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Biology and feeding potential of *Coccinella transversalis* (Fab.) on cabbage aphid, *Brevicoryne brassicae* (Linn.)

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Abstract
The present investigation was conducted to study the biology and consumption rate of coccinellid predator, *Coccinella transversalis* (Fab.), on cabbage aphid, *Brevicoryne brassicae* (Linn.) in the biocontrol laboratory during 2017-18 at NIPHM, Hyderabad. It was observed that, incubation period, grub period of four instars, pre pupal and pupal period was 2.5 ± 0.53, 15.1 ± 0.74, 1.2 ±0.46 and 3.1 ± 0.32 days, respectively. Oviposition period of female was 13.0 + 1.33 days with average fecundity of 205.2 ± 30.11eggs. 4th instar grubs consumed significantly more aphids when compared to 1st, 2nd and 3rd instars. Predation rate of grub (total grub period) and adult was 75 - 84 and 48 - 50 aphids/ day. Total consumption of aphids during 1st to 4th instar grub stage was 268 to 329 aphids and 2352 to 2450 aphids. *C. transversalis* consumed total of 2695 to 2773 aphids during its total life period from grub to adult.

Keywords: *Coccinella transversalis*, *Brevicoryne brassicae*, biology, feeding potential

1. Introduction
Coccinellidae form an important group of predators. More than 4,500 predacious species of Coccinellidae family have been described [1]. Indian coccinellid biodiversity comprises of approximately three hundred species with two hundred sixty one species of known prey record constituting fifty seven genera, which are predacious on various insect and acarine pests [2]. The ladybird beetles have been known worldwide as a predator of a number of insects. They are distributed in many countries of Asia, including India [3]. They are the most commonly known of all beneficial insects. They are the great economic important as predaceous both in their larval and adult stages on various important crop pests such as aphids, coccids and other soft bodies insects including aphids [4]. While the species *C. transversalis* feed on many species of aphids [5]. This predaceous Coccinellidae is also found in association with those insects infesting beans, cotton, mustard, brinjal, groundnut and cabbage [6]. The aphid is one of the most destructive pests and its distribution is worldwide. Both adult and nymphs cause damage by sucking the sap from the flowers, buds, pods, tender shoots and reduce the market value of the product [7]. The cabbage aphid, *Brevicoryne brassicae* (Linn.), is one of the most important insect pests of the family Aphididae. The cabbage aphid, *B. brassicae* are grayish-green with a waxy covering that gives them a grayish-white appearance. They have short siphunculi. Adults are present in both wingless and winged form. However, wingless females producing live young (nymphs) are the most common. It is one of the most serious sucking pests of brassica plants [8, 9] Investigated the larval voracity and development of this predator feeding on *Aphis gossypii* infesting cotton. The aphid infestation not only deteriorates the quality of the crop, but also decreases the yields. Direct injury results in loss of plant vigour and stunted growth and indirectly the honey dew excreted by the aphids and sooty mold hinder the growth of the plants. These insects transmit cauliflower mosaic, blacking spot of cabbage and cabbage viruses A& B [10]. Predatory Coccinellidae play a major role in keeping these aphids under control [11]. Among the different species of predatory Coccinellidae, *Coccinella transversalis* (Fab.) is one of the potential predators against aphids in cabbage ecosystem. The important features of *C. transversalis* includes its wide geographic distribution and host range, tolerance to certain pesticides, enhanced searching ability, voracious larval feeding capacity and easy rearing in laboratory. [12] Reported the predatory efficiency of the larvae of this predator on *Aphis craccivora* Koch. The development and feeding potential of Coccinellidae

varies with the food and the environmental conditions.

The study of the biology of *C. transversalis* on different aphid species would help to use this insect of proper biological control. But the review of biology of *C. transversalis is* limited therefore, the present study was undertaken to determine the biology and predatory potential, feeding behaviour and the larval morphology of grubs and adults of *C. transversalis* on cabbage aphid, *B. brassicae*.

2. Material and Methods

Studies on the biology and feeding potential of *C. transversalis* on *B. brassicae* were conducted at biocontrol laboratory, National Institute of Plant Health Management (NIPHM), Hyderabad during 2017-18. Stock culture of the *C. transversalis* was initiated by collecting large number of adults (male and female) from the cabbage field of NIPHM, Hyderabad. The adults acclimatized under laboratory conditions by rearing for two generations on cabbage aphids before initiating the experiments.

2.1 Host rearing (Cabbage aphid*, B. brassicae*)

The cabbage leaves infested with aphids kept in plastic boxes were supplied as food for *C. transversalis* continuously starting from egg to adult. The leaf stalks of aphid infested cabbage leaves were endowed with water soaked cotton to prevent the drying of leaves.

2.2 Biology of *C. transversalis*

One pair of adults collected from the lab reared *C. transversalis* culture, was released into glass beaker (1000 ml) covered with muslin cloth. Ten such sets were maintained. Each container was provided cabbage leaves infested with aphids. Eggs laid by the female Coccinellidae on leaves or periphery of the jar were collected after 2 to 3 days, by gently brushing with a soft camel hair brush and kept in petri dish to minimize cannibalism among emerging grubs. Aphids were provided daily in each individual petri dish to the predatory grubs until pupation. The adults emerged out from pupae were collected individually and transferred to a glass jar for mating. Newly emerged adults were provided with host (prey) as described earlier. Observations were recorded on total number of instars, duration of each instar, total grub period and pupal period. After the emergence, adults were collected and observed under microscope to differentiate the sex. The total number of eggs laid (fecundity) by each female during its lifetime, the longevity of male and female adults and their sex ratio were also recorded.

2.3 Studies on feeding potential of grubs of *C. transversalis*

Ten newly hatched grubs of *C. transversalis* were obtained from stock culture and kept individually in petri dishes. The grubs were fed individually in petri dish with cabbage aphid. The experiment was replicated 10 times. Required number of prey was provided daily in the morning hours *i.e*. 10, 15, 30 and 40 number of cabbage aphids for I, II, III and IV instar grubs respectively. The number of aphids consumed was checked daily and new aphids were placed as per their requirement. Instar-wise feeding potential of grubs was recorded.

2.4 Feeding potential of adult beetles of *C. transversalis* on *B. brassicae*

To study the prey consumption of adults, newly emerged beetles were collected from the stock culture. Each individual was kept in separate petri dish (5cm) and 50 cabbage aphids were provided in each petri dish. The experiment was replicated 10 times.

Observations on duration of different life stages, feeding potential of the predator were taken as per the methodology followed by [13]. The data obtained in various experiments were analysed as per the ANOVA technique.

3. Results and Discussion

3.1 Morphology of *C. transversalis*

Body of *C. transversalis* was oval in shape, strongly convex dorsally. Head was wider with a pair of prominent compound eyes and frons punctate, clypeus straight. Antenna 11 segmented, last segment enlarged and rounded. The scape is broad, long, twice the length of pedicel. Pronotum was broad and finely punctate. Elytra sparsely punctate, epipleuron was well developed. Coxal line curved and complete femoral line angulate. Legs are well developed and adopted for walking and running. The femora are elongate and shallowly grooved on the ventral side to receive the tibiae at rest. The tibias are slender and numbers of segments are same for all legs in both male and female whereas the tarsus ends with a pair of claws. Tegmen was observed with Y shaped medium lobe long as lateral lobes. Sipho short and curved at base and pointed at apex. Siphonal capsule having inner processes hooked and bifid and external processes broad (Plate 1). It was observed that female body was larger than male.

[14] Observed that The Body somewhat elongated, ventrally black. Head almost inserted, not visible from above. Pronotum black with anterolateral orange spots. Elytra dull orange to yellowish brown, with black spots variably arranged. On each elytron the first irregular patch small; the second patch across elytra large; the third only rounded spots across the elytra, with broad longitudinal black band along the inner junction of elytra. The studies of [15] reported that newly emerged adult of *C. transversalis* was yellow in colour and its permanent central coloration appeared after 3 to 4 h. Body oval and convex with head black, posterior corners with 2 yellowish spots, eyes brownish, antennae are clavate and ll-segmented whereas the mouth parts black in colour. Elytra looks like orange or red with 3 transverse black bands. Legs are black, slender, elongated and provided with short hairs. Ventral surface black with short hairs. Size of the adult varied from 5.43-6.80 mm in length. While [16] reported the morphological characteristics of predator *Coccinella transversalis* in which head black in colour. Pronotum black, anterio laterally orange whereas Scutellum also black and elytra looks dull orange to yellowish brown Black. Their findings were similar to the present findings.

3.2 Biology

Females start laying eggs after 3.3 + 0.48 days of emergence. A single female lays 205.2 ± 30.11 eggs during ovipositional period of 13.0 ± 1.33 days. The incubation period was 2.5 + 0.53 days (Table 1 and Plate 2). This results in corroborate with the [17] who observed 253.85 ±38.76 eggs per female coccinellid and individual female laid a minimum of 173 and maximum of 528 (av. 253.85 ± 38.76) eggs during her duration. Hatching percentage of the eggs ranged from 79 to 93 with an average of 88.19 ± 1.67. Similarly, [18] have reported a hatching percentage of 89.86 at higher prey density. Sex-ratio (M: F) of *C. transversalis* was revealed as 1: 1.32.

The freshly laid eggs of *C. transversalis* were yellowish

orange which gradually became black before hatching. Eggs were spindle shaped, laid in groups containing 17– 25 eggs. During the present studies, *C. transversalis* was observed to pass through four larval instars. The duration of first, second, third and fourth instars completed in 3.0 + 0.67, 3.2 + 0.42, 3.7 + 0.48, 5.2 ± 0.92 days, respectively and total grub period was completed in 15.1 + 0.74 days. [19] Noticed that the larval stage of *C. transversalis* lasted for 10.30 days when fed on *A. craccivora*. Whereas [17] reported that the grub period of first, second, third and fourth instar ranged from 3 to 6, 3 to 6, 4 to 6 and 7 to 9 days with an average duration of 4.73 ± 0.23, 3.93 ± 0.28, 5.13 ± 0.19 and 7.53 ± 0.22 days, respectively. Total grub period was varied from 19 to 23 days with a mean duration of 21.33 ± 0.39 days. The duration of individual instars noticed in present study is in close agreement with the finding of [15] who recorded 4.69, 3.92, 5.00 and 7.69 days duration for first, second, third and fourth larval instar of *C. transversalis*.

The mature 4th instar grub reduced its mobility, stopped feeding and attached to a point to become a pre-pupa. The pre pupal and pupal period was 1.20 + 0.46 and 3.10 + 0.32 days, respectively. The results are in conformity with the [20]. Similar findings noticed from [17] studies which shows that the average pre-pupal and pupal stage lasted for 2.47 ± 0.13 (2 to 3 days) and 8.27 ± 0.15 (7 to 9 days) days, respectively. More or less similar duration of pre-pupae (2.62 days) and pupae (8.6 days) for *C. transversalis* have been recorded by [15].

After the adult emergence, it was observed that female longevity is greater males. Longevity of female and males were 37.0 ± 2.10 and 30.0 ± 1.80 days, respectively. These findings deviated from the results of [15, 20] which recorded that the Average longevity of male and female was 21.13 ± 1.02 and 22.17 ± 1.27 days, respectively. Present findings are similar with the report of [15] deviated from the present finding. They reported that the adult longevity of *C. transversalis* ranged from 38 to 45 days

3.3 Feeding potential of *C. transversalis* on cabbage aphid, *B. brassicae*

The number of cabbage aphids, *Brevicoryne brassicae* consumed by different grub and adult stages of *C. transversalis* were mentioned in the Table 2 and Fig.1

Studies on feeding potential of *C. transversalis* grubs on *B. brassicae* revealed that the mean daily consumption of aphids by their successive instars as 4 to 6, 11 to 13, 20 to 25 and 36 to 40 with average of 5.30 ± 0.67, 12.40± 0.70, 23.30± 1.89 and 38.20 ±1.81aphids respectively. In duration of 2-4 days, first instar of *C. transversalis* consumed total of 10 to 18 aphids with average of 15.20 ± 2.60 aphids meanwhile the 2nd, 3rd and 4th instars consumed 36 to 48,60 to 100,152-185 with average of 39.50 ± 3.81, 86.30 ± 13.71 and 167.30 ± 12.35 respectively. Total consumption in grub stage of *C. transversalis* was 268 to 329 aphids with average of 308.30 ± 32.48 aphids in 14-16 days of grub period. Studies on feeding potentiality of *C. transversalis* adults on *B. brassicae* revealed that the average per day consumption of aphids is 48 to 50 aphids per day with an average of 49.40±0.70 and total consumption of aphids during adult period of 49 to 50 days is 2420.60 ± 34.26. Total feeding potential of *C. transversalis* during its total life cycle of 61 -65 days is 2728.90 ±31.53 aphids. [10] reported that the first instar larvae of *C. transversalis* were less voracious than older instars and reported that the voracity (no. of aphids consumed / 24h) of *C. transversalis* increased in succeeding instars. Fourth instar larva of *C. transversalis* consumed 65.67 apterous adults of *L. erysimi* in 24h and the overall consumption during the entire fourth instar was 252.90 apterous adults.

[11] reported that the relative consumption rate of first, second, third and fourth instar larvae was significantly different on *A. gossypii* (17.11, 35.05, 53.61 and 78.77 nymphs/day), followed by *A. nerii* (5.40, 14.80, 32.70 and 65.03 nymphs/day) and *L. erysimi* (4.0, 9.34, 17.80 and 31.96 nymphs/day) respectively. Similarly, relative consumption rate of *Coccinella transversalis* Fab on *Aphis craccivora* Koch (Homoptera: Aphididae) on field beans In Manipur was studied by [15] whereas a single larva consumed as many as 401 to 736 aphids during its development. Preference for young nymphs may be due to their smaller size and lower numbers of encounters would be necessary to capture the smaller aphids [21].

[2] Observed that the first instar larvae of *C. transversalis* were less voracious than older instars. The voracity (no. of aphids consumed / 24h) of *C. transversalis* increased in succeeding instars. The fourth instar larva of *C. transversalis* consumed 65.67 apterous adults of mustard aphid, *Lipaphis erysimi* in 24h and the overall consumption during the entire fourth instar was 252.90 apterous adults. [22] Reported that *C. transversalis* on average devoured 38.8 *Brevicoryne brassicae* per day with the feeding range of 25-50 aphids per day. Their findings were similar to the present findings.

[11] Adult female and male was higher on *A. gossypii* (145.08 and 121.04 nymphs/day), followed by *A. nerii* (62.93 and 58.27/ nymphs/day) and *L. erysimi* (56.56 and 44.99 nymphs/day), respectively. The difference in the findings may be attributed to change in the host species and the prevailing environmental conditions during the experimental period.

3.4 Feeding behaviour

The mode of feeding of the larvae and the adults was similar; they attack any part of the prey but very often in the soft part of the abdomen. The grubs showed chewing action and the whole prey was consumed. During feeding, the predator held the prey up by raising their head, so that they cannot get any support from the substratum. The gradual increase in the feeding rate of older larvae was due to their increased requirement of food due to their increased size. The larvae and adults exhibited cannibalism in the laboratory. Similar observation was reported by [15]. It is inferred that *C. transversalis* had the long life span and high predatory potential against *B. brassicae* and may be suitable for purpose of utilization in bio control based organic farming promoted by NIPHM.

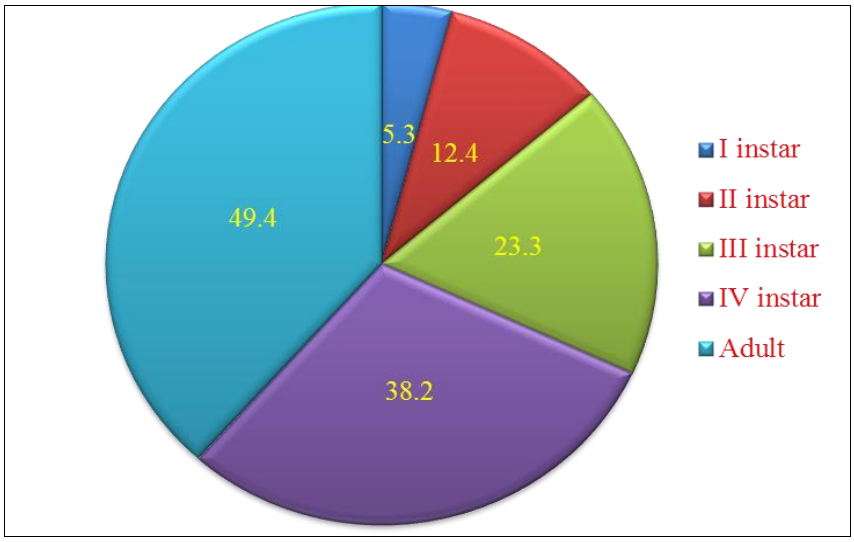
[23] Studied the searching efficiency of a predaceous ladybird beetle, *Coccinella transversalis* Fabricius for brinjal aphid, *Aphis gossypii* Glover reviled that Prey consumption by fourth instar larvae of *C. transversalis* increased significantly. However, there is a lack of information about foraging behaviour of *Coccinella transversalis* Fab. The foraging behaviour and predatory efficiency of Coccinellidae may be affected by many factors including their developmental stage [24].

Table 1: Biology of *C. transversalis* (n = 10)

Stage	Range (days)	Duration (Mean±SD)
Pre oviposition	3-4	3.3 ± 0.48
Oviposition period	12-16	13.0 ± 1.33
Post oviposition	4-6	4.6 ± 0.84
Fecundity	160-252	205.2 ± 30.11
Incubation period	2-3	2.5 ± 0.53
Grub stages		
I instar	2-4	3.0 ± 0.67
II instar	3-4	3.2 ± 0.42
III instar	3-4	3.7 ± 0.48
IV instar	4-6	5.2 ± 0.92
Total grub period	12-18	15.1 ± 0.74
Pre pupal period	1-2	1.2 ± 0.46
Pupal period	3-4	3.1 ± 0.32
Adult longevity		
Female	33-41	
Male	21-39	

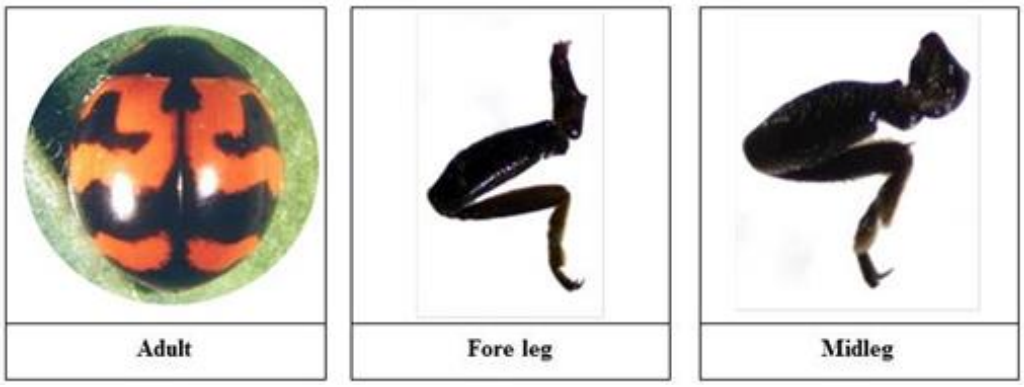
Table 2: Feeding potential of *C. transversalis* on cabbage aphid, *B. brassicae*

Stage	Consumption of aphids/day		Total consumption of aphids	
	Range	Mean±SD	Range	Mean±SD
Grub stage				
I	4 to 6	5.30 ± 0.67	10 to 18	15.20 ± 2.62
II	11 to 13	12.40 ± 0.70	36 to 44	39.50 ± 3.81
III	20 to 25	23.30 ± 1.89	60 to 100	86.30 ± 13.71
IV	36 to 40	38.20 ± 1.81	152 to 185	167.30 ± 12.35
Total	75 to 84	79.20 ± 2.94	268 to 329	308.30 ± 32.49
Adult	48 to 50	49.40 ± 0.70	2352 to 2450	2420.60 ± 34.26
Total life cycle	124 to 133	128.40 ± 6.30	2695 to 2773	2728.90 ± 31.53



a. Aphid consumption per day

Fig 1: Feeding potential of *C. transversalis* on *B. brassicae*



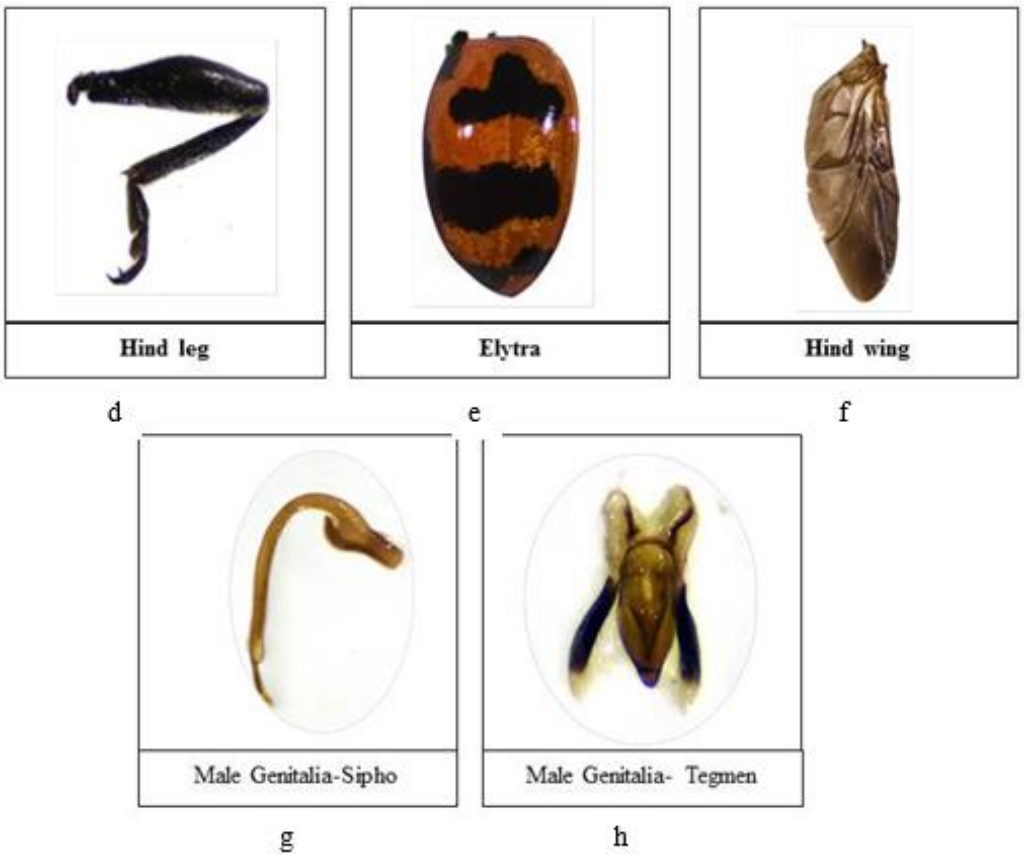


Plate 1: Morphological characters of *C.transversalis* (a) Adult (b) Fore leg (c) Middle leg (d) hind leg (e) Elytra (f) Hind wing (g) Male genitalia- Sipho (h) Male Genitalia Tegmen

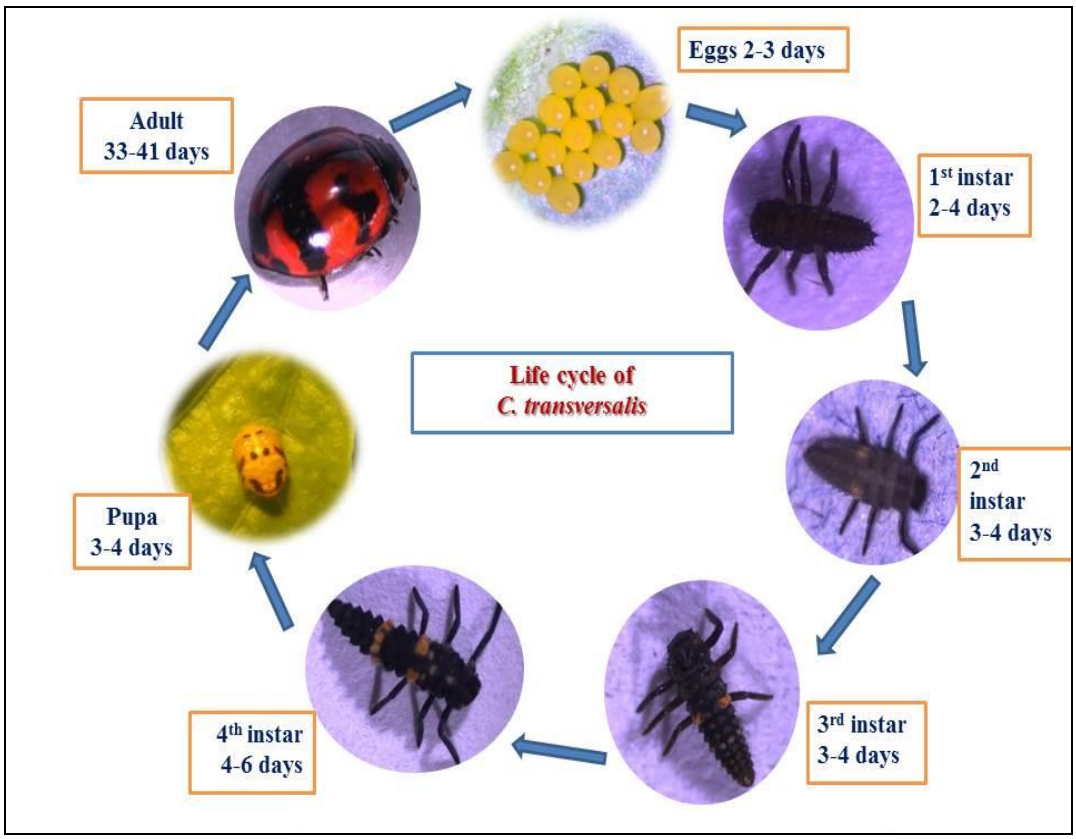


Plate 2: Biology of *C.transversalis* on *B. brassicae*

4. Conclusion

In conclusion, It was observed that, incubation period, grub period of four instars, pre pupal and pupal period was 2.5 ± 0.53, 15.1 ± 0.74, 1.2 ±0.46 and 3.1 ± 0.32 days, respectively. Oviposition period of female was 13.0 + 1.33 days with average fecundity of 205.2 ± 30.11eggs.whereas its high prey consumption rate, *C. transversalis* may play a more effective role in controlling *B. brassicae*. Field studies are needed to

confirm the feeding efficiency and foraging behaviour of how behavior of different life stages of this predators and it may be used in biological pest control strategies.

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