International Journal of Tropical Insect Science Vol. 38, No. 4, pp. 387–393, 2018 doi:10.1017/S174275841800019X
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Effect of host plants on life history traits of *Phenacoccus solenopsis* (Homoptera: Pseudococcidae)

Abdul Manan Dogar[1], Mahmood Ayyaz[2], Naeem Abbas[1,3]*, Sarfraz Ali Shad[1]* and Afifa Naeem[1]

[1]Department of Entomology, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan, Pakistan; [2]Department of Plant Productions and Technologies, Faculty of Agricultural Sciences and Technologies, Nigde University, Nigde, Turkey; [3]Department of Entomology, University College of Agriculture and Environmental Sciences, The Islamia University of Bahawalpur, Bahawalpur, Pakistan

(Accepted 10 April 2018)

Abstract. Cotton mealybug, *Phenacoccus solenopsis* Tinsley is an important polyphagous insect pest and causes severe losses to different crops worldwide. In the current study, we investigated the effect of different host plants, such as *Caesalpinia pulcherrima*, *Plumeria rubra*, *Anthurium andraeanum*, *Jasminum sambac*, and *Hibiscus rosasinensis*, on the biological parameters of *P. solenopsis*. The survival rate from crawler to adult, female nymphal duration, development time from crawler to female adult, and female adult weight were significantly different on the different hosts. Male nymphal duration, development time from crawler to male adult, pupal weight, emergence rate of male adults, and mean relative growth rate for male were similar on all the tested host plants. Pupal duration and generation time of male and female on *H. rosasinensis* were significantly shorter than on the other hosts. Adult male and female *P. solenopsis* longevity was significantly shorter on *H. rosasinensis* compared to other hosts. The fecundity was lower on *C. pulcherrima* and *A. andraeanum* and hatchability was lower on *C. pulcherrima* than on the other hosts. The net reproductive rate, the intrinsic rate of natural increase, and biotic potential and mean relative growth rate for female of *P. solenopsis* were significantly different on the tested hosts. Our results point to the role of host plants in increasing the populations of *P. solenopsis* and could help to design cultural management strategies.

Key words: biotic potential, host plants, mean relative growth rate, management, *Phenacoccus solenopsis*

Introduction

Among the sucking insect pests, cotton mealybug, *Phenacoccus solenopsis* Tinsley (Homoptera: Pseudococcidae) is an important polyphagous insect pest and causes severe losses to different crops (i.e. 58–73.8%) (Zhang *et al.*, 2004; Abbas *et al.*, 2005; Zhou *et al.*, 2013). Cotton mealybug has been reported as a serious pest of various crops, including vegetables and ornamentals in Australia, USA, Cyprus, Egypt, France, Iran, Israel, Japan, Pakistan, India, China, and Turkey (Hodgson *et al.*, 2008; Wang *et al.*, 2010; Kaydan *et al.*, 2013; Fand and Suroshe, 2015). It is an important pest of cotton, *Gossypium hirsutum* L., Malvaceae and caused 30–60% yield losses during 2005–2009 in Pakistan and India (Fand and Suroshe, 2015). The cotton mealybug is also an important pest of ornamental plants, such as *Hibiscus rosasinensis* L. and *Hibiscus syriacus* L. belonging to the family Malvaceae,

*E-mail: naeemsurbana@gmail.com; sarfrazshad@bzu.edu.pk

Brugmansia aurea Lagerh and *Cestrum nocturnum* L. belonging to the family Solanaceae, *Lantana camara* L. belonging to the family Verbenaceae, and vegetables (such as *Solanum esculentum* Lam., *S. melongena* L., and *Capsicum annuum* L.) belonging to the family Solanaceae (Fand and Suroshe, 2015; Çalışkan *et al.*, 2016).

Host plants play a significant role in the growth and spread of *P. solenopsis* and affect the life history parameters (Abbas *et al.*, 2010; Arif *et al.*, 2013). Like other arthropod pests, host plant range is an important ecological characteristic of mealybug species. Host plant range defines the resource base of a pest, which helps in determining the population dynamics and the interaction with other insect species, parasites, and predators (Calatayud *et al.*, 2002; Neuenschwander, 2003). Effect of various host plants on the life table and biological parameters of *P. solenopsis* has been reported by various workers from different parts of the world (Aheer *et al.*, 2009; Mamoon-ur-Rashid *et al.*, 2012; Arif *et al.*, 2013; Kedar *et al.*, 2013; Çalışkan *et al.*, 2016). However, no information of complete biological parameters of *P. solenopsis* on different ornamental and crop plants exists. Therefore, a comparative study on the biological parameters of *P. solenopsis* reared on various host plants is necessary to develop better control strategies against this pest.

Large-scale adaptation of chemicals for the control of insect pests has led to insecticide resistance in a number of polyphagous insect pests and many other problems, like health hazards, environmental pollution, and secondary pest problems, which have increased (Malik *et al.*, 2015; Rehman *et al.*, 2015). Therefore, the management of insect pests by behavioural manipulation or push–pull strategies can be helpful in integrated pest management programmes (Ravindhran and Xavier, 1997). Host plants can play a pivotal role not only in population growth but also lead to the outbreak of certain polyphagous insect pests (Abbas *et al.*, 2010). Because of the importance of behavioural manipulation in insect pest management strategies, this phenomenon has gained admiration in the last few years. The main emphasis is to reduce the usage of insecticides to make an eco-friendly agro-ecological climate (Foster and Harris, 1997). The current study was conducted to evaluate the impact of six host plants on the biological parameters of *P. solenopsis* under laboratory conditions.

Materials and methods

Host plants

Six host plants *viz.* gul-e-ancha (*C. pulcherrima*, Sw., Fabaceae), 'gul-e-cheen' (*P. rubra*, Apocynaceae), anthurium (*Anthurium* spp., Araceae), Arabic jasmine (*Jasminum sambac* Aiton, Oleaceae), and China rose (*Hibiscus rosasinensis* L., Malvaceae) were obtained from the Botanical Garden of Bahauddin Zakariya University, Multan, Pakistan. Freshly picked leaves of selected host plants were used throughout the experiment.

Collection and rearing

About 200 adults of *P. solenopsis* were collected from the cotton fields located in Ali Pur, Pakistan (29.388155 °N, 70.919013 °E) in 2013. The adults were brought to the laboratory and reared in plastic jars (22 × 13 cm) on soft and freshly plucked twigs with leaves from each tested host plant. The older twigs with leaves were changed with fresh ones after 2–3 days. The culture on each host was maintained at 27 ± 2 °C temperature, 65 ± 5% RH, and 10/14 (L/D) photoperiod (Afzal *et al.*, 2015).

Biological parameter of P. solenopsis

For testing the effects of host plants on the biological parameters of *P. solenopsis*, the field population was reared for two generations on each host plant to adapt to the new host plant and eliminate the maternal effects before starting the experiment. A total of 150 newly hatched crawlers were randomly collected from each host population to study biological parameters. Crawlers were weighed with weighing balance and reared in plastic jars (500 mL) containing freshly picked twigs with leaves of selected host plants. The dried leaves were replaced with fresh leaves after 2–3 day intervals. The plastic jars were arranged in three replicates for each host population, and 50 crawlers were used for each replicate. All insects were kept at the laboratory conditions mentioned above. The data were recorded on a daily basis. The survival rate (%), male nymphal duration (crawler to second instar, days), female nymphal duration (crawler to third instar, days), number of pupae, weight of pupae (mg), and pupal period (days) were observed. Moreover, the emergence rate of male (%), fecundity (number of eggs/female), male and female longevity (days), generation time (days), and female adult weight (mg) were also determined.

Statistical analysis

The hatchability (%) was determined according to Abbas *et al.* (2012) as follows:

$$\text{Hatchability} = \text{All neonates}/\text{All eggs}.$$

The net reproductive rate (R_0) was calculated using the following formula as reported by Jia *et al.*

Table 1. The developmental parameters of *Phenacoccus solenopsis* on different host plants

Biological parameters	*Caesalpinia pulcherrima*	*Plumeria rubra*	*Anthurium andraeanum*	*Jasminum sambac*	*Hibiscus rosasinensis*
Crawlers	150	150	150	150	150
Survival rate from crawler to adult (%)	79.33 ± 0.67b	89.33 ± 1.76a	83.33 ± 1.76ab	77.33 ± 1.76b	80.00 ± 1.15b
Male nymphal duration (days)	11.17 ± 0.44a	11.82 ± 0.21a	11.82 ± 0.21a	11.50 ± 0.12a	10.90 ± 0.09a
Female nymphal duration (days)	19.33 ± 0.17ab	19.65 ± 0.28a	18.65 ± 0.28bc	19.43 ± 0.12ab	18.04 ± 0.10c
+DT from crawler to adult (days)	13.63 ± 0.41a	14.65 ± 0.43a	13.57 ± 0.15a	13.97 ± 0.19a	13.74 ± 0.06a
+DT from crawler to adult (days)	21.80 ± 0.15ab	22.48 ± 0.46a	21.20 ± 0.29ab	21.90 ± 0.23ab	20.87 ± 0.04 b
Male generation time (days)	30.63 ± 1.17a	31.06 ± 1.00a	30.22 ± 0.25a	31.30 ± 0.35a	24.64 ± 0.10b
Female generation time (days)	59.38 ± 1.54ab	63.15 ± 1.34a	58.34 ± 0.14b	62.23 ± 0.18ab	53.71 ± 0.14c
Number of pupae	3.00 ± 0.58b	5.67 ± 0.33a	4.33 ± 0.33ab	4.00 ± 0.58ab	5.33 ± 0.67ab
Pupal weight (mg)	0.73 ± 0.04a	0.74 ± 0.003a	0.79 ± 0.06a	0.72 ± 0.01a	0.83 ± 0.03a
Female weight (mg)	1.78 ± 0.049c	1.92 ± 0.02bc	2.02 ± 0.04b	2.43 ± 0.03a	1.99 ± 0.01b
Pupal duration (days)	9.67 ± 0.33a	9.67 ± 0.33a	9.83 ± 0.17a	9.67 ± 0.09a	4.80 ± 0.10b
Emergence rate of male adults (%)	91.67 ± 8.33a	64.44 ± 9.88a	61.67 ± 7.26a	73.89 ± 3.89a	83.33 ± 9.62a

Means followed by the same letter in rows are non-significantly different ($P > 0.05$).
+DT: development time

(2009) and Abbas *et al.* (2012):

$$R_0 = N_{n+1}/N_n,$$

where N_n is the population quantity of the parental generation and N_{n+1} is that of the next generation.

Mean relative growth rate (MRGR) of both sexes were determined according to Afzal *et al.* (2015):

$$\text{MRGR} = [W1\ (\text{mg}) - W2\ (\text{mg})]/T,$$

where $W1$ is the initial crawler weight, $W2$ is the pupae weight for male or third instar weight for female, and T is the developmental time (days) from crawler to pupae for male or crawler to third instar for female.

Biotic potential was determined according to Abbas *et al.* (2016) as follows:

$$\text{Biotic potential} = \text{Log fecundity}/T.$$

Data were analysed by the analysis of variance (ANOVA) using Statistix 8.1v (Anonymous, 2005) and means were compared by Tukey's honestly significant difference (HSD) test ($P < 0.05$).

Results

Survival rate, nymphal duration, development time, and generation time

The survival rate from crawler to adult of *P. solenopsis* was significantly different on the tested five host plants ($F = 6.66$, df = 4, $P < 0.01$). The highest survival rate (89.33%) was on *P. rubra* and lowest survival rate (77.33%) was on *J. sambac* (Table 1). Male nymphal duration was not significantly different on all the tested host plants ($F = 2.65$, df = 4, $P < 0.09$). The female nymphal duration was significantly lower on *H. rosasinensis* compared to all the other tested hosts ($F = 10.70$, df = 4, $P = 0.001$) except *A. andraeanum*.

The development time from crawler to male adult was not significantly different on all the host plants ($F = 2.33$, df = 4, $P = 0.13$; Table 1). Similarly, the development time from crawler to female adult on *P. rubra* was significantly longer compared with the *H. rosasinensis* ($F = 5.22$, df = 4, $P = 0.02$). Male generation time on *C. pulcherrima, P. rubra, A. andraeanum*, and *J. sambac* was significantly longer compared to the *H. rosasinensis* ($F = 16.50$, df = 4, $P < 0.001$). Similarly, the female generation time on *H. rosasinensis* was highly significantly shorter than on the *C. pulcherrima, P. rubra*, and *J. sambac* ($F = 16.50$, df = 4, $P < 0.001$).

Number of pupae, pupal and female weight, pupal duration, and emergence rate of male

Number of pupae on *C. pulcherrima* was significantly lower ($F = 4.29$, df = 4, $P = 0.03$) than on *P. rubra* but was not significantly different than on other host plants (Table 1). The pupal weights of *P. solenopsis* did not differ significantly among all the tested hosts ($F = 2.07$, df = 4, $P = 16$). The pupal duration on *A. andraeanum, J. sambac, P. rubra*, and *C. pulcherrima* was significantly longer compared to the pupal duration on *H. rosasinensis* ($F = 90$, df = 4, $P < 0.001$). Average female adult weight on *C. pulcherrima* was significantly lighter as compared

Table 2. Adult longevity, fecundity, and hatchability of *Phenacoccus solenopsis* on different host plants

Biological parameters	Host plants: *Caesalpinia pulcherrima*	*Plumeria rubra*	*Anthurium andraeanum*	*Jasminum sambac*	*Hibiscus rosasinensis*
Adult male longevity (days)	7.33 ± 0.60ab	6.75 ± 0.14ab	6.82 ± 0.04ab	7.67 ± 0.33a	6.10 ± 0.06b
Adult female longevity (days)	37.58 ± 1.69a	40.67 ± 0.88a	37.13 ± 0.19a	40.33 ± 0.33a	32.83 ± 0.17b
Fecundity (eggs/female lifetime)	34.81 ± 0.96c	55.17 ± 1.33b	37.65 ± 1.11c	70.30 ± 3.27a	50.15 ± 0.91b
Hatchability (%)	80.67 ± 2.21c	94.04 ± 1.28ab	87.62 ± 0.89b	96.08 ± 1.36a	91.34 ± 1.14ab

Means followed by the same letter in rows are non-significantly different ($P > 0.05$).

Table 3. The growth parameters of *Phenacoccus solenopsis* on different host plants

Biological parameters	Host plants: *Caesalpinia pulcherrima*	*Plumeria rubra*	*Anthurium andraeanum*	*Jasminum sambac*	*Hibiscus rosasinensis*
Net reproductive rate	25.63 ± 1.26d	46.22 ± 0.29b	30.28 ± 0.42d	61.44 ± 3.07a	38.80 ± 0.49c
Intrinsic rate of natural increase	0.18 ± 0.005c	0.21 ± 0.005b	0.20 ± 0.003bc	0.23 ± 0.005a	0.21 ± 0.001bc
Biotic potential	0.14 ± 0.001b	0.14 ± 0.003ab	0.14 ± 0.002ab	0.15 ± 0.003a	0.15 ± 0.0004a
Mean relative growth rate of male	0.05 ± 0.002a	0.04 ± 0.001a	0.05 ± 0.005a	0.04 ± 0.001a	0.05 ± 0.003a
Mean relative growth rate of female	0.08 ± 0.002c	0.08 ± 0.001c	0.09 ± 0.002b	0.11 ± 0.001a	0.09 ± 0.001b

Means followed by the same letter in rows are non-significantly different ($P > 0.05$).

to other host plants ($F = 54.60$, df = 4, $P < 0.001$) except on *P. rubra*. Emergence rate of male adults was not significantly different on all tested host plants ($F = 2.43$, df = 4, $P = 0.11$).

Adult longevity, fecundity, and hatchability

Adult male *P. solenopsis* longevity on *J. sambac* was significantly longer than on *H. rosasinensis* ($F = 3.60$, df = 4, $P = 0.05$) (Table 2). Similarly, adult female longevity was shorter on *H. rosasinensis* compared to all other hosts ($F = 13.10$, df = 4, $P = 0.001$). The number of eggs per female produced on *J. sambac* was significantly higher than on all the other hosts ($F = 66.60$, df = 4, $P < 0.001$). The percent hatching of eggs on *C. pulcherrima* was highly significantly lower compared to other tested hosts ($F = 17.60$, df = 4, $P < 0.001$).

Net reproductive rate, intrinsic rate of natural increase, and biotic potential

The net reproductive rate on tested hosts was highly significantly different ($F = 86.80$, df = 4, $P < 0.001$). The highest net reproductive was observed on *J. sambac* and lowest on *C. pulcherrima* (Table 3). Similarly, the intrinsic rate of natural increase ($F = 17.90$, df = 4, $P < 0.001$) and biotic potential ($F = 7.78$, df = 4, $P = 0.004$) were also highly significantly different on the different hosts.

Mean relative growth rate

The mean relative growth rate for male *P. solenopsis* did not differ significantly among all the tested hosts ($F = 1.81$, df = 4, $P = 0.20$), while the mean relative growth rate for female *P. solenopsis* on *J. sambac* was significantly higher compared with the other tested host plants ($F = 45.80$, df = 4, $P < 0.001$). The MRGR of female was highest on *J. sambac* and lowest on *C. pulcherrima* and *P. rubra* (Table 3).

Discussion

Host plants play an important role in the outbreaks of insect pests (Umbanhowar and Hastings, 2002). The biological parameters of a particular insect pest can vary on different hosts, and this factor determines the plant suitability for herbivorous hosts. Rapid development times and greater reproductive rates of insect pests on a particular host indicate the higher suitability of a host (Awmack and Leather, 2002; Saeed *et al.*, 2010). The developmental and reproductive rates provide important clues about the host's ability to support the whole life cycle of insects. However, these data should be associated to other parameters like mortality before pupation or adult maturation, which ultimately determine host suitability (Saeed *et al.,* 2010). In the present study, developmental time from crawler to male/female adult of *P. solenopsis* varied on different types of hosts. Shorter developmental time on a specific host could result into a shorter life cycle and rapid population growth (Singh and Parihar, 1988; Saeed *et al.,* 2010), which might reduce generation time. The variations in developmental rates of insects on various hosts could be due to the differences in nutrient contents and phytochemicals produced as a response to damaged tissue because, as a defence mechanism, plants produce phytochemicals in response to the herbivory damage (Goussain *et al.*, 2005; Saeed *et al.,* 2010; Khan *et al.,* 2012). More nitrogen contents in host plants increased the survival, longevity, fecundity, and hatchability of sucking insect pests, as well as hatching capacity of their eggs (Kalaiselvi and Kalaivani, 2011). However, further studies are required to explore the biochemical reasons for such variations.

In this study, the body weights of *P. solenopsis* females had a significant association with number of eggs laid. On *A. andraeanum, J. sambac,* and *H. rosasinensis*, females were heavier, and laid the maximum number of eggs. Previously, the relationship between body weight and fecundity was observed in other insect pests, such as *Spodoptera exigua* (Greenberg *et al.*, 2001), *Aedes albopictus*, *Aedes geniculatus* (Armbruster and Hutchinson, 2002), *Plutella xylostella* (Saeed *et al.,* 2010), and *Musca domestica* (Khan *et al.,* 2012) where fecundity was significantly associated with body weight of the insect. In addition to differences in developmental times and body weights, marked alterations in survival rate from crawler to adults among the different host plants were seen. Nymphs fed on *P. rubra* and *A. andraeanum* had considerably higher survival rates compared to the other host plants. Higher survival rate on *P. rubra* and *A. andraeanum* might be due to lower early mortality, which could be attributed to the suitability of these host plants. The death of juvenile stages of an insect population, however, is a key factor in assessing the adult population (Saeed *et al.,* 2010). Similarly, the host plants can also have a significant effect on the number of adults and their longevity.

The females developed from the nymphs of *P. solenopsis* reared on *J. sambac* laid a higher number of eggs compared with the other hosts. In contrast to this study, previously highest fecundity (nymphs/female) of *P. solenopsis* on *H. rosasinensis* was reported (Sana-Ullah *et al.,* 2011; Mamoon-ur-Rashid *et al.,* 2012; Arif *et al.,* 2013). The suitability of hosts as a nymphal food depends on various factors that might alter the oviposition behaviour of the insect pests consuming such type of food (Khan *et al.,* 2012). Host plant chemical cues also play a key role in the oviposition behaviour of insect pests (Reddy and Guerrero, 2004). The differences in fecundity on various host plants might demonstrate chemical cues that mediate host plant selection in *P. solenopsis* (Saeed *et al.,* 2010). However, further studies should explore the role of these chemical cues of host plants in attracting females for oviposition.

The information of differences in host plants could have practical application for the management of *P. solenopsis*. *Phenacoccus solenopsis* has the potential to become an important pest in any crop system, due to its broad host range, including field crops, vegetables, ornamentals, and weeds. The present results suggest that the tested host plants can play an important role in the spread and survival of *P. solenopsis;* therefore, the management of *P. solenopsis* is necessary on these hosts. The results presented here could be helpful in designing management strategies, including cultural control.

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