REPRODUCTIVE BEHAVIOUR OF TWO APHIDOPHAGOUS LADYBEETLES, *CHEILOMENES SEXMACULATA* AND *COCCINELLA TRANSVERSALIS*

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Abstract Reproductive behaviour of two aphidophagous ladybeetles, *Cheilomenes sexmaculata* and *Coccinella transversalis* was studied. A premating period of 5.0±0.5 and 11.7±0.4 days and a pre-oviposition period of 5.5±0.7 and 12.7±0.5 days was observed for *C. sexmaculata* and *C. transversalis*, respectively. Males of both the species exhibited courtship in five steps, *viz.* approach, watch, examine, mount and attempt. Sexually immature, recently mated and ovipositing females rejected male advances in both the species. Chemical, visual and behavioural cues probably play a role in mate recognition. Quiescent mating occurred in *C. sexmaculata*, whereas abdominal shakings in the form of bouts and strokes were characteristic in *C. transversalis*. *C. sexmaculata* had a relatively prolonged mating duration (133.4±8.9 min) than *C. transversalis* (37.9± 2.0 min), possibly due to the absence of active processes, *i.e.*, bouts and strokes. The active processes in *C. transversalis* decreased with multiple matings in a day. Unmated adults of both the species mated more vigorously than the mated ones. Reproductive performance of both the species was best after multiple matings.

Key words *Cheilomenes sexmaculata, Coccinella transversalis,* reproduction, courtship, mating

1 INTRODUCTION

Investigations on the sexual activities of predaceous coccinellids are of immense practical relevance as they aid mass multiplication (Hodek and Ceryngier 2000). These sexual activities can be discriminated into mate recognition, courtship and mating. Certain studies implicate the role of chemical and visual cues in mate recognition (Hemptinne *et al.* 1996, Omkar and Srivastava 2002). However, in *Adalia bipunctata* (Linnaeus), the behavioural cues such as, immobility of the female on being stroked by the male and raising of abdomen, are

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*Address for correspondence: Dr. Omkar, Reader, Ladybird Research Laboratory, Department of Zoology, University of Lucknow, Lucknow-226007, India, Ph. No. 0091-0522-2740382, Email: omkaar55@hotmail.com important for initiation of mating (Hemptinne *et al.* 1998). Prominent courtship is a feature in a few predaceous coccinellids, which culminates in mating (Obata 1987, Obata and Johki 1991, Maisin *et al.* 1997, Omkar and Srivastava 2002). Mating behaviour in predaceous coccinellids has been investigated poorly in the past with only a single study on the comparative behaviour of the mating process in four ladybeetles (Obata and Johki 1991). Hence, more comparative studies are needed to relate various patterns involved in mate-recognition, courtship and other sexual activities.

Cheilomenes sexmaculata (Fabricius) and *Coccinella transversalis* Fabricius are two such aphidophagous coccinellids of Indian subregion, which are commonly found in the agricultural and horticultural fields preying on aphids. Earlier, major investigations have been made on their ecology, including their interactions with prey community (Bind, 1998; Agarwala and Yasuda, 2000; James, 2001) with meagre emphasis on their reproductive activities. Hence, present investigations were designed to generate empirical data on comparative account of the sexual activities of these two most commonly occurring and economically important ladybeetles.The difference in sizes of the two ladybeetles sharing common prey habitat was a major reason for their selection as models as it was felt that a good overview of difference in behaviour and responses, if any, would be obtained. In the present study, sexual maturation period, pre-mating-, mating- and post-mating-behaviours, mate recognition cues, influence of sexual status of individuals and number of matings on oviposition period, fecundity and hatchability have been studied.

2 MATERIALS AND METHODS

2.1 Feeding and Rearing conditions

Ladybeetles, *C. sexmaculata* and *C. transversalis* were provided with *ad libitum* supply of their preferred aphids, *Aphis craccivora* (on *Dolichos lablab* twig) and *Aphis gossypii* (on *Lagenaria vulgaris* leaf), respectively, as has been determined previously (Omkar and Bind 2004, Omkar and James 2004), in both stock cultures and experimental setups at 25±2°C and R.H. 65%±5%.

2.2 Pre-mating and pre-oviposition periods

Newly emerged adults of *C. sexmaculata* and *C. transversalis* were sexed and kept separately in glass Petri dishes (9.0 × 2.5 cm) (conditions as above). The adults were paired daily at 1 000 hrs and separated at 1 800 hrs. Ten pairs were observed continuously over this period (selected as per convenience), for the establishment of a genital connection, after which they were de-paired till the next day when the same pairs were reformed. After mating the female was isolated and time of first oviposition recorded. Since, recent studies indicate that mating is a male-dominated phenomenon and that mature unmated males can force females to mate (Pervez 2002), the criteria of maturity in the present study was taken as pre-mating periods in males and pre-oviposition periods in females.

2.3 Courtship and mating behaviour

Seven-day-old unmated adults of *C. sexmaculata* and 12-d-old unmated adults of *C. transversalis* of both the sexes, which were isolated after emergence, were kept in glass Petri dishes (9.0 × 2.5 cm.) to observe courtship and mating behaviour patterns under a binocular stereoscope (at 16 and 40× magnifications). All the observations in this experimental subset were made in ten replicates.

2.4 Mate recognition

Five different mating models (dummies) were provided to unmated males to study the cues, which help in mate recognition. For the purpose, a 7-d-old unmated *C. sexmaculata* male and a 12-d-old unmated *C. transversalis* male were introduced in Petri dishes containing models in the centre. The models were: (i) freshly dead conspecific female, (ii) 1-d-dead conspecific female, (iii) freshly dead conspecific male, (iv) one-month-old dead and frozen conspecific female (at −10°C), and (v) freshly dead heterospecific female; *Propylea dissecta* in case of *C. sexmaculata* and melanic *Coccinella septempunctata* for *C. transversalis* because of their physical resemblance. Models (i), (iii) and (v) were prepared by placing cotton swabs dipped in 70% alcohol on their heads till they died. The male behaviour was studied under a binocular stereoscope (at 16 and 40 × magnifications). Ten observations were made for each model and a new male used each time.

2.5 Effect of previous matings

To observe the effect of sexual status of male and female on the duration of copulation, four different combinations of male and female ladybeetles were made and these pairs were: (i.) unmated male and virgin female, (ii.) mated male and virgin female, (iii.) unmated male and mated female, and (iv.) mated male and mated female. The mated males and females selected for the investigations were mated thrice previously. Five replicates were observed for each combination.

2.6 Effect of multiple matings

To record the effect of one, two and multiple matings (five matings) on the oviposition period, fecundity and percent hatching, male and female ladybeetles were kept separately after emergence until the age of 7 days for *C. sexmaculata* and 12 days for *C. transversalis* and then allowed to mate only once, twice or five times. The ladybeetles were separated daily after a single mating and the same pair reformed the next day for the next mating(s), wherever required. The females were maintained and observed for their entire lifetime after mating to conclusively determine their oviposition period and fecundity. All the eggs were incubated and observed till hatching to calculate percent hatching. The observations were made in ten replicates.

The data were analyzed using one-way ANOVA and the comparison of means was done using Bonferroni's method using the software "Statistix-4.1" on PC.

3 RESULTS

3.1 Pre-mating and pre-oviposition periods

A pre-mating period of 5.0±0.5 days in *C. sexmaculata* and 11.7±0.4 days in *C. transversalis* after emergence was recorded (Fig. 1). A difference in the pre-mature copulatory attempts by the immature males of two coccinellid species was observed. Immature males of *C. sexmaculata* attempted to court the females (1–3 times), however, they failed to establish genital contact. Conversely, the males of *C. transversalis* did not make any courtship attempts when immature. The immature females of *C. sexmaculata* rejected the advances of immature males by either running away from the male or by shaking her abdomen. Receptive females stopped walking and slightly raised the tips of their abdomens. The pre-oviposition periods of *C. sexmaculata* and *C. transversalis* were 5.5±0.7 and 12.7±0.5 days, respectively (Fig. 1).

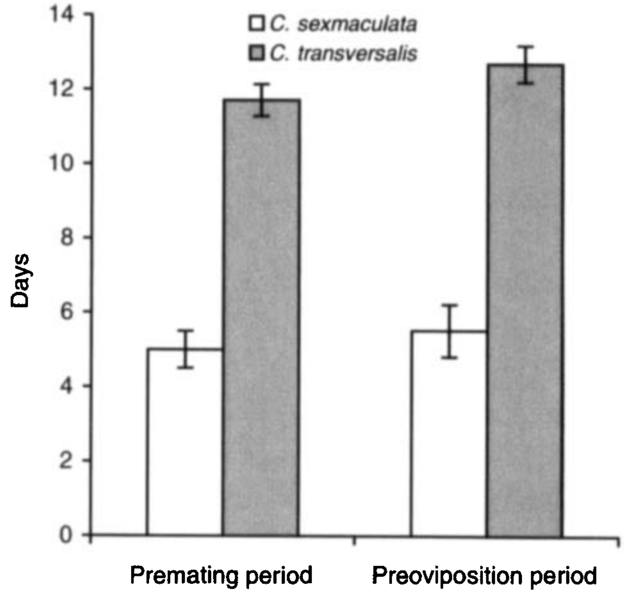

Fig. 1 Pre-mating and pre-oviposition periods of *Cheilomenes sexmaculata* (*Cs*) and *Coccinella transversalis* (*Ct*).

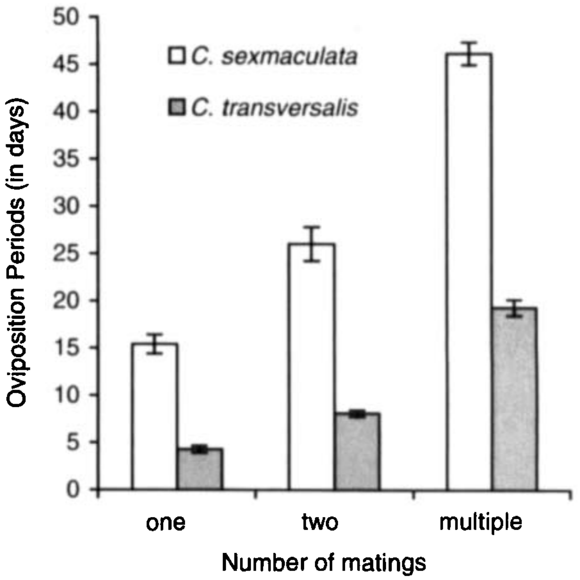

Fig. 2 Influence of number of matings on oviposition of period of *Cheilomenes sexmaculata* (*Cs*) and *Coccinella transversalis* (*Ct*).

3.2 Courtship and mating behaviour

The sexually mature males of *C. sexmaculata* and *C. transversalis* displayed similar patterns of courtship behaviour. The male initiated courtship as he approached the female ladybeetle from a distance of about 1-0.5 cm, contacted and examined by tapping/touching her antennae with his own. In the course of examination he also tapped the female elytra by his forelegs. During mating, the male mounted over the elytra of female, gradually moved posteriorly and inserted his aedeagus into the genitalia of female beetle. The male held the elytra of female with its fore- and middle legs, whereas the hindlegs were kept at substratum. Occasionally, the male beetle rubbed the elytra of female with his mouthparts and forelegs. Sometimes, the female slowly moved ahead. Pairs were usually observed mating at substrata that allowed elevation of female abdomen. In males, two slender unjointed accessory copulatory organs, the parameres (one on either side of the aedeagus) having fine hairs, were observed vibrating continuously on the ventral surface of the female abdomen during copulation.

A prominent difference in the mating patterns of males of both the species was observed. *C. sexmaculata* showed quiescent matings while the adults of *C. transversalis* mated actively. In *C. sexmaculata* the males did not show much movement except for the occasional stroking of the female's elytra with his mouthparts and forelegs. On the contrary, in *C. transversalis* the mating posture was maintained as such for only a certain period of time, which is known as the *latent period,* after which, the male started lateral body shakings (*bouts*), comprising of a number of *units.* During bouts, the male gripped the female by first two pairs of legs and the hindlegs were placed on the substratum for support and balance. A rhythmic pattern of bouts was observed in the entire course of mating with a brief period of rest (*interval*). Up and down body movements (*strokes*), were also noticed between the bouts.

Prominent mating termination displays were observed in both the species. The females either kicked away the males with their hindlegs to terminate mating or her increased movement was sufficient for dislodging the males. Occasionally, the females of both the species dropped down from the side or upper surface of the Petri dishes, thereby terminating the mating. After separation, both the males and females rubbed and cleaned their mouthparts and antennae with the help of their forelegs. No ejection of spermatophore was observed after the termination of the mating in both the species.

3.2 Mate recognition

When the males of *C. sexmaculata* and *C. transversalis* were provided with different dummies, the behaviour of males of both species differed towards the mating models. When sexually mature unmated males of *C. sexmaculata* and *C. transversalis* were kept with freshly dead conspecific females, they approached the dead female bodies, watched from the sides and examined them by touching their mouthparts and antennae. Thereafter, they climbed over the abdomen of the dead females and tried to establish the genital contact. In the process, they made a few (ranging 3–10) unsuccessful mating attempts. After 10–25 seconds, they descended down from the elytra of females after having failed to establish the genital contact and moved away.

When mature unmated males of both the species were kept with 1-d-dead females, the males watched, examined and thereafter climbed over the abdomen of the dead females. But, after 1–2 unsuccessful mating attempts, they descended and moved away within 5–20 seconds. When freshly dead conspecific males were provided as models, the live males of both species turned the direction of movement but did not come close to the models and maintained distance (2 cm). When dummies of one-month-old frozen conspecific females and freshly dead heterospecific females were provided as mating models, the males watched and examined them, but did not make copulatory attempts.

3.3 Effect of previous matings

A prominent decrease in the mating duration from the mating between unmated male and virgin female to the mating between once mated male and females in both the species was observed. The mating duration was maximum when unmated individuals copulated and minimum in case of mating between previously mated individuals in both the species. The mating durations in case of matings between unmated individuals, unmated male and mated female, mated male and virgin female and mated individuals in *C. sexmaculata* and *C. transversalis* varied significantly. The differences in the mating durations in different mating conditions were statistically significant in the two ladybeetles, *C. sexmaculata* ($F = 767.57$; $P < 0.001$, df $= 9$) and *C. transversalis* ($F = 49.52$; $P < 0.001$, df $= 9$) (Table 1). The individuals of *C. sexmaculata* mated longer than *C. transversalis.* Other than the pronounced significant effect on the mating duration ($F = 49.52$; $P < 0.001$, df $= 9$) in *C. transversalis*, the latent period ($F = 14.17$; $P < 0.001$, df$=9$), interval ($F = 27.78$; $P < 0.001$, df$=9$), units per bout ($F = 6.10$; $P < 0.01$, df$=9$) and number of bouts ($F = 56.59$; $P < 0.001$, df$=9$) also differed significantly with the change in sexual status of mating individuals (Table 1). The mating duration, number of bouts and units were highest in case of mating between unmated male with virgin female and lowest in case of mated male with mated female, while the data on latent period and interval showed a vice-versa trend. The comparison of change in male and female status of both the ladybeetles reveals prominence of male sexual status in determining the duration of mating (Table 2).

Table 1 Influence of sexual status on the copulation period of *Cheilomenes sexmaculata* (*Cs*) and *Coccinella transversalis* (*Ct*) and latent period, interval, units and number of bouts of the latter.

Mating	*Cs*	*Ct*	*C. transversalis*			
combinations	Copulation period (in min.)		Latent period (in sec.)	Interval (in sec.)	Units/Bout during copulation	No. of bouts during copulation
Unmated male × Virgin female	133.4 ± 2.8^{a}	37.9 ± 2.0^{a}	4.8 ± 0.3^{a}	2.6 ± 0.1^{a}	4.4 ± 0.1^{a}	184.8 ± 6.9^{a}
Unmated male × Mated female	122.3 ± 2.7^{b}	33.1 ± 0.6^{b}	5.1 ± 0.4^{a}	3.1 ± 0.3^{b}	4.1 ± 0.1^{a}	169.0 ± 0.7^{ab}
Mated Male × Virgin female	111.4 ± 2.2^{c}	20.9 ± 1.2^{bc}	7.2 ± 0.5^{b}	3.4 ± 0.1^{b}	3.9 ± 0.1^{ab}	158.6 ± 4.8^{bc}
Mated male × Mated female	94.6 ± 4.2^{d}	17.2 ± 1.5^{c}	7.6 ± 0.6^{b}	$3.7.\pm0.1^{bc}$	3.8 ± 0.1^{b}	155.5 ± 5.8^{c}
F-value	767.57*	49.52*	14.17*	27.78*	6.10**	56.59*

Values are Mean ± S.E.

* and ** denote values significant at $P < 0.001$ and $P < 0.01$, respectively.

Same alphabet in the column denotes data not to be statistically significant

Table 2 Influence of sexual status of *Cheilomenes sexmaculata* (*Cs*) and *Coccinella transversalis* (*Ct*) on the mating durations.

S. No.	Sexual Status		Mating Durations	
			Cs	*Ct*
1	Unmated male × Virgin female	Unmated male × Mated female	$F = 141.86$ $P < 0.001$	$F = 5.43$ N.S.
2	Unmated male × Virgin female	Mated male × Virgin female	$F = 633.06$ $P < 0.001$	$F = 54.90$ $P < 0.001$

3.4 Effect of multiple matings

The oviposition period, fecundity and percent hatchability varied in relation to different number of matings and were found to be maximum in the case of multiple matings and minimum when single mating took place in *C. sexmaculata* and *C. transversalis.* The oviposition periods when subjected to one, two and multiple matings in case of *C. sexmaculata* were 15.4 ± 1.0, 26.0 ± 8.6 and 46.1 ±1.2 days ($F = 505.76$; $P < 0.001$, df = 9), respectively. When *C. transversalis* was subjected to one, two and multiple matings significant difference in oviposition periods was seen, which were 4.3 ± 0.4 days, 8.1 ± 0.4 and 19.3 ± 0.9 days ($F = 188.51$; $P < 0.001$, df = 9), respectively (Fig. 2).

Fecundity of *C. sexmaculata* varied significantly after one, two and multiple matings, which were 69.8 ± 2.7, 123.2 ± 5.0 and 860.7 ± 2.2 eggs ($F = 415.96$; $P < 0.001$, df = 9), respectively. Fecundity on being subjected to one, two and multiple matings in case of *C. transversalis* was 59.1 ± 2.2, 136.9 ± 6.7 and 541.8 ± 21.0 eggs ($F = 179.63$; $P < 0.001$, df = 9), respectively (Fig. 3).

Hatching percent after one, two and multiple matings was 37.2 ± 2.3, 42.0 ± 3.2 and 64.3 ± 1.3 ($F = 50.21$; $P < 0.001$, df = 9) in *C. sexmaculata* and 74.4 ± 1.4, 84.4 ± 1.5 and 93.1 ± 1.1 ($F = 300.70$; $P < 0.001$, df = 9) in *C. transversalis*, respectively (Fig. 4). Thus, the values of oviposition period, fecundity, and hatching percent were highest after multiple matings and lowest after a single mating in both the ladybeetle species.

4 DISCUSSION

4.1 Pre-mating and pre-oviposition periods

Adults of *C. transversalis* took more time to mature as compared to those of *C. sexmaculata.* This can probably be attributed to the species. The time interval required for elytral hardening may also be responsible for the presence of a pre-mating period (Hodek per. comm., Omkar and Srivastava 2002). The increased willingness of immature *C. sexmaculata* males towards females may perhaps be attributed to their relatively smaller size and thus greater activity. A prominent incidence of mating refusals by the immature females towards the premature mating attempts of male *C. sexmaculata* may be ascribed to the immature state of their gonads. Similar observations were also recorded in a similar study on *C. septempunctata* (Omkar and Srivastava 2002).

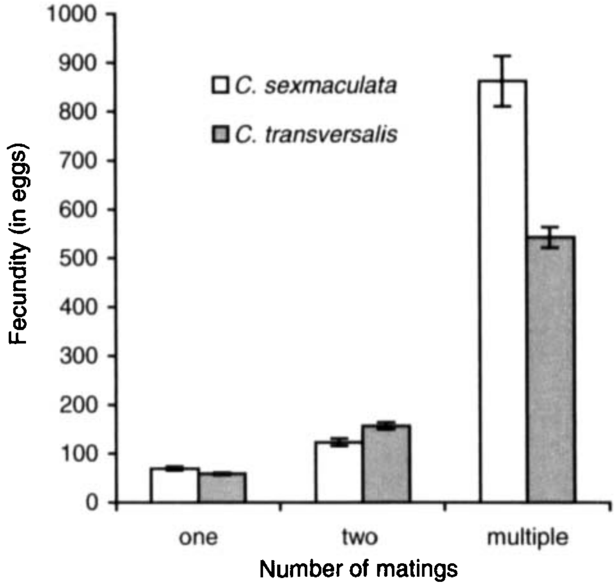

Fig. 3 Influence of number of matings on fecundity of *Cheilomenes sexmaculata* (*Cs*) and *Coccinella transversalis* (*Ct*).

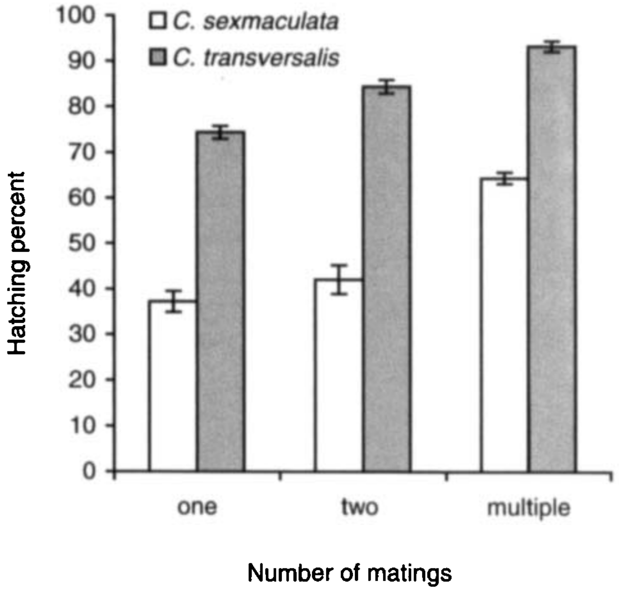

Fig. 4 Influence of number of matings on hatching percent of *Cheilomenes sexmaculata* (*Cs*) and *Coccinella transversalis* (*Ct*).

4.2 Courtship and mating behaviour and cues involved in mate recognition

The male is relatively smaller and more active individual than the female and dominates the courtship display. The male is probably stimulated by the chemical releases of the female ladybeetle in the microcosm they inhabit. The males of *C. sexmaculata* and *C. transversalis* exhibited five steps of courtship towards their respective females owing to the probable presence of chemicals on her body surface (Obata 1987). A prominent difference in mating behaviour of the two species was evident. Active processes, such as bouts and strokes, were characteristic in *C. transversalis*, while the mating in *C. sexmaculata* was more or less quiescent. No ejection of spermatophore was noticed after the termination of mating in either of the species. The process of sperm transfer in *C. sexmaculata* has in a previous study been observed to start soon after genital contact without formation of spermatophore (Obata 1987). The ejection of spermatophore was prominent in *C. septempunctata* (Omkar and Srivastava 2002).

The female terminated mating by kicking away the male with her hindlegs after pronounced period of mating, which suggests that the female initiates the termination of mating possibly after her satiation, as has also been pointed out by Wang *et al.* (1990). The observations suggest that the female also exhibits rejection display at the times when she was not sexually mature, had recently mated or was about to oviposit. Similar observations in ladybeetles have also been reported earlier (Majerus 1994, Omkar and Srivastava 2002).

Males of both the species actively responded to the presence of a freshly killed female by exhibiting the various steps of courtship and even attempting mating perhaps because of their stimulation owing to the presence of certain olfactory cues emanating from the female. The mating attempts by the males may be attributed not only to the presence of visual and possible chemical cues but also to the presence of behavioural cues, such as stillness of female and raising of abdomen as reported in *A. bipunctata* which plays a role in male stimulation (Hemptinne *et al.* 1998) The courtship display by both the males was relatively less pronounced when kept with one-day-old dead female. This can be attributed to the probable waning presence of chemicals. The presence of chemical factor as a key stimulus triggering male response secreted and released by potential female mates and the presence of olfactory receptors on the antennae of beetles have also been suggested earlier (Wang *et al.* 1991). This view is further strengthened by the observation that the male touches the antennae of the female with his own during the courtship. Other than the perception of chemical cues released by the female, the male possibly recognizes the species-specific alkanes present on the cuticular surface (Hemptinne *et al.* 1998) through antennal contact. These alkanes might also be sex specific. Though, courtship appears to be male dominated, it is initiated by the release of chemical cues by the females as also the termination of mating is female dependent.

Males of both the species performed similar courtship display in the presence of long (one month) frozen dead conspecific as well as freshly dead heterospecific females. Their courtship displays were limited to only watch and examine probably due to the weakening/ absence of chemical signals. The slight discolouration of the one-month frozen female might also be responsible for the limited display. The reluctance of male to approach the freshly dead conspecific male may possibly be ascribed to the absence of conspecific olfactory signals. Visual cues may have a role in the reluctance displayed by *C. transversalis* male towards *C. septempunctata* and *C. sexmaculata* towards *P. dissecta* used as dummies. The visual cues have a lesser role can be suggested by the observation that the male *C. sexmaculata* also consistently ignored the dead conspecific male that is similar in appearance to the female of the species. The stillness of the models is also known to play a role in determining the response of the males (Hemptinne *et al.* 1998).

The absence of copulatory attempts in case of one month frozen dead female of *C. sexmaculata* may be attributed to the absence of attractant chemical and disfigurement due to the freezing process. These observations led to the conclusion that the male ladybeetle recognizes the potential mate with the help of chemical and visual cues. The major role appears to be the chemical cues since the final steps of mounting and copulatory attempt are not exhibited in the possible absence of attractant chemicals. Similar observations were also reported in *H. axyridis* (Obata 1987).

4.3 Effect of previous matings

Similar results for both the species in relation to unmated and previously mated individuals reveal that mating duration was maximum when unmated adults copulated and minimum when previously mated adults copulated. This indicates that the unmated ladybeetles copulated more vigorously in comparison to mated ones. The present results are in conformity with the findings on *H. axyridis* (Obata 1987).

The longest mating duration when unmated males copulated may also be attributed in part to the unfamiliar situation and the degree of mate deprivation, as also recorded in the case of pale morph of *P. dissecta* (Omkar and Pervez, unpublished data). Unmated males in other ladybeetles are known to provide greater quantity of ejaculates (Savalli and Fox 1999). This might be a reason for the longer mating duration and delayed initiation of termination of mating by the females due to the possible higher fitness of levels of unmated males.

The shorter mating duration of *C. transversalis* was probably associated with the vigorous mating activity, involving active processes (bouts and strokes). This tremendous activity is performed at the cost of high-energy consumption, which probably limits the mating duration, owing to early exhaustion and energy consumption. Conversely, the mating in *C. sexmaculata* was a quiescent type, with probable lesser energy requirements and hence resulted in increased mating durations.

4.4 Effect of multiple matings

The lower oviposition period, fecundity and hatching percent in response to a single mating could be because of three possible reasons: (1) the amount of sperm provided by the male may be limited, (2) the female's ability to store sperm may be limited, and/ or (3) the sperm may lose their viability over time in the spermatheca. A single mating seems to act as oviposition stimulus though the stimulus is for the short term and repeated matings are required to obtain a long and continuous oviposition. On the contrary, a single mating acts as a potent oviposition stimulator in the pale morph of *P. dissecta* (Omkar and Pervez, unpublished data). Except for the hatching percent, which was greater in *C. transversalis,* other parameters, *viz.* fecundity and oviposition period, were greater in *C. sexmaculata* when subjected to multiple matings. The more prominent response to multiple matings by *C. sexmaculata* may also be an adaptation to the interspecific competition in nature as immature stages are more vulnerable owing to their small size. High fecundity and egg viability, as an outcome of multiple matings were also recorded in other ladybeetles, *C. montrouzieri* (Kaufmann 1996), and *C. septempunctata* (Omkar and Srivastava 2002), as the quantity of sperm after single mating may not be sufficient for the fertilization of the entire ova (Lawrence 1990).

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二种食蚜瓢虫 *Cheilomenes sexmaculata* 和 *Coccinella transversalis* 的生殖行为

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在实验室中对二种食蚜瓢虫， *Cheilomenes sexmaculata(Cs)* 和 *Coccinella transversalis(Ct)* 的生殖行为进行了研究。观察发现 *Cs* 和 *Ct* 交配前期分别为 5.00 ± 0.50 和 11.70 ± 0.43 天，而产卵前期则分别是 5.51 ± 0.7 和 12.67 ± 0.49 天。两种雄蛾的求偶行为表现出五个阶段，即靠近、观察、检查、伪装及交配尝试。性不成熟的、近期交配过且正在产卵的两种雌蛾会拒绝雄蛾的进一步行为．化学的和视觉的行为似乎在配偶识别中扮演一个角色． *Cs* 交配相对地平静，而 *Ct* 的腹部摇动和敲击是特征。与 *Ct* 交配时间 (37.90 ± 1.99 分钟) 相比， *Cs* 相对地延长的交配期间 (133.43 ± 8.87 分钟)，可能与缺少腹部来回摇动和敲击这些活跃的过程有关。经历了一天的多次交配后， *Ct* 的交配的活跃程序减少了．两种未交配过的瓢虫在交配过程中比使那些已交配过成虫显得精力更充沛．两种瓢虫的生殖表现在多次交配中得以改善．

关键词　*Cheilomenes sexmaculata*quad *Coccinella transversalis*　生殖　求偶　交配