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HORTICULTURAL STUDIES

RESEARCH PAPER

Two-Sex Life Table Analysis of *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) on Lettuce, Parsley, and Rocket

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Abstract

Phenacoccus solenopsis Tinsley (Hemiptera: Pseudococcidae), commonly known as the cotton mealybug, is a polyphagous pest causes significant economic losses worldwide. This study aimed to determine two-sex life table analysis of *P. solenopsis* on lettuce (*Lactuca sativa*), parsley (*Petroselinum crispum*), and rocket (*Eruca sativa*). Experiments were conducted under controlled conditions at 26°C, 65 ± 10% relative humidity, and a 16:8 light-dark cycle. The results indicated that lettuce was more suitable for *P.* solenopsis development compared to parsley and rocket. Total fecundity of *P. solenopsis* was recorded as 221.45, 158.00, and 121.64, on lettuce, parsley, and rocket respectively. In addition, oviposition period of *P. solenopsis* was 14.00, 9.73, and 8.45 days on lettuce, parsley, and rocket respectively. The highest values of net reproductive rate (R_0), intrinsic rate of increase (r), and finite rate of increase (λ) were obtained as 97.44 offspring female^{-1}, 0.14 day^{-1}, 1.16 day^{-1}, respectively from lettuce in this present research. The results showed that lettuce was the better host plant for *P. soleneopsis* than parsley and rocket. However, further studies should be done about host plant pest interactions to provide successful control measures against *P. solenopsis.*

1. Introduction

Although the origin of *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) is in the U.S.A (Tinsley, 1898; Abbas et al., 2010), this mealybug species was detected in different regions worldwide, such as Neaarctic, Neotropical, Oriental regions, around the World (Ben-Dov et al., 2015; Fand and Suroshe, 2015). This pest is a polyphagous species and determined on 226 host plants from 66 families (Garcia et al., 2016). Especially, in India and Pakistan cotton is main host for this pest and causing up to 60% damage to cotton crops (Fand and Suroshe, 2015). Additionally, several economically important vegetables and ornamentals serve as host plants for this mealybug (Fand and Suroshe, 2015). This pest was first detected on ornamental plants in 2012 in Adana province of Türkiye (Kaydan et al., 2013). Since then, this pest has continued to spread across in Türkiye and detected on 72 host plants from 55 families between 2012 and 2017 (Çalışkan and Ulusoy, 2018). *Phenacoccus solenopsis* can feed on all green parts of plants, and easily spread to uninfected areas by wind, water, agricultural activities and especially via international trade (Fand and Suroshe, 2015). Due to its high reproductive capability, cotton mealybug reaches higher population density on its host plants and causing significant economic damage to both agricultural and ornamental crops (Joshi et al., 2010).

The host plant is a significant factor in developing effective control strategies against *P. solenopsis*, with life table studies providing essential insights into its biology (Arif et al., 2013).

A life table is a crucial factor for studying population dynamics, as it offers comprehensive details for individuals within a cohort (Carey, 1993). Examining life table parameters can help to calculate reproductive and mortality patterns of organisms across various hosts (Price et al., 1980). The age-stage, two-sex life table analysis, first developed by Chi and Liu (1985) and Chi (1988). This approach allows for the inclusion of both sexes in the calculation of life table parameters, thereby providing a more comprehensive and accurate assessment of the biological and demographic characteristics of populations.

There were many studies carried about biology of cotton mealybug on many host plants by different researchers. Keçe (2019), Çalışkan et al. (2016), El Aalaoui and Sbaghi (2022), and Cai-Lang et al. (2017) have studied biology of *P. solenopsis* on varied host plants, such as different vegetables and ornamental species. In addition, some studies were carried out on different cotton varieties and other host plants for *P. solenopsis* (Prasad et al., 2012; Kumar et al., 2013; Ata, 2019). Above studies illustrated that, the two-sex life table parameters of *P. solenopsis* has been examined on various vegetables and ornamental plants. However, there is no study conducted about the biological parameters of *P. solenopsis* on lettuce, parsley, and rocket. This study aimed to determine the life table parameters of *P. solenopsis* on these three host plants (lettuce, parsley, and rocket) under controlled conditions.

2. Material and Methods

2.1. Plant materials

Parsley (*Petroselinum crispum*), lettuce (*Lactuca sativa*), and rocket (*Eruca sativa*) have been used as a host plant of *P. solenopsis* in this study. The plants used in the experiments were obtained pre-grown from external sources, and their leaves were washed daily before being used in the experiments. This study was carried out biological control laboratory of Plant Protection Department in Eskişehir Osmangazi University between 2023 and 2024.

2.1. Mealybug culture

Phenacoccus solenopsis culture has been grown in the controlled condition in climate cabinets at 26°C, 65 ± 10% relative humidity (RH), 16:8 light-dark (L:D) cycle. Sprouted potatoes were used for the maintenance of *P. solenopsis* culture.

2.3. Experimental design

Mated female individuals were transferred to 9 mm petri dishes containing agar for each host plant separately. Twenty four hour's later, mated mealybugs started to lay their eggs and hatched in few hours. First nymphal stages of individuals were transferred to 6 mm petri dishes with agar for each host plant (parsley, rocket, and lettuce) separately. Daily control has been done to detect immature stages of *P. solenopsis* on lettuce, parsley and rocket separately and host plant leaves were changed when its dried.

After pre-adult stage completed, one male mated with female in the same petri dishes and both female and male longevity were recorded daily. In addition, female was observed with pre-oviposition, oviposition and post-oviposition durations for individuals. Daily and total laid eggs were recorded for each host plant (parsley, lettuce and rocket) in this study. The experiments were conducted with 50 replications for each host plant at 26°C, 65 ± 10% RH, 16:8 L:D in the climate cabinet.

2.4. Statistical analysis

The life table analysis of *P. solenopsis* on lettuce, parsley, and rocket were performed with TWOSEX-MS Chart program developed by Chi and Liu (1985), Chi (1988), and Chi (2014). Age-specific survival rate (l_x), age-stage-specific fecundity (f_{xj}), age-specific fecundity (m_x), and age-stage-specific survival rate (s_{xj}) were determined with daily records of all individuals for each host plant separately (Wei et al., 2020; Chi et al., 2022). In addition, life table parameters were calculated for each host plant in this study

One hundred thousand (100.000) bootstraps were applied to calculate means and standard errors. The paired bootstrap method ($p<0.05$) was used to determine statistically significant differences between each host plant for the life table parameters of *P. solenopsis*. (Chi et al., 2022)

3. Results and Discussion

Total preadult periods for female *P. solenopsis* were 18.27±0.36, 19.82±0.30, 18.82±0.30 days and for male individuals 19.40±0.16, 20.60±0.37, 19.50±0.17 days on lettuce, rocket and parsley respectively. The highest preadult periods were detected on rocket for both male and female individuals. The immature stages of *P. solenopsis* showed significant differences for three different host plants (lettuce, rocket, and parsley) statistically ($p<0.005$) (Table 1).

The lowest adult preoviposition period (APOP), and total preoviposition period (TPOP) for *P. solenopsis* were detected as 7.73±0.56, and 26±0.65 on lettuce. In addition, the highest oviposition period was recorded as 14±1.18 days on lettuce as well in this study. Regarding total fecundity, the highest values were detected on lettuce and the lowest values were obtained from rocket (Table 2). There were statistical differences determined between host plants ($p<0.05$). However,

Table 1. The preadult stages of *Phenacoccus solenopsis* on different host plants.

Host plant	First nymphal stage (Mean±SE)		Second nymphal stage (Mean±SE)		Third nymphal stage (PP) (Mean±SE)		Total preadult (Mean±SE)	
	Female	Male	Female	Male	Female	Male	Female	Male
Lettuce	6.09±0.16a*	7.1±0.23b	4.73±0.19a	6.1±0.1b	7.45±0.25b	6.2±0.20a	18.27±0.36a	19.40±0.16a
Rocket	6.64±0.15b	6.50±0.17a	5.36±0.24b	5.90±0.28a	7.82±0.26b	8.2±0.25c	19.82±0.30b	20.60±0.37b
Parsley	6.55±0.21b	6.60±0.22a	5.91±0.16b	6.20±0.13b	6.36±0.31a	6.70±0.30b	18.82±0.30a	19.50±0.17a

*Same letters within the column are not statistically important in accordance with paired bootstrap test (p<0.05)

Table 2. Biological parameters of *Phenacoccus solenopsis* on different host plants.

Host plant	APOP (Mean±SE)	TPOP (Mean±SE)	Oviposition period (Mean±SE)	Post-oviposition period (Mean±SE)	Total fecundity (Mean±SE)	Adult longevity (Mean±SE)	
						Female	Male
Lettuce	7.73±0.56a*	26±0.65a	14±1.18b	3.09±0.25b	221.45±18.33b	24.82±1.22c	4.3±0.15a
Rocket	9.45±0.51b	29.27±0.52b	8.45±1.34a	2.63±0.20a	121.64±19.31a	20.54±1.15a	4.8±0.40b
Parsley	10.36±0.39b	29.18±0.39b	9.73±1.19a	2.27±0.23ab	158±17.12a	22.36±1.06b	4.3±0.29a

APOP: Adult pre-oviposition period, TPOP: Total pre-oviposition period.
*Same letters within the column are not statistically important in accordance with paired bootstrap test (p<0.05).

Table 3. Life table parameters of *Phenacoccus solenopsis* on lettuce, rocket, and parsley.

Host plant	r (day^{-1}) (Mean±SE)	R_0 (offspring) (Mean±SE)	λ (day^{-1}) (Mean±SE)	GRR (offspring) (Mean±SE)	T (day) (Mean±SE)
Lettuce	0.148±0.008b*	97.44±23.33b	1.160±0.009b	238.97±24.12b	30.74±0.67a
Rocket	0.121±0.008a	53.52±14.52a	1.129±0.009a	144.03±22.96a	32.739±0.51b
Parsley	0.128±0.008a	69.52±17.31b	1.137±0.009a	180.59±19.39a	32.96±0.56b

r: intrinsic rate of increase, R_0: Net reproduction rate, λ: finite rate of increase, GRR: Gross reproductive rate.
*Same letters within the column are not statistically important in accordance with paired bootstrap test (p<0.05).

there were differences detected between host plants in terms of female and male longevity in this study (p<0.05) (Table 2).

Life table parameters of *P. solenopsis* on lettuce, rocket, and parsley was found statistically significant in this study (p<0.05). The highest R_0 was found on lettuce (97.44±23.33) and lowest result were obtained from rocket (53.52±14.52) in this study (Table 3). λ and r values were highest for lettuce and were lowest on rocket. In addition, GRR (Gross reproductive rate) was highest for lettuce (238.97±24.12) and the lowest for rocket (144.03±22.96) in this study (Table 3). Regarding life table parameters, lettuce showed better performance as a host plant than parsley and rocket. Although lettuce may be better host plant for *P. solenopsis,* this pest can be completed its generation and may cause damage on parsley and rocket. Results indicated that three host plants are suitable for *P. solenopsis* but lettuce may be more suitable than parsley and rocket in this study. In addition, Figures 1, 2, and 3 have demonstrated the population parameters of *P. solenopsis* on lettuce, parsley, and rocket, respectively.

Host plants choice is significant to determine biology of insect pests. Biological parameters of pests may change on different host plants. Studies conducted for life table parameters may help to detect reproductive rates and other parameters of insects under laboratory conditions on various host plants (Awmack and Leather, 2002; Umbanhowar and Hasthings, 2002; Saeed et al., 2010). Cotton is known as the main host plant for *P. solenopsis* but host plant range has been spreading to non-origin geographical areas in recent years due to climate change (Fand et al., 2014). In life table studies some parameters helps to comment properly about suitability of host plants such as shorter TPOP and APOP, and higher fecundity, net reproductive rate (Abbes et al., 2024).

Some researchers have been carried out studies about the biology of cotton mealybug on varied host plants. Abbes et al. (2024) investigated the host suitability of three economically important crops (tomato, potato, and eggplant) for the invasive polyphagous pest *P. solenopsis* using age-stage two-sex life tables to assess pest fitness, life table parameters, and eggplant notably induced the highest R_0 (243.32), λ (1.18), and fecundity (276.50), alongside extended longevity of adult (males: 6.50 days, females: 24.15 days). Cai-Liang et al. (2017) assessed the impact of various vegetable host plants (potato, purple sweet potato, cucumber, lettuce, and cabbage) on the growth, development, and reproduction of *P. solenopsis* under controlled laboratory conditions (25±1°C, 60%±5% RH, 14:10 L:D) and results indicated that potato demostrated the shortest developmental generation duration and highest average survival rate, whereas cucumber resulted in the longest developmental duration and lowest survival rate. Female longevity peaked on lettuce, while male longevity was highest on potato. These findings demonstrated that different vegetable hosts significantly influence the population growth parameters of *P. solenopsis*, with potato emerging as the most conducive to the pest's growth and reproduction among the vegetables tested in that

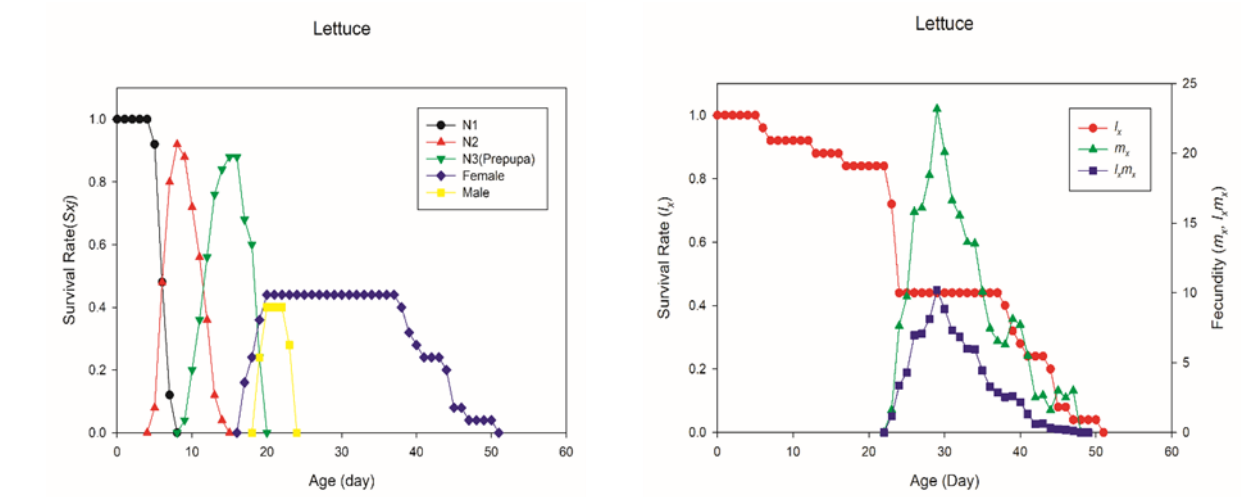

Figure 1. Age-stage survival rate (*Sxj*), age-specific survival rate (l_x) and fecundity (*mx, lxmx)* of *P. Solenopsis* on lettuce.

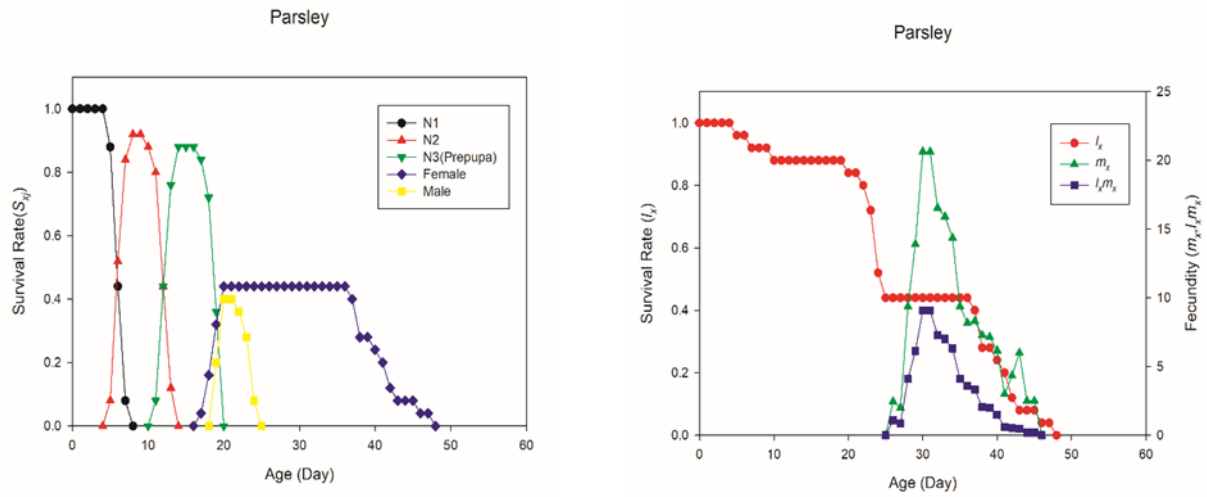

Figure 2. Age-stage survival rate (*Sxj*), age-specific survival rate (l_x) and fecundity (*mx, lxmx)* of *P. Solenopsis* on parsley.

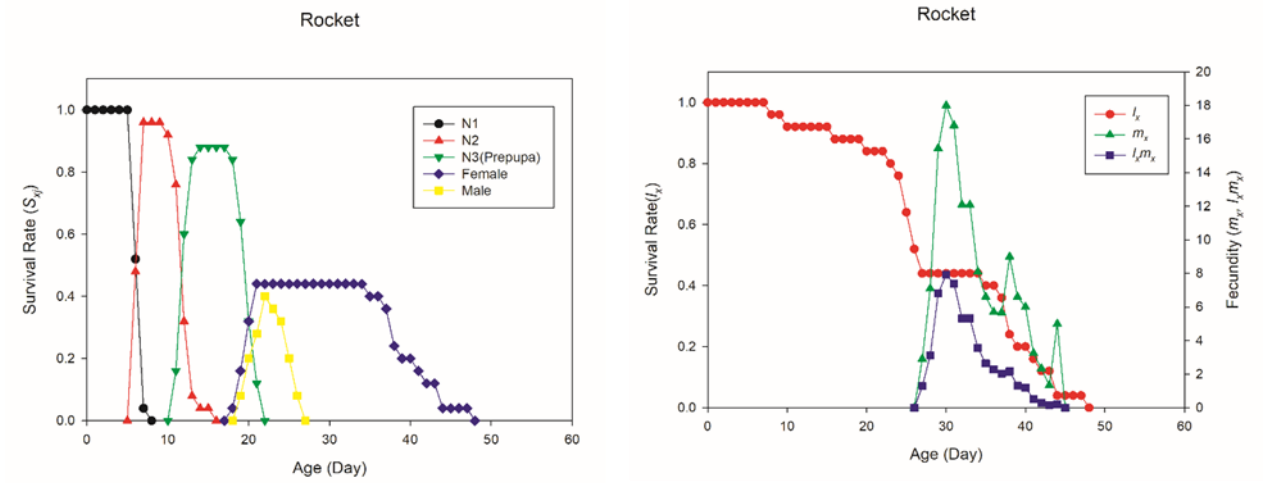

Figure 3. Age-stage survival rate (*Sxj*), age-specific survival rate (l_x) and fecundity (*mx, lxmx)* of *P. Solenopsis* on rocket.

study (Cai-Liang et al., 2017). Another study conducted for *P. solenopsis* on pepper, tomato, eggplant, cotton under laboratory conditions in 2018-2019 and the results indicated eggplant as the most suitable host, exhibiting the highest values for key life table parameters, including (R_0) of 184 nymphs per female, (r_m) of 0.269 per day, (λ) of 1.31 per day, and (GRR) of 264 nymphs per female in that study (Keçe, 2019). Nagrare et al. (2018) assessed biology of the invasive cotton mealybug on five preferred host plants (China rose, okra, cotton, congress grass, tomato) under controlled laboratory conditions, revealing that the mean development time for females varied from 13.57

days on congress grass to 16.61 days on cotton, which was identified as the most favorable host due to its longest ovipositional period (15.20 days), highest female longevity (27.40 days),highest fecundity (328.30 eggs), and highest intrinsic rate of increase (0.19 day−1), net reproductive rate (284.3), thereby highlighting the significant impact of host plant species on the population dynamics of *P. solenopsis*. Dogar et al. (2018) studied the effect of various host plants (*Jasminum sambac*, *Anthurium andraeanum*, *Plumeria rubra*, *Hibiscus rosasinensis, Caesalpinia pulcherrima*) on *P. solenopsis* and the findings indicated that *H. rosasinensis* shortened pupal and generation times and reduced adult longevity, whereas *C. pulcherrima* and *A. andraeanum* led to lower fecundity and hatchability, highlighting the importance of host plants in *P. solenopsis* population dynamics and informing potential cultural management strategies. Another study investigated population growth parameters of the cotton mealybug, on *B. aurea*, *H. syriacus, C. nocturnum,* and *H. rosa-sinensis* under controlled conditions, revealing that rearing on *H. syriacus* resulted in the highest GRR (342.6), R_0 (258.0), λ (1.3380), r (0.2911), and shortest (T) (19.1 days), highlighting the significant impact of host plant species on the population dynamics and potential management strategies of *P. solenopsis* (Çalışkan et al., 2016). As observed in studies conducted by various researchers, some vegetable and ornamental species can be as suitable host plants for *P. solenopsis*. Particularly, eggplant was identified as the most suitable host plant by Abbes et al. (2024) and Keçe (2019). Conversely, Nagrare et al. (2018) found cotton to be the most suitable host plant. Additionally, Dogar et al. (2018) and Çalışkan et al. (2016) generally focused on ornamental plants. Cai-Liang et al. (2017) studied various host plants and found that lettuce was a partially better host plant, which supports with the findings of this study. In the present study, lettuce, parsley, and rocket were investigated. The results indicated that lettuce may be the most suitable host plant for *P. solenopsis.* However, parsley and rocket did not show as favourable results, suggesting that further detailed studies should be conducted under different conditions for these plants.

4. Conclusion

In conclusion, the present study investigated two-sex life table parameters of *Phenacoccus solenopsis* on three different host plants: lettuce, parsley, and rocket. The findings revealed significant variations in several key parameters among these hosts. Lettuce demonstrated better suitability as a host for *P. solenopsis* compared to parsley and rocket, as evidenced by shorter pre-adult development periods, higher fecundity rates, and greater reproductive success. Specifically, lettuce exhibited the shortest adult pre-oviposition period (APOP) and total pre-oviposition period (TPOP), highest oviposition period, and net reproduction rate (R_0), indicating it as the most conducive host for sustaining *P. solenopsis* populations under laboratory conditions. Conversely, parsley and rocket showed less favourable results in terms of life table parameters such as pre-adult development times and reproductive output. However, this pest can complete its life cycle and reproduction on both parsley and rocket, this situation showed that, their potential as secondary hosts for *P. solenopsis*. These findings contribute valuable insights into the host plant preferences and reproductive capabilities of *P. solenopsis*, crucial for developing targeted pest management strategies in agricultural crops and ornamental plants. Further research could explore additional factors influencing *P. solenopsis* dynamics on various hosts under different environmental conditions to enhance pest control effectively and successfully.

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