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Life history and predatory potential of eleven spotted beetle (*Coccinella undecimpunctata* Linnaeus) on cotton mealybug (*Phenacoccus solenopsis* Tinsley)

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Cotton mealybug (*Phenacoccus solenopsis* Tinsley) proved a menace to subcontinent south East Asia economy since 2005. After introduction of this notorious Caribbean pest it was necessary to identify biological control agents in country which exist in prevailing environment and successfully suppress the pest. In this study eleven spotted ladybird beetle (*Coccinella undecimpunctata* Linnaeus) proved the best predator whose population structure, biological parameters and predatory potential were determined using no choice feeding trials. It was concluded that 1st instar larvae of eleven spotted beetle 1st instar is an effective bio-control agent which consumed on an average 91.99 1st instar cotton mealybug wheras 2nd, 3rd instar and adult consumed 45.00, 44.00, 5.44 cotton mealybug respectively. *C. undecimpunctata* L. 2nd instar larvae devoured 97 1st instar, 35.66 2nd instar and 45.00, 3rd instar cotton mealybug and 7.11 adult stage cotton mealybug respectively, whereas 3rd instar *C. undecimpunctata* took in 121.66 1st instar, 51.66 2nd instar and 54.33 3rd instar cotton mealybug and 8.21 adult stage cotton mealybug respectively. The larvae of 4th instar *C. undecimpunctata* preyed 93.00 1st instar, 35.00 2nd instar and 33 3rd instar cotton mealybug respectively and 7.33 adult stage cotton mealybug respectively. Adult female of this beetle consumed higher number of mealybugs than adult male during its whole life. Regarding biological parameters it was proved from the results that *C. undecimpunctata* is an effective bio control agent of cotton mealybug which can be used in integrated pest management program successfully.

Key words: *Coccinella undecimpunctata* L, cotton mealybug instars, predatory efficiency, life cycle.

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INTRODUCTION

Cotton is known as “Silver Fibre” crop of Pakistan. It is attacked by a number of insect pests, which not only reduce the cotton yield but also deteriorate the lint quality. Among these 150 delimiting pests of cotton crop, cotton mealybug proved a menace to Pakistan economy since 2005 (Centre for AgroInformatics Research, 2007). In 2005, *Phenacoccus solenopsis* Tinsely (Sternorrhyncha: Coccoidea: Pseudococcidae) was found causing serious

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damage to cotton crop in Punjab and Sindh Provinces, Pakistan (Abbas et al., 2010). Pakistan is the third largest exporter of cotton in world. The outbreak of this major pest is of economic importance. The infestation was recorded from 11 out of the 18 cotton-growing areas covering 45,000 sq.km. This outbreak of mealybug was observed on both Bt cotton and non-Bt cotton and the growers response has been to use large amounts of pesticides (US$ 121.4 million worth in the Punjab in two months in 2007. Such amount of pesticides increasing management costs, development of insecticide resistance, rising environmental consciousness. Biological control with *Coccinellids* has contributed greatly and suppressed the pests below economic damage level (Hoy and Nguyen, 2000). Efforts had been emphasized on evaluation of predators of such noxious pest, biology, control potential and other important parameters of predators and parasitoids (Mahmood et al., 2011). Twenty three species of predators have been reported from cotton field including *Coccinellids*, *Chrysopids*, *Lagaeids* and *formicids* (Cheema et al., 1980) in Pakistan, but *Coccinella undecimpunctata* L., has novel importance in cotton pests management (Nielsen, 1997; Marshall, 2005). These beetles are of extremely diverse habits found from ornamental (Wheeler et al*.,* 1981), orchards to cash and fiber (cotton) crops, which can seriously manipulate crop economy, help in maintaining natural balance in ecosystem (Soares and Serpa, 2007) and enrichment of biodiversity in ecosystem (Orbycki and King, 1998).

Ecological studies on *Coccinellid* in subcontinent Ecosystem revealed that *C. undecimpunctata* laid eggs near prey (Khan and Suhail, 2001), increased in numbers when prey density increased, and became quiescent when the prey species declined (Kenneth and Hagen, 1970). Species increased its population size in a fairly short time under suitable weather conditions (Hameed and Hussnain, 1984). *Coccinellid* fecundity increased with cool temperature and increase in prey density. Various authors across the subcontinent particularly entomologists emphasized that eleven spotted beetle population should be enhanced in cash crops as of cotton and wheat to get an effective control over the sucking pests complex for better crop yields (Fayyaz, 1998; Bellows, 2001). However introduction of invasive species cotton mealybug delimitate need for enhancement of cotton production (Government of Pakistan, 2008), identification of biological control agents (Tanwar et al., 2011), evaluation of their predatory potential (Ghafoor et al., 2011), identification and maintenance of conservation resources of predators and parasitoids, life history studies and ecological studies of such beneficial organisms. Quantitative assessment of efficacy of *Coccinellid* for pest species in agricultural system, relation of food source to Biological parameters, adult's longevity, fecundity, oviposition, food and environmental relations to *C. undecimpunctata* L. life parameters is the urge of time in ecosystem. Essence of life history and predatory potential of predators and parasitoids can be estimated from the fact that thousands of dollars have been spent in subcontinent of South East Asia to control invasive Caribbean pest through Biological Control agents (CGS projects, 2008).

Keeping in view needs of Country's economy the present studies were conducted to determine predatory efficiency and life history of indigenous predator *C. undecimpunctata* L for the management of cotton mealybug to reduce overreliance on insecticides and to provide base line population data for further experimentation under field.

MATERIALS AND METHODS

The experiment was conducted in Cotton Mealybug laboratory in Entomological Research Institute, Faisalabad. For the purpose of life history and predation studies temperature and humidity were maintained at 25±2°C and 65±5% R.H through the use of air conditioner and humidifier (Honeywell Quicksteam 3-Gallon Warm Moist Humidifier connected with thermo-hygrometer) at 4000 Lux maintained through tube lights connected with lux meter (Testo 540 Lux meter, JMW Limited, Calibration lab Warwick house England). The experiment was laid out in completely randomized split design consisting of 20 treatments, and each treatment comprised of 4 replicates. Predating efficiency was calculated at each instar stage on mealybug 1st, 2nd, 3rd and adult stage. Life table parameters were studied in plastic vials, 15/16*100 mm fitted with plastic lid. Predating efficiency was evaluated. Photographs of each instar was taken through EM-310M digital microscope eyepiece camera with USB 2.0 output 3.2 M / Resolution 2048×1536, 110 mm(H) x 55 mm (D) and 23 mm adapter having Sensor: 1/2" and enhanced color CMOS mounted on Labomed Model digizoom digital zoom stereo microscope.

Rearing of *P. solenopsis* (Tinsely)

Cotton mealybug was reared on bottle gourd Lagenaria siceraria in cages measuring 45 × 30 × 12 cm. The culture was used for experimentation.

Collection of adult beetles and rearing

Adult beetles were collected from cotton fields as well as from other crops during 2nd week of February, 2010 through sweep net technique. The specimens were brought to laboratory and placed in cages measuring 45 × 30 × 12 cm and were fed on mealybugs. The experiment was kept under observation and sexual balance was maintained.

Eggs

Eggs were collected on towel tissue paper and were placed in 9 cm diameter Petri-dishes which were kept on moist tissue papers. The data regarding color, duration and size were recorded.

1st instar

1st instar of *C. undecimpunctata* on emergence, were placed in plastic vials, 15/16*100 mm fitted with plastic lid. Cotton mealybug

Table 1. Average consumption of cotton mealy bug by predator *C. undecimpunctata.*

Instars of predator	Average cotton mealy bugs instars consumed by C. *undecimpunctata*			
	1st instar	2nd instar	3rd instar	Adult
1st instar	91.999^{e}	45.333^{d}	44.00^{d}	5.44^{c}
2nd instar	97.00^{c}	35.667^{e}	45.00^{d}	7.11^{c}
3rd instar	121.666^{d}	51.666^{c}	54.33^{c}	8.21^{c}
4th instar	93.001^{e}	35.00^{e}	33.00^{e}	7.33^{c}
Pupae	0.000^{f}	0.000^{f}	0.000^{f}	0.000^{d}
Adult male	388.11^{b}	123.02^{b}	87.01^{b}	46.08^{b}
Adult female	451.21^{a}	141.21^{a}	93.05^{a}	58.11^{a}
LSD value	3.398	2.799	3.167	3.203

each instar 1st, 2nd 3rd and adult were released in each cage 30, 20, 15 and 10 each day respectively to evaluate predating efficiency of beetle. First instar larvae size, color, duration was also recorded.

2nd instar

After moulting 1st instar larvae of *C. undecimpunctata*, 2nd instar appeared. Its diameter, size, color, duration were recorded and were offered cotton mealybug 40, 30, 20 and 10 for each replicate. Predating efficiency was calculated.

3rd instar

The 3rd instar larvae of *C. undecimpunctata* color, size, and duration were measured and were offered Cotton mealybug 1st, 2nd, 3rd and adult instar at 40, 15, 20 and 10 respectively. Predating efficiency were determined daily intervals.

4th instar

The 4th instar larvae of *C. undecimpunctata* parameters were studied as per description of earlier instars. Predating efficiency was determined day after intervals.

Pupae

Pupal size, color and weight of *C. undecimpunctata* were recorded. Daily changes in pupae skin texture were observed.

Adult

Adult size, color and weight of *C. undecimpunctata* were recorded. Differences between male and female were observed and pairing was made. Adult Pre ovi-positional period, post ovi-positional period, natality, fertility, fecundity, mortality and adults' survival rate were also determined.

Data collection and statistical analysis

Data were collected after 24 h interval for predating efficiency while for biological parameter it was conducted after 12 h intervals. Data were statistically analyzed using MSTAT-C program (Anonymous, 1989) and means were separated at significance level 0.05 using DMRT (Duncan Multiple Range Test Method).

RESULTS AND DISCUSSION

Predating efficiency

Total consumption by *C. undecimpunctata* L. on different instars of mealy bugs presented in Table 1 indicated that 3rd instar larvae of the predator consumed significantly higher numbers of 1st, 2nd and 3rd instars mealy bugs as compared to 1st,2nd and 4th instar of the predator. Results of present studies were similar to Sattar et al. (2007) who reported that 3rd instar larvae of the *Chrysoperla carnea* consumed significantly higher numbers of 1st, 2nd and 3rd instar of mealybugs as compared to 1st and 2nd instar. However in *C. carnea* 3rd instar had long duration as compared to other instars while in *C. undecimpunctata* 4th instar larvae is also present. Less feeding of fourth instar larvae might be due to short duration and pre-pupation period, in which insect feeding is ceased in most of cases.

Per day mean consumption of C. *undecimpunctata* larvae on 1st, 2nd and 3rd instars of the *P. solenopsis* were depicted in Tables 2, 3 and 4, respectively. The out comes of present studies revealed that there was a significant difference in per day consumption of *C. undecimpunctata* on different instars of cotton mealy bugs. The 1st instar larvae of the predator consumed 23.00, 11.33 and 11.00 mealy bugs of 1st, 2nd and 3rd instars, respectively. The results of present studies were in conformity with results of Noia et al. (2008) and Mari et al. (2005), who reported that *C. undecimpunctata* 1st instar consumed 55.10 mustard aphids (*Lipaphis erysimi*), 2nd instar consumed 32.333, 11.89 and 15.00 mealybugs of 1st, 2nd and 3rd instars, respectively. The results of present studies were similar to Noia et al. (2008), who reported intra-guild and extra-guild prey densities. Results were also similar to Mari et al. (2005) depiction that 2nd instar *C. undecimpunctata* consumed81.00 mustard aphids.

The results of present studies were in contradiction to Moura et al. (2006) and Cabaral et al. (2006) evaluations on predating efficiency of *C. undecimpunctata* on aphids. Low consumption of *P. solenopsis* than mustard aphid

Table 2. Average per day consumption of 1st instar of mealybug by C. *undecimpunctata.*

Instars of *C. undecimpunctata*	Average daily mealy bug consumed by 1st instar predator				Mean
	1st	2nd	3rd	4th	
1st	23.333^{a}	23.000^{a}	23.333^{a}	22.333^{a}	22.99
2nd	33.000^{a}	31.000^{a}	33.000^{a}	0.0000^{b}	24.25
3rd	30.333^{ab}	31.333^{a}	31.000^{a}	29.000^{b}	30.41
4th	24.000^{a}	23.667^{a}	22.667^{a}	22.667^{a}	23.25
Grand total					100.90

Table 3. Average per day consumption of 2nd instar of mealy bug by *C. undecimpunctata.*

Instars of *C. undecimpunctata*	Average daily mealy bug consumed by 2nd instar predator				Mean
	1st	2nd	3rd	4th	
1st	9.667^{b}	12.333^{a}	10.000^{b}	13.333^{a}	11.333
2nd	12.000^{a}	13.000^{a}	10.667^{b}	0.00^{c}	11.889
3rd	13.333^{a}	12.000^{a}	13.000^{a}	13.333^{a}	12.916
4th	9.333^{ab}	7.667^{c}	10.000^{a}	8.000^{bc}	8.750
Grand total					44.888

Table 4. Average per day consumption of 3rd instar of mealy bug by *C. undecimpunctata.*

Instars of *C. undecimpunctata*	Average daily mealy bug consumed by 3rd instar predator				Mean
	1st	2nd	3rd	4th	
1st	5.667^{a}	4.000^{a}	4.333^{a}	2.000^{a}	4.00
2nd	9.000^{b}	6.667^{a}	7.333^{b}	0.00^{c}	5.75
3rd	12.333^{bc}	9.000^{a}	9.333^{c}	3.667^{b}	8.58
4th	8.667^{ab}	11.000^{a}	8.333^{ab}	4.000^{a}	8.00
Grand total					26.33

Table 5. Per day mean consumption of adult stage of mealybug by *C. undecimpunctata.*

Instars of *C. undecimpunctata*	Average daily mealy bug consumed by adult of C. *undecimpunctata*				Mean
	1st	2nd	3rd	4th	
1st	0.50^{c}	0.59^{c}	0.93^{a}	0.85^{b}	0.7175
2nd	1.12^{c}	1.33^{a}	1.21^{b}	1.01d	1.1675
3rd	1.11^{b}	1.00^{c}	1.00^{c}	2.21^{a}	1.33
4th	1.66^{a}	1.00^{c}	1.02b	1.00^{c}	1.17
Grand total					17.54

might be due to fact that mealy bugs are covered with waxy layer, which makes the prey unpalatable for consumption by predators (Jonathan, 2005). The predator *C. septempunctata* consumed less *B. brassicae* than other species due to waxy coating on B. *brassicae* (Ashraf et al., 2010).

Per day mean consumption of C. *undecimpunctata* adult male and female on 1st, 2nd and 3rd instars of the mealybug is presented in Tables 5 and 6 respectively. Per day consumption of adult male C. *undecimpunctata* on 1st, 2nd and 3rd instars of cotton mealybug was 1.400, 1.47 and 1.47, respectively and that of adult female C.

Table 6. Total consumption of mealybug by adult (male) *C. undecimpunctata* and female *C. undecimpunctata.*

Instars of mealy bug	Adult male	Adult female
1st	388.11	451.21
2nd	123.02	141.21
3rd	87.01	93.05
Adult	46.08	58.11
LSD	19.98	19.97

Table 7. Studies on Biology of eleven spotted beetle (*C. undecimpunctata* L.).

Stages	Size (L mm × W mm)	Color	Duration (days)	Morphological characters
Egg	0.5 × 0.25	Yellowish orange.	2-3	Egg shape is oval Laid in clusters Each cluster containing 10-15 eggs.
1st instar	1.5 × 0.5	Black like small alligator.	3-4	Head and legs are black in color. Body is dark grey. Thorax has one white dot surrounded by two black dots. Four longitudinal rows of hair are present on abdomen.
2nd instar	2 × 0.75	Black like small alligator.	2-3	Body is elongate. Two black dots are present. Four longitudinal rows of hair are present.
3rd instar	2.5 × 1.0	Black like small alligator.	3-4	Body is larger than 2nd instar.
4th instar	5.0 × 2.5	Black like small alligator.	3-4	Body is larger in size.
Pupae	4.0 × 2.0	Dark brown.	4-5	Firstly pure yellow later on changed to oranges brown and reddish brown.
Adult (male)	0.3 × 0.2	Light orange in color containing eleven black spots on each elytron.	32-41	Smaller in size and eleven spots are present on elytra.
Adult (female)	0.5 × 0.25	Dark orange in colour containing eleven black spots on elytron.	37-55	Larger in size and eleven spots are present on elytra as compare to male.

undecimpunctata was 1.07, 1.13 and 1.27, respectively.

Life history

Female of eleven spotted ladybird beetle, C. *undecimpunctata* L. laid clusters of yellowish orange eggs that turned into dark yellow before hatching. Each cluster had an average of 10-15 eggs. Data in Table 7 unveiled that eggs incubation period was about 2-3 days and size of a single egg was 0.5 × 0.25 mm. Table 7 also indicated that average duration of 1st, 2nd, 3rd and 4th larval instars were 3-4, 2-3, 3-4 and 3-4 days respectively and they were black in color and small alligator like. 1st, 2nd, 3rd and 4th larval instars were 1.5 × 0.5 mm, 2 × 0.75 mm, 2.5 × 1.0 mm and 5.0 × 2.5 mm in size respectively. The pupa was dark brown in color and pupal period was 4-5 days. Size of pupa was 4.0 × 2.0 mm.

Results of present studies are very similar to Solangi et al. (2007) who reported that the mean incubation period

Table 8. Percent emergence, sex ratio, total life period in days and mortality of adults in *C. undecimpunctata*.

Emergence (%)		Sex ratio	Fecundity (eggs)			Total life period (days)		Mortality (%)
Male	Female	Male : female	Lowest	Highest	Average	Male	Female	Average
47	53	1 : 1.5	507	679	593	50-64 (means)	54-77 (means)	3

of ten eleven spotted lady-bird beetle in the laboratory was 3.7±0.94 days within the range of 2-5 days, while 1st, 2nd, 3rd and 4th instar larvae period was 3.1±1.19, 3.1±0.87, 3.5±1.26 and 3.3±0.94 days within the range of 2-5, 2-4, 2-6 and 2-5 days respectively and pupal period was 5.6±0.96 days within the range of 4 to 6 days. In another study egg production per female averaged 142.33, incubation period of eggs 2-9 days, 4 larval instars and last larval stage duration 7.0, 7.5, 12.0, 16.0 and 23.0 days, pupal development average 2.5 days at 30ºC and 7.5 days at 14ºC and egg to adult life cycle duration 12, 14, 21, 27.5 and 38.5 days at 30, 26, 22, 18 and 14ºC, respectively was reported by Eraky and Nasser (1995).

Results in the Table 8 revealed that mean adult male and female emergence was 40 and 60%, respectively. Male to female sex ratio was averaged 2:3. The results indicated that highest, lowest and average fecundity recorded was 679, 507 and 593, respectively. Total life period of adult male and female was 50-64 and 54-77 days, respectively and average mortality was 3.0%.

Results of present studies were in agreement to Solangi et al. (2007) who reported that the emergence of adult male and female was 7.4±2.63 (38.50±13.12%) and 8.9±3.66 (43.38±8.24%) and total life period of adult male and female was 36.5±4.47 and 46.0±9.14, respectively. Solangi et al. (2007) also reported that sex ratio (male: female), average and highest fecundity and average mortality of adults was 1:1.25±1:0.45, 593.4±86.5 and 740 eggs and 17.57±14.51, respectively.

CONCLUSION AND RECOMMENDATIONS

It is recommended by analyzing results of present studies on biology and predatory efficiency of *C. undecimpunctata* (Linneaus) on cotton mealybug (*P. solenopsis* Tinsely) that C. *undecimpunctata* is an efficient bio-control agent for pest control and it must be included in IPM program for suppression of Cotton mealybug in Pakistan, because of its high fecundity, easily rearing ability and efficient suppression of invasive Carrabin pest.

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