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PREDATORY POTENTIAL OF SOME NATIVE COCCINELLID PREDATORS AGAINST *PHENACOCCUS SOLENOPSIS*, TINSELY (PSEUDOCOCCIDAE: HEMIPTERA)

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ABSTRACT

Predatory potential of *Menochillus sexmaculatus, Coccinella septempunctata, Brumus suturalis, Hippodemia convergens* and their four instars against first instar nymphs of cotton mealy bug, *Phenacoccus solenopsis* was investigated under laboratory conditions. The results showed significant variation in the predatory potential, in term of total, per-day and percent consumption, of four predatory coccinellid species and their instars. The four evaluated predatory species of coccinellids caused more than 80% consumption and contributed significant and prominent role in the consumption of first instar nymphs of cotton mealybug; however, *C. septempunctata* and *B. suturalis*, registering total consumption of 538 and 536 nymphs/life and percent consumption of 95 and 92 %, respectively, was found better predator as compared to other two species. All the life stages of four predatory coccinellid species performed well registering more than 80% consumption of first instar nymphs of cotton mealybug, except fourth instar grubs (77.9% consumption); however, adult stage was found more effective predatory stage as maximum and highly significant predation (percent consumption) was registered by this stage (96.7%). Second, third and first instar grubs of all evaluated predatory coccinellid beetles showed 87.6, 86.1 and 81% consumption, respectively. In conclusion, all the predaceous life stage (four instars and adults) of *M. sexmaculatus, C. septempunctata, B. suturalis, H. convergens,* especially *C. septempunctata, B. suturalis,* were found potential predaceous stages/predator for first instar nymphs of cotton mealybug and hence, should be evaluated in the fields for their potential effectiveness when used alone or in combination with other IPM tactics.

Keywords: Performance, predaceous coccinellids, cotton mealybug

INTRODUCTION

A number of mealybug species have been reported attacking vegetables, fruit trees, glasshouse- and field-crops around the world (Cox, 1983, 1987; Fuchs *et al.*, 1991; Osborne *et al.*, 1994; Oetting, 2004; Rothwangle *et al.*, 2004; Williams, 2004; Watson and Kubiriba, 2005; Moghaddam, 2006; Zaka *et al.*, 2006; Tanwar *et al.*, 2007; Daane *et al.*, 2008) and cause very substantial economic losses to these crops (Zeddies *et al.*, 2001; Arif *et al., 2008,*2009). Out of various mealybug species, *Phenacoccus solenopsis,* due to its invasive behavior, was found as an invasive and damaging species on various crops causing economical losses **(**Fuchs *et al.*, 1991; Patricia, 2002; Granara de Willink, 2003**).** The incidence and severity of the CMB outbreak in the Indian Punjab was worst in villages adjoining the Pakistan boundary, where the infestation consisted of a mixture of species, mostly *P. solenopsis* and *M. hirsutus* (Monga *et al.*, 2008). *P. solenopsis* has a devastating impact on cotton production in India (NCIPM, 2008; Nagrare *et al.*, 2009). A survey carried out in Baroda during November 2006 revealed that 25-30% cotton fields were infested with mealybug and 20-90% plants were adversely affected causing a reduction of 50% yield in highly infested fields (Jhala *et al*., 2008a,b). Infestation of mealybug at most of the places in North and Central zones ranged from mild (10-20%) to high (40-60%) during 2007 and 2008 but reduced to traces in 2009 (Tanwar *et al.,* 2011). Similar reports of damage by *P. solenopsis* were received from some vegetable-growing areas of Thailand (Tanwar *et al.*, 2007; USDA, 2008; Bambawale, 2008; Hodgson *et al.*, 2008). In Punjab the losses caused by the mealybug were estimated to be Rs. 159 crores to cotton growers during kharif season 2007 (Anonymous, 2008, 2009). Study carried out in Punjab of Pakistan during 2007-08 indicated losses to the tune of 3.1 million bales from the targeted output of 14.3 million bales due to mealybug attack (Anonymous, 2007).

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The control of *P. solenopsis* totally depends on the foliar application of synthetic and nonselective insecticides which are causing not only ecological backlash but also environmental and health hazards (Saeed *et al.*, 2007; Dhawan *et al.*, 2008); however the cover spray of insecticides are not giving satisfactory control of this pest because of its high reproductive potential and strong biophysical resistance due to egg-sac and very thick waxy covering on the body (Saeed *et al.*, 2007; Saini and Ram, 2008; Gogi *et al.,* 2010)

Predaceous coccinellids are important natural enemies of arthropod pests, including whiteflies, aphids, mealy bugs, scales and mites (Obrycki and Kring, 1998) and has been using continuously for centuries because of their easy collection. *Coccinella septempunctata* (Coleoptera: Coccinellidae) is an important coccinellid species, which feeds on soft-bodied insects such as aphids, thrips, white flies, mites and lepidopterous eggs (Hagen, 1987). Lady beetles are voracious feeders and may be numerous where prey is plentiful and use of broad spectrum and non-selective chemical is limited. *C. septempunctata* may consume several hundred aphids a day. About 75 species of predatory coccinellids are recorded from Pakistan. These species belong to 37 genera, 2 subgenera in 14 tribes and five subfamilies (Rafi *et al.,* 2005). *Brumoides suturalis, Menochilus sexmaculatus, Coccinella septempunctata* and *Anegleis cardoni* are the important predators of sugarcane pyrilla in NWFP. *B. suturalis* is found to be more abundant in non-sprayed areas of sugarcane in Mardan and Swabi. *M. sexmaculatus* occurred regularly where no pesticides were applied (Rafi *et al.,* 2005). Convergent lady beetles, *Hippodamia convergens* (Coleoptera: Coccinellidae), are a popular choice for aphid control because these beetles are easily collected and redistributed. Several billion *H. convergens* adults are collected annually from their over wintering sites. These beetles are then sold to commercial growers and home gardeners for augmentative biological control (Dreistadt and Flint, 1996). Tanwar *et al.* (2007) reported coccinellid beetles such as *Cheilomenes sexmaculata* (Fabricius), *Rodolia fumida* Musant, *Scymnus coccivora* Aiyar and *Nephus regularis* (Sicard) as important predators of mealybug nymphs. However, the use of coccinellid predators as biological control of mealybug in Pakistan is very limited. It is, therefore, very imperative to evaluate the potential of predatory coccinellids as biocontrol agents of cotton mealybug.

The major objective of the present research was to investigate the predatory potential of *Menochillus sexmaculatus, Coccinella septempunctata, Brumus suturalis, Hippodemia convergens* for cotton mealybug, *Phenacoccus solenopsis* under laboratory conditions, which would ultimately help in designing an effective IPM strategy to control this novel pest.

MATERIALS AND METHODS

Culture of mealybug

The twigs of shoe flower (*Hibiscus rosa-chinensis*) infested with mealybug were collected from the shoe flower plants and brought into IPM laboratory, Department of Agri. Entomology, University of Agriculture, Faisalabad,Pakistan. The adult females with ovisac were separated from the twigs and inoculated with camel hair brush on the fruits of pumpkin (*Cucurbita moschata*) placed inside the glass cages (90 x 90 x 90 cm^3). These cages were placed inside the incubator maintained at 28±1°C and 65±5% rh. The mealybugs were mass-reared and multiplied in such cages upto three generation (F_3) on the pumpkin fruits. The first instars nymphs of F_3 from the culture were used for the experimentation of present studies.

Coccinellid predatory beetles

The adults of four coccinellid predatory beetles, *Menochilus sexmaculatus*, *Coccinella septempunctata, Brumoides suturalis*, *Hippodamia convergens,* were collected from different plants and were reared on mealybug population cultured on pumpkin fruits in separate cages of dimension 90 x 90 x 90 cm^3. The pupae and eggs of each coccinellid predatory beetle were collected from the culture. The collected pupae were placed in small petridishes; whereas, the eggs of beetles were placed on water socked tissue papers, which were then placed inside the incubator maintained at 28±1°C and 65±5% rh. The newly emerged adults from the pupae and first instar nymphs from eggs, almost of same age, were collected and used for different experimentations of present studies.

Experimentation

Evaluation of predatory potential of four instars of coccinellid predatory beetles

A set of fifty petridishes, each having well settled twenty first instar nymphs of mealybug on a piece of pumpkin fruit, was prepared for each instar of each predatory beetle, when required. Four such sets of petridishes were prepared for each instar of each predatory beetle, which serve as four replicates. A newly emerged first instar grub of each predatory beetle was released into each petridish of the respective set of petridishes. The grubs were released into petridishes through small hole made in the lid-piece of the petridish. After the release of the grub, the hole was plugged in with cotton swab. The petridishes were observed daily for counting the number of consumed and unconsumed mealybug's nymphs till the first instar grub metamorphosed. After each counting, the population of first instar of cotton mealybug in each petridish was maintained upto twenty nymph/petridish till the first instar grub metamorphosed. This procedure was used for each instar of grubs of each predatory beetle; however, the population of first instar nymphs of cotton mealybug per petridish was maintained upto 30, 40 and 50 mealybug nymphs/petridish after each counting for second, third and fourth instar of each grub, respectively. Total, per-day and percent consumption of mealybug nymph by each instar of each predatory beetle were calculated by the following formulae:

$$\text{Total consumption} = \sum_{I=1}^{O=1} X + \sum_{I=1}^{O=2} X + \sum_{I=1}^{O=3} X + \ldots\ldots\ldots + \sum_{I=1}^{O=n} X$$

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O: observation; X: number of mealybug nymphs consumed by first instar bug; I: instar
Similar formula was used for calculating total consumption of second, third and fourth instar.

$$\text{Per-day consumption} = (\sum_{I=1}^{O=1} X + \sum_{I=1}^{O=2} X + \sum_{I=1}^{O=3} X + \ldots\ldots\ldots + \sum_{I=1}^{O=n} X) / D$$

O: observation; X: number of mealybug nymphs consumed by first instar; I: instar; D: longevity of instar (days)
Similar formula was used for calculating per-day consumption of second, third and fourth instar.

$$\text{Percent consumption} = [(\sum_{I=1}^{O=1} X + \sum_{I=1}^{O=2} X + \sum_{I=1}^{O=3} X + \ldots.. + \sum_{I=1}^{O=n} X) / (\sum_{I=1}^{O=1} N + \sum_{I=1}^{O=2} N + \sum_{I=1}^{O=3} N \ldots.. + \sum_{I=1}^{O=n} N] \times 100$$

O: observation; X: number of mealybug nymphs consumed by first instar; I: instar; N: Total mealybug nymphs offered to first instar grub
Similar formula was used for calculating percent consumption of second, third and fourth instar.

Evaluation of predatory potential of adults of coccinellid predatory beetles

A set of five petridishes, each having well settled hundred first instar nymphs of mealybug on a piece of pumpkin fruit, was prepared for adults of each predatory beetle. Four such sets of petridishes were prepared for each predatory beetle, which serve as four replicates. A pair (1 male: 1 female) of newly emerged adults of each predatory beetle was released into each petridish of the respective set of petridishes by the same procedure as described in the section of "*Evaluation of predatory potential of four instars of coccinellid predatory beetles*". The petridishes were observed daily for counting the number of consumed and unconsumed mealybug's nymphs till the death of the adults of each predatory beetle. After each counting, the population of first instar of cotton mealybug in each petridish was maintained upto hundred nymph/petridish till the death of the adults. This procedure was used for each predatory beetle. Total, per-day and percent consumption of mealybug nymph by adult each predatory beetle was calculated by the following formulae:

$$\text{Total consumption} = \sum_{AS=1}^{O=1} X + \sum_{AS=1}^{O=2} X + \sum_{AS=1}^{O=3} X + \ldots\ldots\ldots\ldots + \sum_{AS=1}^{O=n} X$$

O: observation; X: number of mealybug nymphs consumed by adults of first predatory species; AS: adults of predatory species
Similar formula was used for calculating total consumption by the adults of second, third and fourth predatory species.

$$\text{Per-day consumption} = (\sum_{AS=1}^{O=1} X + \sum_{AS=1}^{O=2} X + \sum_{AS=1}^{O=3} X + \ldots\ldots + \sum_{AS=1}^{O=n} X) / D$$

O: observation; X: number of mealybug nymphs consumed by adults of first predatory species; AS: adults of predatory species; D: longevity of instar (days)
Similar formula was used for calculating per-day consumption of second, third and fourth predatory species.

$$\text{Percent consumption} = [(\sum_{AS=1}^{O=1} X + \sum_{AS=1}^{O=2} X + \sum_{AS=1}^{O=3} X + \ldots.. + \sum_{AS=1}^{O=n} X) / (\sum_{AS=1}^{O=1} N + \sum_{AS=1}^{O=2} N + \sum_{AS=1}^{O=3} N \ldots.. + \sum_{AS=1}^{O=n} N] \times 100$$

O: observation; X: number of mealybug nymphs consumed by adults of first predatory species; AS: adults of predatory species; N: Total mealybug nymphs offered to first instar grub
Similar formula was used for calculating percent consumption of second, third and fourth predatory species.

Statistical analysis

The data obtained on total, per-day and percentage consumtion for instars or adults were analyzed statistically by applying analysis of variance technique according to procedure given by Mari *et al.* (2005). Then the means of significant treatments were compared by Tukey's Honestly Significant Difference Test at 5 % probability with the help of an IBM compatible computer using M-Stat package.

RESULTS

ANOVA parameters show that predatory species and life stages as well as their associated interaction had highly significant effects on the total, per-day and percent consumption of first instar nymphs of mealybug by coccinellid predatory beetles (Table 1).

Table 1
Different parameters of ANOVA for predatory species, instars and their associated interaction.

Source of variation (S.O.V)	*d.f.* (S.O.V./Error)	Total consumption		Per day consumption		Percent consumption	
		F_{value}	P_{value}	F_{value}	P_{value}	F_{value}	P_{value}
Predator species	3/29	12.16	<0.001	7.55	<0.001	3.3	<0.05
Life stages	3/29	2885.24	<0.0001	6.21	<0.001	546.24	<0.0001
Predator species x Life stages	9/29	20.11	<0.001	3.13	<0.001	5.99	<0.001

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Predatory potentials in term of interaction associated between life stages and predatory species

Total consumption

Total consumption of first instar nymphs of cotton mealybug by different instars and adults of various predatory species of coccinellids varied significantly amongst different life stages of four predatory beetles. The predatory potential in term of total consumption of fourth instar (> 200) of all evaluated predatory species of coccinellids was maximum and significantly different from that of other life stages; however, fourth instar of *C. septempunctata* showed significantly the maximum predatory potential (> 250 nymphs) followed by that *H. convergens*, *M. sexmaculatus* and *B. suturalis*. The third instar grubs of *M. sexmaculatus* and *B. suturalis* registered significantly higher total consumption (>100 but < 150 nymphs) than third instar grubs of *C. septempunctata* and *H. convergens,* which consumed first instar nymphs of mealybug statistically similar (nonsignificant) to those consumed by adults of all evaluated predatory species (> 80 but ≤ 110 nymphs). The predation in term of total consumption of adults of all predatory coccinellid species was found nonsignificant. The predatory potential in term of total consumption of first and second instar grubs of evaluated predatory coccinellid species, except second instar of *B. suturalis*, was found nonsignificant but significantly lower (< 50 nymphs) than all other life stages of all predatory beetles (Fig. 1a).

Per-day consumption

Per-day consumption of first instar nymphs of mealybug by different instars and adults of various predatory species of coccinellids varied significantly amongst different life stages of four predatory beetles. The predatory potential in term of per-day consumption of fourth instar of all evaluated predatory species of coccinellids ranged from 37 to 46 nymphs, being significantly higher in *H. convergens* and lower in *M. sexmaculatus*; however was found significantly different from that of other life stages. The third instar grubs of all evaluated predatory coccinellid beetles registered per-day consumption in the range of 30-33 nymphs, being nonsignificantly higher in third instar grubs of *C. septempunctata* and lower in third instar grubs of *B. suturalis*. The predation in term of per-day consumption of second instar grubs and adults of all predatory coccinellid species ranged from 22-26 nymphs, being nonsignificantly higher *C. septempunctata* and lower in *B. suturalis* in case of adults; whereas, being nonsignificantly higher in *B. suturalis* and lower *H. convergens* in case of second instar grubs. The predatory potential in term of per-day consumption of first instar grubs of evaluated predatory coccinellid species was found nonsignificant but significantly lower (< 15 nymphs) than all other life stages of all predatory beetles (Fig. 1b).

Percent consumption

Percent consumption of first instar nymphs of cotton mealybug by adults of all predatory coccinellid beetles, first, second and third instar grubs of *M. sexmaculatus*, *C. septempunctata* and *B. suturalisi* and fourth instar of *B. suturalisi* was found more than 80% and nonsignificant; whereas, the same for first, second, third and fourth instar grubs of *H. convergens* as well as of fourth instar grubs of *M. sexmaculatusi* and *C. septempunctata* were found in the range of >70 but <80% consumption (Fig. 1c).

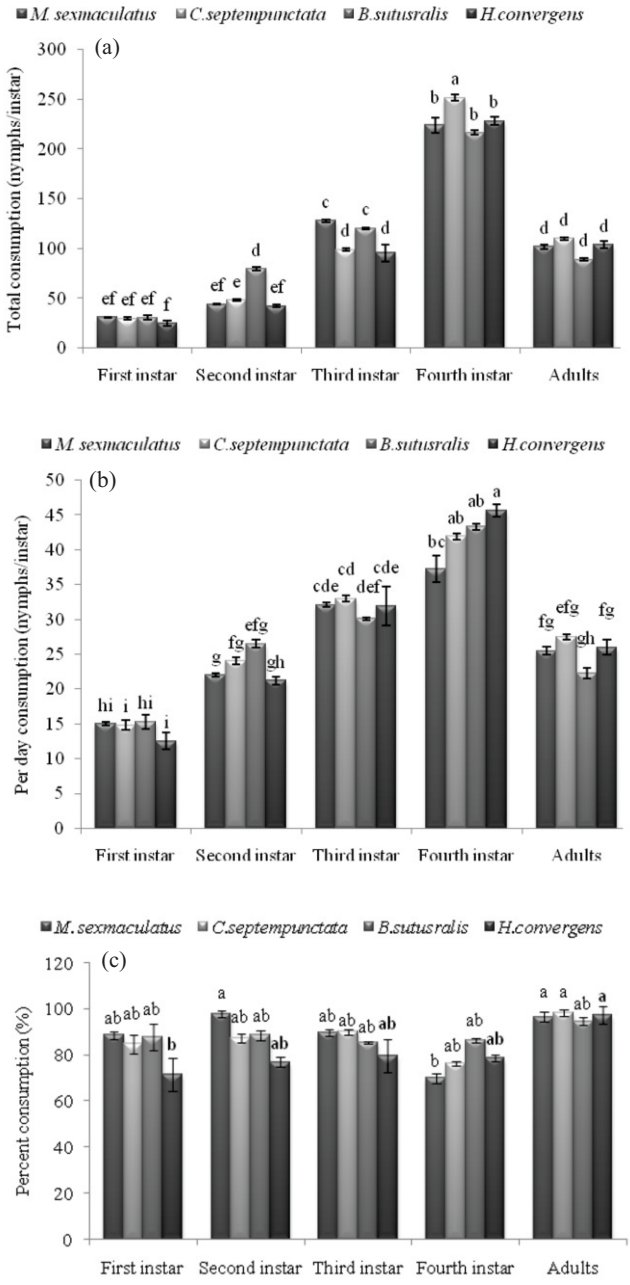

Fig. 1
Total (a), perday (b) and perent consumption (c) (Mean±SE) of first instar mealybug's nymphs by different life stages of four coccinellid predatory beetles during their respective stadium (means of the bars having similar letters donot differ significantly at α =5%).

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Predatory potentials of four coccinellid beetles

A highly significant variation was observed in the total, per-day and percent consumption of first instar of cotton mealybug by *M. sexmaculatus*, *C. septempunctata, B. suturalis*, *H. convergens*. Total consumption ranged from 495 to 538 nymphs/life, being significantly higher in *C. septempunctata, B. suturalis* (both registered nonsignificant variation in total consumption) and lower in *H. convergens*. The per-day consumption was observed in the range of 132-141 nymphs/day, which was significantly higher in *C. septempunctata* and lower in *M. sexmaculatus.* The percent consumption ranged from 87 to 85% nymphs, being significantly higher in *C. septempunctata* and lower in *H. convergens*. In conclusion, all the evaluated predatory species of coccinellids caused more than 80% consumption and contributed significant and prominent role in the consumption of first instar nymphs of cotton mealybug; however, *C. septempunctata* and *B. suturalis* was found better predator as compared to other two species (Fig. 2).

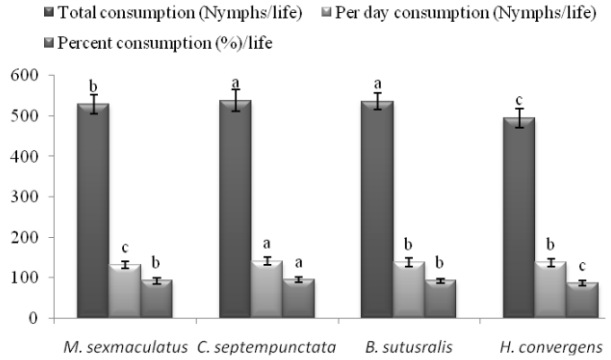

Fig. 2
Total, perday and perent consumption (Mean±SE) of different coccinellid predators during whole of their life cycle (means of the bars having similar letters for same dependent variable donot differ significantly at α =5%).

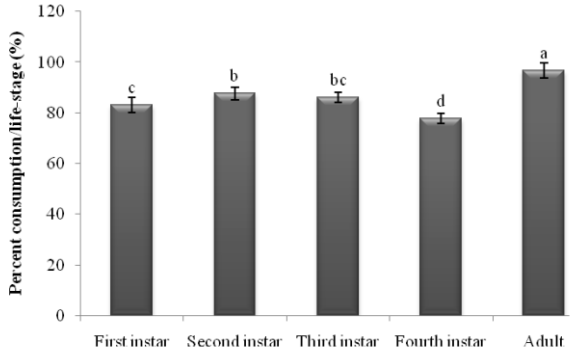

Fig. 3
Percent consumption (Mean±SE) of each life-stage, irrespective of the four coccinellid predatory beetles (means of the bars having similar letters donot differ significantly at α =5%).

Predatory potentials of life stages irrespective of coccinellid species

Significant variation was observed in the predatory potentials in term of percent consumption of five life stages irrespective of their predatory species. Maximum and highly significant predation (percent consumption) was observed by the adult stage (96.7%) followed by that of second (87.6%), third (86.1%), first (81%) and fourth (77.9%) instar grubs of all evaluated predatory coccinellid beetles. The predation of second and third instar grubs was found statistically similar but different from all other life stages (Fig. 3).

DISCUSSION

Predaceous coccinellids are important entomophagous predators of arthropod pests, including whiteflies, aphids, mealy bugs, scales and mites (Obrycki and Kring, 1998) and has been using continuously for decades because of their easy collection. In the present studies, predatory potential of four coccinellid predators including *M. sexmaculatus, C.a septempunctata, B. suturalis, H. convergens* against first instar nymphs of cotton mealy bug, *Phenacoccus solenopsis* were investigated under laboratory conditions. The results showed significant variation in the predatory potential, in term of total, per-day and percent consumption, of four predatory coccinellid species and their instars. The four evaluated predatory species of coccinellids caused more than 80% consumption and contributed significant and prominent role in the consumption of first instar nymphs of cotton mealybug; however, *C. septempunctata* and *B. suturalis*, registering total consumption of 538 and 536 nymphs/life and percent consumption of 95 and 92 %, respectively, was found better predator as compared to other two species. These findings are similar to those of Hagen (1987) who also reported *C. septempunctata* as an important coccinellid species of soft bodied insect pests. According to Rafi *et al.* (2005), *C. septempunctata* may consume several hundred aphids a day. These finding are contradictory to the findings of present studies, where maximum consumption of *C. septempunctata* was found 536-538 nymphs/life. This variation in the predatory potential may be attributed to the difference in prey species used in the studies. The finding of present studies revealed that *M. sexmaculatus, C. septempunctata, B. suturalis, H. convergens* were important predatory beetles against first instar nymphs of cotton mealy bug, *Phenacoccus solenopsis*. Rafi *et al.* (2005) also reported *B. suturalis, M. sexmaculatus* and *C. septempunctata* as important predators of sugarcane pyrilla in NWFP. The results of Dreistadt and Flint (1996) who documented convergent lady beetles, *H. convergens* (Coleoptera: Coccinellidae), as a popular choice for aphid control also confirm the results of present findings. The finding of Tanwar *et al.* (2007) that coccinellid beetles such as *C. sexmaculata* (Fabricius), *Rodolia fumida* Musant, *Scymnus coccivora* Aiyar and *Nephus regularis* (Sicard) asare important predators of mealybug nymphs also confirm the finding of present studies that coccinellids species are potential biocontrol agents for

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cotton mealybug. All the life stages of four predatory coccinellid species performed well registering more than 80% consumption of first instar nymphs of cotton mealybug, except fourth instar grubs (77.9% consumption); however, adult stage was found more effective predatory stage as maximum and highly significant predation (percent consumption) was registered by this stage (96.7%). This variation in the predatory potential of varius life stage of all predatory coccinellid species may be attributed to variation in their diet requirements. Second, third and first instar grubs of all evaluated predatory coccinellid beetles showed 87.6, 86.1 and 81% consumption, respectively. The maximum predation by adult stage may be due tyo the fact that logevity of this stage is more as compared to other life stages of evaluated coccinellid species. Similarly, this stage, especially female adults, required more food to perform their routine activities like searching food, mate, shelter, etc. as well for the oogenesis, spermatogenesis and maturation of eggs in respective sex. In conclusion, all the predaceous life stage (four instars and adults) of *M. sexmaculatus, C. septempunctata, B. suturalis, H. convergens,* especially *C. septempunctata, B. suturalis,* were found potential predaceous stages/predator for first instar nymphs of cotton mealybug and hence, should be evaluated in the fields for their potential effectiveness when used alone or in combination with other IPM tactics.

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