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Lifehistory of mealybug *Phenacoccus solenopsis* tinsley (Hemiptera: Pseudococcidae) on different host plants and its relative effect of antibiosis

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Key words: *Phenacoccus solenopsis*, development time, fecundity, survival, host plant.

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Abstract

Phenacoccus solenopsis Tinsley, (Hemiptera; Pseudococcidae) is a serious pest of many agronomic and horticultural crops in the world. Present research was conducted in Department of Entomology, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi Pakistan. The research was performed in two experiments. For experiment I, life history parameters (Female and male developmental time, survivorship, sex ratio, female longevity and fecundity, relative growth rate and intrinsic rate of population increase) were observed on five different horticultural plants hibiscus, okra, brinjal, chrysanthemum and cucumber. In experiment II, 3 preferred hosts for *P.solenopsis* were chosen, the hosts were shuffled and effect of antibiosis characteristics were observed for similar life history parameters. In experiment I, The results revealed male and female developmental time as shorter on hibiscus, okra and brinjal. The longevity and fecundity was associated with developmental rate. The females laid more number of sacs with shorter life span suggesting hibiscus, okra and brinjal to be suitable hosts compared with chrysanthemum and cucumber. The oviposition period can also be related to the higher number of egg sacs laid. Nymphs fed on hibiscus, okra and brinjal survived more, while on cucumber and chrysanthemum showed high mortality. Low survival could be credited to the unsuitability of hosts. Higher relative growth rates, reproductive and intrinsic rates on hibiscus and okra reinforces that these plants are more favorable hosts. It reflects the potential of host plant to add to *P. solenopsis* population. While, in experiment II, the findings indicated that the shuffling of hosts effect negatively to the developmental time, longevity and fecundity. The *P. solenopsis* showed best growth rate when reared on same hosts but it decreases when replaced with alternative hosts. The survival rate was decreased after shuffling the hosts and the same trend was observed for the net reproductive and intrinsic rates of population increase.

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Introduction

Mealybugs are considered as important insect pests attacking ornamental and other agricultural crops. The presence of *P. solenopsis* has been confirmed from 22 countries of various bio-geographical zones (Hodgston *et al.* 2008). However, its comparative biological behavior on different host plants has been little studied. Akintala and Ande (2008) found first record of *P. solenopsis* in 2008 on hibiscus rosa sineses in Nigeria. Its sudden outbreak on cotton and other crops in many countries poses serious concerns (Wang *et al.* 2010). Economically important families such as fabaceae, cucurbitaceae, solanaceae and Malvaceae are recorded as its major hosts (Culik and Gullan, 2005; Wang *et al.,* 2009;2010; Zhu *et al.* 2011).

The surveys and biological studies conducted in Pakistan supports the evidence of *P. solenopsis* presence and menace on 154 alternative host plants including cotton (Abbas *et al.*, 2005; Zaka *et al.,* 2006; Arif *et al.*, 2009; Abbas *et al.,* 2010; Aheer *et al.* 2009). A new invasive species of genus *Phenacocuus cockerel* (Hemiptera; Pseudococcidae) attacking cotton in Pakistan is found similar to *P.solenopsis* (Abbas *et al.* 2009). Arif *et al.* (2009) conducted a field survey and recorded *P. solenopsis* from 154 plant species of 53 families in Pakistan. Among these 20 were field and horticultural crops, 64 weeds and 25 were bushes and trees. China rose followed by okra was observed as most favorite hosts by *P. solenopsis*. It was also observed on twenty two host plants from December 2006 to November 2007 in surrounding areas of faislabad city. Its biology showed three nymphal stages in females and two in case of males. In females, pupal stage was absent. Bisexual reproduction with ovoviviparity is found. Total life span for adult males was found to be 2 to 3 days and 45- 85 days for females.

Considering its invasiveness on wide range of host plants in Pakistan and maximum prevalence on china rose, okra and other horticultural crops the present study was designed to find out the effect of shuffling of hosts on biology and life history of *P. solenopsis*. The biological parameters studied for relative effect of antibiosis on three different host plants are female and male development time, Female longevity and fecundity, survivorship, male to female ratio, relative growth rate and intrinsic rate of population increase.

Materials and method

The research was conducted in Department of Entomology, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi.

Hosts plants

The proposed research was conducted on five different horticulture plants. Five selected plants were Hibiscus (*Hibiscus rosacchinesis*), Okra (*Abelmoschus esculentus*), brinjal (*Solenum melongena*), cucumber (*cucumis sativus* L.) and chrysynthemum (*Chrysynthemum morifolium*). The plants were grown in pots and were used after 4-5 weeks.

Rearing of phenacoccus solenopsis

Adult females collected from the field were brought to laboratory. They were reared on their respective host plants for at least one generation. Two to three plants were used for rearing purpose.

Experiment 1

Biology of *Phenacoccus solenopsis* on five selected host plants, the adult females of respective hosts were placed in separate marked plastic petri-dishes. The petridishes lined with moist filter paper were provided with leaf disc of respective host plant over it at standard conditions of 25±2˚C, and 60±10% RH and L:D (14: 12). Adult females were checked daily for egg sacs.

Life history parameters

Leaf discs of five to six weeks plants were cut and placed individually in petri dishes. On each leaf disc one mature female was released. The feed was changed regularly at every alternate day. Life history parameters from hatching to maturity were estimated. Ovisacs were collected from host plants and were further studied for eggs hatching period and

hatching percentage, duration of nymphs and number of instars and weight of third instar nymph for relative growth rate (RGR), Difference in male to female life span and oviposition periods, number of ovisacs laid by single female or a pair, survival and hatching percentage of eggs/nymph laid, male to female ratio and intrinsic rates.

In experiment II

Three of these five hosts with moderate to high performance were taken for further analysis. Mealybugs reared on these host plants were reared for at least one more generation and then reshuffled to observe the relative effect of antibiosis characteristics. Similar parameters used in experiment I were followed. Thermometers and hygrometers were used to record the daily temperature and humidity range.

Statisical analysis

Data collected was analysed statistically and means were compared using least significance difference test and Duncun's multiple range test (DMR) at 0.05% probability level.

Results

Female and male developmental time

Our results showed that different host plants had a significant ($F_{(4, 24)} = 7.18$, $P < 0.0001$) influence on female developmental time. The incubation period significantly (>0.05) increased when nymphs fed on chrysanthemum (2.54 ± 0.25 days) and decreased on hibiscus (1.82 ± 0.24 days) (Table 1). The developmental time was longest on brinjal (33.82±1.40 days) followed by okra (31.77 ± 0.46 d) and hibiscus (31.69 ± 0.54 d) and shortest on chrysanthemum (19.94± 1.61 d) (Table 1). Of the four, three instars the first, second and third instar development took significantly longer on Chrysanthemum. In contrast fourth instar development took significantly shorter time on chrysanthemum (8.5 ± 4.2 days) than on the four hosts. There was no significant difference found for 4th instar female developmental time on all hosts except on chrysanthemum (Table 1).

Table 1A. Developmental time (Mean ± SE) for *P. solenopsis* on host plants at LSD 0.05 for experiment I.

	Developmental period in days (Mean ± SE)								
				For female			For male		
Hosts	Incubation period	1st instar	2nd instar	3rd instar	4th instar	Total life span (F)	pupa	Adult	Total life span (M)
Hibiscus	1.82 c ± 0.24	2.84 c ± 0.15	3.01 b ± 0.20	3.51 bc ± 0.18	20.20 a ± 0.40	31.69ab ± 0.54	5.60 a (± 0.09)	1.34 b (± 0.27)	15.12 a (± 0.40)
Okra	2.16 bc ± 0.29	3.32 bc ± 0.09	3.00 b ± 0.18	3.80 ab ± 0.09	19.50 a ± 0.38	31.77 ab ± 0.46	5.17 a (± 0.27)	1.75 ab (± 0.18)	15.41 a (± 0.31)
Brinjal	2.42 bc ± 0.35	4.05 ± 0.79 ab	3.72 ± 0.47 ab	3.24 c ± 0.11	21.00 a ± 0.54	33.82 a ± 1.40	4.90 a (± 0.27)	2.06 a (± 0.10)	16.89 a (± 1.38)
Chrysanthe-mum	3.38 a ± 0.39	4.38 a ± 0.18	4.15 a ± 0.21	4.02 a ± 0.15	8.5 b ± 4.2	19.94 c ± 1.61	2.40 b (± 1.40)	0.34 c (± 0.21)	5.52 b (± 3.38)
Cucumber	2.54 b ± 0.25	4.76 a ± 0.17	3.9 a ± 0.18	3.34 c ± 0.11	15.90 a 0.43	± 30.68 b ± 0.84	4.76 a (± 0.17)	1.54 ab (± 0.29)	18.15 a (± 0.71)
LSD Value	7.73	1.05	8.03	0.44	5.80	2.85	2.085	0.602	50.42

Similarly, Host plants had a significant impact on the male development time from egg to adult ($F_{(4, 24)} = 22.5$, $P < 0.0001$). The mean developmental time from egg to adult on chrysanthemum was 5.52 ± 3.38 days, which was significantly shorter than other four hosts. Total life span of male was observed longest on cucumber (18.15±0.71 days) (Table 1).

Female fecundity, survival and sex ratio

Difference in hosts affected female fecundity significantly ($F_{(4, 24)} = 8.31$, $P < 0.0008$). It was observed highest for females hosted by okra (2.74 ±

0.27 sacs/female) followed by brinjal (2.55 ± 0.28 sacs/female) and lowest for chrysanthemum (0.60 ± 0.40sacs/female) (Table 2). However, host plant did not significantly affected percentage egg hatchability ($F_{(4, 24)} = 0.24$, $P < 0.914$) or pupal survival ($F_{(4, 24)} = 21.06$, $P < 0.000$) except for chrysanthemum (Table 2). Survival of nymphs from first instar to fourth instar differed significantly ($F_{(4, 24)} = 8.31$, $P < 0.0008$) among host plants being highest in okra followed by hibiscus and brinjal and lowest in chrysanthemum (Fig. 1).

Table 2. Female fecundity and longevity (Mean ± SE) for *P. solenopsis* on host plants at LSD 0.05 for experiment I.

Hosts	Total females	Mature females	Average life	No. of sacs per female	Eggs per sac	%age hatchability	%age survivorship
Hibiscus	36.00 a ± 3.20	6.8 bc± 0.37	23.40 a ± 0.24	1.88ab± 0.16	74.20a ± 4.42	89.20 ± 0.86	10.2
Okra	38.60 a ± 2.67	19.80 a± 2.95	23.20 a ± 0.37	2.74 a± 0.27	77.20 a ± 5.2	89.60 ± 0.92	28.44
Brinjal	24.80 b ± 1.9	10.60 b± 2.01	25.40 a ± 0.50	2.55 ab± 0.28	72.00a ± 7.77	87.00 ± 3.03	16.7
Chrysanthemum	4.20 d± 0.96	1.20 d± 0.58	6.80 c ± 2.08	0.60 c± 0.40	75.80a ± 3.26	51.20 ± 3.30	3.09
Cucumber	11.60 c ± 1.77	3.40 cd ± 0.87	17.60 b ± 0.50	1.72 b± 0.24	78.20a ± 3.54	64.80 ± 7.28	6.53
LSD Value	6.453	4.781	3.93	0.88	15.18		

Host plants significantly affected the sex ratio and percentage female progeny ($F_{(4, 24)} = 40.82$, $P < 0.000$). The highest percentage of female progeny was recorded from okra (38.60 ± 2.67) followed by hibiscus (36.00 ± 3.20) and lowest from *P.solenopsis* reared on chrysanthemum (4.20 ± 0.96) (Table 3). Total number of males emerged per ovisac were highest for the okra and hibiscus with no significant difference found among means ($F_{(4, 24)} = 27.54$, $P < 0.000$) (Table 3). Except for chrysanthemum (1:7) and cucumber (1:4.83) sex ratio did not differ significantly from each other as shown in Fig. 2.

Table 3. Male to female ratio and Population growth parameters (Mean ± SE) for *P. solenopsis* on host plants at LSD 0.05 for experiment I.

Hosts	Total no. of male	Female	M:F	Net reproductive rate	Intrinsic rate	Relative growth rate
Hibiscus	14.4 a ±1.63	38.0 a ± 4.50	1:2.63	31.96	1	0.708
Okra	15.00 a± 1.51	38.6 a ± 2.67	1:2.57	43.65	1.37	0.450
Brinjal	7.6 b ± 1.50	24.8 b ± 1.98	1:3.26	23.5	0.69	0.393
Chrysanthemum	0.6 c ± 0.40	4.2 d ± 0.96	1:7	2.17	0.108	0.207
Cucumber	2.4 c ± 0.50	11.6 c± 1.77	1:4.83	21.46	0.69	0.310
LSD Value	3.792	7.247				

Relative growth rate and intrinsic rate

P. solenopsis which fed on hibiscus and okra were heavier (0.708, 0.45mg) while observed lighter on chrysanthemum (Table 3). The net reproductive rate were witnessed as lowest for the population reared on chrysanthemum which in turns showed same trend for intrinsic rate as 2.17 and 0.108 respectively (Table 3). The population rate was maximum on okra and hibiscus.

Oviposition period

The fourth instar stage was observed for different stages and host plant effect significantly the pre-ovipositon period ($F_{(4, 24)} = 18.61$, $P < 0.000$), ovipositon period ($F_{(4, 24)} = 67.78$, $P < 0.000$), and post ovipostion period ($F_{(4, 24)} = 3.87$, $P < 0.0219$). Total oviposition period was observed highest on brinjal (21.0 ± 0.54 d) followed by okra (20.2 ± 0.40 d) and lowest on chrysanthemum (06.0± 2.73 d) with

significant difference among means ($F_{(4, 24)} = 21.95$, $P < 0.000$) as mentioned in table 4.

Experiment ii

Effect of shuffling of hosts on life history parameters of p.solenopsis

Developmental time

Shuffling of hosts did not showed any significant ($F_{(8, 44)} = 2.56$, $P < 0.0277$) difference among the means of female and male developmental time. However, female developmental time was highest when reared on brinjal (H3, shifted from hibscus) 34.39 ± 0.79 days followed by 34.36±0.99 days on H6 (brinjal shifted from okra) and was lowest for hibiscus (H5,from okra) 29.13 ± 2.27 days (Table 5). The trend from highest to lowest was H3>H6>H8>H7>H2>H9>H4>H1>H5.

Table 4. Oviposition period (Mean ± SE) for *Phenacoccus solenopsis* on host plants at LSD 0.05 for experiment I.

Hosts	Means ±SE in days			
	Pre-Oviposition period	Ovi-position period	Post ovi-position period	Total period
Hibiscus	13.3 ± 0.48 a	5.5 ± 0.27 b	1.5 ± 0.57 ab	20.2 ± 0.4 a
Okra	11± 0.63 ab	7.3 ± 0.37 a	1.2 ± 0.25 abc	19.6 ± 0.36 ab
Brinjal	10.4 ± 0.92 b	8.1 ± 0.96 a	2.3 ± 0.51 a	21 ± 0.54 a
Chrysanthemum	3.6 ±1.08 c	0.3 ± 0.2 c	0.1 ± 0.1 c	6 ± 2.73 c
Cucumber	11 ± 0.7 ab	3.9 ± 0.67 b	1 ± 0.22 bc	15.9 ± 0.43 b

Similarly, shuffling of hosts did not affected male development time significantly ($F_{(8, 44)} = 1.84$, $P < 0.1055$). however, it was found highest for brinjal (H7) 16.89 ± 1.38 days and was lowest for brinjal (H3) 14.41 ± 0.33 (Table 5) with hibiscus as primary host.

Table 5. Developmental time (Mean ± SE) for *P. solenopsis* on host plants at LSD 0.05 for experiment II.

		Female developmental time in days					Male developmental time in days			
No of hosts	Hosts	Incubation period	1st instar	2nd instar	3rd instar	4th instar	Total life span (F)	pupa	Adult	Total life span (M)
H1	Hibiscus to hibiscus	1.82 c ± 0.24	2.84 c ± 0.15	3.01b ±0.20	3.51bc ± 0.18	20.20a ± 0.40	31.69ab ± 0.54	5.60a ±0.09	1.34a ±0.27	15.12b ± 0.45
H2	Hibiscus to okra	2.30 a ± 0.28	3.40 ab ± 0.32	3.38a ±0.19	3.26 a ± 0.31	20.60a ± 0.53	32.89 a ± 0.67	4.56ab ±0.22	1.60a ±0.27	15.12b ± 0.44
H3	Hibiscus to brinjal	2.48 a ± 0.33	2.97 b ± 0.09	3.13a ±0.18	3.20 a ± 0.16	22.7 a ± 0.78	34.39 a ± 0.79	4.16 b ± 0.25	1.50a ±0.13	14.41b ± 0.33
H4	Okra to okra	2.16 bc ± 0.29	3.32 bc ± 0.09	3.00b ±0.18	3.80 a ± 0.09	19.50a ± 0.38	31.77ab ± 0.46	5.17ab ± 0.27	1.75a ±0.18	15.41b ± 0.31
H5	Okra to hibiscus	2.25 a ± 0.42	3.56 ab ± 0.20	3.02a 0.29	± 3.34 a ± 0.20	18.6 a ± 1.39	29.13 b ± 2.27	5.48 a ± 0.19	1.04a ±0.24	15.35b ± 0.34
H6	Okra to brinjal	2.22 a ± 0.35	3.24 ab ± 0.14	3.17 a ± 0.20	3.13 a ± 0.20	22.6 a ± 0.69	34.36 a ± 0.99	4.64ab ± 0.22	1.52a ±0.29	14.92b ± 0.75
H7	Brinjal to brinjal	2.42 bc ± 0.35	4.05 ab ± 1.77	3.72ab ± 0.47	3.24 c ± 0.11	21.00a ± 0.54	33.82 a ± 1.40	4.94ab ± 0.27	2.06a ±0.10	16.89b ± 1.38
H8	Brinjal to okra	2.20 a ± 0.31	2.88 b ± 0.25	3.42 a ± 0.22	3.30 a ± 0.26	22.0 a ± 0.70	34.00 a ± 0.61	4.80ab ± 0.18	1.48a ±0.30	33.81a ± 0.78
H9	Brinjal to hibiscus	2.70 a ± 0.18	2.99 b ± 0.30	3.96 a ± 0.23	3.71 a ± 0.38	19.3 a ± 0.68	32.48 a ± 1.24	5.58 a ± 0.22	1.10a ±0.16	32.40a ± 1.24
	LSD Value	0.414	0.974	0.787	0.682	2.108	3.068	0.656	0.661	2.249

Female fecundity, survival percentage and sex ratio

The shuffling of host among different host plants significantly affected the female fecundity ($F_{(8, 44)} = 3.51$, $P < 0.0051$). females laid highest number of sacs on okra (H8) 3.52 ± 0.31 sacs/female (Table 6) with brinjal as primary host. similarly, no significant difference was found among means of eggs/sac ($F_{(8, 44)} = 1.25$, $P < 0.3009$).

There is no significant difference found for host

shuffling on egg hatch, 1st and 2nd instar survival percentages, However, means differ significantly for 4th instar (mature females) ($F_{(8, 44)} = 6.73$, $P < 0.000$) as shown in Fig. 3. Highest survival was found on brinjal (H3) 20.20 ± 2.22 females (hibiscus as primary host) with 26.40 days average lifespan of female and lowest on hibiscus (H1 and H9) 6.8 ± 0.37 and 6.60 ± 0.50 females with hibiscus and brinjal as primary host respectively. The host hibiscus produced maximum number of females and males with significantly different means ($F_{(8, 44)} = 5.58$, $P < 0.0002$). However, sex ratio as shown in table 7 was highest for okra (H8) brinjal as primary host and lowest for brinjal (H7) with okra primary host.

Table 6. Female longevity and fecundity (Mean ± SE) for *Phenacoccus solenopsis* on host plants at LSD 0.05 for experiment II.

	Female life span (Mean ± SE)							
No of hosts	Hosts	Total females	Mature females	Average life	No. of sacs per female	Eggs per sac	%age hatchability	%age survival for female
H1	Hibiscus to hibiscus	36.00abc ± 3.20	6.8 c± 0.37	23.40abc ± 0.24	1.88 b± 0.16	72.40a ± 4.42	89.20 ± 0.86	75.6%
H2	Hibiscus to okra	37.20 ab ± 1.74	19.60 ab ± 2.44	23.20abc ± 0.48	2.36 ab ± 0.36	90.00 a ± 7.11	89.80 ± 1.06	71%
H3	Hibiscus to brinjal	37.20 ab ± 2.13	20.20 a± 2.22	26.40 a ± 0.50	2.94 ab ± 0.42	76.20 a ± 2.31	76.40 ± 2.82	76.5%
H4	Okra to okra	38.60 ab ± 2.67	19.80 a± 2.9	23.20abc ± 0.37	2.74 ab± 0.27	77.20 a ± 5.20	89.60 ± 0.92	77%
H5	Okra to hibiscus	44.20 a ± 3.30	13.00 abc ± 3.64	21.20 c ± 1.46	1.77 b ± 0.08	82.00a ± 3.64	86.40 ± 1.28	79%
H6	Okra to brinjal	31.40 bc ± 1.86	18.40 ab ± 2.24	26.00 ab ± 0.70	2.69 ab± 0.28	82.00 a ± 3.03	89.00 ± 1.51	61.7%
H7	Brinjal to brinjal	24.80 c ± 1.98	10.60 bc ± 2.01	25.40 ab ± 0.50	2.55 ab ± 0.28	72.0 a ± 7.77	87.00 ± 3.03	51.1%
H8	Brinjal to okra	29.64 bc ± 2.27	13.40abc ± 1.43	25.00abc ± 0.70	3.52 a± 0.31	85.00 a ± 4.84	77.20 ± 4.06	62%
H9	Brinjal to hibiscus	31.53 bc ± 2.37	6.60 c ± 0.50	22.20 bc ± 0.86	2.50 ab ± 0.25	84.40 a ± 3.26	84.20 ± 2.28	60.5%
	LSD Value	7.163	5.281	2.108	0.813	14.97		

Oviposition period

The results disclosed that shuffling of host plants on oviposition period has a significant influence ($F_{(8, 44)} = 4.03$, $P < 0.0021$) (Table 8). The trend from highest to lowest was observed as H3> H6> H8> H7> H2 >H1 >H4> H9 > H5.

Relative growth rate and intrinsic rate

The intrinsic rate of population increase was higher for hibiscus (H5) as 1.43 and lower for brinjal (H7) as 0.69 (Table 7). The values for relative growth rate showed 0.70 mg for hibiscus while on shuffling of host to okra (H4) and hibiscus (H5) the RGR was 0.45 and 0.32 (Table 7). For the host okra (H2) RGR was noted as 0.45 and on shuffling to brinjal (H6) and brinjal (H7) it showed as 0.49 and 0.39. On brinjal (H3) it was 0.50 and minimum on 0.31 hibiscus (H9) when shifted from brinjal and 0.40 on okra (H8).

Table 7. Male to Female ratio and population growth parameters (Mean ± SE) for *P. solenopsis* on host plants at LSD 0.05 for experiment I.

		Male to female ratio					
	Hosts	Total males	Total females	M:F	Net reproductive rate	Intrinsic rate	Relative growth rate (RGR)
H1	Hibiscus to hibiscus	14.4 ±1.63	38.0 ±4.50	1:2.64	31.96	1.00	0.70
H2	Hibiscus to okra	14.8 ± 0.73	37.20 ± 1.74	1:2.51	39.46	1.19	0.45
H3	Hibiscus to brinjal	12.4 ± 2.18	37.20 ± 2.13	1:3.00	46.24	1.34	0.50
H4	Okra to okra	15.0 ± 1.51	38.60 ± 2.67	1:2.57	43.65	1.37	0.45
H5	Okra to hibiscus	17.0 ± 1.70	44.20 ± 3.30	1:2.60	41.88	1.43	0.32
H6	Okra to brinjal	15.4 ± 2.5	31.40 v 1.86	1:1.90	31.56	0.91	0.49
H7	Brinjal to brinjal	7.6 ± 1.50	24.80 ± 1.98	1:3.26	23.50	0.69	0.39
H8	Brinjal to okra	9.20 ± 1.15	29.64 ± 2.27	1:3.30	30.81	0.90	0.40
H9	Brinjal to hibiscus	10.6 ± 1.02	31.53 ± 2.37	1:2.67	26.84	0.82	0.31
	LSD Value	4.848	7.163				

Discussion

Developmental time

The results of present studies revealed great variation in developmental time, longevity and fecundity, survivorship, sex ratio, ovipositional period, Relative growth rate and intrinsic rate for the selected five hosts. Results revealed that developmental time for the female was shorter on hibiscus , okra and brinjal and similar were the results for male developmental time. Arif *et al.* (2009) also observed the shorter female lifespan on china rose as compared to cotton with a non-significant difference. Shorter developmental time reduced generation time and hence cause increase in population (Singh and Parihar, 1998). On chrysanthemum all the nymphal stages took longer time for development while on cucumber the time taken was also more than other three hosts. Serran and Lapointe (2002) also found that the host plant species influence the difference in female developmental time when reared on five different hosts' species at a meridic diet. The ranking of hosts for developmental time of *P. solenopsis* in descending order is brinjal > okra> hibiscus> cucumber> chrysanthemum.

Table 8. Ovipositon period (Mean ± SE) for *P. solenopsis* on host plants at LSD 0.05 for experiment II.

		Means ±SE in days			
	Hosts	Pre-Oviposition period	Oviposition period	Post oviposition period	Total period
H1	Hibiscus to Hibiscus	13.3 ± 0.48 ab	5.5 ± 0.27 b	1.5 ± 0.57 a	20.2 ± 0.4 ab
H2	Hibiscus to Okra	11.8 ± 0.86 abc	6.8 ± 0.66 b	1.9 ± 0.33 a	20.6 ± 0.53 ab
H3	Hibiscus to Brinjal	8.6 ± 0.92 c	11.5 ± 1.22 a	2.55 ± 0.42 a	22.7 ± 0.78 a
H4	Okra to Okra	11± 0.63 abc	7.3 ± 0.37 b	1.2 ± 0.25 a	19.6 ± 0.36 ab
H5	Okra to Hibiscus	11.2 ± 1.39 abc	5.64 ± 0.21 b	1.76 ± 0.22 a	18.6 ± 0.39 b
H6	Okra to Brinjal	14.2 ± 0.51 a	6.5 ± 0.54 b	1.9 ± 0.67 a	22.6 ± 0.69 a
H7	Brinjal to Brinjal	10.4 ± 0.92 bc	8.1 ± 0.96 ab	2.3± 0.51 a	21 ± 0.54 ab
H8	Brinjal to Okra	9.5 ± 0.5 c	11.2 ± 1.09 a	1.3 ± 0.25 a	22 ± 1.58 ab
H9	Brinjal to Hibiscus	8.9 ± 0.33 c	8.8 ± 0.86 ab	1.5 ± 0.35 a	19.3 ± 0.68 ab

Female fecundity, survivorship and sex ratio

The average number of females emerged were maximum when reared on hibiscus, okra and brinjal with no significant difference and average life was also maximum. On chrysanthemum the females were not able to complete their lifecycle. So, survival affected the fertility and longevity on female life span. Persad and Azam (2002) also reported the average life span as 28 days on hibiscus. The longevity and fecundity was associated with developmental time. Sahito and Abro (2012) indicated it as 24.8 days in average on okra which were similar to above mentioned results. The host plants pattern for suitability of hosts for longevity of *P.solenopsis* stands asbrinjal>hibiscus>okra>cucumber>chrysanthemum .

Survivorship is an important parameter for the suitability of any host. The viability of eggs was maximum for hibiscus, okra and brinjal with no significant difference. Results were similar with findings of Amaraskere *et al.* (2008) showing maximum survival of *P. solenopsis* on hibiscus. This research also indicated hibiscus, okra and brinjal the most favorable and cucumber and chrysanthemum as unfavorable hosts for survival *of P. solenopsis*. The females laid more number of sacs with shorter lifespan suggesting hibiscus, okra and brinjal to be more nutritious when compared with chrysanthemum and cucumber. Sahito and Abro (2012) found fecundity and fertility of *P. solenopsis* higher on okra in summer when studied on different host plants. Abbas *et al.* (2010) also observed significant differences by different host plants on number of embryos per adult females. Cotton followed by *H. rosasinesis* and okra were the most favored hosts producing maximum number of offspring's.

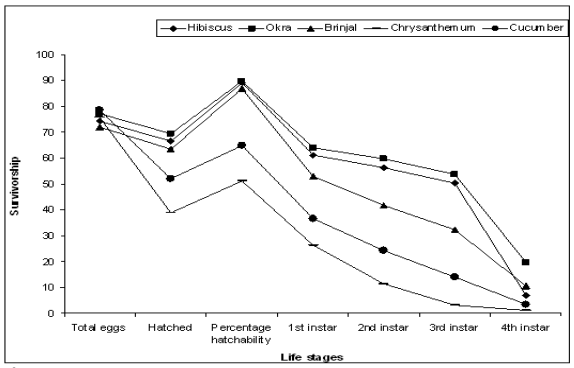

Fig. 1. Comparison for survivorship in life-stages of *P. solenopsis* on host plants of Experiment I.

An oviposition period can also be related to higher number of egg sacs laid. A marked difference was also found in survival of nymphs on different host plants (Fig 1). This has a significant effect on adult longevity and fecundity. Early morality could be the reason for survival fluctuations and is a key factor in establishment of adult population. Nymphs fed on hibiscus, okra and brinjal survived more, while on cucumber and chrysanthemum showed high mortality. Low survival could be credited to the unsuitability of hosts.

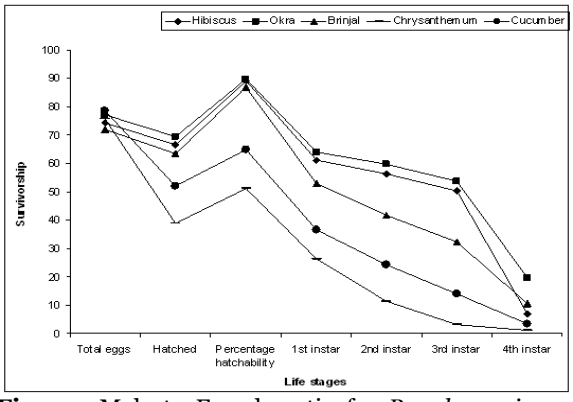

Fig. 2. Male to Female ratio for *P. solenopsis* on different host plants for experiment I.

Sex ratio

The difference in sex ratio was found maximum on chrysanthemum and minimum for okra (Fig. 3). The rate of survival for chrysanthemum and cucumber could be the reason for lesser males emerged. The maximum number of females on hibiscus and okra reinforces the suggestion for their favorability. The male's population was very low as compared to females irrespective of the host. Present findings are in agreement with the studies of Hanchinal *et al.* (2010) reporting the marked difference in male to female ratio without any difference for the host. Abbas *et al.* (2012) reported the ratio for hibiscus as 1: 1.29 as average.

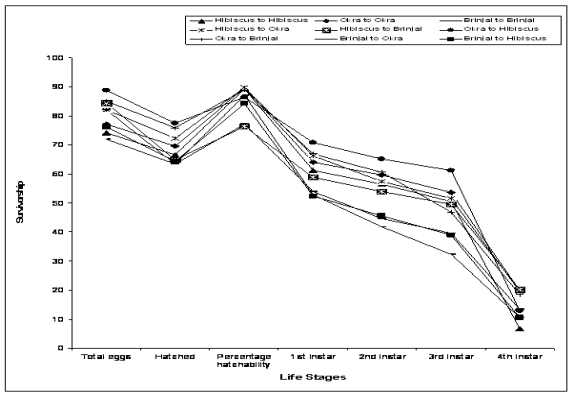

Fig. 3. Comparison for survivorship (mean ± SE) of different stages of *P. solenopsis* between hosts selected for experiment II.

Ovipositional period

Shorter pre-ovipositional period add increased reproductive period and increased reproductive capacity of insects on host reflects hosts suitability (Van-Lenteren and Noldus, 1996). The results indicated okra and brinjal as the best hosts for oviposition. Hence, the population rate for *P. solenopsis* could be maximum for these hosts. However, the population increase and susceptibility of host also depends upon the survival and viability of eggs. The females with longer ovipositional period died later while with shorter ovipositional period died soon after laying the egg sacs. On average hibiscus, okra and brinjal were best suited hosts and chrysanthemum was less suitable host for oviposition.

Relative growth and intrinsic rate

The higher reproductive rate and intrinsic rates for the *P. solenopsis* reared on hibiscus and okra again reinforces that these plants are most favorable hosts. It reflects the potential of host plants to add to *P. solenopsis* population.

Discussion for experiment ii

Plants heterogeneity can significantly influence the population dynamics for herbivore insects (Hunter, 1997; Hunter *et al.* 2000). Difference in plant quality can cause difference in birth and death rates for

insects and are influenced by plant induced changes in parameters such as growth, survival and fecundity (Lill *et al*., 2002, Denno *et al*., 1995, Abrahamson and Weis, 1997). Dixon (1987) reported that temperature and food quality are important factors which determine development rate.

The results of present research suggested that when the host was same for next generation cycle it takes shorter time for development while on shuffling it takes more time. It indicates shuffling of host effects negatively to insect lifecycle. The nutritional quality and phago-stimulant factors could be the reason for the effect of host plants on developmental time (Talekar and Shelton, 1993). The results also revealed that when brinjal hosted *P. solenopsis*, it took maximum time for adjustment irrespective of the previous host (Okra and hibiscus). *P. solenopsis* took comparatively lesser time when hosted by okra with a non significant difference among means (irrespective of the first hosts hibiscus and brinjal). However, Hibiscus was observed as most favorable host for *P. solenopsis* to complete its lifespan in a minimum time. The insects with shorter generation time have higher rates of population increase and develop resistance to insecticides more quickly as compared to insects with longer generation time (Li, 1995).

There was no significant difference observed among the hosts when observed for female longevity. However, it was maximum on brinjal irrespective of the 1st host and female life span was reduced on okra and hibiscus. The pattern was observed as brinjal>okra>hibiscus, Suggesting hibiscus as least suitable for longevity of female.

Fecundity and survival could be affected directly or indirectly by variations in host plant quality. Change in development time, body size and reproductive strategies are indirect effects of plant quality on fecundity and survival (Awmack and Leather, 2002). The shuffling of host affected survival %age negatively of female (4th instar) showing reduction in survival rate. On host brinjal survival percentage was observed minimum for egg, 1st, 2nd and 3rd instar (83.2, 79, 77.5 and 51.1%respectively) as compared to other hosts where mortality was observed higher only in 4th instar stage (mature females).

Nutritive value (i.e. increased nitrogen contents) likely leads to increased fecundity and increased defensive chemistry reduces survival rates (Awmack and Leather, 2002). Increased feeding or assimilation rate due to increased titer of digestive enzyme could be a reason for increased growth rate, shorter developmental time and higher fecundity (Woods, 1999).

Poor quality plant may exhibit modifications of Oviposition behavior in herbivore. There might be reduction in number of eggs laid on each plant, adjust the size or eggs nutritional contents or resorb the egg (Awmack and Leather, 2002) which in response influence the offspring fitness and hence influence both survival and fecundity. Fitness costs associated with resistance has been defined in life-history traits of several insects when reared on untreated host plants. Depending on nutritional quality of host plants insect adopt different feeding strategies. (Wood, 1999).

An assessment of effect of different host plants on Oviposition of *P. solenopsis* reveal that when host was changed from hibiscus to brinjal it took minimum time to adjust and oviposit with maximum ovipositional time showing brinjal as best host. The reason could be high nutritional value supplemented by brinjal as compared to hibiscus. Female survived for maximum period of time suggesting greater response to brinjal. The favorability for ovipositional period suggests the pattern of hosts as brinjal >okra> hibiscus. Shuffling of hosts in all replications showed positive response for ovipositional period. Berdegu'e *et al.* (1998) showed that herbivores show strong host plant Oviposition preference that can complete development on more than one host as compared to those which complete development on one host plant. Thompson (1988) suggests that those hosts are preferred by female for Oviposition which shows higher survival percentage for eggs and older larvae

can show mobility to nutritionally favorable host plants.

The adaption of insects to certain plants could also be determined by sex ratio on emerging of adults. The maximum number of females emerged when reared on hibiscus (H5) however change of host also affected the female emergence significantly and minimum on brinjal (H7) for same host. The overall trend seems minimum for brinjal. The results suggest hibiscus could be the favorable host for population growth. But survival rate for mature females could be the main hindrance. However, hibiscus also showed lesser emergence of females when shifted from brinjal.

Favorability or non-favorability of alternative host could be a reason in some cases for variation in results. Biochemical tests for the selected host's plants could reveal other possibilities of host favorability in this regard.

Birch (1948) stated r_m as best single statistic for evaluating the influence of ecological factors on population growth. The results derived indicated that *P. solenopsis* has highest intrinsic rate on hibiscus and okra with same hosts.

On shuffling of hosts development time increases as *P. solenopsis* took more time for adjustment but the female fecundity also increases showing that when *P. solenopsis* changes the host it spreads more fastly but due to low survival rates infestation could be controlled.

Insects could opt different feeding techniques depending upon the nutritive quality of host plants (Wood 1999). If the plants are Less suitable, fitness costs could slows down or stop the insect adaptations if the fitness costs are higher. *P.solenopsis* when reared on hibiscus it showed heavier weight. It reduces its weight on hibiscus when shifted from a different host. This also depends on the suitability of alternative host to which it was shifted. On okra it did not showed any difference with shuffling of hosts. However, results were not similar in case of brinjal. When the host was shifted the insect gained the weight.

In these findings each single value is the average of 3-5 replications in total so the results for some of the parameters may show difference of non significant values.

The study adds up to the body of knowledge that variations in host plants can affect the population ecology of *P. solenopsis*. Moreover, the data serves to emphasize that cultural management strategies could be designed keeping in view the favorability of hosts for a particular insect. Understanding the differences in host plants and their effect on polyphagous herbivore insects could have practical implication for insect pest management. The factors which determine the suitability of hosts are developmental time, survival and reproductive rates (Awmack and Leather, 2002). Keeping in mind these factors for a specific host plants and insect the management strategies could be planned. Further biochemical and molecular studies of *P. solenopsis* may reveal the reasons for the effect of hosts on mealybug physiology. Hariston *et al.* (1960) argued in his "world is green" hypothesis that earth is covered with plants hence there herbivores could not be food limited.

Conlusion

Based on these studies it can be concluded that brinjal, hibiscus and okra are favorable hosts than cucumber and chrysanthemum and could be used as trap crops. The shuffling of hosts effect the insect life history parameters negatively. However, it also depends on the favorability of alternative host. The potential incompatibility of alternative host plants could act as biological control agents of these polyphagous insect pests.

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Abbas G, Arif MJ, Saeed S, Karar H. 2009. A new invasive species of genus *Phenacoccus cockerell* attacking cotton in Pakistan. International Journal of Agriculture and Biology **11(1),** 54-58.

Abbas G, Arif MJ, Saeed S. 2005. Systematic status of a mealybug of genus *Phenacoccus* Cockerell (Pseudococcidae) a serious pest of cotton *Gossypium hirsutum* L. in Pakistan. Pakistan Entomologist **27,** 83-84.

Abbas G, Arif MJ, Ashfaq M, Aslam M, Saeed S, 2010. Host plants, distribution and over wintering of cotton mealybug (*Phenacoccus solenopsis*, hemiptera: Pseudococcidae). International journal of Agriculture Biology **12,** 421-425.

Abbas G, Arif MJ, Saleem MS, Shah F. 2012, Studies on biology of *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudcoccidae) in Punjab, Pakistan- A Pest of cotton and other crops. Pakistan Entomologist **34(2),** 131-136.

Abrahamson WG, Weis AE. 1997. Evolutionary Ecology Across Three Trophic Levels. Princeton University Press, Princeton, New Jersey. 456 P.

Aheer GM, Shah Z, Saeed M. 2009. Seasonal history and biology of cotton mealybug, *Phenacoccus solenopsis* tinsley. Journal of Agricultural Research, **47(4),** 423-431.

Akintola AJ, Ande AT. 2008. First record of *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on Hibiscus rosa-sinensis in Nigeria. Agricultural Journal **3,** 1-3. http://dx.doi.org/10.3923/ijar.2008.1.26

Amarasekare KG, Mannion CM, Osborne LS, Epsky ND. 2008. Life history of *Paracoccus marginatus* (Hemiptera: Pseudococcidae) on four host plant species under laboratory conditions. Environmental Entomology **37,** 630-635. http://dx.doi.org/10.1603/0046225X(2008)37[630:LHOPMH]2.0.CO;2

Arif MI, Rafiq M, Ghaffar A. 2009. Host plants of cotton mealy bug (*Phenacoccus solenopsis*): A new menace to cotton agroecosystem of the Punjab. International Journal Agricultural Biology **11,** 163-167.

Awmack CS, Leather SR. 2002**.** Host plant quality and fecundity in herbivorous insects. Annual Review ofEntomology **47,** 817-844. http://dx.doi.org/10.1146/annurev.ento.47.091201.145300

Berdegue's M, Reitz SR, Trumble JT. (1998). Host plant selection and development in *Spodoptera exigua*: do mother and offspring know the best? Entomologia Experimentalis et Applicata **89,** 57-64. http://dx.doi.org/10.1046/j.15707458.1998.00381.x

Birch LC. 1948. The intrinsic rate of natural increase of an insect population. Journal of Animal Ecology, **17,** 15-26.

Culik MP, Gullan PJ. 2005. A new pest of tomato and other records of mealybugs (Hemiptera: Pseudococcidae) from Espirito Santo, Brazil. (Summary In Portuguese). Zootaxa **964,** 1-8.

Denno RF, McClure MS, Ott JR. 1995. Interspecific interactions in phytophagous insects: competition reexamined and resurrected. Annual Review of Entomology **40,** 297-331. http://dx.doi.org/10.1146/annurev.en.40.010195.001501

Dixon AFG. 1987. Parthenogonetic reproduction and the rate of increase in aphids. In: Minks AK, Harrewijn P, ed. Aphids, their biology, natural enemies and control. Vol **2A.** Elsevier, Netherlands, 269-287.

Hairston NG, Smith FE, Slobodkin LB. 1960.

Community structure, population control and competition. American Naturalist **94,** 421-424.

Hanchinal SG, Patil BV, Bheemanna M, Hosamani AC. 2010. Population dynamics of mealybug, *Phenacoccus solenopsis* Tinsley and its natural enemies on Bt. Cotton. Karnataka Journal of Agricultural Sciences **23,** 137-139.

Hodgson CJ, Abbas G, Arif MJ, Saeed S, Karar H. 2008. *Phenacoccus solenopsis* Tinsley (Sternorrhyncha: Coccoidea: Pseudococcidae), a new invasive species attacking cotton in Pakistan and India, with a discussion on seasonal morphological variation. Zootaxa **1913,** 1-33.

Lill JT, Marquis RJ, Ricklefs RE. 2002. Host plants influence parasitism of forest caterpillars. Nature **417,** 170-173. http://dx.doi.org/10.1038/417170a

Persad A, Azam K. 2002. Comparison of life table parameters for *Maconellicoccus hirsutus, Anagyrus kamali, cryptolaemus montrouzeiri* and *Scymnus coccivora*. Bio-control **47,** 137-49. http://dx.doi.org/10.1023/A:1014581616965

Sahito HA, Abro GH. 2012. Biology of mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on okra and china rose under laboratory conditions. Pakistan Entomologist **34,** 121-124.

Serrano MS, Lapointe SL. 2002. Evaluation of host plants and meridic diet for rearing of *Maconellicoccus hirsutus* (Hemiptera: Pseudococcidae) and its parasitoid *Anagyrus kamali* (Hymenoptera:Encyrtidae). Florida Entomologist **85,** 417-425. http://dx.doi.org/10.1653/0015404(2002)085[0417:EOHPAA]2.0.CO;2

Singh OP, Parihar SBB. 1998. Effect of different hosts on the development of *Heliothis armigera* Hub. Bulletin of Entomological Research **29,** 2168-2172.

Talekar NS, Shelton AM. 1993. Biology, ecology and management of the diamond backmoth. Annual Review of Entomology **38,** 275-301. http://dx.doi.org/10.1146/annurev.en.38.010193.001423

Li T. 1995. Shortest generation time, University of florida Book of insect records. University of florida, p. 13-14.

Thompson JN. (1988). Evolutionary ecology of the relationship between Oviposition preference and performance of offsoring in phytophagous insects. Entomologia Experimentalis et Applicata **47,** 3-14. http://dx.doi.org/10.1111/j.15707458.1988.tb02275.x

Van-Lenteren JC, Noldus PJJ. 1990. Whitefly-plant relationships; behavioral and ecological aspects. In: Gerling D (ed.) White-flies: bionomics pest status and management. Intercept Ltd, Andover, Hants, 47-90 P.

Wang Y, Watson GW, Zhang R. 2010. The potential distribution of an invasive mealybug *Phenacoccus solenopsis* and its threat to cotton in Asia. Agricultural and Forest Entomology **12,** 403-416. http://dx.doi.org/10.1111/j.1461-9563.2010.00490.x

Wang YP, Wu SA, Zhang RZ. 2009. Pest risk analysis of a new invasive pest, *Phenacoccus solenopsis* to China. (In Chinese; summary in English). Chinese Bulletin of Entomology **46,** 101-106.

Woods HA. (1999). Patterns and mechanisms of growth of fifth-instar *Manduca sexta* caterpillars following exposure to low or high protein food during early instars. Physiological and Biochemical Zoology **72,** 445-454.

Zaka SM, Saeed S, Bukhari SA, Baksh E. 2006. Mealybug *Phenacoccus solenopsis* (Pseudococcidae:

Homoptera) a novel pest of cotton in Pakistan. 34th SAARC Science Conference. University of Veterinary and Animal Sciences, Lahore, Pakistan, 32 p.

Zhu YY, Fang H, Yao-Bin. 2011. Bionomics of mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on cotton. Acta Entomologica Sinica **54,** 246-252.