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Predatory Potential and Life History Characteristics of Eleven Spotted Beetle, *Coccinella undecimpunctata* L. Reared on Cotton Mealybug, *Phenacoccus solenopsis* Tinsley

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Abstract.- Cotton mealybug, *Phenacoccus solenopsis* T**.** (Sternorrhyncha: Coccoidea: Pseudococcidae) 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 are indigenous and successfully suppress the pest. In present studies eleven spotted ladybird beetle female (*Coccinella undecimpunctata* L.) predating efficiency was determined against cotton mealybug. Adult female during whole life consumed 1519 mealy bugs during whole life cycle through devouring 854, 308, 269 and 86 1st, 2nd, 3rd instar and adult stage cotton mealybug respectively. While adult male during entire life consumed 1420 cotton mealybug through consuming 792, 291, 263, 74 1st, 2nd, 3rd instars and adult cotton mealybug. The population structure and biological parameters were also determined through no choice feeding trials. Adult female of *C. undecimpunctata* consumed higher number of mealybug than adult male during its whole life. Experiment demonstrated that *C. undecimpunctata* is an effective bio control agent of cotton mealybug which can be used in integrated pest management program successfully for the management of this notorious pest on cotton crop.

Keywords: *Coccinella undecimpunctata* larval stages, cotton mealybug instars, predation potential, life history.

INTRODUCTION

Cotton mealybug is an important polyphagous pest feeding on 157 host plants including ornamentals, weeds, shrubs and cash crops (Abbas *et al.*, 2010; Vennila *et al.*, 2013). It is multivolatine, highly fecundative (Hameed *et al.*, 2012; Kedar *et al.*, 2013), invasive insect pest possessing ovoviviparous reproduction and covered with waxy layer (Hodgson *et al.*, 2008; Aheer *et al.*, 2009) that makes pest control much difficult. Whole subcontinent agricultural economy collapsed due to pest attack since 2005 (Centre for Agro Informatics Research, 2007; Wang *et al.*, 2010). Government of Pakistan has recommended an array of pesticides for pest control (Saeed *et al.*, 2007), but this made problem intense, up-surgence of secondary pests (Vennila *et al.*, 2011) and increased pest pressure of sucking and minor pest due to pesticide resistance (Udukeri *et al.*, 2009). Insecticidal control is not only expensive but the indiscriminate use of pesticides caused phytotoxicity and destruction of beneficial organisms such as predators, parasitoids, microorganisms in Pakistan and in the world (Nikam *et al.*, 2010; Mahmood *et al.*, 2011).

For control of mealybugs population, biological control is also an important tactic because it is safe, economical and environmental friendly (Pala and Saini, 2010; Neetan and Agarwal, 2012; Hameed *et al.*, 2013). Coccids are 36% of prey of Coccinellid species (Hodek, 2009). Integrated pest management programmes based on bio-control involve various techniques, importation bio-control, Augmentation bio-control and conservation (Chang, 2005) but the presence of indigenous predators and parasitoids in cotton ecosystem delimits the need for importation and emphasizes the need for conservation through modifying environment, protection and enhancement of Coccinellid (Mahmood *et al.*, 2011; Tanwar *et al.*, 2011). Aim of present work was to determine predatory potential of Coccinellid beetles against the cotton mealy bug and to chalk out their role for area wide control of mealybugs in pest management programmes.

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MATERIALS AND METHODS

The experiment was conducted in ambient conditions in cotton mealybug laboratory at Entomological Research Institute, Ayub Agricultural Research Institute, Faisalabad. For 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 30 treatments, and each treatment comprised of 5 replicates. Predating efficiency at each larval stage of predator was calculated on mealybug 1st, 2nd, 3rd and adult stage. Each cotton mealybug larval stage was considered a single treatment. So 1st larval stage of predator was exposed to 4 treatments and 5 replicates. Four treatments were 1st, 2nd, 3rd and adult larval stage cotton mealybug. Similarly other larval stages of predators were exposed to these 4 treatments. Density of cotton mealybug for each predator larval stage was changed depending upon predator predating capacity. Life table parameters were studied in plastic vials, 15/16*100mm fitted with plastic lid. Photographs of each larval stage was taken through EM-310M digital microscope, eyepiece camera with USB 2.0 output 3.2M/ Resolution 2048x1536, 110mm(H) x 55mm (D) and 23mm 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 in cages measuring 45 x 30 x 12 cm. The culture was used for experimentation.

Collection and rearing of adult beetles

Adult beetles were collected from cotton fields as well as from other crops during 2nd week of Feb. through hand collection technique. The specimens were brought to laboratory and placed in cages measuring 45 x 30 x 12 cm and were fed on mealy bugs. The experiment was kept under observation and sexual balance was maintained.

Determination of predating efficiency and biological parameters

Predating efficiency was determined after 24 hours interval. Biological characters of each predator larval stage *viz*., colour, shape, size, duration, adult pre ovi-positional period, post ovi-positional period, natality, fertility, fecundity, mortality and adults survival rate were also determined after 8 hours interval. Eggs were collected on towel tissue paper and were placed in 9 cm diameter petri-dishes which were kept on moist tissue papers. 1st larval stage of *C. undecimpunctata* on emergence, were placed in plastic vials, 15/16*100mm fitted with plastic lid. Cotton mealybug each larval stage 1st, 2nd 3rd and adult were released in each cage 30, 20, 15 and 10 each day respectively to evaluate predating efficiency of beetle. After moulting 1st larval stage larvae of *C. undecimpunctata* shifted to 2nd larval stage through metamorphosis. Cotton mealybug as prey in 40, 30, 20 and 10 specimens were offered for each replicate in treatments respectively. Each cotton mealybug larval stage was considered as separate treatment. For 3rd larval stage predator cotton mealybug 1st, 2nd, 3rd and adult @ 40, 35, 20 and 10 were provided in different treatments. Predating efficiency was determined day after intervals. For Fourth larval stage predator *P. solenopsis* population to each replicate was increased to 55, 40, 30 and 20 in treatments. Pupae color, texture changes were determined. Adult larval stage predators were offered 100, 70, 60, 40 1st, 2nd, 3rd and adult larval stage cotton mealybugs to both sexes. Biological parameters of adult larval stages were also determined.

Statistical analysis

Data were collected every after 24 hours interval for predating potential and after 08 hours for biological parameter. 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 of C. undecimpunctata

Predation of 1st larval stage of P. solenopsis:

Data in the Table I revealed significant differences in mean consumption of 1st larval stage cotton mealybug at 5% level of significance. *C. undecimpunctata* adult female consumed significantly higher number of 1st instar *P. solenopsis i.e.* 451.2 as compared to other instars of cotton mealybug. Adult male predator consumed 388.1 individuals of host which was less than adult female. Second larval stage of *C. undecimpunctata* consumed 97.0 1st larval stage *P. solenopsis.* First and 4th larval stages of *C. undecimpunctata* devoured statistically similar *P. solenopsis i.e.* 91 and 93 individuals of *P. solenopsis.* As cotton mealybug grew in size its utilization by *C. undecimpunctata* was significantly reduced.

Predation of 2nd larval stage of P. solenopsis

Again the adult of *C. undecimpunctata* consumed statistically more *P. solenopsis.* The adult female gulped statistically more individuals of 2nd instar of prey *i.e.* 141 as compared to adult male which gobbled 123 individuals of cotton mealybug which were less than adult female. Among larval larval stages, 3rd larval stage of *C. undecimpunctata* on an average devoured higher individuals of host *i.e.* 52 as compared with other larval stages. First larval stage consumed 45 individuals of *P. solenopsis* whereas 2nd and 4th larval stage consumed statistically similar individuals *i.e.* 36 and 35.

Predation of 3rd larval stage of P. solenopsis

In case of 3rd instar of host, adults of *C. undecimpunctata,* consumed statistically more 3rd instar as compared to other larval stages. The adult female devoured statistically more individuals of 3rd instar of prey *i.e.* 93 as compared to adult male which gulped 87 individuals of *P. solenopsis* which was less than adult female. Among predator stages, 3rd larval stage of *C. undecimpunctata* on an average predated higher individuals of *P. solenopsis i.e.* 54 as compared to other larval stages. First and 2nd larval stages of predator gobbled 44 and 45 individuals of *P. solenopsis* which were statistically similar whereas 4th larval stage consumed statistically less individuals *i.e.*, 33.

Predation of adult of P. solenopsis

Again adult of *C. undecimpunctata* consumed statistically more *P. solenopsis* adults as compared to other larval stages. The adult female gobbled statistically higher adults of *P. solenopsis i.e.* 58 as compared to adult male which devoured 46 individuals of host which was less than adult female. All larval stages of *C. undecimpunctata* gulped statistically similar individuals of *P. solenopsis i.e.* 5, 7, 8, and 7 individuals of CMB adult.

Total predation in entire lifecycle

For completion of life cycle adult male and female predated higher individuals of prey *i.e.* 1519 and 1492 which were higher than larval stages as shown in Figure 2. Third larval stage devoured maximum number of individuals *i.e.* 235 as compared with 1st, 2nd and 4th larval stages. The results of present studies were in contradiction to Moura *et al.* (2006) and Cabral *et al.* (2006) evaluations on predating efficiency of *C. undecimpunctata* on aphids. Low consumption of *P. solenopsis* than mustard aphid might be due to fact that mealybugs 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 *on 1st, 2nd, 3rd larval stages and adult larval stage of the* P. solenopsis

Per day mean consumption of *C. undecimpunctata* larvae on 1st, 2nd, 3rd and adult larval stage of *P. solenopsis* are depicted in Figure 3. The outcomes of present studies revealed that there was a significant difference in per day consumption of *C. undecimpunctata* on different larval stages of cotton mealy bugs. The 1st larval stage of the predator on an average consumed 23.00, 11.33 and 4.00 mealy bugs of 1st, 2nd and 3rd instars respectively. The results of present studies were inconformity with results of Noia *et al.* (2008) and

Table I.- Total consumption of cotton mealybug by C. *undecimpunctata.*

Larval stages of *C. undecimpunctata*	Total cotton mealy bugs larval stages consumed by C. *undecimpunctata*			
	1st larval stage	2nd larval stage	3rd larval stage	Adult
Larva stage 1	91.999 e	45.333 d	44.00 d	5.44 c
stage 2	97.00 c	35.667 e	45.00 d	7.11 c
stage 3	121.666 d	51.666 c	54.33 c	8.21 c
stage 4	93.00 e	35.00 e	33.00 e	7.33 c
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 at 5%	3.398	2.799	3.167	3.203

Note: Means sharing similar letters are not significantly different by DMR Test at 0.05% level of significance

Mari *et al.* (2005) who reported that *C. undecimpunctata* 1st larval stage consumed 55.10 mustard aphids (*Lipaphis erysimi*), 2nd larval stage consumed 32.333, 11.89 and 15.00 mealybugs of 1st, 2nd and 3rd larval stages, respectively. The results of present studies were similar to Noia *et al.* (2008) who reported intraguild and extra-guild prey densities. Results were also similar to Mari *et al.* (2005) depiction that 2nd larval stage *C. undecimpunctata* consumed 81.00 mustard aphids.

Per day mean consumption of *C. undecimpunctata* adult male and female on 1st, 2nd and 3rd larval stages of the mealybug is presented in Figure 3. Per day consumption of adult male *C. undecimpunctata* on 1st, 2nd and 3rd larval stages of cotton mealybug was 1.40, 1.47 and 1.47 respectively and that of adult female C. *undecimpunctata* was 1.07, 1.13 and 1.27, respectively.

Life history of C. undecimpunctata

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.

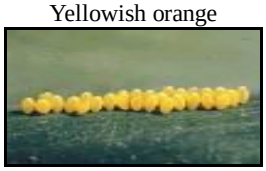
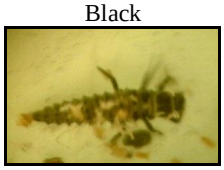
Table II and Figure 1 indicated average duration of 1st, 2nd, 3rd and 4th larval stages were 3-4, 2-3, 3-4 and 3-4 days respectively and they are black in color and small alligator like. 1st, 2nd, 3rd and 4th larval stages were 1.5 × 0.5 mm, 2.0 × 0.75 mm, 2.5 × 1.0 mm and 5.0 × 2.5 mm in size respectively. 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 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 larval stage 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 stages 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 Table III revealed that mean adult male and female emergence was 40 and 60 %, respectively. Male to female sex ratio 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 percent.

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),

Table II.- Studies on biology of eleven spotted beetle *C. undecimpunctata* L.

Larval stages	Size (LxW)	Color	Duration	Morphological Characters
Egg	0.5 × 0.25mm	Yellowish orange 	2-3 days	Egg shape is oval. Eggs are laid in clusters. Each cluster contains 10-15 eggs.
Larva larval stage1	1.5 × 0.5 mm	Black 	3-4 days	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.
Larva larval stage 2	2.0 × 0.75mm	Black 	2-3 days	Body is elongate. Two black dots are present. Four longitudinal rows of hair are present.
Larva Larval stage 3	2.5 × 1.0 mm	Black 	3-4 days	Body is larger than 2nd larval stage. Morphological characters similar
Larvae larval stage 4	5.0 × 2.5 mm	Black 	3-4 days	Body is larger in size.
Pupae	4.0 × 2.0 mm	Dark brown 	4-5 days	Firstly pure yellow later on changed to oranges brown then changed to reddish brown.
Adult (male)	0.3 × 0.2 mm	Light orange in color containing eleven black spots on each elytron 	32-41 days	Smaller in size and eleven spots are present on elytra
Adult (female)	0.5 × 0.25mm	Dark orange in colour containing eleven black spots on elytron 	37-55 days	Larger in size and eleven spots are present on elytra as compare to male

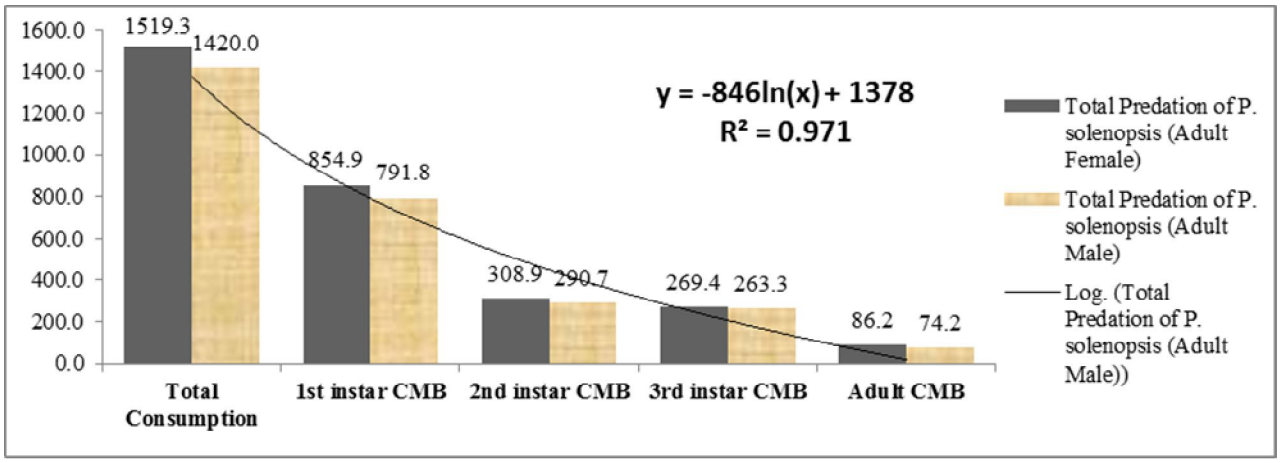


Fig. 1. Total consumption of cotton mealybug larval stages in predator life.

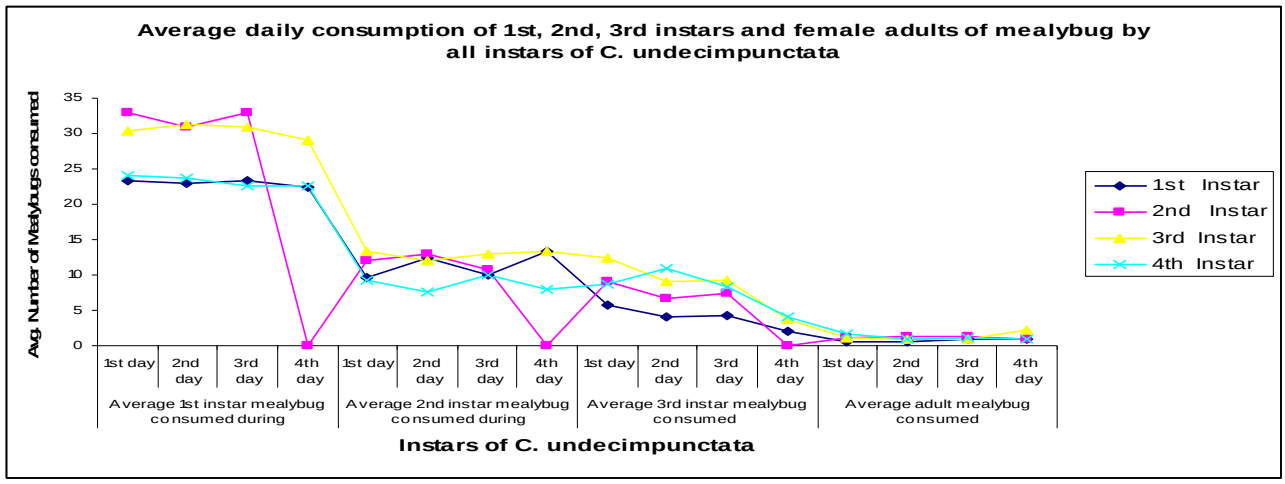


Fig 2. Per day consumption of cotton mealybug larval stages during immature larval stages of predator.

Table III.- 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)		Average % mortality
Male	Female	Male : Female	Lowest	Highest	Average	Male	Female	
47	53	1 : 1.5	507	679	593	50-64	54-77	3

average and highest (use of the) 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 that C. *undecimpunctata* is an efficient bio-control agent for this notorious pest because of its high fecundity, easily rearing ability and efficient suppression of invasive Carrabin pest. So it must be included in IPM program for suppression of Cotton mealybug in Pakistan.

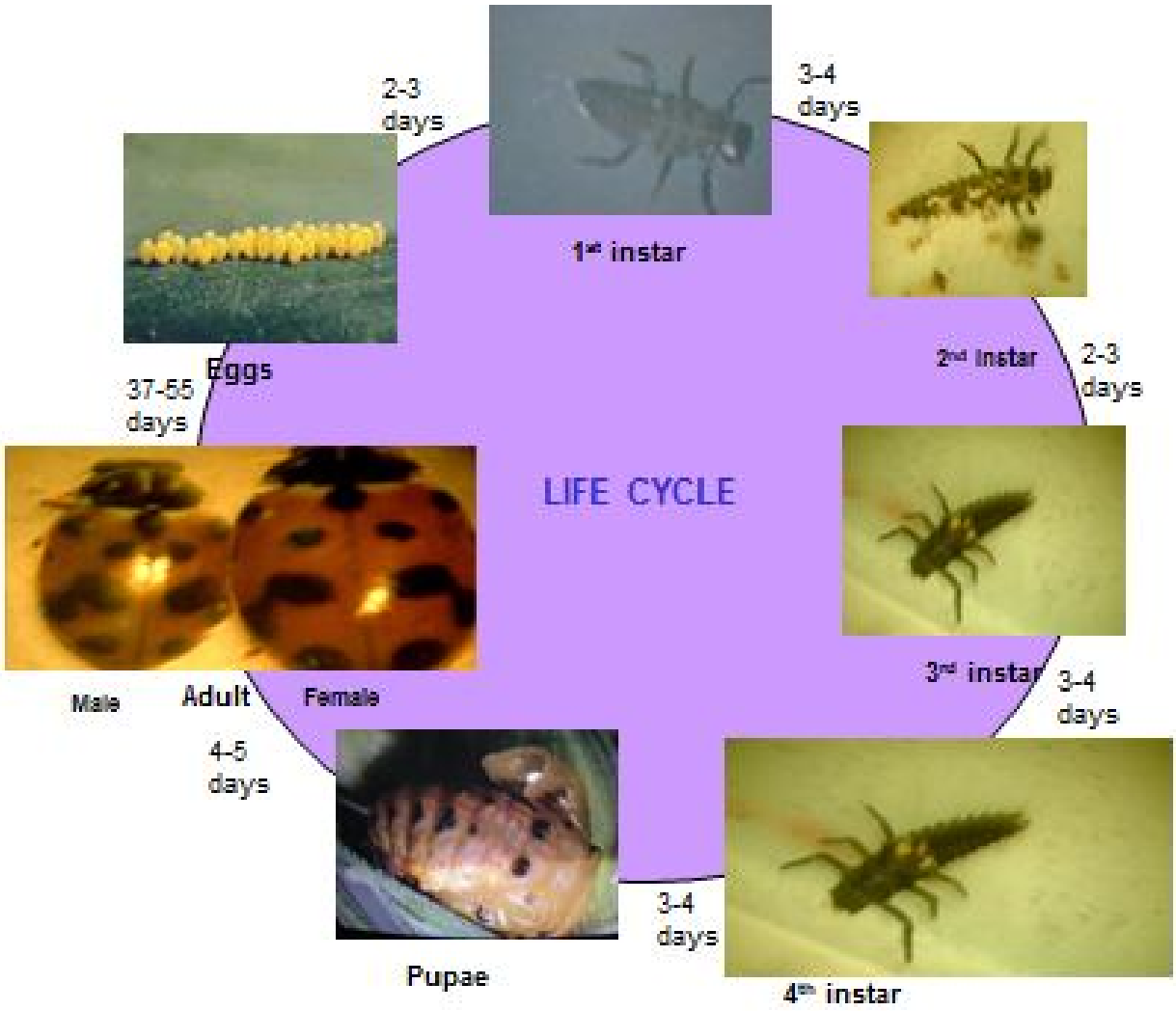


Fig. 3. Life cycle of eleven spotted beetle (*Coccinella undecimpunctata*) on cotton mealybug (*P. solenopsis*)

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REFERENCES

ABBAS, G., ARIF, M. J., ASHRAQ, M., ASLAM, M. AND SAEED, S., 2010. Host plants distribution of cotton mealybug (*Phenacoccus solenopsis* Tinsley; Hemiptera: Pseudococcidae). *Int. J. agric. Res*., **12**: 421-425.

ANONYMOUS, 1989. *MSTAT-C. Micro computer statistical programme.* Michigan State University, Michigan Lansing, USA.

ASHRAF, M., ISHTIQ, M., ASIF, M., ADREES, M. AND AYUB, M. N., 2010. Studies on laboratory rearing of ladybird beetle (*Coccinella septempunctata* L.) to observe its fecundity and longevity on natural and artificial diet. *Int. J. Biol.*, **2**: 165-173.

CABRAL, S., SOARES, A. O. AND GARCIA, P., 2009. Predation by *Coccinella undecimpunctata* L. (Coleoptera: Coccinellidae) on *Myzus persicae* sulzer (Homoptera: Aphididae): Effect of prey density. *Biol.*

Contr., **50**: 25-29.

CENTRE FOR AGRO INFORMATICS RESEARCH, 2007. *Mealybug: Cotton crop's worst catastrophe in District Multan during 2005-2006*. Published by FAST Notational University of Computer and Emerging Sciences, 81pp.

CHANG, G., 2005. *Biological pest control in access science*, McGraw Hill Companies, http://www.accessscience.com.

ERAKY, S. A. AND NASSER, M. A. K., 1995. Effect of constant temperatures on development and predation prey efficiency of ladybird beetle, *Coccinella undecimpunctata* L. (Coleoptera: Coccinellidae). *Assiut J. agric. Sci.*, **24**: 223-231.

HAMEED, A., AZIZ, M. A. AND AHEER, G. M., 2012. Impact of ecological conditions on biology of cotton mealy bug *Phennacoccus solenopsis* Tinsely (Sternorrhyncha: Coccoidea: Pseudococidae) in laboratory. *Pakistan J. Zool.*, **44**: 685-690.

HAMEED, A., SALEEM, M., AHMAD, S., IJAZ AZIZ, M. AND KARAR, H., 2013. Influence of prey consumption on life parameters and predatory potential of *Chrysoperla carnea* against cotton mealy bug. *Pakistan J. Zool.*, **45**: 177-182.

HODEK, I. AND HONEK, A., 2009. Scale insects, mealy bugs, whiteflies, and psyllids (Hemiptera: Sterrnorhyncha) as prey of ladybird. *Biol. Contr*., **51**: 232-243.

HODGSON, C., ABBAS, G., ARIF, M. J., SAEED, S. AND KARAR, H., 2008. *Phenacoccus solenopsis* Tinsley (Sterrnorhyncha: Coccoidea: Pseudococcidae) an invasive mealy bug species damaging cotton in Pakistan and India with discussion on seasonal and morphological variation, *Zootaxa*, **1913**: 1-35.

JONATHAN, G. AND LUNDGREN, R. N., 2005. Wiedenmann tritrophic interactions among Bt (Cry3Bb1) corn, aphid prey, and the predator *Coleomegilla maculata* (Coleoptera: Coccinellidae). *Environ. Ent*., **34**: 1621–1625.

KEDAR, S.C., SAINI, R.K. AND RAM, P., 2013. Bionomics of mealybug, *Phennacoccus solenopsis* on cotton in Haryana. *J. Cotton Res. Dev*., **27**: 99-103

MAHMOOD, R., ASLAM, M. N., SOLANGI, G. S. AND SAMAD, A., 2011. *Historical perspectives and achievements in biological management of cotton mealybug* Phennacoccus *solenopsis Tinsely in Pakistan*. 5th Asian meeting ICAC. www.icac.org/tis/regional-networks/asian_network/meeting_5/document/papers/mahmood,R.pdf

MARI, J.M., RIZVI, N.H., NIZAMANI, S.M., QURESHI, K.H. AND LOHAR, M. K., 2005. Predatory efficiency of *Menochilus sexmaculatus* Fab and *Coccinella undecimpunctata* Linneaus (Coccinellidae: Coleoptera) on alfa alfa aphid *Theriophiis trifolii* (Monell). *Asian J. Pl. Sci.*, **4**: 354-358.

MOURA, R., GARCIA, P., CABRAL, S. AND SOARES, A.O., 2006. Does pirimicarb affect the voracity of the euriphagous predator, *Coccinella undecimpunctata* L. (Coleoptera: Coccinellidae). *Biol. Contr.*, **38**: 363–368.

NEETAN AND AGARWAL, N., 2011. *Biological control of mealybug* Phenacoccus *solenopsis Tinsley on Cotton: A boon for Indian farmers*. http://www.scribed.com/doc/57428701/Neetan-paper_corrected_1

NIKAM, N.D., PATEL, B.H. AND KORAT, M., 2010. Laboratory and field efficacy of selected insecticides against mealybug, *Phenacoccus solenopsis* Tinsley infesting cotton. Karnatka. *J. agric. Sci*., **23**: 712-715.

NOIA, M., BORGES, I. AND SOARES, A., 2008. Intraguild predation between the aphidophagous ladybird beetles *Harmonia axyridis* and *Coccinella undecimpunctata* (Coleoptera: Coccinellidae): the role of intra and extraguild prey densities. *Biol. Contr.*, **46**: 140 – 146.

PALA, R. AND SAINI, R.K., 2010. Biological Control of *solenopsis* mealybug *Phenacoccus solenopsis* Tinsely on cotton: A typical example of fortuitous biological control. *Biol. Contr.*, **24**: 104-109.

SAEED, S., AHMAD, M., AHMAD, M. AND KWON, Y. J., 2007. Insecticidal control of the mealybug *Phenacoccus gossypiphilous* (Hemiptera: Pseudococcidae). *Ent. Res*., **37**: 76–80.

SOLANGI, B.K., LANJAR, A.G. AND LOHAR, M.K., 2007. Biology of 11spotted beetle *Coccinella undecimpunctata* L. (Coccinellidae: Coleoptera) on mustard aphid *Lipaphis erysimi* Kalt. *J. appl. Sci*., **7**: 3086-3090.

TANWAR, R.K., JEYAKUMAR, P., SINGH, A., JAFRI, A.A. AND BOMBAWALE, O.M., 2011. Survey of cotton mealybug *Phennacoccus solenopsis* (Tinsely) and its natural enemies. *J. environ. Biol*., **32**: 381-384.

UDUKERI, S.S., PATEL, S.B., HIREKURUBER, R.B., GURUPARASAD, G. S., SAHILA, H.M. AND MATTI, P.V., 2009. Management of sucking pests in cotton with new insecticides. *Karnatka J. agric. Sci*., **22**: 798-802.

VENNILA, D., RAMASUNDRAM, P., RAJ, S. AND KIRAN, M.S., 2011. Cotton IPM and its current status, *CICR Tech. Bull.*, **8**: 1-13.

VENNILA, S., PARASAD, Y. G., PRABAHARKAR, M., AGARWAL, M., SREEDEVI, G. AND BOMBAWALE, O.M., 2013. Weed hosts of cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae). *J. environ. Biol*., **34**: 153-158

WANG, Y., WATSON, G.W. AND ZHANG, R., 2010. Potential distribution of an invasive mealybug *Phenacoccus solenopsis* Tinsley and its threat to cotton in Asia. *Agric. Forest Ent*., **12**: 403-416.

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