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Research Article

Biological parameters of *Tetranychus mexicanus* (McGregor) (Acari: Tetranychidae) in papaya and passion fruit[1]

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ABSTRACT

The main crops attacked by *Tetranychus mexicanus* (McGregor) include papaya (*Carica papaya* L.) and passion fruit (*Passiflora edulis* Sims); however, the biological parameters of the mite in these hosts remain unknown. This research aimed to analyze the biology, development, survival and reproduction, as well as estimate the fertility life table of *T. mexicanus* in papaya and passion fruit, in an acclimatized chamber. The duration of the developmental stages of *T. mexicanus* was established and the reproductive parameters of the females were determined and used to construct the life table. The egg-adult period was 11.2 ± 0.07 and 12.0 ± 0.11 days, with a survival rate of 92.0 ± 0.04 and 79.0 ± 0.06 % for the *T. mexicanus* populations, respectively in papaya and passion fruit. Both the egg-adult periods and survival rates were significantly different. The fecundity was 106.0 ± 8.96 and 81.7 ± 7.21 eggs/♀, with a net reproduction rate (R_0) of 86.8 ± 0.15 and 56.7 ± 0.12 ♀/♀/generation, respectively the for papaya and passion fruit populations, with significant differences. The results indicate that *T. mexicanus* has a high capacity to develop, survive and reproduce on both hosts, especially on papaya.

KEYWORDS: Caricaceae, Passifloraceae, spider mite, Amazonian agroecosystems.

RESUMO

Biologia de *Tetranychus mexicanus* (McGregor) (Acari: Tetranychidae) em mamoeiro e maracujazeiro

Entre as principais culturas atacadas por *Tetranychus mexicanus* (McGregor) estão o mamoeiro (*Carica papaya* L.) e o maracujazeiro (*Passiflora edulis* Sims); porém, a biologia do ácaro nesses hospedeiros não é conhecida. Objetivou-se analisar a biologia, desenvolvimento, sobrevivência e reprodução, bem como estimar a tabela de vida de fertilidade de *T. mexicanus* em mamoeiro e maracujazeiro, em câmara climatizada. A duração das fases de desenvolvimento de *T. mexicanus* foi estabelecida e os parâmetros reprodutivos das fêmeas foram determinados e usados para elaboração da tabela de vida. O período de ovo-adulto foi de 11,2 ± 0,07 e 12,0 ± 0,11 dias, com sobrevivência de 92,0 ± 0,04 e 79,0 ± 0,06 % para as populações de *T. mexicanus*, respectivamente em mamoeiro e maracujazeiro. Tanto os períodos de ovo-adulto quanto as sobrevivências foram significativamente diferentes. A fecundidade foi de 106,0 ± 8,96 e 81,7 ± 7,21 ovos/♀, com taxa líquida de reprodução (R_0) de 86,8 ± 0,15 e 56,7 ± 0,12 ♀/♀/geração, respectivamente para as populações do mamoeiro e maracujazeiro, com diferenças significativas. Os resultados indicam que *T. mexicanus* tem elevada capacidade de desenvolvimento, sobrevivência e reprodução nos dois hospedeiros, principalmente no mamoeiro.

PALAVRAS-CHAVE: Caricaceae, Passifloraceae, ácaro de teia, agroecossistemas amazônicos.

INTRODUCTION

Papaya (*Carica papaya* L.) and passion fruit (*Passiflora edulis* Sims) are among the most cultivated tropical fruits in the Amazonas State, which is the largest producer in the northern region of Brazil (IDAM 2021).

Several insects and mites have caused problems in papaya and passion fruit agroecosystems in Brazil (Fancelli et al. 2016, Martins et al. 2016). Among the plant mites reported in the country are several species of spider mites (Tetranychidae) (Flechtmann & Moraes 2017), mostly of the *Tetranychus* genus.

Tetranychus mexicanus (McGregor) (Acari: Tetranychidae) has been mentioned as a pest in tropical and subtropical crops (Vacante 2015) such as papaya and passion fruit (Morais et al. 2015, Neves et al. 2015, Santos et al. 2018, Silva et al. 2021). Colonies of *T. mexicanus* are found on the abaxial surface of leaves, especially on the middle and basal

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leaves, under large amounts of web (Ochoa et al. 1991). The damage caused is typical of *Tetranychus*, starting with chlorotic lesions that, with continuous feeding, coalesce to form chlorotic spots and lead the leaf to dry and drop (Moraes & Flechtmann 2008, Hoy 2011). In Amazonas, *T. mexicanus* has been reported to cause severe damage to papaya and passion fruit (Vasconcelos & Silva 2015).

The biology of *T. mexicanus* is still poorly understood, having been studied in some Annonaceae (*Annona coriacea* Mart., *A. muricata* L. and *A. squamosa* L.), peach palm (*Bactris gasipaes* Kunth) and citrus [*Citrus aurantifolia* (Christm.)] (Paschoal 1968, Sousa et al. 2010, Stein & Daólio 2012). For papaya and passion fruit, there is still no information on population estimates, including their development, survival and reproduction. This information is important for integrated pest management and can be used, in conjunction with monitoring, to predict population outbreaks (Dent 2000).

Thus, this study aimed to determine the development, survival and reproduction of *T. mexicanus* in papaya and passion fruit, establishing the life table of this mite for both hosts.

MATERIAL AND METHODS

The research was carried out at the Universidade Federal do Amazonas, in Manaus, Amazonas State, Brazil, from April to December 2010. The entire experiment was conducted in an acclimatized chamber at the temperature of 25.0 ± 0.2 ºC, relative humidity of 76.0 ± 3.6 % and photophase of 12 h.

The stock rearing of *T. mexicanus* was initiated from individuals collected in papaya (Hawaii cultivar) and passion fruit (Amarelo Azedo cultivar) plantations already established at the experimental area. To confirm the species, samples of adult mites were mounted (Moraes & Flechtmann 2008) on a slide for microscopy with Hoyer's medium. Males were mounted individually, in a lateral position, and females were mounted in sets of three females per slide, in a dorsoventral position. The slides were then placed to dry in an oven at 45 ºC, for 72 h. The slides were observed under a phase-contrast microscope and the mites were identified based on the description of the species (McGregor 1950). The other mites were transferred to rearing units and maintained on the leaf of the respective host in which they were collected.

The rearing for the population from papaya used an adaptation of the methodology described by Vasconcelos et al. (2004). A leaf of the host, with the abaxial surface facing up, was placed on filter paper and this assemblage was placed on a 1-cm-thick polyethylene foam. The entire assemblage was placed on a tray and the foam was kept moist with distilled water. To prevent the mites from escaping and maintain leaf turgidity, the leaf margins were surrounded with hydrophilic cotton moistened in distilled water.

Due to the irregularity of the passion fruit leaf surface, an adaptation of the methodology described by McMurtry & Scriven (1965) was used to rear these mites. The leaf was superimposed, with the abaxial surface facing downwards, on a sheet of rubberized material (EVA type), which, in turn, was superimposed on 1-cm-thick polyethylene foam, with the assemblage being maintained inside a tray. The leaf petiole was wrapped in hydrophilic cotton and placed in contact with foam moistened with distilled water. Both the passion fruit and papaya rearing units were maintained under laboratory environmental conditions. Every four days, the mites were transferred to new units.

To start the biological studies, at 30 days after the start of rearing, 50 adult female of *T. mexicanus* from each population were transferred to a new rearing unit, maintaining the same host. Beforehand, the leaves were inspected to ensure that they did not contain any species of mite. The units were placed in an acclimatized chamber and the females oviposited for 4 hours, then removed, and the eggs counted. Every 12 hours, the eggs were evaluated to determine the incubation period and viability.

After hatching, the larvae were individualized in experimental units containing a 3-cm-diameter disk of either papaya or passion fruit leaf, with the abaxial surface facing upwards and superimposed, respectively on 4-cm-diameter filter paper disks and 1-cm-thick polyethylene foam. The entire assemblage was placed in a 5-cm-diameter Petri dish. The foams were kept permanently moistened with distilled water, and the edge of the leaf disks was surrounded by hydrophilic cotton moistened with distilled water. Every three days, the units were replaced. Observations of these units continued to occur every 12 h, to determine the duration and viability of the larval, protonymph and deutonymph phases.

After emergence, the females were kept in the experimental units and permanently mated with males from the experiment or, when necessary, obtained from stock rearing. In this phase, evaluations were conducted every 24 h, determining the preoviposition, oviposition and postoviposition periods, fecundity and longevity of females and males.

The sex ratio was determined based on adults of the F1 generation, from eggs produced on the fourth and fifth days of oviposition. With the data obtained for each population, the parameters of the fertility life table were calculated (Southwood & Henderson 2000).

The study was conducted in a completely randomized design, with two treatments - the *T. mexicanus* population on papaya and passion fruit. All analyzes were performed with the R 4.0.0 software (R Core Team 2020), using the "bootstrap" and "drc" statistical packages, adopting a significance level of 5 % ($p < 0.05$).

Survivals, sex ratio and life table parameters were subjected to the Jackknife method to generate pseudoreplicates in the two populations (Maia et al. 2000). The duration of the egg, larva, protonymph and deutonymph phases; egg-adult period; longevity; survival, preoviposition, oviposition and postoviposition periods; total and daily fecundities; sex ratio; and the parameters of the life table of the two populations were submitted to the t-test.

The Weibull distribution was used to describe the survival of each population (Bouras & Papadoulis 2005). The estimates for the parameters of shape (c) and scale (b) were obtained through the least squares method, after the linearization of the Weibull method. Then, the value of the parameter c from each population was used to classify the survival curve as type I, II or III (Pinder et al. 1978). To describe the degree of association between the survival observed in the evaluations in each population of *T. mexicanus* and the survival estimated by the Weibull distribution, these were submitted to Pearson's correlation analysis. Shape and scale parameters and correlation coefficients for the two models were compared using the confidence interval ($CI_{95\%}$) for the difference between two means (Miao & Chiou 2008).

RESULTS AND DISCUSSION

The egg and protonymph stages of *T. mexicanus* in papaya and passion fruit hosts presented no difference in duration (Table 1). The larval, deutonymph and egg-adult stages were shorter in the papaya host. For adults, a difference was found only in the longevity of males, with a longer duration for the papaya population.

For the survival of populations in each development stage, the passion fruit population only achieved a greater survival in the egg stage (Table 1). In the other phases, as well as in the egg-adult period, the greatest survival was always for the papaya population. The observed survival curves and those estimated by the Weibull model for *T. mexicanus* in papaya and passion fruit show adjustments with correlation coefficient values greater than 95 %

Table 1. Duration (mean ± standard error) of life cycle stages and survival (mean ± standard error) of *Tetranychus mexicanus* in papaya and passion fruit hosts.

Life stage[1]	Host	Female (♀) (days)	Male (♂) (days)	♂ + ♀ (days)	Survival (%)[2]
Egg	Papaya	4.4 ± 0.02 a[3] (61)[4]	4.5 ± 0.00 a (8)	4.4 ± 0.02 a (69)	97.3 ± 0.03 b (75)
	Passion fruit	4.5 ± 0.05 a (49)	4.6 ± 0.06 a (11)	4.5 ± 0.04 a (60)	100.0 ± 0.00 a (76)
Larva	Papaya	2.3 ± 0.05 b (61)	2.6 ± 0.18 b (8)	2.3 ± 0.05 b (69)	94.5 ± 0.04 a (73)
	Passion fruit	2.6 ± 0.05 a (49)	2.7 ± 0.14 a (11)	2.6 ± 0.05 a (60)	85.5 ± 0.05 b (76)
Protonymph	Papaya	1.9 ± 0.04 a (61)	1.9 ± 0.18 a (8)	1.9 ± 0.04 a (69)	100.0 ± 0.00 a (69)
	Passion fruit	1.9 ± 0.05 a (49)	1.9 ± 0.09 a (11)	1.9 ± 0.04 a (60)	95.4 ± 0.04 b (65)
Deutonymph	Papaya	2.5 ± 0.05 b (61)	2.7 ± 0.16 b (8)	2.6 ± 0.05 b (69)	100.0 ± 0.00 a (69)
	Passion fruit	2.9 ± 0.08 a (49)	2.8 ± 0.14 a (11)	2.9 ± 0.07 a (60)	96.8 ± 0.04 b (62)
Egg-adult	Papaya	11.2 ± 0.07 b (61)	11.3 ± 0.37 b (8)	11.2 ± 0.07 b (69)	92.0 ± 0.04 a (75)
	Passion fruit	11.9 ± 0.13 a (49)	12.0 ± 0.20 a (11)	12.0 ± 0.11 a (60)	79.0 ± 0.06 b (76)
Longevity	Papaya	21.8 ± 1.69 a (51)	59.8 ± 3.73 a (8)	26.9 ± 2.30 a (59)	-
	Passion fruit	21.0 ± 1.45 a (42)	31.8 ± 4.04 b (11)	23.3 ± 1.53 a (53)	-

[1] Temperature: 25.0 ºC; relative humidity: 76.0 %; photophase: 12 h. [2] Mean and standard error determined from pseudoreplicates by the Jackknife method. [3] For days of duration, for each phase, period, longevity or percentage of survival, means followed by the same letter (in the column, between hosts) do not differ from each other by the t-test, at 5 % of probability. [4] Number of repetitions.

in both hosts (Figure 1), being higher for papaya. The shape parameter was higher than one in both populations and higher in papaya. In both cases, the survival curves were classified as type I, where the mortality rate increases with age. The scale parameter was also higher in the papaya population, presenting a slower decline in the *T. mexicanus* population on this host.

The papaya and passion fruit hosts provided the development and survival of immature *T. mexicanus*, as well as showed population growth in adulthood. Thus, under favorable environmental conditions, this mite has the biotic potential to reach populations that cause economic damage to these crops. For *T. mexicanus*, favorable environmental conditions are low precipitation and relative humidity (RH) along with high temperature (Oliveira 1987, Silva et al. 2021). In Amazonas, the annual mean temperature and RH are 26.8 ºC and 85.3 %, respectively (Brasil 2021), facilitating the occurrence of *T. mexicanus* in agroecosystems for papaya and passion fruit production, mostly in the period of less rainfall, which, in Amazonia, is usually between July and November.

Some biological parameters of *T. mexicanus* have already been established in *Annona* spp. (27 ºC; 75 % RH), *B. gasipaes* (25 ºC; 60 % RH) and *C. aurantifolia* (19-25 ºC; without RH control) (Paschoal 1968, Sousa et al. 2010, Stein & Daólio 2012). These parameters include the duration of the egg-adult period and survival, which were, respectively, 9.9-12.1 days and 61.8-90.8 % in *Annona* spp.; 13.6 days and 59.2 % in *B. gasipaes*; and 19.5 days and unreported survival in *C. aurantifolia*. The values of the biological parameters determined for the populations on papaya and passion fruit demonstrate that *T. mexicanus* is more adapted to these hosts than *B. gasipaes* and *C. aurantifolia*. The populations on papaya and passion fruit exhibited similar biological parameters as those of populations studied in *Annona* spp.

Other species of *Tetranychus* that occur in papaya or passion fruit in Brazil have already had their biology studied in one of these hosts. For papaya, the biology of *T. bastosi* Tuttle, Baker and Sales is known at 25 ºC and 70 % RH and *T. urticae* Koch at 26 ºC and 70 % RH, and, in passion fruit, *T. marianae* McGregor at 25 ºC and 80 % RH (Noronha 2006, Moro et al. 2012, Lima et al. 2017). Among the biological parameters determined in these studies, the duration of the egg-adult period and survival were, respectively, 11.3 days and unreported survival for *T. bastosi*, 9.4-10.2 days and 94.1-100.0 % for *T. urticae* and 10.7 days and 92.0 % for *T. marianae*. These parameters were close to those observed for *T. mexicanus* on papaya and passion fruit.

For reproductive parameters, females of the two *T. mexicanus* populations presented no difference in the duration of the preoviposition, oviposition and postoviposition periods (Table 2). During oviposition, daily and total fecundity were higher in the papaya population. The generations from these

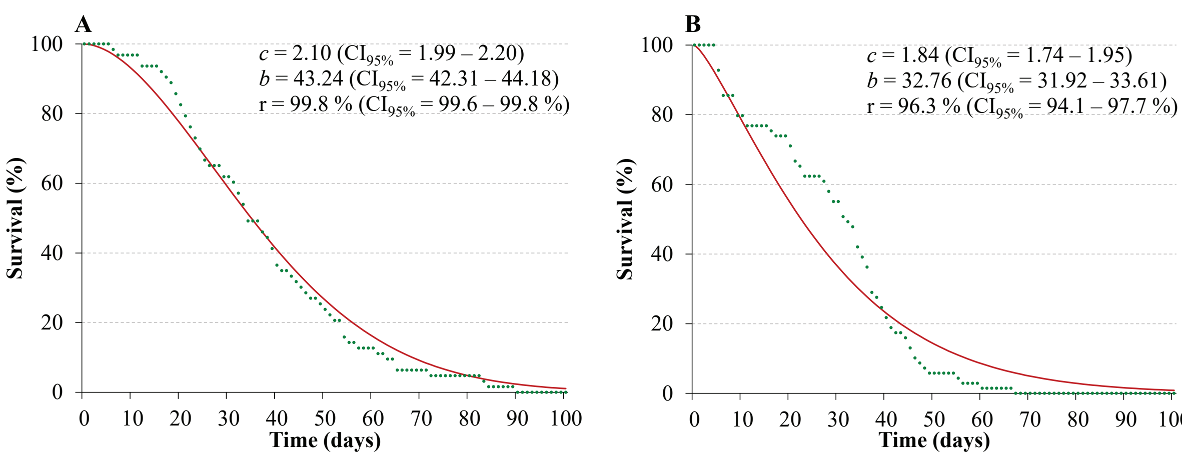

Figure 1. Survival of *Tetranychus mexicanus* in papaya (A) and passion fruit (B) hosts, with values observed (dotted line) and estimated with the Weibull distribution model (solid line), as well as estimates of shape (*c*) and scale (*b*) parameters and correlation coefficient (r), with respective confidence intervals at 95 % of probability. Temperature: 25.0 ºC; relative humidity: 76.0 %; photophase: 12 h.

Table 2. Mean ± standard error of reproductive parameters and fertility life table for *Tetranychus mexicanus* in papaya and passion fruit hosts.

Parameter (unit)[1]	Papaya	Passion fruit
Preoviposition (days)	0.6 ± 0.07 a[2] (51)[3]	0.6 ± 0.08 a (42)
Oviposition (days)	19.4 ± 1.60 a (51)	19.2 ± 1.40 a (42)
Postoviposition (days)	2.1 ± 0.42 a (51)	1.2 ± 0.19 a (42)
Daily fecundity (eggs/female/day)	5.0 ± 0.23 a (51)	3.9 ± 0.20 b (42)
Total fecundity (eggs/female)	106.0 ± 8.96 a (51)	81.7 ± 7.21 b (42)
Sex ratio of F1 generation (%)[4]	90.8 ± 0.00 a (643)	90.0 ± 0.00 a (389)
Time to double the population (TD) (days)[4]	3.7 ± 0.00 b (51)	4.2 ± 0.00 a (42)
Time between each generation (T) (days)[4]	23.7 ± 0.01 b (51)	24.4 ± 0.02 a (42)
Net reproduction rate (R_0) (♀/♀/generation)[4]	86.8 ± 0.15 a (51)	56.7 ± 0.12 b (42)
Innate ability to increase in corrected number (r_m') (progeny/♀/day)[4]	0.189 ± 0.00 a (51)	0.165 ± 0.00 b (42)
Finite increase ratio (λ) (progeny/♀/day)[4]	1.208 ± 0.00 a (51)	1.180 ± 0.00 b (42)

[1] Temperature: 25.0 ºC; relative humidity: 76.0 %; photophase: 12 h. [2] For each parameter, means followed by the same letter (on the row, between hosts) do not differ from each other by the t-test, at 5 % of probability. [3] Number of repetitions. [4] Mean and standard error determined from pseudoreplicates by the Jackknife method.

eggs were predominantly female, with no difference in the sex ratio between the two populations. In the fertility life table, the population doubling time and the time between each generation were higher in the passion fruit population. However, the life table parameters most directly related to population growth (i.e., net reproduction rate, innate ability to increase in corrected number and finite increase rate) were higher in the papaya population.

The biotic potential of *T. mexicanus* in the two tropical fruit trees and the local climatic conditions justify the frequent occurrence of this mite in production areas in Amazonia. The main occurrences of *T. mexicanus* as a pest have been recorded in plants from tropical and subtropical environments, especially fruit trees, or plants kept under greenhouse conditions (Flechtmann 1996, Flechtmann & Knihinicki 2002, Andrade et al. 2007, Seeman & Beard 2011, Stein & Daólio 2012, Pena et al. 2015, Vacante 2015, Silva et al. 2019). To prevent this problem, the pest must be monitored in the seedling production stage, in the greenhouse and in the orchards, in addition to avoiding the planting of papaya and passion fruit in nearby areas. It is also necessary to be careful with other host species, as *T. mexicanus* is a polyphagous species, with a record of occurrence in at least 110 plant species belonging to 44 families (Migeon & Dorkeld 2021).

The daily fecundity of *T. mexicanus* established in *Annona* spp., *B. gasipaes* and *C. aurantifolia* were, respectively, 2.1-4.3 (total fecundity/longevity), 0.8 and 1.4 eggs/female (Paschoal 1968, Sousa et al. 2010, Stein & Daólio 2012). For papaya, the spider mites *T. bastosi* and *T. urticae* exhibited a daily fecundity of, respectively, 2.1 and 2.0-2.6 eggs/female (total fecundity/longevity); while, in passion fruit with *T. marianae*, the daily fecundity was 3.7 eggs/female (Noronha 2006, Moro et al. 2012, Lima et al. 2017). The reproductive parameters of *T. mexicanus*, *T. bastosi*, *T. urticae* and *T. marianae*, in the aforementioned hosts, were close to those observed for *T. mexicanus* in papaya and passion fruit, indicating a similar biotic potential of these *Tetranychus* species in these hosts.

CONCLUSION

The *Tetranychus mexicanus* populations on papaya and passion fruit showed a type I survival curve, an innate capacity for an increase greater than zero, and a finite rate of increase greater than one, with increasing population growth and adaptation to these hosts, especially papaya.

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