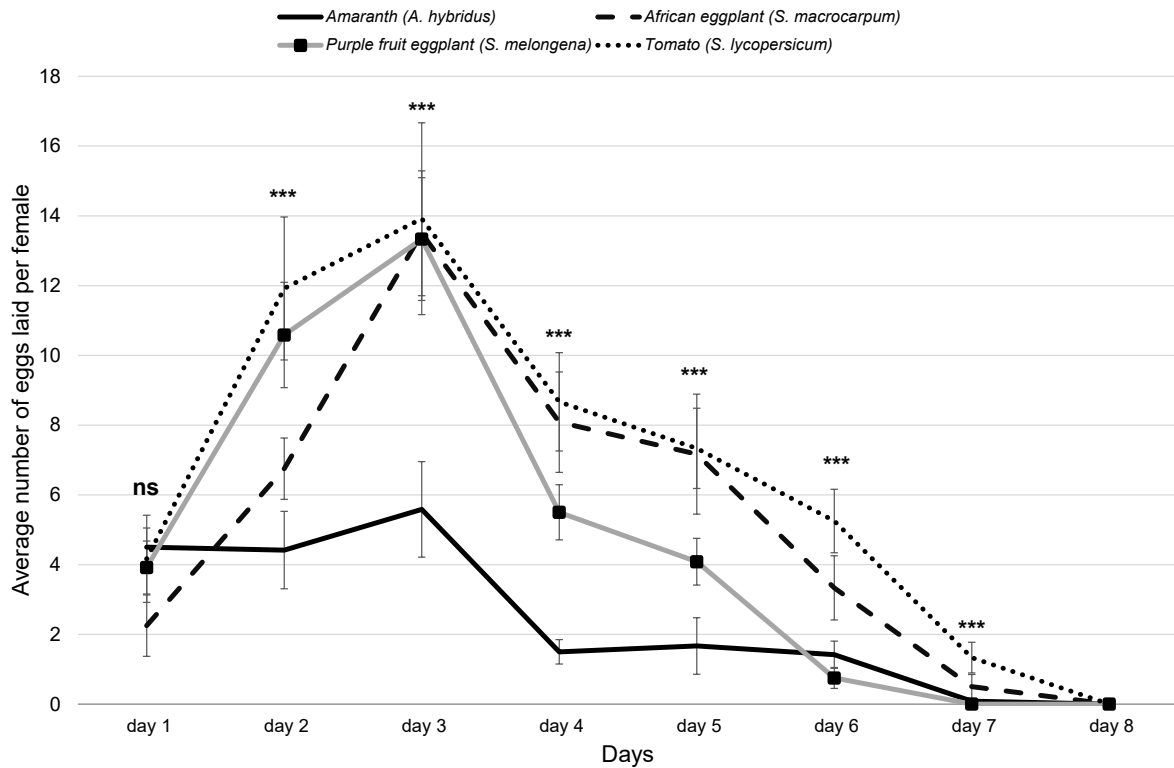


Fig. 1. Dynamics of the average number ( $\pm$ SE) of eggs laid per female *T. evansi*.

\*\*\*  $p < 0.001$ ; ns—not significant.

Table 3. The quantity of eggs, as well as the hatching, emergence, and larval survival rates, (mean  $\pm$  SE) in relation to the tested plants.

Tested plants	Number of laid eggs/female	Egg hatching rate (%)	Emergence rate (%)	Larval survival rate (%)
Tomato ( <i>S. lycopersicum</i> )	52.58 $\pm$ 5.4 <sup>A</sup>	96.85 $\pm$ 1.28 <sup>A</sup>	50.55 $\pm$ 2.81 <sup>A</sup>	52.12 $\pm$ 2.66 <sup>A</sup>
African eggplant ( <i>S. macrocarpum</i> )	41.58 $\pm$ 3.46 <sup>B</sup>	97.44 $\pm$ 0.87 <sup>A</sup>	61.37 $\pm$ 7.80 <sup>A</sup>	62.91 $\pm$ 7.89 <sup>A</sup>
Purple fruit eggplant ( <i>S. melongena</i> )	38.16 $\pm$ 3.31 <sup>B</sup>	94.24 $\pm$ 2.28 <sup>A</sup>	20.99 $\pm$ 4.93 <sup>B</sup>	23.05 $\pm$ 6.17 <sup>B</sup>
Amaranth ( <i>A. hybridus</i> )	19.16 $\pm$ 2.36 <sup>C</sup>	80.54 $\pm$ 4.75 <sup>B</sup>	0 $\pm$ 0 <sup>C</sup>	0 $\pm$ 0 <sup>C</sup>
Probabilities	$\chi^2 = 23.21$ ; n = 4; N = 48; $p < 0.001$	$\chi^2 = 11.76$ ; n = 4; N = 48; $p = 0.008$	$\chi^2 = 30.65$ ; n = 4; N = 48; $p < 0.001$	$\chi^2 = 28.50$ ; n = 4; N = 48; $p < 0.001$

n—number of treatments; N—total of replicates

**The average number of emerging mites and sex ratio**

The mean numbers of emerged individuals counted on the tomato and the African eggplant were significantly higher than those recorded on the purple

fruit eggplant ( $p < 0.001$ ) (Table 4). There were significantly more offspring produced on the tomato and the African eggplant. The sex ratio was in favor of females on the tomato and the African eggplant but male-biased on the purple fruit eggplant.

Table 4. Mean number of the emerging adults and the sex ratio for four tested plants.

Tested plants	F1 emerging mites			
	Females	Males	Total	Sex-Ratio
Tomato ( <i>S. lycopersicum</i> )	22.33±2.68 <sup>A</sup>	3.91±1.18 <sup>A</sup>	26.25±2.94 <sup>A</sup>	0.20±0.07 <sup>B</sup>
African eggplant ( <i>S. macrocarpum</i> )	20.91±3.68 <sup>A</sup>	4.08±1.10 <sup>A</sup>	25.00±3.98 <sup>A</sup>	0.23±0.07 <sup>B</sup>
Purple fruit eggplant ( <i>S. melongena</i> )	4.66±0.96 <sup>B</sup>	3.00±0.89 <sup>A</sup>	7.66±1.78 <sup>B</sup>	0.51±0.09 <sup>A</sup>
Amaranth ( <i>A. hybridus</i> )	0±0 <sup>C</sup>	0±0 <sup>C</sup>	0±0 <sup>C</sup>	0±0 <sup>C</sup>
Probabilities	$\chi^2 = 36.75$ ; n = 4; N = 48; $p < 0.001$	$\chi^2 = 11.34$ ; n = 4; N = 48; $p < 0.009$	$\chi^2 = 33.35$ ; n = 4; N = 48; $p < 0.001$	F = 7.05; n = 4; N = 48; $p = 0.001$

n—Number of treatments; N—Total of replicates

**DISCUSSION**

The results of this study have revealed different performances of *T. evansi* on different tested food substrates. There were significant differences between the tomatoes and eggplants in the average duration of the *T. evansi*'s development, indicating that the tomato substrate was more favorable. Several authors have mentioned the effect of host plants on the life parameters of the Tetranychidae species (Agrawal 2000; Wekesa *et al.* 2011; Attia *et al.* 2019). Murungi *et al.* (2010) reported that the duration of the development of *T. evansi* from an egg to an adult varied among different African Solanaceae species. In this study, no larvae have reached the nymphal stage on the amaranths; it is, therefore, the most unsuitable host. Similar studies, reported by Onyambus *et al.* (2011), showed that *T. evansi* did not complete its development on *S. habrochaites* Knapp and D.M. Spooner and *S. peruvianum* L. The results reported by Murungi *et al.* (2010) have revealed that *T. evansi* behaved differently on five African nightshade species. Among the plant species tested, *S. sarrachoides* was an unsuitable host in terms of the mites' survival and fecundity. The negative effects of amaranths on the biological parameters of *T. evansi* could imply the presence of chemical compounds in this plant that repel or prevent the mite from effectively feeding on it. The differential adaptation between Solanaceae and Amaranthaceae to the tomato red spider mite could be an important factor

to take into account when looking for integrated pest management solutions.

*Tetranychus evansi* females' lifespan was approximately the same (11 days) on all host plants. Previous studies have reported that the lifespan of *T. cinnabarinus* on tomatoes at 25 and 30°C was 12.8 and 9.3 days, respectively (Lebdi Grissa and Sahraoui 2006), while on potatoes, it was 12.7 and 13 days, respectively (Lebdi Grissa 2003). For *T. evansi*, Djossou *et al.* (2020) observed lifespans of 10.7 and 9.8 days on the Kèkèfo and Akikon tomatoes, respectively (at 27°C). These data suggest that, under laboratory conditions, a female's lifespan is approximately two weeks.

Our study showed that *T. evansi*'s spawning could be influenced by the host plant. Females had higher spawning and longer oviposition on the tomatoes and the African eggplants than on other tested food substrates. This suggests that a local adaptation of *T. evansi* to host plants could be genetically correlated to a reduction in its performance on other host plants. Previous studies have revealed different efficacy levels of phytophagous mites on different host plants (Wekesa *et al.* 2011); namely, the mites had high egg laying rates on appropriate hosts (Attia *et al.* 2019). Djossou *et al.* (2020) also reported that the oviposition period of *T. evansi* has increased on preferential hosts. A spawning peak was reached on the third day, on which females have laid more eggs on tomatoes

and eggplants. The choice of the food substrate, therefore, influenced the fertility rate. Females were more fertile on Solanaceae than on Amaranthaceae. This could be explained by the pubescence of Solanaceae, which provides a greater chance for *T. evansi* to lay eggs. Quershi *et al.* (1969) showed that the pubescence of the host plant plays an essential role in *T. evansi*'s fecundity. Wekesa *et al.* (2011) reported that *T. evansi* laid a higher number of eggs on eggplants, tomatoes and nightshades than on green peppers, which have smooth leaves.

The sex ratio was in favor of females on suitable host plants (tomatoes and African eggplants). This is a general characteristic of the mite species of the Tetranychidae family (Helle and Sabelis 1985), in which the proportion of females increases with the abundance of nutritional resources. The average emergence and the larval survival rates were influenced by the choice of the host plant, indicating the essential role of host plants in the population dynamic. The results of the present study confirm the adaptation of *T. evansi* to Solanaceae, on which it reproduces rapidly, leading to a very high population density.

### CONCLUSION

Our study has demonstrated the influence of four plants on the biological parameters of *T. evansi*. The results indicate that the *T. evansi* spider mites develop better on Solanaceae, specifically tomatoes, which are its preferred host plant. On the other hand, amaranths are an unfavorable host for the development of the *T. evansi* spider mite. Therefore, the differential effect of the host plants on the *T. evansi*'s reproductive potential could be a key factor to consider in developing an integrated mite management strategy. Amaranths may be used in a crop rotation system in order to improve agricultural practices and promote a non-chemical control of *T. evansi*.

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