

BIOLOGY AND PREDATORY POTENTIAL OF
Coccinella septempunctata **AND** *Coccinella*
transversalis **FEEDING ON** *Lipaphis erysimi* **IN**
MUSTARD ECOSYSTEM



**THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE
OF**

**MASTER OF SCIENCE (AGRICULTURE)
IN
ENTOMOLOGY AND AGRICULTURAL ZOOLOGY**

Supervisor
Dr. R. N. Singh

Submitted by
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काशी हिन्दू
विश्वविद्यालय



BANARAS HINDU
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***DEDICATED TO MY
BELOVED PARENTS***

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CERTIFICATE

To
The Registrar (Academic)
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Through: The Head, Department of Entomology and Agricultural Zoology, Institute of Agricultural Sciences, B.H.U., Varanasi.

Dear Sir,

I have great pleasure in forwarding the thesis entitled “**Biology and predatory potential of *Coccinella septempunctata* and *Coccinella transversalis* feeding on *Lipaphis erysimi* in mustard ecosystem**” submitted by **Miss Jaya Paliwal, I.D No. 19412EAZ003**, in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture) in Entomology and Agricultural Zoology**, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi and placing on record that she has completed the requisite residential requirements as contained in the statute of the University.

I certify that the entire scheme of investigation presented herein was planned and carried out solely by the candidate under my guidance and supervision. The data presented in the thesis, to the best of my knowledge and belief, are genuine and original.

Thanking you,

Yours faithfully

Forwarded by

(Dr. R. N. Singh)

Head of the Department

Supervisor

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**By
*Jaya Paliwal***

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Date:
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CHAPTER I



INTRODUCTION

INTRODUCTION

India is an agriculture-dependent country. It has large geographic area of 328.7 mha, out of which the reported net sown area and gross cropped area are 140.1 (43%) and 198.4 (60%) mha, respectively (Anonymous, 2017). Agriculture being an important component of the Indian economy constitutes 17.8% of gross value added with the growth rate of 3.4% for the financial year 2020-21 (Anonymous, 2021). However, the overall economic share of agriculture is shrinking, i.e., from 51.8% to around 15.8% from 1950-51 to 2018-19, respectively (in terms of Gross Value Added at current prices) as compared to the other growing sectors, still it continues to account for more than 50% employment especially in rural areas (Kumar, 2019).

India has diverse climate and weather conditions; therefore it's a home to a variety of crops that are of different utilities. Some crops are grown to feed the hunger need of continuously growing population like rice, wheat, maize, etc., while some are grown for commercial and industrial purposes like sugarcane, jute, cotton, etc. On average, the estimated production of food grains, oilseeds, and sugarcane are 295.67, 33.50, and 358.14 mt, respectively for the year 2019-20 (Anonymous, 2020). India holds 1st position in oilseed production and contributes about 14 per cent of the global oilseeds area, with 7 and 10 per cent of total vegetable and edible oil, respectively (Kumar, 2019). There are nine major oilseed crops viz. groundnut, castor, sesame, rapeseed & mustard, linseed, soybean, sunflower, niger seed, and safflower, which cover a total area of 25.5 mha, and the total production of these oilseed crops is 32.26 mt with an average yield of 1265 kg/ha (Anonymous, 2019).

Among all the major oilseed crops, being the rich source of unsaturated fatty acid with a low concentration of saturated fatty acids, the oil of mustard has become nutritionally more important nowadays. The oil obtained from mustard seeds is known for its culinary fats for over 3000 years by the Indian and Chinese. It is grown all over the world but the primary center of its origin is

Afghanistan and Central Asia, whereas Asia minor, Iran, some parts of China, and India are the secondary centers of origin (Vavilov, 1949). Besides the utility of oil obtained from mustard, the seeds, sprouts, leaves, tender plants are also useful to human health, when they are consumed as spices and vegetables.

The economically important part of the mustard plant is its seeds which are a rich source of nutrients such as proteins, fats, crude fibers, and minerals. Among minerals, some minerals like calcium, phosphorous, and iron are present prominently which constitute about 490, 700, and 7.9 mg per 100 gm of seeds, respectively (Gopalan *et al.*, 2007).

India covers 6.23 mha area under mustard-rapeseed cultivation which accounts for the total production of 9.34 mt with a productivity of approximately 1499 kg/ha. Mustard is grown in all major parts of the country, however; Rajasthan is the leading state in terms of both area and production which is 38.02 and 43.69 per cent, respectively followed by Haryana and Uttar Pradesh (Anonymous, 2019).

As compared to major oilseeds crops, the production and yield of mustard are not reaching its potential, as it is severely affected by a large number of pests. There are more than 43 insect species which infest mustard-rapeseed crops in India (Purwar *et al.*, 2004) Out of which the painted bug, *Bagrada hilaris* (Burmeister), the leaf miner, *Phytomyza horticola* (Goureau), the mustard aphid, *Lipaphis erysimi* (Kalt), the mustard sawfly, *Athalia lugens proxima* (Klug), are of major importance. (Pradhan *et al.*, 2020). Among all these insect pests, the mustard aphid, *Lipaphis erysimi* (Kaltenbach) (Homoptera: Aphididae) is a commonly occurring and relatively most destructive pest of mustard (Singh *et al.*, 2002).

Mustard aphid, *Lipaphis erysimi* (Kaltenbach) belonging to the order Hemiptera, suborder Sternorrhynca, family Aphididae can cause up to 35-73 and 5-6 per cent reduction in yield and oil content, respectively (Shylesha *et al.*, 2006). They cause both direct and indirect types of damages. In direct damage, both nymphs and adults suck cell sap resulting in yellowing and wilting of infested plant parts and also the formation of colonies underside of leaves causing crinkling and blistering of leaves (Sarwar, 2013). Some other symptoms of an aphid infestation include curling and finally drying of leaves resulting in the development of feeble pods and pods with

small seeds. Apart from direct damages, aphids excrete honeydew which leads to the development of fungal growth (sooty mold) that further obstructs the photosynthesis and transpiration which are necessary processes for the growth and development of the plant (Santos *et al.*, 2013) and also serve as vectors of some viral diseases such as turnip mosaic virus (Kafle, 2015) which are considered as indirect damages. Mostly these are found in growing parts of plants including tips, flowers, developing pods however, in severe conditions cover the whole plant (Nelson and Rosenheim, 2006). The population of mustard aphid reaches its peak from the end of the January to the first week of March (Narjary *et al.*, 2013).

It is necessary to manage the pest population below the economic threshold level (ETL) to prevent economic losses. There are several methods that are used to control the insect pests such as cultural, physical, mechanical, chemical, biological, etc. Among all these methods, the chemical method is the most adaptive method among farmers as it is easy to use and gives quick and effective results, however, these chemicals might cause harm to the environment in various ways like contamination of soil and water, toxic to fish, birds, non-target and beneficial insects as well as human beings and plants (Aktar *et al.*, 2009).

Therefore, there is a need to enhance the use of biological methods as it is socially acceptable, environmentally safe, and economically feasible. It is one of the effective methods to manage insect pests in the crop ecosystem. According to Paul DeBach, biological control is defined as “the action of parasites, predators or pathogens in maintaining another organism’s population density at a lower average than would occur in their absence”. There are several natural enemies which feed on mustard aphids which include nearly sixteen syrphids species, six species of coccinellids, four species of hymenopterous parasitoids, four species of entomopathogenic fungi, and one chamaemyiid predator. Coccinellids are the major predators among all the natural enemies of *L. erysimi*.

Coccinellids are also known as ladybird beetles or ladybug which belongs to order Coleoptera and family Coccinellidae. According to a leading theory, the name “ladybird” came from ladybird’s bright red shell, which is somewhat similar to the red cloak of “the Virgin Mary” often picturized in biblical paintings, and the seven spots of *Coccinella septempunctata* is said to symbolize its seven joys and seven sorrows,

hence also known as seven spotted beetle (Anonymous, 2018; Miller *et al.*, 2008). Coccinellids are one of the beneficial insects which prey upon various sucking insect pests such as aphids, mites, scales, thrips, mealybugs, etc. (Boopathi *et al.*, 2020). Aphids are the most preferable food for ladybird whereas mite, coccids, honeydew, mildew, pollens, and nectar are reported as secondary food (Bianchi *et al.*, 2004).

Female ladybug lays 5-30 yellowish colour eggs in the cluster and its fecundity is 1000 eggs in a life cycle. The Incubation period of the egg ranges between 2-10 days after that hatching takes place and the 1st instar larva emerges, then it starts feeding, there are four instars in the lifecycle of coccinellids. A fully grown larva can consume up to 350-400 aphids and stops feeding before entering to the pupal stage, then pupation take place, the pupa is usually yellowish-orange with black markings and the pupal period lasts for 7-15 days. The adult emerges from the pupa and with time their pale yellow colour develops into deep bright colours (Hadley, 2020).

There are many species under the genus *Coccinella* among which *Coccinella septempunctata* and *Coccinella transversalis* are very effective (Bakhetia and Sekhon, 1989). *C. septempunctata* feeds on various species of aphids such as *L. erysimi*, *A. crassivora*, *H. coriandri*, *R. nymphae* and *M. rosae* but it shows maximum predatory potential and development against *L. erysimi* (Ali *et al.*, 2007). In the same way *C. transversalis* also shows maximum predatory preferences and development against *L. erysimi* and least against *M. rosae* (Ali *et al.*, 2009).

Study of predating potential and biology of coccinellids will be of great importance for further exploitation of coccinellids in the biological control of mustard aphid which otherwise can cause considerable economic damage. Therefore, keeping all these facts and figures in mind, the present experiment has been oriented to investigate with the following objective:

- ❖ To study the biology of predatory coccinellids viz. *C. septempunctata* and *C. transversalis*.
- ❖ To study the predatory potential of *C. septempunctata* and *C. transversalis* against mustard aphid, *L. erysimi*.



CHAPTER II



REVIEW OF LITERATURE

REVIEW OF LITERATURE

Coccinellidae is a widespread family of small to large sized beetles from 0.8 to 18 mm (0.03 to 0.71 in) with over 6000 species which are found all over the world. Coccinellid beetles also known as lady bird beetle attracted attention of economic entomologist because of their predatory habits on agricultural pest (aphids, mealy bugs, scale-insects, whiteflies. thrips, leafhoppers, mites and other small soft bodied insect pests) (Omkar and Pervez, 2000), hence played a great role in biological control of agricultural pest. The historical achievement in the field of biological control was the introduction of *Rodalia cardinalis* Mulsant from Australia into California (USA) in 1889 for the control of cottony cushion scale, *Icerya purchasi* Maskell in declined citrus orchards. Because of the harmful side effects of toxic chemicals the interest is increasing in the study of predaceous coccinellids, other advantages of these beetles over other predators are that they are tolerant to many insecticides and also the larvae are apparently not killed by systemic insecticides which are otherwise injurious to other predators (Saharia, 1982).

Among various species of coccinellids *C. septempunctata* and *C. transversalis* has been found to be the efficient predators of various aphid species. The relevant literature on various aspects of the *C. septempunctata* and *C. transversalis* studies conducted have been reviewed under different headings:

2.1 Predatory potential of *C. septempunctata*

2.2 Biology of *C. septempunctata*

2.3 Predatory potential of *C. transversalis*

2.4 Biology of *C. transversalis*

2.1 Predatory Potential of *C. septempunctata*

Nirmala *et al.*, (1996) studied the predatory potential of *C. septempunctata*

on cabbage aphid, *Brevicoryne brassicae* Linn. and reported that the total consumption by individual larvae for complete larval development was 291.65 ± 1.19 and an average consumption by adult was 141.33 ± 1.78 aphid nymphs/day.

Suhail *et al.*, (1999) studied the predatory potential of *C. septempunctata* on *Aphis gossypii* and found that it consumed 60.56 aphids per day.

Gour and Pareek (2003) studied the feeding potential of *C. septempunctata* on mustard aphid *L. erysimi* and reported that the consumption of first, second, third and fourth larval instars were 22.86-24.53, 71.13-71.67, 178.66-185.48 and 333.14-338.70 mustard aphids, respectively.

Omkar and Shrivastava (2003) observed the predatory potential of *Coccinella septempunctata* and *Coccinella transversalis* on searching ability of these species and prey population. The larva of *C. septempunctata* consumed maximum no. of aphid species when three different species of aphids *i.e.*, *Rhopalosiphum maidis*, *Myzus persicae* and *Macrosiphum rosae* were given. The predatory potential increases with increase in prey density, for both the species of coccinellids. It was found that searching efficiency and feeding potential of *C. septempunctata* was relatively higher than the *C. transversalis*.

Jandial and Malik (2006) studied the feeding potential of *C. septempunctata* on *L. erysimi* and *Myzus persicae* in laboratory conditions and reported that greater preference was shown for *L. erysimi* than *M. persicae* by both grubs and adults. Also feeding potential was found to be increased with increase in grub's age in *C. septempunctata* *i.e.*, 40.00, 51.40 and 74.8 aphids of *L. erysimi* consumed per insect by second, third and fourth instar, respectively under starved condition. The mean consumption was found to be 58.85 and 51.10 aphids, *L. erysimi* and *M. persicae* respectively under starved conditions.

Khurseed *et al.*, (2006) reported that among the larval instars, the aphids consumed/day by older larvae were more than those consumed by younger ones in their studies conducted on predating potential and biology of *C. septempunctata* on mustard aphid *L. erysimi*. The mean total no. of aphids consumed by fourth instar was 209.3 ± 19.36 whereas total mean consumption by adult was 1042.3 ± 52.89 .

Mandal and Patnaik (2006) studied the feeding potential of four coccinellids *i.e.*, *C. septempunctata*, *C. repanda*, *C. sexmaculata* and *Mieraspis discolor* on three different hosts and reported that *C. septempunctata* consumed the highest number of aphids. It consumed 1066.10 of *L. erysimi*, 950.76 of *M. persicae* and 873.16 of *B. brassicae* in its life time, while consumption of *L. erysimi* by *C. repanda*, *C. sexmaculata* and *Mieraspis discolor* was 1023.69, 768.84 and 595.12, respectively, *M. persicae* was 932.81, 527.85 and 516.32, respectively and *B. brassicae* was 822.96, 478.52 and 451.83 of respectively.

Ali and Rizvi (2007) studied the performance of *C. septempunctata* on five different aphid species under the controlled conditions, they found that the period of overall development was significantly longer on *L. erysimi* (62.75 ± 1.430) and shorter on *M. rosae* (47.55 ± 0.678) in *C. septempunctata*, whereas the overall development period of grubs was significantly longer on *H. coriandri* (17.00 ± 0.533). Females requires a longer development period than male irrespective of aphid species. In grub stages, the last stage consumed more aphids with respect to other stages and females devoured more aphids of all species as compared to male. The overall consumption rate of *C. septempunctata* was found significantly higher on *L. erysimi* (1142.75 ± 18.706) than other aphid species.

Solang *et al.*, (2007) studied the feeding potential of different instars grubs of *C. septempunctata* at different prey density during 2005. The aphid consumption at host density 10 was 1.1 ± 0.10 , 1.65 ± 0.96 , 1.95 ± 0.09 and 2.8 ± 0.14 under laboratory condition by 1st, 2nd, 3rd and 4th instar grubs of *C. septempunctata*, respectively. However, the aphid consumption increased to 1.65 ± 0.05 , 2.0 ± 0.11 , 2.65 ± 0.18 and 3.95 ± 0.20 under field condition by 1st, 2nd, 3rd and 4th instar grubs of *C. septempunctata*, respectively when prey density increased to 30. As aphid consumption increases with increase in prey density, it was concluded that aphid consumption by different instar grubs of *C. septempunctata* is affected significantly ($P < 0.05$) by host density.

Sattar *et al.*, (2008) studied the predating potential of *Coccinella septempunctata* on cotton aphid and results showed that 77.8 ± 5.15 cotton aphids were consumed per *C. septempunctata* and it was also revealed that fourth instar consumed highest number of aphids as aphid consumption by 1st, 2nd, 3rd, and 4th instars was

21.9, 555.9, 107.4 and 227.3 aphids, respectively.

Ali *et al.*, (2009) studied the comparative predating potential of three coccinellid species larvae on mustard aphid *L. erysimi* and on the basis of observations they reported that there was an increase in consumption rate with the advancement in age of all the three species of coccinellids such as consumption by first, second, third and fourth larvae was as follow *C. septempunctata* (18.90±0.289, 34.00±1.155, 50.90±1.173, 78.70±2.310), *C. transversalis* (16.40±0.289, 31.80±0.866, 50.70±0.866, 69.50±2.021) *M. sexmaculatus* (15.10±0.288, 28.70±0.577, 50.10±0.577, 66.20±0.866). The total larval feeding revealed that maximum consumption was shown by *C. septempunctata* (182.5±4.908 aphid nymphs) followed by *C. transversalis* (168.4±2.309 aphid nymphs) and *M. sexmaculatus* (160.1±2.308 aphid nymphs), as compared to other two species the larvae of *C. septempunctata* is an effective bio-control agent.

Bunker and Ameta (2009) studied the predating potential of three different predators *i.e.*, *Coccinella septempunctata*, *Chelomenes sexmaculata* and *Chrysoperla carnea* against four different species of aphids during 2004 and 2005 studies revealed that mustard aphid *Lipaphis erysimi* was most preferred by *C. septempunctata* and *C. carnea*. The consumption of mustard aphid by first, second, third, fourth instar and adult was 23.67, 50.80, 73.13, 82.80 and 60.13 aphids per day during the year 2004 and 25.33, 54.00, 75.40, 84.33 and 63.07 aphids per day during 2005.

Rai *et al.*, (2009) studied the effect of different prey densities of *C. septempunctata* (second, third, fourth instar larva and adult) on *L. erysimi i.e.* 20, 40, 80, 100, 200, 400 and 800 and reported that the prey consumption by second, third, and fourth instar larva of *C. septempunctata* shows an increased trend from lower pest density to higher pest densities, hence prey density influenced the preying capacity of all stages of *C. septempunctata*. It was reported that fourth instar shows maximum functional response (287.7±2.87) followed by third and second instar grub on prey density of 800.

Sharma and Joshi (2010) conducted experiment on predating potential of ladybird beetle *C. septempunctata* on mustard and cotton aphid *L. erysimi* and *A. gossypii*, respectively and they reported that highest number of mustard aphid was

consumed by the 4th instar larvae of *C. septempunctata* which was 6.50 ± 0.80 , 6.10 ± 0.73 and 6.40 ± 0.96 for 1st, 2nd, and 3rd hours, respectively in unstarved condition whereas 11.20 ± 0.91 , 8.30 ± 0.94 and 8.00 ± 1.05 consumption for 1st, 2nd, and 3rd hours, respectively in starved conditions.

Prabhakar and Roy (2010) in their experimental studies on consumption rates of different coccinellid predators on different aphid species in North-East Bihar reported that *C. septempunctata* consumed highest number of *Aphis craccivora* (65.6 ± 3.01) followed by *Lipaphis erysimi* (63.7 ± 0.65) and lowest on *Aphis gossypii* (59.2 ± 2.3). The high consumption rate on aphid nymphs in comparison to adult aphids was also observed.

Singh *et al.*, (2009) evaluated the feeding potential of *C. septempunctata* on mustard aphid, *Lipaphis erysimi* (Kalt.) and reported that the total consumption by first, second, third and fourth instar grub were 19.72, 57.50, 159.11 and 312.78 aphids, respectively and overall consumption of grub was 549.11 aphids. The average consumption by adult female and male were 120.62 and 107.15 aphids/day/individual, respectively.

Gupta *et al.*, (2012) studied the stage specific functional response of *C. septempunctata* to *Lipaphis erysimi* (Kalt.) and *Brevicoryne brassicae* and reported that the type-2 response was exhibited by the predatory stages of *C. septempunctata* on both the aphid species. In lowest handling time (7.9 min), the highest attack rate (0.0192) was found when adult female consumed *Lipaphis erysimi* (Kalt.). The predicted values of consumption of *L. erysimi* by fourth instars, adult males and females compared with those of *B. brassicae* has shown significant difference, hence it reported that *L. erysimi* is preferred over the *B. brassicae* and that the adult females consume significantly more than adult males.

Kumar *et al.*, (2013) studied the predatory potential of *C. septempunctata* along with three other ladybirds on two different aphids, *Aphis craccivora* and *Lipaphis erysimi*. It was observed that fourth instar grub and adult females of *C. septempunctata* performed better on *L. erysimi* over *A. craccivora*.

Singh and Singh (2013) studied the preying capability of coccinellid along with its different larval stages and syrphid flies on mustard aphid and found that the

grubs of *C. septempunctata* consumed highest number of mustard aphids (61.42 aphids/day) in their larval period. Among all the stages, the last larval stage of predators was found to be most effective predator against mustard aphid *L. erysimi*.

Pareek *et al.*, (2014) studied the predatory potential of *C. septempunctata* and reported that the first, second, third and fourth instar grub consumed 27.0 ± 5.35 , 34.22 ± 4.29 , 91.44 ± 25.13 and 237.37 ± 88.37 of coriander aphid (*Hyadphis coriandri*), respectively, hence the total consumption of a grub was 380.62 ± 81.66 aphids. The daily consumption of male and female beetle was 52.5 ± 4.74 and 63.5 ± 10.87 , respectively, while total consumption during its life span was 1345.0 ± 227.66 and 1948 ± 123.4 , respectively.

Varshney *et al.*, (2016) studied the predating potential of *C. septempunctata* on *L. erysimi* at different temperature and reported that aphid consumption by larval instar was 424.4 ± 2.78 during its life span at 27 ± 2 °C and 272.64 ± 1.79 aphids at 23 ± 2 °C. The adult female and male consumed more aphids at 27 ± 2 °C *i.e.*, 103 ± 1.52 and 116.6 ± 1.46 aphids/day respectively.

Arshad *et al.*, (2017) based on his studies about relationship between *C. septempunctata* and aphids of four different species *i.e.*, spinach, coriander, cabbage and pea aphids, reported that predation by 3rd and 4th instar of *C. septempunctata* on aphids was more than early stages in the no choice feeding assay, whereas in the free choice assay, the preference was significantly high for pea aphid (77.647).

Mishra and Kanwat (2017) studied the feeding potential of ladybird beetle *C. septempunctata* Linn. on mustard aphid *Lipaphis erysimi* under laboratory conditions and reported that 610.25 aphids were consumed during its larval development. Aphids consumed by the female are more than males of the same species *i.e.*, 153.64 and 121.55, respectively.

Manpoong *et al.*, (2017) studied the predating potential of different predators against *L. erysimi* and reported that *C. septempunctata* consumed highest number of aphids *i.e.*, 4312 ± 537.74 aphids as its mean lifetime consumption and among different larval instars consumption rate of fourth instar was maximum with 85.11 ± 01.39 aphids/day.

Yadav *et al.*, (2016) studied the feeding potential of *C. septempunctata* on mustard aphid, *Lipaphis erysimi* and reported that an average consumption of *C. septempunctata* larva was 69.26 ± 35.90 mustard aphids per day, while the total larval consumption was 363.07 ± 41.38 aphids on an average. The overall consumption by an adult was 2429.83 ± 262.28 aphids on an average.

Maharajan *et al.*, (2018) conducted the experiment to compare the efficacy of two different species of coccinellids (*C. septempunctata* and *Adonia variegata*) against four different species of aphids *i.e.*, *Myzus persicae*, *Lipaphis erysimi*, *Brevicoryne brassicae* and *Aphis crassivora* at Khumaltar, Nepal and based on the studies, feeding potential of *C. septempunctata* was found to be highest on mustard aphid *Lipaphis erysimi* *i.e.*, 183 aphids and lowest on *Aphis crassivora* *i.e.*, 126 aphids, on the other hand *A. variegata* also showed highest feeding potential on *L. erysimi* (155.4 aphids) and lowest when feed on *B. brassicae* (112 aphids), hence as feeding potential of *C. septempunctata* was more than *A. variegata*, it can be concluded that *C. septempunctata* is more promising as aphid predator and beneficial in biological control.

Sahito *et al.*, (2019) studied on use of *C. septempunctata* in biological control for mustard aphid *L. erysimi* under laboratory conditions and they found that consumption by first, second, third and fourth larval stages of *C. septempunctata* was 2, 19, 34 and 48 aphids per day, while 40 aphids/day was consumed by adult stage and concluded that this species of ladybird beetle can be used fruitfully as a controlling agent for sucking pests, to minimize their population in mustard crop.

Sarker *et al.*, (2019) studied the predatory potential of *C. septempunctata* on different species of aphid in laboratory conditions and reported the consumption of first, second, third, and fourth instar larva was 16.67 ± 0.58 , 23.33 ± 1.53 , 41.33 ± 0.58 , and 151.67 ± 1.15 of *A. crassivora*, respectively.

Kumari *et al.*, (2020) studied the predatory potential, biology and functional response of *C. septempunctata* and reported that the mean consumption rate increases with successive larval instars and also with increase in prey density. The mean consumption by fourth instar was found to be 23.3 and 65.4 at prey density 25 and 125, respectively. Aphids consumed by adult was maximum *i.e.*, 78.3 at 125 prey

density.

2.2 Biology of *Coccinella septempunctata*

Nirmala *et al.*, (1996) studied about the biology of *Coccinella septempunctata* on cabbage aphid, *Brevicoryne brassicae* Linn. and reported that the mean fecundity was 466.00 ± 1.97 eggs. The average duration of first, second, third, and fourth instar were 2.0 ± 0.35 , 1.67 ± 0.31 , 1.33 ± 0.18 and 2.33 ± 0.25 days, respectively.

El Tayeb and Zaitoon (1996) studied about the biology of four coccinellid species; *Adonia variegata* Goeze, *Coccinella novemnotata* Herbst, *C. septempunctata* L., and *C. undecimpunctata* L. on two different species of aphid; *Brevicoryne brassicae* (L.) and *Rhopalosiphum padi* L.

Seema *et al.*, (2000) conducted the biology studies of *Coccinella septempunctata* var *divaricata* and reported the average duration of different larval instars during two months. The average duration of first, second, third, fourth instar larva were 3.56, 2.60, 2.48, 4.35 and 3.66, 2.38, 2.49, 3.86 during February and March, respectively.

Rai *et al.*, (2002) studied the biology and morphometrics of *C. septempunctata* associated with rice ecosystem and reported that pre-oviposition period and fecundity was 7.52 ± 0.34 days and 661.49 ± 13.33 egg/female. The mean incubation period was 1.76 ± 0.16 days and the development period of was 1.6 ± 0.15 , 1.4 ± 0.11 , 1.96 ± 0.12 and 2.68 ± 0.16 of first, second, third, fourth instar larva, respectively, while the mean pupal period was found to be 7.52 ± 0.34 days.

Pareek (2003) studied the biology of *Coccinella septempunctata* on *Lipaphis erysimi* and reported the life span. The period of first, second, third, fourth instar larva were 2, 2, 3, and 4 days, respectively. The life span of male and female *C. septempunctata* was 22.83 and 26.63 days, respectively.

Khurseed *et al.*, (2006) studied about the biology of *Coccinella septempunctata* on *Lipaphis erysimi* and observed that the larval and pupal period were 16 ± 1.73 and 7.5 ± 0.87 days, respectively which was more in first generation as

compared to the second generation *i.e.*, 13.5 ± 0.87 and 6.5 ± 0.87 days, respectively and the similar trend was found in longevity of males and females.

Ali and Rizvi (2007) studied the development of *Coccinella septempunctata* on five different species of aphids and reported that overall development of *C. septempunctata* was significantly longer on *Lipaphis erysimi* and shorter on *M. rosae* and results of adult longevity also found to be same *i.e.*, higher on *Lipaphis erysimi* and shorter on *M. rosae*. Irrespective of aphid species the female required longer period for its development as compared to the male.

Singh *et al.*, (2009) studied the biology of *C. septempunctata* on mustard aphid, *L. erysimi* and reported that the fecundity of female *C. septempunctata* and incubation period was 357.45 ± 22.41 and 4.40 ± 0.22 , respectively. The ovipositional, larval, pupal and total developmental periods were 4.32 ± 0.26 , 10.95 ± 0.35 , 5.35 ± 0.15 and 20.70 ± 0.72 , respectively. The longevity of adult was found to be 122.90 ± 3.12 .

Skouras *et al.*, (2015) studied the growth, development and reproduction of *C. septempunctata* along with two more species and reported that the mean fecundity of *C. septempunctata* at 23° C was 586 eggs. The oviposition period was observed to be 73.4 days. The intrinsic rate of increase (r_m), mean generation time (T) and population duplication time (DT) was found to be 0.06female/female/day, 69.3 and 11.4 days, respectively.

Varshney *et al.*, (2016) conducted an experiment on biology studies of *Coccinella septempunctata* on *Lipaphis erysimi* at two temperature regimes *i.e.*, $30\pm 2^{\circ}$ C and $25\pm 2^{\circ}$ C. The incubation, total grub, preoviposition and pupal period were 2.6 ± 0.51 , 8.7 ± 1.63 , 6.5 ± 3.53 and 5.1 ± 1.10 , respectively at $30\pm 2^{\circ}$ C which was less than that found at $25\pm 2^{\circ}$ *i.e.*, 2.9 ± 0.73 , 11.1 ± 1.52 , 7.7 ± 2.49 and 5.8 ± 0.918 , respectively. However, the fecundity, oviposition period, hatch-ability of eggs, male and female longevity (232 ± 70.46 , 12.8 ± 3.91 , 82.87 ± 6.66 , 22.70 ± 2.21 and 26.60 ± 4.45 , respectively) were higher at $30\pm 2^{\circ}$ C as compared to that at $25\pm 2^{\circ}$ C which is 169.8 ± 61.12 , 7.9 ± 1.37 , 71.68 ± 4.08 , 16.2 ± 1.31 and 21.50 ± 1.95 , respectively.

Mishra and Kanwat (2017) conducted an experiment on biology studies of *Coccinella septempunctata* on *Lipaphis erysimi* under laboratory conditions and reported that the egg incubation period was 3 days with 86.66 percent hatchability and

the total eggs laid by female in its lifespan was 657.7 eggs. The Pre-oviposition, oviposition and post-oviposition periods were found to be 6.7, 13.4 and 3.3 days, respectively. The total grub period was 9.27 days in which it passes through four instars and it passes the pupal period in 6.52 days. The average female and male longevity was found to be 25.5 and 21.08 days, respectively.

Sipio *et al.*, (2017) studied the biology of *Coccinella septempunctata* on different species of aphids and reported that maximum fecundity was shown by female on mustard aphid (1241.24 ± 10.25) and lowest pre-oviposition period was found when female fed on cabbage and mustard aphids. The maximum period of oviposition was recorded on cabbage aphid followed by mustard and akk aphids, respectively. The lowest larval cannibalism per cent (14.0 ± 5.77) and maximum adult emergence per cent was seen on mustard aphid, while highest larval mortality per cent on cabbage and akk; 20.0 ± 83.0 and 23.0 ± 10 , respectively. The minimum development period of 1st, 2nd, 3rd and 4th instar larvae was observed when fed with mustard aphid followed by cabbage aphid, *Brevicoryne brassicae* and Akk aphid, *Aphis nerii*, respectively. The adult male of *Coccinella septempunctata* showed highest longevity (69.68 ± 11.25 days) on cabbage aphid, whereas highest female longevity was recorded 85.0 ± 8.41 and 91.23 ± 10.81 days of akk and cabbage aphids, respectively.

Yadav *et al.*, (2016) studied the biology of *Coccinella septempunctata* on mustard aphid *Lipaphis eryimi* and reported that the mean fecundity, incubation period and hatching percent were 582.44 ± 93.15 eggs per female, 4.40 ± 0.77 days, and $73.30 \pm 5.27\%$, respectively, while pre-oviposition, oviposition and post oviposition periods were 7.92 ± 2.45 , 21.60 ± 3.39 , and 7.16 ± 1.77 days, respectively. The duration of first, second, third and fourth instar grubs were 3.73 ± 0.78 , 2.80 ± 0.76 , 3.50 ± 0.78 and 3.63 ± 0.85 , respectively with the length and breadth of 1.58 ± 0.16 and 0.49 ± 0.06 , 2.79 ± 0.11 and 0.80 ± 0.06 , respectively. The pupal period, male and female adult longevity were 6.73 ± 1.11 , 31.33 ± 3.28 and 37.30 ± 3.44 days, respectively, while their length and breadth were 4.43 ± 0.26 , 6.95 ± 0.44 and 5.46 ± 0.36 mm, respectively.

Sahito *et al.*, (2019) studied the bio-control of mustard aphid *Lipaphis erysimi* by using *C. septempunctata* as a predator under laboratory conditions and reported that the duration of first, second, third and fourth grub's instar were 4.08,

5.32, 6.80, and 8.00, respectively. The pupal period was recorded of 6.04 days and the longevity of females and males was found to be 43.76 and 39.36 days, respectively.

Kumar *et al.*, (2019) studied the biology of *C. septempunctata* on *Lipaphis erysimi* and it was found that egg incubation period was 3.33 ± 0.33 days and the duration of first, second, third and fourth grubs' instar were 2.33 ± 0.33 , 2.33 ± 0.33 , 3.67 ± 0.33 and 4.67 ± 0.33 days, respectively. The pupal period, adult female and male longevity last for 5.67 ± 0.33 , 36.67 ± 0.33 and 30.67 ± 0.67 days, respectively. The *C. septempunctata* exhibits the mean fecundity of 349.67 ± 10.11 eggs/ female on *L. erysimi* during her life.

2.3 Predatory potential of *Coccinella transversalis*

Omkar and Srivastava (2003) studied the predatory potential of *Coccinella transversalis* on different species of aphid and reported that the maximum consumed aphid was *M. persicae* (224.80 ± 1.93) by fourth instar grub of *C. transversalis* at prey density of 800 and minimum number of *M. rosae* (17.40 ± 0.58) at prey density of 25 in 24 hours.

Rai *et al.*, (2009) studied the effect of different prey densities of *C. transversalis* (second, third, fourth instar larva and adult) on *L. erysimi* i.e., 20, 40, 80, 100, 200, 400 and 800 and reported that the prey consumption by second, third, and fourth instar larva of *C. transversalis* showed an increased trend from lower pest density (20) to higher pest densities, hence prey density influences the preying capacity of all stages of *C. transversalis*. It was reported that fourth instar shows maximum functional response (187.7 ± 2.56) followed by third and second instar grub on prey density of 800.

Borah and Dutta (2010) studied the feeding potential of *C. transversalis* and reported that aphid *L. erysimi* consumed by 1st, 2nd, 3rd, 4th larval instar, adult male and female were 19.95 ± 3.23 , 34.25 ± 4.36 , 58.30 ± 7.54 , 65.67 ± 8.23 , 58.32 ± 5.23 and 62.17 ± 5.76 , respectively.

Ali *et al.*, (2010) studied the feeding potential of *C. transversalis* on different species of aphid. The consumption of aphids by *C. transversalis* were 26.70 ± 1.044 , 48.00 ± 1.333 , 65.20 ± 1.794 and 89.60 ± 1.368 nymphs of *H. coriandri* per

larva of first, second, third, and fourth larval stages, respectively, which was most preferred and *M. rosae* was least preferred 15.10 ± 5.86 , 26.10 ± 1.110 , 35.70 ± 1.856 and 58.70 ± 1.422 nymphs per larva by first, second, third, and fourth larval stages, respectively. *Lipaphis erysimi* is preferred most by the adult male and females of *C. transversalis* 731.40 ± 5.235 and 827.30 ± 6.100 nymphs, respectively, and *M. rosae* least 288.40 ± 6.743 and 421.30 ± 4.492 nymphs, respectively.

Santosh (2011) studies the predating potential of *C. transversalis* on three different species and reported that the larvae consumed total of 265.86 ± 43.706 , 250.18 ± 26.439 and 120.24 ± 9.427 aphids when reared on *L. erysimi*, *M. persicae* and *A. craccivora*, respectively. The adult of *C. transversalis* consumed 3229.5 ± 675.716 , 2529.8 ± 494.682 and 2299.4 ± 562.18 aphids of *A. craccivora*, *L. erysimi* and *M. persicae*, respectively. The total aphids consumed in its entire lifetime were 3349.78 ± 675.246 , 2795.68 ± 508.780 and 2549.54 ± 565.608 , *A. craccivora*, *L. erysimi* and *M. persicae*, respectively.

Kumar *et al.*, (2013) studied the predatory potential of *C. transversalis* along with three other ladybirds on two different aphids, *Aphis crassivora* and *Lipaphis erysimi* and reported that *C. transversalis* along with *Cheilomenes sexmaculata* and *Propylea dissecta* performed better on *Aphis crassivora* except for *C. septempunctata* which preferred *L. erysimi*.

Chakraborty and Korat (2014) studied the predating potential of *C. transversalis* on different aphid species and reported that they consumed maximum number of *A. crassivora* (528.47 ± 11.79) followed by *A. gossypi* (402.67 ± 4.75) and *Lipaphis erysimi* Kalt. (223.27 ± 5.08).

Bukero *et al.*, (2014) studied the predatory potential of *C. transversalis* on different species of aphid in laboratory conditions and reported that first, second, third, and fourth larval stage consumed 17.11, 35.05, 53.61, and 78.77 nymphs/day of *A. gossypi*, respectively, while 5.40, 14.80, 32.70, and 65.03 nymphs/day of *A. nerii* and 4.0, 9.34, 17.80, and 31.96 nymphs/day, respectively of *L. erysimi*. The consumption rate order is same in adult as larva. The adult male and female consumed *A. gossypi* 121.04 and 145.08 nymph/day, respectively, *A. nerri* 58.27 and 62.93 nymph/day, respectively and 44.99 and 56.56 nymph/day, respectively *L. erysimi*.

Darshana and Shukla (2014) studied the predatory potential of *C. transversalis* on different aphid hosts viz., *Aphis craccivora* Koch, *Lipaphis erysimi* (Kalt.) and *Myzus persicae* Sulzer and reported that total larval consumption of *C. transversalis* was maximum number on *Lipaphis erysimi* (Kalt.) (265.86 ± 43.706), followed by *M. persicae* and *A. craccivora*, 250.18 ± 26.439 and 120.24 ± 9.427 , respectively. The total consumption during entire lifespan was highest on *A. craccivora* (3349.78 ± 675.246) followed by *L. erysimi* and *M. persicae* i.e., 2795.68 ± 508.780 and 2549.54 ± 565.608 , respectively.

Rajan *et al.*, (2018) studied the feeding potential of *C. transversalis* against cabbage aphid *Brevicoryne brassicae* and reported that fourth instar consumed a greater number of aphids than first, second and third instar. The predation rate of adult was 48-50 aphids/day and total consumption by adult and grub from first to fourth instar was 2352 to 2450 and 268 to 329 aphids, respectively. Hence, the total consumption of *C. transversalis* in its life span was 2695 to 2773 aphids.

Gurung *et al.*, (2018) studied the predatory potential of *C. transversalis* against *Lipaphis erysimi* and reported that the daily consumption of each instar grub, viz. first, second, third, and fourth were 15.4 ± 4.39 , 27.2 ± 5.40 , 37.15 ± 5.27 , 44.3 ± 7.60 aphids per grub per day, respectively, while the female consumed more than male i.e., 35.76 ± 0.68 and 33.23 ± 0.96 days, respectively, per day consumption was maximum by fourth instar grubs.

Sarker *et al.*, (2019) studied the predatory efficacy of *C. transversalis* against three different aphids (*Aphis gossypii*, *A. craccivora*, *A. fabae*) and reported that *A. craccivora* was most preferred by *C. transversalis* and fourth instar larvae consumed highest number of *A. craccivora* (21.56 ± 1.72) followed by *A. fabae* (12.33 ± 1.74) and *A. gossypii* (13.99 ± 0.77).

2.4 Biology of *Coccinella transversalis*

Debaraj and Singh (1990) studied the biology of *C. transversalis* on *Aphis craccivora* and reported that the life cycle was completed in 38-45 days. The incubation period, period of first, second, third, and fourth instar larvae were 8-10, 4.69, 3.92, 5.0, and 7.69, respectively. The total larval, pre-pupal and pupal periods were 19-23, 2.62 and 8.6 days, respectively.

Junsung *et al.*, (2002) studied the biology of *C. transversalis* and reported that fecundity of female and incubation period was 645.27 ± 213.37 eggs and 2.55 ± 0.5 days, respectively. The period of first, second, third, fourth instar larvae and pupa were 1.9 ± 0.31 , 1.33 ± 0.35 , 2.17 ± 0.38 , 2.87 ± 0.57 , and 3.17 ± 0.38 days, respectively. The lifespan of adult female and male was recorded to be 45.53 ± 18.15 and 37.4 ± 16.95 days, respectively.

Ali *et al.*, (2009) studied the biology of *Coccinella transversalis* on different aphid species *Lipaphis erysimi* Kaltenbach, *Aphis craccivora* Koch, *Hyadaphis coriandri* (Das), *Rhopalosiphum nymphae* Linnaeus and *Macrosiphum rosae* Linnaeus. The female's response towards egg production and prey consumption was highest on *L. erysimi* and lowest on *M. rosae* and the loss of the progeny was minimum with regard to *L. erysimi*. The reproductive period, reproductive time ratios, reproductive rate, post-reproductive period, were significantly maximum on *L. erysimi*. Hence, *L. erysimi* proved to be the most suitable species for the reproductive performance of *C. transversalis*.

Deho *et al.*, (2009) studied the biology of *C. transversalis* on *Aphis gossypii* and reported that the pre-copulation, copulation and post copulation period were 4.7 ± 0.3 , 49.7 ± 2.71 and 3.1 ± 0.31 minutes, respectively and the average oviposition and post oviposition period was found to be 35.8 ± 1.64 and 3.2 ± 0.2 days, respectively. The incubation period, period of first, second, third and fourth instar larvae were 3.4 ± 0.39 , 3.6 ± 0.22 , 3.9 ± 0.27 , 4.1 ± 0.23 , and 3.9 ± 0.22 days, respectively.

Santosh (2011) studied the biology of *C. transversalis* and reported that mean egg period when it was reared on *A. craccivora* and *M. persicae* was 2.70 ± 0.76 and 2.70 ± 0.76 days, respectively. The average fecundity of *C. transversalis* on *M. persicae*, *A. craccivora*, and *Lipaphis erysimi* was 377.36 ± 28.96 , 376.46 ± 47.32 , and 364.88 ± 27.44 eggs per female, respectively. The mean total larval and total pupal period when reared on *A. craccivora* were 12.90 ± 1.44 and 2.62 ± 0.63 days, respectively and when reared on *L. erysimi* these were and 12.68 ± 1.63 and 2.62 ± 0.69 days, respectively.

Shukla and Jadhav (2014) conducted the biology studies of *Coccinella transversalis* on different species of aphids and reported the mean fecundity on *Myzus*

persicae, *Aphis craccivora*, *Lipaphis erysimi* were 377.36 ± 28.96 , 376.46 ± 47.32 , and 364.88 ± 27.44 eggs per female, respectively. The egg, total larval, pupal, adult male and female periods on *Aphis craccivora* was 2.70 ± 0.76 , 12.90 ± 1.44 , 2.62 ± 0.63 , 31.58 ± 3.22 and 39.10 ± 3.37 days, respectively, whereas on *Myzus persicae* these periods were 2.70 ± 0.76 , 12.98 ± 1.93 , 2.52 ± 0.61 , 29.08 ± 4.25 and 37.12 ± 2.27 days, respectively, while on *Lipaphis erysimi* these periods were 2.70 ± 0.76 , 12.68 ± 1.63 , 2.62 ± 0.69 , 30.12 ± 4.49 and 33.88 ± 2.56 days, respectively. Total life cycle of male and female *C. transversalis* on *A. craccivora*, *L. erysimi* and *M. persicae* were 50.80 ± 3.92 , 49.12 ± 4.87 and 48.28 ± 5.38 days and 58.32 ± 3.92 , 52.88 ± 3.48 and 56.32 ± 3.07 days, respectively.

Chakraborty and Korat (2014) studied the biology and morphometry of *C. transversalis* and reported that the fecundity of adult female was 253.85 ± 38.76 eggs, with the average length and breadth of 1.06 ± 0.01 and 0.47 ± 0.01 mm, respectively and the average incubation period was 9.27 ± 0.30 days. The larval and pupal period were 21.33 ± 0.39 and 8.27 ± 0.15 days, respectively. The average duration of first, second, third and fourth instar larvae were 4.73 ± 0.23 , 3.93 ± 0.28 , 5.13 ± 0.19 and 7.53 ± 0.22 days, respectively and their length were 2.49 ± 0.02 , 3.47 ± 0.02 , 5.72 ± 0.02 and 9.48 ± 0.06 mm, respectively. The female and male beetle lives for 22.17 ± 1.27 days and 21.13 ± 1.02 , respectively and the total life period of male and female was 63.50 ± 1.15 and 62.47 ± 1.05 days, respectively.

Rajan *et al.*, (2018) studied the biology of *C. transversalis* against cabbage aphid *Brevicoryne brassicae* and reported that incubation period was 2.5 ± 0.53 , total grub period, pre pupal period and pupal period was recorded to be 15.1 ± 0.74 , 1.2 ± 0.46 and 3.1 ± 0.32 days, respectively, with the average fecundity of 205.2 ± 30.11 eggs and 13.0 ± 1.33 days of oviposition period.

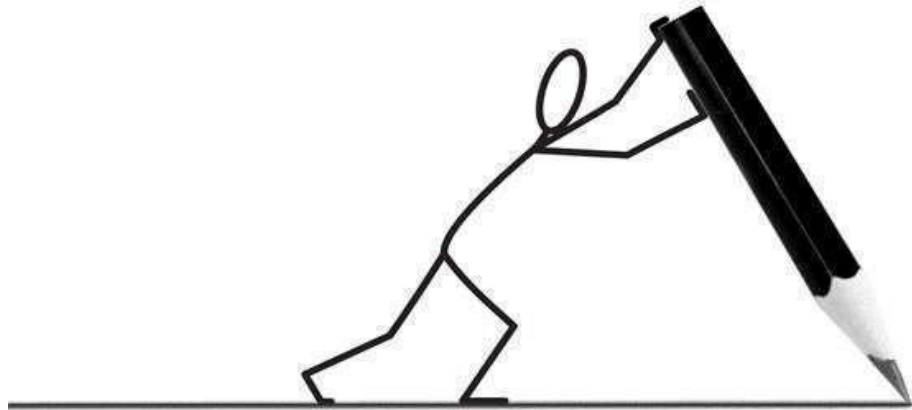
Gurung *et al.*, (2018) studied the biology of *C. transversalis* on *L. erysimi* and reported that the mean incubation, total larval, pre-pupal, and pupal period were 5.2 ± 1.28 , 9.85 ± 1.47 days, 4.05 ± 0.68 and 5.35 ± 0.81 days, respectively. The male and female have entire life span of 40.3 ± 4.91 and 42.65 ± 5.84 days, respectively.

Bista (2020) studied the effects of prey quantity on development, survival and reproductive attributes of *Coccinella transversalis* Fabricius and reported that on

abundant prey the pre-oviposition period was shortest (6.40 ± 0.40 days) and on scarce prey it was longest (9.20 ± 0.49 days). As the prey quantity increases the oviposition period also increases significantly being longest (55.10 ± 1.75 days) on abundant prey and shortest (38.50 ± 2.14 days) on scarce prey. The rest of the attributes like lifetime fecundity, egg viability, reproductive rate, reproductive time ratio, longevity of male and female were all highest *i.e.*, 1604.10 ± 45.61 eggs, $90.82 \pm 0.80\%$, 29.20 ± 0.61 egg/day, 3.70 ± 0.26 , 65.80 ± 1 and 70.30 ± 1.30 days, respectively on abundant diets, whereas lowest *i.e.*, 794.60 ± 30.84 eggs and $82.72 \pm 0.67\%$, 20.90 ± 0.83 eggs/day, 1.95 ± 0.16 , 58.80 ± 1.60 and 56.20 ± 1.75 days respectively on scarce diet.



CHAPTER III



MATERIAL

AND

METHODS

MATERIAL AND METHODS

The present investigations on the biology and predatory potential of coccinellids on mustard aphid *Lipaphis erysimi* infesting mustard crop were conducted in the Department of Entomology and Agricultural Zoology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, U.P. during 2020-2021. Geographically it lies in the North-East Plain Zone of Eastern Uttar Pradesh. It is situated at an altitude of 80.71 meters above mean sea level and is located between 25⁰18' North latitude and 80⁰36' East longitudes. The materials used and the methodology followed in the study are described in this chapter.

3.1 Materials

3.1.1 Glasswares

1. Glass jars for rearing the coccinellids *C. septempunctata* and *C. transversalis*.
2. Reagent bottle for storing the honey solution.
3. Petri plates for biology and predating potential studies of *C. septempunctata* and *C. transversalis*.
4. Beaker.

3.1.2 Equipment

1. Microscope

3.1.3 Experimental material

1. Infested mustard twigs and leaves to rear the coccinellids.
2. Mustard aphid, *Lipaphis erysimi* was collected from infested mustard plants at BHU Agro-farm.
3. Predator, *C. septempunctata* and *C. transvesallis* were collected from mustard plants at BHU Agro-farm.

3.1.4 Miscellaneous

1. Black and white muslin clothes and rubber bands to cover the rearing jar containing coccinellids culture.
2. Cotton, tissue paper, blotting paper, plastic jar, etc.
3. Needle, thread, scissors, forceps, camel hair brush of various sizes for handling different stages of aphids and coccinellids.
4. Honey solution (10%) as supplement food for adult stages of coccinellid predators.
5. Agar.

3.2 Methodology

3.2.1 Programme of research work

It includes the following activities

1. Culturing of *C. septempunctata* and *C. transversalis*.
2. Biological studies of *C. septempunctata* and *C. transversalis*.
3. Studies on feeding potential of *C. septempunctata* and *C. transversalis* on *Lipaphis erysimi*.

3.2.2 Culturing of *C. septempunctata* and *C. transversalis*

The nucleus cultures of *C. septempunctata* and *C. transversalis* were maintained on *Lipaphis erysimi* infested mustard twigs in the laboratory. Five pairs of the adult predators collected from mustard field at agro-farm, BHU, were released in a jar containing mustard twigs and leaves infested with mustard aphids collected from agro-farm breeding plot, BHU. A cotton swab soaked in water is kept in the jar to maintain the humidity and some cotton swabs soaked in honey solution are attached to the nylon cloth and hangs in the jar as supplement food for the adult. Some black paper foldings are kept inside the jar to support the oviposition and the jars were covered with a clean muslin cloth and tied with a rubber band and maintained at $27 \pm 2^\circ\text{C}$ and $65 \pm$

5% RH. The cotton swabs and food (aphid-infested mustard twigs and leaves) are changed daily in the morning. The eggs are laid on the underside of leaves or the paper foldings, are collected with the help of a moist camel hairbrush and placed in the petri plates. The newly hatched grubs were reared individually (to avoid cannibalism) by providing the sufficient number of mustard aphids to develop laboratory culture for further studies.

3.2.3 Biological studies of *C. septempunctata* and *C. transversalis*

The biology of two prominent coccinellid species *i.e.*, *C. septempunctata* and *C. transversalis* was studied under laboratory conditions. Newly emerged ten pairs of *C. septempunctata* and *C. transversalis* were sexed, paired and released into glass jars with sufficient quantity of mustard aphid as prey maintained separately for their biology studies.

3.2.3.1 Egg

The eggs laid on leaves, paper foldings, or walls of the jar are collected by a moist camel hairbrush and kept in Petri plates having moist filter paper at the base to avoid desiccation of the eggs. The Incubation period was studied using 20 eggs of each coccinellid species from lab cultures and was kept in the separate Petri plates. Each Petri plates represents one replicate. Eggs were examined with the help of a hand lens (10X magnification) twice a day, for any hatch-out of grubs. The period from egg-laying to its hatching is called as Incubation period and was computed for each replicate. Mean \pm S.D was worked out to denote the average period of incubation for eggs of both species of coccinellids.

3.2.3.2 Larva

Newly hatched larvae are provided with the sufficient amount of mustard aphids that are collected from the infested

mustard field and the number of aphids increased proportionately with the gradual development of larva. The presence of cast-off skin was taken as the period of cessation of one instar and the start of the next. The duration of each instar was determined by recording the days between two moulting. The data on the number of instars and the total larval period were recorded. Mean \pm S.D was computed for each instar of grub to denote the instar-wise grub periods of both the species *C. septempunctata* and *C. transversalis*.

3.2.3.3 Pupa

The larvae after passing through four instars entered into the pupal stage. The pupal period was represented by the time when a grub just stopped feeding, till an adult beetle emerged out of it. The pupa was kept undisturbed in the respective Petri plates until the emergence of an adult. Periodical observations were taken to record the pupal period. Mean \pm S.D of ten observations for the pupal period were computed to determine the average pupal period of both the species *C. septempunctata* and *C. transversalis*.

3.2.3.4 Adult

The time an adult ladybird beetle emerged from the pupa till its death is denoted as adult longevity. The emerged adults (males and females) are provided with mustard aphids as food in individual Petri plates for further rearing and recording the longevity of the male and female separately. Periodical observations were recorded after every 24 hours to compute the average period of survival of beetles, sex-wise for each replication.

3.2.3.5 Pre-oviposition, oviposition, post-oviposition

To study the preoviposition period, five pairs of newly emerged adults are kept in five different plastic jars along with

its prey mustard aphid and each plastic jar represent one replicate and are observed daily for egg-laying. The food is changed daily. The period from emergence to initiation of egg-laying was computed for each replication to denote the pre-oviposition period. Mean±S.D was worked out to denote the average pre-oviposition period.

The oviposition period is computed as the period from initiation of egg-laying till the egg-laying of female ends. Mean±S.D was worked out to denote the average oviposition period of *C. septempunctata* and *C. transversalis*.

The period when the female stop egg-laying till the death of the female is computed as post-oviposition for each replicate. Mean±S.D was worked out to denote the average post-oviposition period of *C. septempunctata* and *C. transversalis*.

3.2.3.6 Fecundity

Fecundity is the total number of eggs laid by a single female during its lifetime. For the purpose of fecundity, the infested twigs and leaves of the jar was examined twice a day to mark the freshly laid eggs. The total numbers of eggs laid daily are counted by using the hand lens. The total number of eggs laid by each female was recorded to denote the fecundity.

3.2.3.7 The entire lifespan

The duration from egg-laying to the death of *C. septempunctata* and *C. transversalis* were studied and recorded under laboratory conditions.

3.2.4 Predatory potential of *C. septempunctata* and *C. transversalis*

To determine the predation potential of grubs and adults of the two common aphidiphagous coccinellids, *C. septempunctata* and *C.*

transversalis that was starved for 24 hours before starting the experiment. Using a camel hair brush, mustard aphids of the same instar were transferred into a leaf which was plugged with agar and wet cotton to reduce the water loss and also to avoid the drying of leaves kept in a Petri plate, in which different predatory stages was released individually.

Then predatory grubs just after hatching were transferred and confined individually in Petri plates, provided with host, mustard aphid. The feeding potential of 1st, 2nd, 3rd, and 4th instar grubs and sex-wise adult beetles of *C. septempunctata* and *C. transversalis* were carried out. The number of consumed aphids was examined by counting the unconsumed and dead aphids with the help of a hand lens after every 24 hours. The known numbers of fresh aphids were provided daily. The predating potential of different stages of both species is determined.

3.2.5 Statistical Analysis

The mean and standard deviation were calculated for the biology studies of predatory coccinellids targeted in the experiment. The data obtained for the number of aphids consumed (feeding potential) by different stages of predatory coccinellids were transformed using square root transformation and then were subjected to one-way analysis of variance (ANOVA).



CHAPTER IV



EXPERIMENTAL

FINDINGS

EXPERIMENTAL FINDINGS

The present studies were conducted to know the predatory potential and biology (developmental parameters) viz., incubation period, mean developmental period of grubs and pupae, total life period of male and female, total fecundity, hatching percentage and longevity of coccinellid predator *C. septempunctata* and *C. transversalis* on mustard aphid, *Lipaphis erysimi*. Functional response studies of *C. septempunctata* and *C. transversalis* were also carried out against the different densities of mustard aphid *Lipaphis erysimi* were conducted at the Department of Entomology and Agricultural Zoology, Banaras Hindu University, Varanasi during 2020-2021. The details of the experimental results are furnished as below: -

4.1 BIOLOGY OF PREDATORY COCCINELLIDS SPP.

The present study of biology of two important coccinellids spp. *C. septempunctata* and *C. transversalis* conducted under laboratory conditions revealed the following information: -

4.1.1 *Coccinella transversalis*

4.1.1.1 Pre-oviposition, oviposition and post-oviposition period

The data collected (Table 1) on pre-oviposition period of *C. transversalis* revealed that pre-oviposition period lasted from 4 to 8 days, when reared on mustard aphid, *Lipaphis erysimi*, with an average of 5.22 ± 0.883 days after emergence. On the otherhand oviposition period during which female can lay egg and post-oviposition period, the interval from last oviposition to death was found to be varying from 21-28 days, with an average of 24.08 ± 1.826 days and 3 to 6 days, with an average of 4.58 ± 0.831 days, respectively.

4.1.1.3 Incubation period and hatching percentage

The incubation period of *C. transversalis* varied from 2 to 5 days, with an average of 2.70 ± 0.766 days when reared on mustard aphid *Lipaphis erysimi* under laboratory conditions. After making irregular cracks in chorion grub wriggles out and their hatching percentage were found to be from 67.85 to 97.43 percent, with an average of 84.73 ± 8.114 percent (Table 2).

4.1.1.2 Fecundity

Eggs are laid in clusters on leaves, black paper folding's and periphery of jar. Freshly laid eggs are spindle shaped and yellow in colour, which turns dark before hatching (Plate 4.1). The fecundity of *C. transversalis* when reared on mustard aphid *Lipaphis erysimi* ranges from 319 to 423 with an average of 364.88 ± 27.448 eggs/female (Table 2).

4.1.1.4 Instar wise grub period

The larva of *C. transversalis* passed through four different instars by moulting, occupying different durations. The biology and duration of *C. transversalis* grubs are studied under the laboratory conditions temperature 27°C and RH 75% which revealed the following results (Table 3): -

4.1.1.4.a First instar grub

Freshly emerged grubs were found to be dark grey in colour with long legs (Plate 4.2). The instar grub took 2 to 4 days, with an average of 2.60 ± 0.638 days to complete its morphological development and transform to the next developmental stage.

4.1.1.4.b Second instar grub

The second instar grub completes its development in 2-4 days interval, with an average of 2.76 ± 0.655 days (Plate 4.3.A).

4.1.1.4.c Third instar grub

The duration of third instar grub was found to be in the range of 2 to 5 days, with an average of 3.58 ± 0.831 (Plate 4.3.B).

4.1.1.4.d Fourth instar grub

Through moulting of third instar stage, the grub enters fourth instar developmental stage, which was found to be bigger in body size than the third instar grub (Plate 4.4). This is the last developmental stage before the grub enters pupation. The fourth instar grub period ranges 3 to 5 days, with an average of 3.74 ± 0.823 days.

4.1.1.4.e Total grub period

The total duration taken by all the four instars of grub stage of *C. transversalis* when reared on mustard aphid, *Lipaphis erysimi* varied from 10 to 17 days, with an average of 12.68 ± 0.633 days (Table 3).

4.1.1.5 Pre-pupal and pupal period

The fourth instar grub stops feeding and became sluggish before pupation. It attaches its abdominal segment at suitable place and become immobile. Pre-pupal shape is curved and within the shed grub skin, pupa is formed (Plate 4.5.A), which was splitted lengthwise at the mid-dorsal line from the lateral arms of the epicranial suture to the anterior margin of sixth abdominal tergite. The pre-pupal period of *C. transversalis* was only of 1 day with an average of 1.00 ± 0.00 days. Freshly emerged pupa is pale yellow in colour which later turns dark with black and orange markings (Plate 4.5.B). The pupal period varied from 2 to 4 days, with an average of 2.62 ± 0.696 days (Table 3).

4.1.1.6 Adult

The freshly emerged adults are yellow in colour with black colour head and later develops different colouration (Plate 4.6).

4.1.1.6.a Sex ratio

The *C. transversalis* fed with mustard aphid, *Lipaphis erysimi* develops into female and male population shows distinct morphological characters in adultstage after emerging from pupation. In the present study it was observed that there were 43 males on 57 females showing sex ratio of 1:1.30 (Table 4).

4.1.1.6.b Adult emergence percentage

After completing pupation period *C. transversalis* adults emerges out. The emergence percentage of adults of *C. transversalis* when reared on mustard aphid, *Lipaphis erysimi* was 57.14 to 100 with an average of 80.36 ± 10.830 per cent.

4.1.1.6.c Adult longevity

The total duration of adult stage of *C. transversalis* is called adult longevity. The adult longevity of both the sexes was studied under laboratory conditions and it was observed that female longevity is greater than male longevity i.e., 29 to 41 (33.88 ± 2.566) and 21 to 40 (30.12 ± 4.492) days, respectively (Table 4).

4.1.1.7 Total life span

The total life span of female *C. transversalis* was varied from 46 to 63 with an average of 52.88 ± 3.48 days while in the case of male, it varied from 40 to 64 with an average of 49.12 ± 4.87 days.

4.1.2 *Coccinella septempunctata*

4.1.2.1 Pre-oviposition, oviposition and post-oviposition period

The data collected on pre-oviposition period of *C. septempunctata* revealed that pre-oviposition period lasted from 4 to 13 days, when reared on mustard aphid, *Lipaphis erysimi*, with an average of 7.92 ± 2.45 days after emergence. On the other

hand oviposition period during which female can lay egg and post-oviposition period, the interval from last oviposition to death was found to be varying from 13-26 days with an average of 21.60 ± 3.39 days and 4 to 10 days with an average of 7.16 ± 1.77 days, respectively (Table 5).

4.1.2.2 Fecundity

Eggs are laid in clusters on leaves, black paper folding's and periphery of jar. Freshly laid eggs are spindle shaped and yellow in colour, which turns dark before hatching. The fecundity of *C. septempunctata* when reared on mustard aphid *Lipaphis erysimi* ranges from 405 to 803 with an average of 582.44 ± 93.15 eggs/female (Table 6).

4.1.2.3 Incubation period and hatching percentage

The incubation period of *C. septempunctata* varied from 3 to 6 days, with an average of 4.40 ± 0.77 days when reared on mustard aphid *Lipaphis erysimi* under laboratory conditions (Table 6). After making irregular cracks in chorion grub wriggles out and their hatching percentage were found to be from 66.67 to 80 percent, with an average of 73.30 ± 5.27 percent.

4.1.2.4 Instar wise grub period

The larva of *C. septempunctata* passed through four different instars by moulting, occupying different durations. The biology and duration of *C. septempunctata* grubs are studied under the laboratory conditions temperature 27°C and RH 75% which revealed the following results (Table 7): -

4.1.2.4.a First instar grub

Freshly emerged grubs were found to be dark grey in colour with long legs (Plate 4.7.A). The instar grub took 3 to 5 days, with an average of 3.73 ± 0.70 days to complete its morphological development and transform to the next developmental stage.

4.1.2.4.b Second instar grub

The second instar grub completes its development in 2-4 days, with an average of 2.80 ± 0.76 days (Plate 4.7.B).

4.1.2.4.c Third instar grub

The duration of third instar grub was found to be in the range of 2 to 5 days, with an average of 3.50 ± 0.78 (Plate 4.8. A).

4.1.2.4.d Fourth instar grub

Through moulting of third instar stage, the grub enters fourth instar developmental stage, which was found to be bigger in body size than the third instar grub (Plate 4.8.B). This is the last developmental stage before the grub enters pupation. The fourth instar grub period ranges 2 to 5 days, with an average of 3.63 ± 0.85 days.

4.1.2.4.e Total grub period

The total duration taken by all the four instars of grub stage of *C. septempunctata* when reared on mustard aphid, *Lipaphis erysimi* varied from 9 to 19 days, with an average of 13.67 ± 1.77 days (Table 7).

4.1.2.5 Pre-pupal and pupal period

The fourth instar grub stops feeding and became sluggish before pupation. It attaches its abdominal segment at suitable place and become immobile. Pre-pupal shape is curved and within the shed grub skin pupa is formed, which was splitted lengthwise at the mid-dorsal line from the lateral arms of the epicranial suture to the anterior margin of sixth abdominal tergite. The pre-pupal period of *C. septempunctata* was only of 1 day with an average of 1.00 ± 0.00 days. Freshly emerged pupa is pale yellow in colour which later turns dark with black and orange markings (Plate 4.9). The pupal period varied from 5 to 9 with an average of 6.73 ± 1.11 days (Table 7).

4.1.2.6 Adult

The freshly emerged adults are yellow in colour with black colour head and later develops different colourations.

4.1.2.6.a Sex ratio

The *C. septempunctata* was fed with mustard aphid, *Lipaphis erysimi* develops into female and male population shows distinct morphological characters in adult stage after emerging from pupation. In the present study it was observed that male and female sex ratio was 1:1.39 (Table 8).

4.1.2.6.c Adult longevity

The total duration of adult stage of *C. septempunctata* is called adult longevity. The adult longevity of both the sexes was studied under laboratory conditions and it was observed that female longevity is greater than male longevity i.e., 30 to 45 (37.30 ± 3.44) and 26 to 39 (31.33 ± 3.28) days, respectively (Table 8).

4.2 PREDATORY POTENTIAL OF COCCINELLIDS SPP.

The predatory potential of two coccinellid species *C. septempunctata* and *C. transversalis* were studied on mustard aphid, *Lipaphis erysimi* infesting mustard, under laboratory conditions revealed the following information

4.2.1 *Coccinella transversalis*

The data on predatory potential of *C. transversalis* on mustard aphid, *Lipaphis erysimi* is presented in Table 9. It showed that mean consumption by the first, second, third and fourth instar grub was 19.95 ± 3.23 , 34.25 ± 4.36 , 58.30 ± 7.54 and 65.67 ± 8.23 aphids, respectively (Fig. 4.1). The average consumption of adult male and female was 58.32 ± 5.23 and 62.17 ± 5.76 aphids, respectively, which shows that female is more voracious feeder than males.

4.2.2 Coccinella septempunctata

The data on predatory potential of *C. septempunctata* on mustard aphid, *Lipaphis erysimi* is presented in Table 10. It showed that mean consumption by the first, second, third and fourth instar grub was 15.86 ± 0.34 , 45.10 ± 0.45 , 124.62 ± 0.88 and 238.82 ± 1.11 aphids, respectively (Fig. 4.2) and the total consumption during larval period was found to be 424.4 ± 2.78 aphids. The average consumption of aphids per day by an adult male and female was 103.2 ± 1.52 and 116.6 ± 1.46 aphids, respectively, which show that adult female of *C. septempunctata* consumed greater number of aphids than adult male per day.



CHAPTER V



DISCUSSION

DISCUSSION

The biology and predatory potential of *C. septumpunctata* and *C. transversalis* on mustard aphid, *Lipaphis erysimi* were studied under laboratory conditions at Acarology Lab, Department of Entomology and Agricultural Zoology, BHU, Varanasi.

5.1 Biology of ladybird beetle *C. transversalis*

The study of biology of *C. septempunctata* and *C. transversalis* on mustard aphid, *Lipaphis erysimi* will help us in knowing the weak and strong links for efficient use in biological control and mass production in laboratory.

5.1.1 Preoviposition, Oviposition and Post-oviposition

The pre-oviposition period of *C. transversalis* on mustard aphid, *Lipaphis erysimi* under laboratory conditions was varied from 4 to 8 with an average 5.22 ± 0.883 days. Gurung *et al.*, (2016) reported that the pre-oviposition period of *C. transversalis* on mustard aphid, *Lipaphis erysimi* was 5.3 ± 1.94 days and Bista (2020) reported pre-oviposition period of 6.40 ± 0.40 days when prey was abundant and 9.20 ± 0.49 days when reared under scarcity of prey.

The present studies revealed that oviposition of *C. transversalis* on mustard aphid, *Lipaphis erysimi* under laboratory conditions was 24.08 ± 1.826 days, which was in close conformity with those of Mari-Bugati (2016) who recorded the oviposition period of 23.62 days of *C. undecimpunctata* on mustard aphid, *Lipaphis erysimi* and 24.22 days on maize aphid. On the other hand, Deho (2009) reported the oviposition period of 35.8 ± 1.64 days. Rajan (2018), Chakraborty and Korat (2014) and Gurung (2018) also reported oviposition period of *C. transversalis* which were 13.0 ± 1.33 , 12.20 ± 1.27 and 9.2 ± 2.14 days, respectively.

The post-oviposition period was found to be varied from 3 to 6 days with an average of 4.58 ± 0.831 days in present studies, which was in agreement with Mari *et al.*, (2016) who reported the post-oviposition of 4.66 days of *C. undecimpunctata* on maize aphid and Rajan *et al.*, (2018) who reported the post-oviposition period of 4.6 ± 0.84 days. The post-oviposition period was also given by Gurung *et al.*, (2016) and Kumar *et al.*, (2019) which was 5.1 ± 0.87 and 4.33 ± 0.88 days, respectively.

5.1.2 Fecundity

The total number of eggs laid by female adult of *C. transversalis* ranged from 319 to 423 with an average of 364.88 ± 27.446 eggs, the present findings are in close conformity with those of Shukla and Jadhav (2014) who reported that the same mean fecundity of *C. transversalis* on mustard aphid, *Lipaphis erysimi* and not in agreement with Junsung (2002) who reported the mean fecundity 645.27 ± 213.37 eggs higher mean fecundity of 645.27 ± 213.37 eggs, while the Chakraborty and Korat (2014) reported the lower fecundity of 253.85 ± 38.76 eggs.

5.1.3 Incubation period and hatching percent

The incubation period of *C. transversalis* on mustard aphid, *Lipaphis erysimi* varied from 2-5 days, with an average of 2.70 ± 0.766 days under laboratory conditions, this data was similar to the findings of Shukla and Jadhav (2014) and was in close conformity with the findings of Rajan *et al.*, (2018) who reported that incubation period of *C. transversalis* against cabbage aphid *Brevicorne brassicae* was 2.5 ± 0.53 days and Junsung (2002) who reported the incubation period of 2.55 ± 0.5 days. It was found that present studies were varied with the findings of Gurung *et al.*, (2018) who reported the incubation period of 5.2 ± 1.28 days of *C. transversalis* on mustard aphid, *Lipaphis erysimi*.

The hatching percentage of *C. transversalis* was found to be 67.85 to 97.43 with an average of 84.73 ± 8.114 percent in the present studies, while Bista (2020) reported that when the food is scarce the hatching percent was 82.72 ± 0.67 percent and with optimum availability of food it goes up to 89.87 ± 0.87 percent.

5.1.4 Instar grub period

5.1.4.a First instar grub

The period of first instar grub was in range of 2 to 4 with an average of 2.60 ± 0.638 days in the present studies. Sarker *et al.*, (2019) reported the first instar grub period of *C. transversalis* were 2.66 ± 1.15 and 2.66 ± 0.58 days on *Aphis craccivora* and *Aphis gossypii*, respectively. Mari *et al.*, (2016) reported the period of first instar grub of *C. undecimpunctata* on mustard aphid, *Lipaphis erysimi* which was 5.23 days.

5.1.4.b Second instar grub

The present findings of second instar grub period were found to be 2 to 4 with an average of 2.76 ± 0.655 days. Sarker *et al.*, (2019) reported the second instar grub period of *C. transversalis* 2.66 ± 0.58 days on *A. fabae* whereas Chakraborty and Korat (2014) and Debaraj and Singh (1990) reported the second instar grub period of 3.93 ± 0.23 and 3.92 ± 0.13 days, respectively.

5.1.4.c Third instar grub period

The third instar grub period of *C. transversalis* on mustard aphid, *Lipaphis erysimi* varied from 2-5 days, with an average of 3.66 ± 0.831 days in present studies which is in agreement with Sarker *et al.*, (2019) who reported the thirist instar grub period of 3.66 ± 0.58 days. Rajan *et al.*, (2018) reported 3.7 ± 0.48 days of third instar grub period of *C. transversalis* on cabbage aphid, *B. brassicae*.

5.1.4.d Fourth instar grub

The developmental period of fourth instar grub of *C. transversalis* on mustard aphid, *L. erysimi* in present studies ranged from 3 to 5 with an average of 3.74 ± 0.823 days, which was found in partially in accordance with Deho (2009) who reported the period of fourth instar grub of *C. transversalis* on *Aphis gossypii* which was 3.9 ± 0.22 days. Yadav *et al.*, (2016) reported 3.63 ± 0.85 days of fourth instar grub

of *C. septempunctata* on mustard aphid *Lipaphis erysimi*.

5.1.4.e Total grub period

The total developmental period of *C. transversalis* grub on mustard aphid, *Lipaphis erysimi* varied from 10 to 17 days, with an average of 12.68 ± 0.633 days in the present studies. Similar results were also reported by Shukla and Jadhav (2014) in his studies of biology of *C. transversalis* on mustard aphid, *Lipaphis erysimi*.

5.1.4 Pre-pupal period

The present findings of pre-pupal period were found to be 1.00 ± 0.00 day, which was in agreement with studies of Rajan *et al.*, (2018) who reported that pre-pupal period of *C. transversalis* against cabbage aphid *Brevicoryne brassicae* was 1.2 ± 0.46 days. The pre-pupal period was not in agreement with the findings of Gurung *et al.*, (2018), who reported the pre-pupal period of 4.05 ± 0.08 days of *C. transversalis* on mustard aphid, *Lipaphis erysimi*.

5.1.5 Pupal period

The present finding of pupal period was found to be in range of 2 to 4 days with an average of 2.62 ± 0.696 days, which was in close conformity with the findings of Shukla and Jadhav (2014) who reported the pupal period of 2.62 ± 0.69 days. It was found that present studies were varied with the findings of Chakraborty and Korat (2014) who reported the pupal period of 8.27 ± 0.15 days on bean aphid *Aphis crassivora*.

5.1.7 Adult

5.1.7.1 Sex ratio

The sex ratio of *C. transversalis* when reared on mustard aphid, *Lipaphis erysimi* was found to be 1:1.32, in the present studies. Tank and Korat (2007) reported sex ratio of 1:1.3 for *C. sexmaculata* when reared on *Aphis gossypii*.

5.1.7.2 Adult emergence percentage

The adult emergence percentage of *C. transversalis* on mustard aphid, *Lipaphis erysimi* varied from 57.14 to 100 with an average of 80.36 ± 10.830 per cent. Sarwer and Saket (2010) reported the adult emergence percentage of 89.6 for *C. septempunctata* on mustard aphid, *Lipaphis erysimi*.

5.1.8 Adult longevity

5.1.8.1 Male

The male longevity of *C. transversalis* grub on mustard aphid, *Lipaphis erysimi* varied from 21 to 40 with an average of 30.12 ± 4.492 days, which is in accordance with the studies of Kumar *et al.*, (2019) who reported the male longevity of 30.67 ± 0.67 days. Similar results were shown by Mari *et al.*, (2016) who reported the male longevity of 30 days of *C. undecimpunctata* on maize aphid. Chakraborty and Korat (2014) reported male longevity of 21.13 ± 1.02 days.

5.1.8.2 Female

The male longevity of *C. transversalis* grub on mustard aphid, *Lipaphis erysimi* varied from 29 to 41 days, with an average of 33.88 ± 2.566 days in the present studies. Yadav *et al.*, (2016) reported the female longevity of 37.30 ± 3.44 days of *Coccinella septempunctata* on mustard aphid *Lipaphis erysimi*.

5.1.9 Total life span

5.1.9.1 Male

The total life span of male varied from 40 to 64 with an average of 49.12 ± 4.87 days in the present studies. Jusung *et al.*, (2002) reported the life span of male of *C. transversalis* to be 37.4 ± 16.95 days.

5.1.9.2 Female

The total life span of female varied from 46 to 63 with an average of

52.88±3.48 days in present studies. Jusung *et al.*, (2002) reported the life span of female of *C. transversalis* to be 45.53±18.15 days.

5.2 *Coccinella septempunctata*

5.2.1 Pre-oviposition, Oviposition and Post-oviposition

The pre-oviposition period of *C. septempunctata* on mustard aphid, *Lipaphis erysimi* under laboratory conditions was varied from 4 to 13 with an average 7.92±2.45 days. Rai *et al.*, (2002) reported that the pre-oviposition period of *C. septempunctata* on mustard aphid, *Lipaphis erysimi* was 7.52±0.34 days. Varshney *et al.*, (2016) reported pre-oviposition period to be 6.5±3.53 days.

The present studies revealed that oviposition of *C. septempunctata* on mustard aphid, *Lipaphis erysimi* under laboratory conditions was 13 to 26 days with an average of 21.6±3.39 days, which was in partially accordance with Rauf *et al.*, (2013), who reported the oviposition period of *C. septempunctata* on *Schizaphis graminum* to be 22.20±0.24 days. Varshney *et al.*, (2016) reported oviposition period of *C. septempunctata* on mustard aphid, *Lipaphis erysimi* to be 12.8±3.91 days.

In the present studies the post-oviposition period was found to be varied from 4 to 6 with an average of 7.16±1.77 days, which was in agreement with the Yadav *et al.*, (2016). Kumar *et al.*, (2019) reported the post-oviposition period of 4.33±0.88 days of *C. septempunctata* on *Lipaphis erysimi*.

5.2.2 Fecundity

The total numbers of eggs laid by female adult of *C. septempunctata* ranged from 405 to 803 with an average of 582.44±93.15, the present findings are in close conformity with the findings of Skouras *et al.*, (2015), who reported that fecundity of *C. septempunctata* was 586 eggs. Mishra and Kanwat (2017) reported that the fecundity of *Coccinella septempunctata* on *Lipaphis erysimi* found to be 657.7 eggs, on the other hand Sipio *et al.*, (2017) reported the fecundity to be 1241.2±10.25 eggs.

5.2.3 Incubation period and hatching percent

The incubation period of *C. septempunctata* on mustard aphid, *Lipaphis erysimi* varied from 3 to 6 days, with an average of 4.40 ± 0.77 days under laboratory conditions, this data was similar to the findings of Singh *et al.*, (2009) who reported that the incubation period of *C. septempunctata* on mustard aphid, *Lipaphis erysimi* was 4.40 ± 0.22 days. Rai *et al.*, (2002) and Kumar *et al.*, (2019) reported the incubation period of 1.76 ± 0.16 and 3.33 ± 0.33 days, respectively.

The hatching percent of *C. septempunctata* was found to be 66.67 to 80 with an average of 73.3 ± 5.27 percent in the present studies, which was in agreement with the Yadav *et al.*, (2016). Others who have reported the hatching percent in the above range were Varshney *et al.*, (2016), Rauf *et al.*, (2013), Mari *et al.*, (2016).

5.2.4 Instar grub period

5.2.4.a First instar grub

The period of first instar grub was in range of 3 to 5 with an average of 3.73 ± 0.7 days in the present studies. Rauf *et al.*, (2013) reported the period of first instar grub to be 3.44 ± 0.07 days. Pareek (2003) reported the period of first instar grub to be 2.00 days.

5.2.4.b Second instar grub

The present findings of second instar grub period were found to be 2 to 4 with an average of 2.80 ± 0.76 days, was found to be in partial accordance with the findings of Seema *et al.*, (2000) who reported the average duration of second instar grub of 2.60 days. Similar results were shown by Rauf *et al.*, (2013) who reported the average duration of second instar grub of *C. septempunctata* on *Schizaphis graminum* which was found to be 2.78 ± 0.10 days.

5.2.4.c Third instar grub

The third instar grub period of *C. septempunctata* on mustard aphid,

Lipaphis erysimi varied from 2-5 days, with an average of 3.50 ± 0.78 days in present studies which is partially in accordance with the studies of Kumar (2019) who reported the 3.67 ± 0.33 days of average duration of third instar grub period. Nirmala *et al.*, (1996) reported the third instar grub period to be 1.33 ± 0.18 of *Coccinella septempunctata* on cabbage aphid, *Brevicoryne brassicae* Linn.

5.2.4.d Fourth instar grub

The developmental period of fourth instar grub of *C. septempunctata* on mustard aphid, *L. erysimi* in present studies ranged from 2 to 5 with an average of 3.63 ± 0.85 days. Seema (2000) reported the average duration of fourth instar grub as 3.86 days for *C. septempunctata* and Sahito *et al.*, (2019) reported the average duration of fourth instar grub as 8.00 days for *C. septempunctata* on mustard aphid, *Lipaphis erysimi*.

5.2.4.e Total grub period

The total developmental period of *C. septempunctata* grub on mustard aphid, *Lipaphis erysimi* varied from 9 to 19 days, with an average of 13.67 ± 1.77 days in the present studies. Similar results were reported by Khurshed *et al.*, (2006) who reported 13.5 ± 0.87 days of total grub period *Coccinella septempunctata* on *Lipaphis erysimi*. Sarwer and Saket (2010) reported the average of total grub period as 13.00 days and Singh *et al.*, (2009) reported the total grub period of 10.95 ± 0.35 days.

5.2.5 Pre-pupal period

The present findings of pre-pupal period of *C. septempunctata* on mustard aphid, *Lipaphis erysimi* were found to be 1.00 ± 0.00 day. Khurshed *et al.*, (2006) reported that the mean pre-pupal period of *C. septempunctata* was 1.5 ± 0.29 days when reared on mustard aphid, *Lipaphis erysimi*.

5.2.6 Pupal period

The present finding of pupal period were in the range of 5 to 9 with an

average of 6.73 ± 1.11 days. Sahito *et al.*, (2019) reported the pupal period of 6.40 days of *C. septempunctata* on mustard aphid, *Lipaphis erysimi*. Khurseed *et al.*, (2006) reported the pupal period of 7.5 ± 0.87 days.

5.1.6 Sex ratio

The sex ratio of *C. septempunctata* on mustard aphid, *Lipaphis erysimi* were found to be 1.0:1.39. Mishra and Kanwat (2017) reported the sex ratio of 1.0:1.6 for *C. septempunctata* on mustard aphid, *Lipaphis erysimi*.

5.1.8 Adult longevity

5.1.8.1 Male

The male longevity of *C. septempunctata* grub on mustard aphid, *Lipaphis erysimi* varied from 26 to 29 with an average of 31.33 ± 3.28 days, this present study was found to be in accordance with the findings of Yadav *et al.*, (2016). Kumar *et al.*, (2019) reported the male longevity of 30.67 ± 0.67 days for *C. septempunctata* on mustard aphid, *Lipaphis erysimi* and Rauf *et al.*, (2013) reported male longevity of 44.73 ± 0.65 days on *Schizaphis granium*.

5.1.8.2 Female

The female longevity of *C. septempunctata* grub on mustard aphid, *Lipaphis erysimi* varied from 30 to 45 with an average of 37.30 ± 3.44 days. Similar results were shown by Kumar *et al.*, (2019) who reported the female longevity of 36.67 ± 0.33 days. Mari *et al.*, (2016) reported the female longevity of 40.9 for *C. undecimpunctata* on mustard aphid, *Lipaphis erysimi*.

5.2 Predatory potential

Studies on feeding potential of natural enemies throws light on two things i.e., most efficient stage of natural enemies and most susceptible or preferred stage of prey or host.

5.2.1 *Coccinella septempunctata*

According to the present studies, when *C. septempunctata* was reared on mustard aphid, *Lipaphis erysimi*, the consumption of first instar grub was found to be 15.86 ± 0.34 aphids, which is in contrary with the findings of Sattar *et al.*, (2008) who reported that the first instar grub of *C. septempunctata* consumed 21.9 cotton aphids. Singh *et al.*, (2009) reported that the consumption of first instar grub was found to be 19.72 aphids.

The second instar grub on an average consumed 45.1 ± 0.45 aphids, as also reported by Jandilal and Malik (2006) who computed the consumption of second instar grub as 40 aphids. The present studies are not in agreement with the findings of Sattar *et al.*, (2008) who computed the mean consumption of second instar grub of 55.9 days.

The average of predatory potential of 3rd instar grub was found to be 124.62 ± 0.88 aphids in the present studies, which is in partial accordance with the studies of Sattar *et al.*, (2008) who reported the average consumption of 107.4 aphids by the third instar grub. It is in contrary with the findings of Sharma and Joshi (2010) who computed the average consumption of third instar grub of *C. septempunctata* as 4.56 ± 0.5 aphids of mustard aphid.

During the course of this present study the 4th instar grub showed an enhanced predation up to 238.82 ± 1.1 aphids. Pareek *et al.*, (2014) observed similar results of 237.37 ± 88.37 aphids as average consumption by fourth instar grub of *C. septempunctata* when reared on coriander aphid, *H. corriandri*. Khurseed *et al.*, (2006) reported the average consumption of fourth instar grub to be 209.33 ± 19.36 aphids, which was found to be in partial accordance with the present studies. In contrary, Jandilal and Malik (2006) reported 74.8 aphids as average consumption of fourth instar grub.

The total number of aphids consumed during larval period was found to be 424.4 ± 2.78 aphids which is in agreement with the findings of Varshney *et al.*, (2016) who reported total number of aphids consumed during larval period was 424.4 ± 2.78 aphids at $27 \pm 2^{\circ}\text{C}$ and in contrary when same was recorded at $23 \pm 2^{\circ}\text{C}$, which was

recorded to be 272.64 ± 1.19 aphids. Nirmala *et al.*, (1996) reported that 291.65 ± 1.19 aphids consumed during the larval period of *C. septempunctata*.

The average consumption by adult female and male was found to be 103.2 ± 1.52 and 116.6 ± 1.46 aphids/day/individual, respectively. The present studies were found to be in agreement with Singh *et al.*, (2009) who reported the average consumption by adult female and male of *C. septempunctata* reared on mustard aphid, *Lipaphis erysimi*, were 120.62 and 107.15 aphids/day/individual, respectively.

5.2.2 *Coccinella transversalis*

According to the present studies, when *C. transversalis* was reared on mustard aphid, *Lipaphis erysimi*, the consumption of first instar grub was found to be 19.95 ± 3.23 aphids, which is in close conformity with the findings of Gurung *et al.*, (2018) who reported the average consumption of first instar grub of *C. septempunctata* to be 15.4 ± 4.39 aphids. In the contrary of present studies Bukero *et al.*, (2014) reported that 4.0 aphids were consumed by first instar grub of *C. transversalis* was reared on mustard aphid, *Lipaphis erysimi*.

The second instar grub on an average consumed 34.25 ± 4.36 aphids, as also reported by Borah and Dutta (2010) in their studies of *C. transversalis* reared on mustard aphid, *Lipaphis erysimi*. Bukero *et al.*, (2014) reported the predatory potential of second instar grub to be 9.34 aphids which is not in agreement with the present studies.

The average of predatory potential of 3rd instar grub was found to be 58.30 ± 7.54 aphids in the present studies, which was in accordance with the studies of Bukero *et al.*, (2014) who reported the average consumption of third instar grub to be 53.61 aphids, when *C. transversalis* was reared on *A. gossypii* and on the contrary Gurung *et al.*, (2018) reported that 37.15 ± 5.27 aphids were consumed by third instar grub of *C. transversalis*.

During the course of this present study the 4th instar grub showed the average consumption of 65.67 ± 8.23 aphids. Borah and Dutta (2010) observed the same results as the present findings, while in contrary Bukero *et al.*, (2014) reported

the average consumption of 4th instar grub to be 31.96 aphids.

The average consumption by adult female and male was found to be 58.32 ± 5.23 and 62.17 ± 5.76 aphids/day/individual, respectively. The present studies were found to be in partial agreement with the findings of Bukero *et al.*, (2014) who reported the average consumption by adult female and male as 44.99 and 56.56 aphids/day/individual, respectively and in contrary he also reported the average consumption by adult female and male as 121.04 and 145.08 aphids/day/individual, respectively when reared on *A. gossypii*.

The present studies revealed that the predatory potential found to be increased with increase in grubs age i.e., highest aphids were consumed by fourth instar grub of *C. transversalis* and *C. septempunctata* which were 65.67 ± 8.23 and 238.82 ± 1.11 , respectively. The overall consumption was found to be maximum for females which shows that female devour a greater number of aphids than males. These present findings were in agreement with the findings of Jandilal and Malik (2006) and Rajan *et al.*, (2018).



CHAPTER VI



SUMMARY

AND

CONCLUSION

SUMMARY AND CONCLUSION

The present studies on “Biology and predatory potential of *Coccinella septempunctata* and *Coccinella transversalis* on mustard aphid, *Lipaphis erysimi*” were carried out during 2020-2021. The biology as well as predatory potential were studied at maintained temperature and relative humidity in the Acarology laboratory, Department of Entomology and Agricultural Zoology, BHU, Varanasi.

Important findings emerged from these studies are summarized here in this chapter.

6.1 BIOLOGICAL STUDIES

6.1.1. Eggs

Freshly laid eggs of *C. transversalis* were spindle shaped vertical, deep yellow in colour and have smooth chorion, usually laid in clusters of 5 to 37. The adult mated female of *C. transversalis* observed to lay 319 to 403 eggs with an average of 364.88 ± 27.446 eggs, while the incubation period was found to be 2.70 ± 0.766 days. Average hatching percent of eggs were observed to be 84.73 ± 8.114 percent.

Likewise, the freshly laid eggs of *C. septempunctata* were cigar or oval shaped, vertical, and laid in cluster of 15-25. The adult mated female of *C. septempunctata* observed to lay 405 to 803 with an average of 582.44 ± 93.15 eggs, while the incubation period was found to be 4.40 ± 0.77 days. Average hatching percent of eggs were observed to be 73.3 ± 5.27 percent.

6.1.2 Larvae

The larva of *C. transversalis* passes through four distinct instars and average duration of each instar was recorded to be 2.60 ± 0.638 , 2.76 ± 0.655 , 3.58 ± 0.831 and 3.74 ± 0.823 days, respectively. The total larval duration ranged from 10 to 17 with an average of 12.68 ± 1.633 days.

Similarly, the larva of *C. septempunctata* also passes through four distinct

instars and average duration of each instar was recorded to be 3.73 ± 0.7 , 2.80 ± 0.76 , 3.50 ± 0.78 and 3.63 ± 0.85 days, respectively. The total larval duration ranged from 9 to 19 with an average of 13.67 ± 1.77 days.

6.1.3 Pre-pupal and pupal period

The average pre-pupal and pupal period of *C. transversalis* were 1.00 ± 0.00 and 2.62 ± 0.696 days, respectively, while the adult emergence percent and sex ratio were found to be 80.36 ± 10.830 per cent and 01:01.3, respectively.

Likewise, the average pre-pupal and pupal period of *C. septempunctata* were 1.00 ± 0.00 and 6.73 ± 1.11 days, respectively, while the sex ratio was found to be 1.0:1.39.

6.1.4 Pre-oviposition, oviposition and post-oviposition period

The average pre-oviposition, oviposition and post-oviposition periods of female of *C. transversalis* were recorded to be 5.22 ± 0.883 , 24.08 ± 1.826 and 4.58 ± 0.831 days, respectively.

Similarly, the average pre-oviposition, oviposition and post-oviposition periods of female of *C. septempunctata* were recorded to be 7.92 ± 2.45 , 21.60 ± 3.39 and 7.16 ± 1.77 days, respectively.

6.1.5 Adult longevity

The longevity of female and male beetle of *C. transversalis* were recorded to be 33.88 ± 2.566 and 30.12 ± 4.492 days, respectively.

Likewise, the longevity of female and male beetle of *C. septempunctata* were recorded to be 37.30 ± 3.44 and 31.33 ± 3.28 days, respectively.

6.1.6 Life span

The average entire life span (from egg to the death of adult) of *C. transversalis* was observed to be 52.88 ± 3.480 and 49.12 ± 4.870 days of female and male, respectively.

6.2 Predatory potential

The average number of aphids consumed by first, second, third and fourth instars of *C. transversalis* were 19.95 ± 3.23 , 34.25 ± 4.36 , 58.30 ± 7.54 and 65.67 ± 8.23 aphids, respectively. The average consumption by adult female and male was found to be 58.32 ± 5.23 and 62.17 ± 5.76 aphids/day/individual, respectively.

Similarly, the average number of aphids consumed by first, second, third and fourth instars of *C. septempunctata* were 15.86 ± 0.34 , 45.1 ± 0.45 , 124.62 ± 0.88 and 238.82 ± 1.11 , respectively, whereas, the feeding capacity of *C. septempunctata* during its total larval period was 424.4 ± 2.78 aphids. The average consumption by adult female and male was found to be 116.6 ± 1.46 and 103.2 ± 1.52 aphids/day/individual, respectively.

CONCLUSION

Coccinellid beetles are important predators against a number of sucking pests in Agri-horticultural crops. The ladybird beetles, *C. septempunctata* and *C. transversalis* observed to complete their metamorphosis through four developmental stages viz., egg, grub, pupa and adult. Except egg and pupal stage, all the developmental stages of the predator were observed to attack the pest and consumed it having differential preference. It is concluded that both the *C. septempunctata* and *C. transversalis* have certain attributes such as high fecundity, amenability of laboratory rearing makes them an ideal candidate for the control of aphid, (*Lipaphis erysimi*). As the predatory potential of *C. septempunctata* was found to be greater with that of *C. transversalis*. For effective control of mustard aphid, *Lipaphis erysimi*, *C. septempunctata* were found to be the effective tool, so as to keep the pest population below economic injury level, it should be utilized in the integrated pest management strategies.





BIBLIOGRAPHY

BIBLIOGRAPHY

- Ahmed, K. S., Majeed, M. Z., Rafi, M. A., Sellami, F. & Afzal, M. (2017).** Biodiversity and Species Distribution of Coccinellids (Coccinellidae: Coleoptera) in District Sargodha (Punjab), Pakistan. *Pakistan Journal of Zoology*, **49(5)**: 1749-1759.
- Aktar, M. W., Sengupta, D. & Chowdhury, A. (2009).** Impact of pesticides use in agriculture: their benefits and hazards. *Interdisciplinary toxicology*, **2(1)**:1.
- Ali, S. S. (2000).** Laboratory observations on exploitation rate of spotted beetle, *Coccinella septempunctata* Linn. against mustard aphid, alfa alfa aphid and corn leaf aphid. Thesis submitted to Sindh Agricultural University, Tandojam, p 41.
- Ali, A. & Rizvi, P. Q. (2007).** Development and predatory performance of *Coccinella septempunctata* L (Coleoptera: Coccinellidae) on different aphid species. *Journal of Biological Sciences*, **7(8)**: 1478-1483.
- Ali, Arshad & Rizvi, Parvez & Khan, Farmanur Rahman. (2009).** Predation by larvae of three coccinellid species on mustard aphid: a comparative study. *Bionotes*.**11**: 125-126.
- Ali, A.R., Rizvi, P.Q. & Pathak, M.A. (2009).** Reproductive performance of *Coccinella transversalis* Fabricius (Coleoptera: Coccinellidae) on different aphid species. *Biosystematica*, **3**: 37-41
- Anjum, Suhail & Sabir, Arshed & Adil, Hussain & Asif, Saeed. (1999).** Predatory Efficacy of *Coccinella septempunctata* L. on Cotton Aphids, *Aphis gossypii* Glov. *Pakistan Journal of Biological Sciences*, **2(3)**: 603- 605.
- Anonymous (2017).** Land use statistics at a glance 2007-08 to 2016-17, Directorate of Economics & Statistics, DAC&FW, Ministry of Agriculture and Farmers

Welfare.

Anonymous (2018) "Why are ladybirds so-called?". *UK Ladybird survey*. Archived from the original on 1 July 2018. Retrieved 15 October 2010.

Anonymous (2019). Agri at a glance 2019, Directorate of economics and statistics, DAC&FW, Ministry of Agriculture and Farmers Welfare.

Anonymous (2019). Fourth advance estimates, Directorate of Economics & Statistics, DAC&FW, Ministry of Agriculture and Farmers Welfare.

Anonymous (2020). Third advance estimate 2019-2020, PIB, Ministry of Agriculture and Farmers Welfare.

Anonymous (2021). Key highlights of economic survey 2020-21, PIB, Ministry of Finance, <https://pib.gov.in/PressReleasePage.aspx?PRID=1693231>

Arshad, A., Rizvi, P. Q. & Khan, F. R. (2010). Predatory performance of *Coccinella transversalis* on different aphid species under natural environment. *Bionotes*, **12(1)**: 31-32.

Arshad, M., Khan, H. A. A., Hafeez, F., Sherazi, R. & Iqbal, N. (2017). Predatory potential of *Coccinella septempunctata* L. against four aphid species. *Pakistan Journal of Zoology*, **49(2)**: 623-627.

Aslam, B., Lanjar, A. G., Solangi, A. W., Memon, A. A., Gulzar, T., Nahyo, S. A. & Buriro, R. A. (2014). Voracity rate and development period of *Coccinella transversalis* (Fabricius) on three aphid species. *Science International (Lahore)*, **26(5)**: 2255-2257.

Bakhetia, D. R. C., Sekhon, B. S., Brar, K. S. & Ghorbandi, A. W. (1989). Determination of economic threshold of *Lipaphis erysimi* (Kaltenbach) on Indian mustard. *Journal of Aphidology*, **3(1-2)**: 125-134.

Bianchi, J.J., Felix, A. & Werf, W. (2004). Model evaluation of the function of prey in non-crop habitats for biological control by ladybeetles in agricultural landscapes. *Ecological Modelling*, **171**: 177-193.

- Bista, M. (2020).** Prey quantity affects development, survival and reproductive attributes of *Coccinella transversalis* Fabricius, 1781 under laboratory conditions. *Nepalese Journal of Zoology*, **4(1)**: 8-15.
- Borah, R. & Dutta, S. K. (2010).** Feeding potential of *Coccinella transversalis* F. on different morphs of mustard aphid, *Lipaphis erysimi* (Kaltenbach). *Journal of Biological Control*, **24(3)**: 271-273.
- Boopathi, T., Singh, S. B., Dutta, S. K., Dayal, V., Singh, A. R., Chowdhury, S. & Lalhruaipuii, K. (2020).** Biology, predatory potential, life table, and field evaluation of *Propylea dissecta* (Coleoptera: Coccinellidae), against *Lipaphis erysimi* (Hemiptera: Aphididae) on broccoli. *Journal of Economic Entomology*, **113(1)**: 88-97.
- Bukero, A., Lanjar, A. G., Solangi, A. W., Faisal, M., Pathan, S. N. & Nahiyoon, S. A. (2015).** Biology of *Coccinella transversalis* Fab. on *Aphis Nerii* Under Laboratory Conditions. *Science International*, **27(4)**.
- Bunker, G. K. & Ameta, O. P. (2009).** Predation potential of *Coccinella septempunctata*, *Coccinella sexmaculata* and *Coccinella cornea* on different species. *Indian Journal of Applied Entomology*, **71(1)**: 76-79.
- Chakraborty, D. & Korat, D. M. (2014).** Biology, morphometry and feeding potential of *Coccinella transversalis* (Fabricious). *The Bioscan*, **9(3)**:1101-1105.
- Debaraj, Y. & Singh, T. K. (1990).** Biology of an Aphidophagous Coccinellid Predator, *Coccinella transversalis* Fab. *Journal of Biological Control*, **4(2)**: 93-95.
- Deho, A. A. (2009).** Biology and feeding potential of lady beetle *Coccinella transversalis* (F) (Coleoptera: Coccinellidae) on *Aphis gossypii*. 55.
- Devi, N., Raj, D. & Verma, S. C. (1996).** Biology and feeding potential of *Coccinella septempunctata* Linn. (Coccinellidae: Coleoptera) on cabbage aphid, *Brevicoryne brassicae* Linn. *Journal of Entomological Research*, **20(1)**: 23-25.

- El Tayeb, A. E. & Zaitoon, A. A. (1996).** Biological parameters for four coccinellid species in central Saudi Arabia. *Biological Control*, **7(3)**: 316- 319
- Gour, I. S. & Pareek, B. L. (2003).** Biology and predation potential of *Coccinella septempunctata* Linnaeus on mustard aphid, *Lipaphis erysimi* (Kalt.) in Semi-Arid region of Rajasthan. *Annals of Biology*, **19(2)**: 225-229.
- Gopalan, C., Sastri. B. V. R. & Balasubramanian, S. (2007).** Nutritive Value of Indian Foods, published by National Institute of Nutrition (NIN), Indian Council of Medical Research.
- Gupta, R. K., Pervez, A., Guroo, M. A. & Srivastava, K. (2012).** Stage-specific functional response of an aphidophagous ladybird, *Coccinella septempunctata* (Coleoptera: Coccinellidae), to two aphid species. *International Journal of Tropical Insect Science*, **32(3)**: 136-141.
- Gurung, B., Ponnusamy, N. & Pal, S. (2018).** Biology And Feeding Potential of Lady Beetle *Coccinella transversalis* (Fabricius) (Coleoptera: Coccinellidae) On *Lipaphis erysimi* (Koch). *Journal of InsectScience*, **31(1-2)**: 47-50.
- Hadley, D. (2020).** The 4 Stages of the Ladybug Life Cycle. Retrieved from <https://www.thoughtco.com/the-life-cycle-of-ladybugs-1968141>
- Jandial, V. K. & Malik, K. (2006).** Feeding potential of *Coccinella septempunctata* Linn. (Coccinellidae: Coleoptera) on mustard aphid, *Lipaphis erysimi* Kalt. and potato peach aphid, *Myzus persicae* Sulzer. *Journal of entomological research*, **30(4)**: 291-293.
- Jesu rajan, S., Sree Latha, E., Vijaya Raghavendra, R. & Sreenivasa Rao, C. H. (2018).** Biology and feeding potential of *Coccinella transversalis* (Fab.) on cabbage aphid, *Brevicoryne brassicae* (Linn.). *Journal of Entomology and Zoology Studies*, **6(6)**:51-56.
- Jung, L., Charernsom, K., Kernasa, O. & Rattanaka, S. (2002).** Study of the coccinellid, *Coccinella transversalis* F. (Coleoptera: coccinellidae), and its

role as biological control agent. *Kaen Kaset*. 28-33.

Kafle, T. K. (2015) Management of mustard aphid *Lipaphis erysimi* (Kalt.) (Homoptera: Aphididae), *International Journal of Applied Sciences and Biotechnology*. **3(3)**: 537–540.

Khurshed, R., Hussain, B., Ahmad, B.S. & Ashraf M. (2006). Biology and feeding potential of *Coccinella septempunctata* Linn. on Mustard Aphid *Lipaphis erysimi* Kalt. *International Journal of Zoological Research*, **2(1)**: 30-33.

Kumar, A., Singh, R., Prasad, C. S., Tiwari, G. N. & Kumar, S. (2017). New records of predatory coccinellids beetles (Coccinellidae: Coleoptera) in Western plain zone of Uttar Pradesh. *Journal of Entomology and Zoology Studies*, **5(3)**: 1140-1147.

Kumar, B., Pandey, G. & Mishra, G. (2013). Predatory performance of aphidophagous ladybirds: a measure of prey suitability? *International Journal of Tropical Insect Science*, **33(2)**: 120-126.

Kumar, S., Singh, R., Kumar, A., Krishna, H. & Kumar, V. (2019). Biology of *Coccinella septempunctata* (Linnaeus) on mustard aphid, *Lipaphis erysimi* (Kalt.). *Journal of Entomology and Zoology Studies*, **7(2)**: 1239-1241.

Kumar, P. (2019). Economic study of mustard (*Brassica oleracea*) growers in Meerut district of Uttar Pradesh. *Journal of Pharmacognosy and Phytochemistry*, **8(1)**: 1443-1447.

Kumari, D., Verma, S. C. & Sharma, P. L. (2020). Biology, feeding potential and functional response of *Coccinella septempunctata* L. against *Aphis gossypii* Glover infesting cucumber. *Journal of Entomology and Zoological Studies*, **8**: 631-636.

Kumar, K. (2019). Agriculture: status, challenges, policies and strategies for India, *International Journal of Engineering Research & Technology*, **08**:12.

Maharjan, B., Thapa, R. B. & Bajracharya, A. S. R. (2018). Efficacy of Two

Species of Coccinellid Predators against Four Different Aphid Pest Species at Khumaltar, Nepal. *Journal of the Institute of Agriculture and Animal Science*, **35(1)**: 127-134.

Mandal, S. M. A. & Patnaik, N. C. (2006). Insect pests and natural enemies associated with cabbage in the coastal belt of Orissa. *Journal of Plant Protection and Environment*, **3(1)**: 76-80.

Manpoong, N. S., Firake, D. M., Behere, G. T. & Rajesh, T. (2017). Biological attributes and feeding potential of three dominant predators of *Lipaphis erysimi* (Kaltenbach). *Journal of Biological Control*, **30(3)**: 190-194.

Mari, J. M., Bugti, G. A., Bin, W. & Na, C. (2016). Biological parameters and preferential feeding response of *Coccinella undecimpunctata* L. on three aphid species. *Journal of Entomology and Zoology Studies*, **4(4)**: 1306- 1310.

Miller, L. T., Stange, L., MacVean, C., Rey, J. R., Frank, J. H., Mizell, R. F. & Heppner, J. B. (2008). Ladybird Beetles (Coccinellidae: Coleoptera). *Encyclopedia of Entomology*, 2120–2131.

Mishra, S. K. & Kanwat, P. M. (2017). Biology and predatory potential of *Coccinella septempunctata* Linn. on *Lipaphis erysimi* Kalt. under controlled conditions. *Plant Archives*, **17(2)**: 1099-1104.

Narjary, B., Adak, T., Meena, M. D. & Chakravarty, N. V. K. (2013). Population dynamics of mustard aphid in relation to humid thermal ratio and growing degree days.

Nelson, E. H. & Rosenheim, J. A. (2006). Encounters between aphids and their predators: the relative frequencies of disturbance and consumption. *Entomologia Experimentalis et Applicata*, **118(3)**: 211-219.

Nirmala, D. R., Desh, S. C., Verma, N. D. & Raj, D. (1996). Biology and feeding potential of *Coccinella septempunctata* Linn. on cabbage aphid, *Brevicoryne brassicae* Linn. *Journal of Entomological Research*, **20(1)**: 23-25.

- Omkar, K. G. & Sahu, J. (2009).** Performance of a predatory ladybird beetle, *Anegleis cardoni* (Coleoptera: Coccinellidae) on three aphid species. *European Journal of Entomology*, **106(4)**: 565-572.
- Omkar, Pervez, A., (2000).** Sexual dimorphism in *Propylea dissecta* (Mulsant) (Coccinellidae: Coleoptera). *Journal of Aphidology*, **14**, 139–140.
- Omkar & Srivastava, S. (2003).** Influence of Six Aphid Prey Species on Development and Reproduction of a Ladybird Beetle, *Coccinella septempunctata*, *Journal of Biological Control*, **48**: 379–393
- Pareek, R. K., Sharma, A. & Kumawat, K. C. (2014).** Feeding potential of *Coccinella septempunctata* L. on coriander aphid, *Hyadaphis coriandri* (Das). *Indian Journal of Entomology*, **76(1)**: 52-54.
- Prabhakar, A. K. & Roy, S. P. (2010).** Evaluation of the consumption rates of dominant coccinellid predators on aphids in north-east bihar. *Bioscan*, **5(3)**: 491-493.
- Purwar, J. P., Singh, R. K. & Mall, P. (2004).** Eco-friendly management of insect pests in rapeseed-mustard. *Indian Farmers Digest*. **37(10)**: 34-35
- Pushendra K. S. & Prakash C. J. (2010).** Feeding Potential of Seven Spotted Ladybeetle, *Coccinella septempunctata* (Linnaeus) on Mustard Aphid, *Lipaphis erysimi* (Kaltenbach) and Cotton Aphid, *Aphis gossypii* (Glover). *Nature and Science*, **8(12)**:198-202.
- Rai, M. K., Ramamurthy, V. V. & Singh, P. K. (2002).** Biological Attributes and Morphometries of *Coccinella septempunctata* (Linnaeus) (Coeinellidae: Coleoptera). *Annals of Plant Protection Sciences*, **10(2)**: 194-197.
- Rai, S., Singh, N. N. & Shankar, U. (2010).** Functional response of grub and adult of *Coccinella septempunctata* (L.) and *Coccinella transversalis* (Fabr.) on mustard aphid, *Lipaphis erysimi* (Kalt.). *Archives of Phytopathology and Plant Protection*, **43(18)**: 1829-1835.
- Rajan, J. & Edpuganti, Sree Latha & Assistant, E & Madhuri, Sneha &**

- Sreenivasa Rao, Cherukuri. (2019).** Predatory coccinellids diversity in organic vegetable farming systems: Conservation and mass production. *Journal of Entomology and Zoology Studies*.**7**: 1148-1151.
- Rauf, M., Khan, J., Rehman, A., Gillani, W. A. & Ali, A. (2013).** Biology and predatory potential of *Coccinella septempunctata* Linn. on *Schizaphis graminum* aphid under controlled conditions. *Pakistan Journal of Agricultural Research*, **26(2)**: 124-129.
- Saharia, D., 1982.** Field evaluation of granular systemic insecticides on *Lipaphis erysimum* and its predator *Coccinella repanda*. *Journal of Agricultural Research [Assam Agricultural University, Jorhat]*, **2**: 181- 185.
- Sahito, H. A., Solangi, R., Kousar, T., Shah, Z. H. & Mangrio, W. M. (2016).** Population fluctuation of aphids, *Lipaphis erysimi* (Kalt) with response of biological control under mustard field conditions. *Journal of Entomology and Zoology Studies*, **4(5)**: 326-331.
- Sahito, H. A., Solangi, R., Kousar, T., Shah, Z. H., Mangrio, W. M. & Rind, M. M. (2019).** Biological control of mustard aphid, *Lipaphis erysimi* (Kaltenbach, 1843) through seven-spotted ladybird beetle, *Coccinella septempunctata* (Linnaeus, 1758) under laboratory conditions. *Pure and Applied Biology (PAB)*, **8(2)**: 1707-1717.
- Santos, A. P., Santos, C., Silva, S., Pinto, G., Torres, L. M. & Nogueira, A. J. A. (2013).** Effect of sooty mold on fluorescence and gas exchange properties of olive tree. *Turkish Journal of Biology*, **37(5)**:620–628.
- Santosh M. J. D. (2011).** Morphometric studies of predaceous coccinellids (Coleoptera: Coccinellidae) and comparative biology of *Coccinella transversalis* (Fabricus), M.Sc. Thesis, Navsari Agricultural University, Navsari. pp.: 1-7.
- Sarker, S., Howlader, A. J., Rain, F. F. & Aslam, A. F. M. (2019).** Predator performance of *Coccinella transversalis* and its molecular identification. *Bangladesh Journal of Zoology*, **47(2)**: 229-241.

- Sarwar, M. & Saqib, S. M. (2010).** Rearing of predatory seven spotted ladybird beetle *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) on natural and artificial diets under laboratory conditions. *Pakistan Journal of Zoology*, **42(1)**: 47-51.
- Sarwar M. (2013).** Studies on incidence of insect pests (aphids) and their natural enemies in canola, *Brassica napus* (Brassicaceae) crop ecosystem. *International Journal of Scientific Research in Environmental Sciences*, **(1)**: 78-84.
- Sattar, M., Hamed, M. & Nadeem, S. (2008).** Biology of *Coccinella septempunctata* Linn. (Coleoptera: Coccinellidae) and its predatory potential on cotton aphids, *Aphis gossypii* Glover (Hemiptera: Aphididae). *Pakistan journal of zoology*, **40(4)**: 239-242.
- Seema K., Singh, I. P. & Sanjeev K. (2000).** Developmental period and survival of *Cocinella septumpunctata* var. *divercata* predatory on *Lipaphis erysimi* Kalt. in mustard. *Madras Journal of Agriculture*, **87(7-9)**: 424-427.
- Shukla, A. & Jadhav, D. S. (2014).** Biology of *Coccinella transversalis* (Fabricius) on different aphid species. *The Bioscan*, **9(1)**: 17-22.
- Singh, Rajendra & Sinha, Tapen & Pandey, R.K. & Tripathi, C. & Kumar, A. (1982).** The functional response of *Coccinella septempunctata* Linn., a coccinellid predator of mustard aphid, *Lipaphis erysimi* Kalt. *Entomon*, **7(1)**: 7-10.
- Singh, K. & Singh, N. N. (2013).** Preying capacity of different established predators of the aphid *Lipaphis erysimi* (Kalt.) infesting rapeseed-mustard crop in laboratory conditions. *Plant Protection Science*, **49(2)**: 84-88.
- Singh, Y. P., Meghwal, H. P., Singh, S. P. & Sharma, K. C. (2009).** Biology and feeding potential of *Coccinella septempunctata* Linnaeus on the mustard aphid, *Lipaphis erysimi* Kaltenbach. *Indian Journal of Entomology*, **71(3)**: 196-198.
- Singh, Y. P. & Sharma, K. C. (2002).** Integrated approach to manage the mustard

aphid, *Lipaphis erysimi* (Kaltenbach) (Homoptera: Aphididae) in oilseed Brassica crops- a review. *Journal of Amphibiology*, **16**: 77-78.

Sipio, F. A., Bukero, A., Khanzada, K. K., Ali, I., Kumbhar, A. A. S., Jat, M. I. & Hussain, R. (2017). Biology of seven spotted beetle, *Coccinella septempunctata* (Linn.) on different aphid species.

Skouras, P. J., Margaritopoulos, J. T., Zarpas, K. D. & Tsitsipis, J. A. (2015). Development, growth, feeding and reproduction of *Ceratomegilla undecimnotata*, *Hippodamia variegata* and *Coccinella septempunctata* fed on the tobacco aphid, *Myzus persicae nicotianae*. *Phytoparasitica*, **43(2)**: 159-169.

Solangi, B. K., Lohar, M. K., Abro, G. H. & Talpur, M. A. (2007). Searching ability and feeding potential of larvae, 7-spotted beetle *Coccinella septempunctata* Linn. under laboratory and field conditions. *Sarhad Journal of Agriculture*, **23(3)**: 705.

Srivastava, S. (2003). Comparative prey consumption and searching efficiency of *Coccinella septempunctata* Linnaeus and *Coccinella transversalis* Fabricius on different aphid species. *Journal of Biological Control*, **17(1)**: 35-41.

Suhail, A., Sabir A.M., Hussain A. & Saeed, A., (1999). Predatory efficacy of *Coccinella septempunctata* L. on cotton *Brevicoryne brassicae*. *Aphis gossypii* Glover. *Pakistan Journal of Biological Sciences*, **2**: 603-605.

Shylesha A. N., Thakur N., Pathak N.S., Rao K. A., Saikia K. R., Surose K., Kodandaram S. & Kalaishekar A. (2006) Integrated management of insect pests of crops in northeastern hill region. *Technical Bulletin No. 19. ICAR RC for NEH Region, Umiam*, **50**:

Tank B. D. & Korat D. M. 2007. Biology of ladybird beetle, *Cheilomenes sexmaculata* (Fab.) in middle Gujarat conditions. *Karnataka Journal of Agriculture Sciences*, **20(3)**: 634-636

Varshney, R., Rachana, R. R. & Bisht, R. S. (2016). Biology and feeding potential of *Coccinella septempunctata* (Linn.) against *Lipaphis erysimi*

(Kalt) at different temperature regimes. *Journal of Applied and Natural Science*, **8(4)**: 1762-1765.

Vavilov, N. I. (1949). The origin, variation, immunity and breeding of cultivated plants. *Chronicles of Botany*, **13**:1-364.

Verma, S. & Kumar, B. (2017). Stage-specific predation attributes of ladybird beetle, *Coccinella septempunctata* (Linnaeus) on mustard aphid. <https://www.researchgate.net/publication/327011769> Stage-specific_predation_attributes_of_ladybird_beetle_Coccinella_septempunctata_Linnaeus_on_mustard_aphid.

Yadav, M. K., Patel, J. J. & Pareek, A. (2016). Biology and predatory potential of lady bird beetle *Coccinella septempunctata* Linn. on mustard aphid, *Lipaphis erysimi* Kalt. *Natural Resource Management: Ecological Perspectives*, At: Indian Ecological Society, SKUAST-Jammu (18-20 February 2016) Volume: **2**: 552

Table 1: Pre-oviposition, oviposition and post-oviposition of *C. transversalis* on mustard aphid, *Lipaphis erysimi*

Sr. No.	Particulars	Minimum	Maximum	Mean \pm SD
1	Pre-oviposition period (days)	4	8	5.22 \pm 0.883
2	Oviposition period (days)	21	28	24.08 \pm 1.826
3	Post-oviposition period (days)	3	6	4.58 \pm 0.831

Here SD stands for "Standard Deviation" and means are significantly different at 5% level of significance.

Table 2: Incubation period, hatching percentage and fecundity of *C. transversalis* on mustard aphid, *Lipaphis erysimi*

Sr. No.	Particulars	Minimum	Maximum	Mean \pm SD
1	Incubation period (Days)	2	5	2.70 \pm 0.766
2	Hatching percentage (%)	67.85	97.43	84.73 \pm 8.114
3	Fecundity (no. of eggs)	319	423	364.88 \pm 27.446

Here SD stands for “Standard Deviation” and means are significantly different at 5% level of significance.

Table 3: Developmental period of different instar grubs, total grub period, pre-pupal and pupal period of *C. transversalis* on mustard aphid, *Lipaphis erysimi*

Sr. No.	Particulars	Minimum	Maximum	Av. \pm S.D.
1	I instar	2	4	2.60 \pm 0.638
2	II instar	2	4	2.76 \pm 0.655
3	III instar	2	5	3.58 \pm 0.831
4	IV instar	3	5	3.74 \pm 0.823
5	Total larval development period(days)	10	17	12.68 \pm 1.633
6	Prepupal period (days)	1	1	1.00 \pm 0.000
7	Pupal period (days)	2	4	2.62 \pm 0.696

Here SD stands for "Standard Deviation" and means are significantly different at 5% level of significance

Table 4: Adult longevity, total life cycle, adult emergence and sex ratio of *C. transversalis* on mustard aphid, *Lipaphis erysimi*

Sr. No.	Particulars	Minimum	Maximum	Mean \pm S.D.
1	Adult longevity (days)			
	Male	21	40	30.12 \pm 4.492
	Female	29	41	33.88 \pm 2.566
2	Total life cycle (days)			
	Male	40	64	49.12 \pm 4.870
	Female	46	63	52.88 \pm 3.480
3	Adult emergence (%)	57.14	100	80.36 \pm 10.830
4	Sex ratio			01:01.3

Here SD stands for "Standard Deviation" and means are significantly different at 5% level of significance

Table 5: Pre-oviposition, oviposition and post-oviposition of *C. septempunctata* on mustard aphid, *Lipaphis erysimi*

Sr. No.	Particulars	Minimum	Maximum	Av. \pm S.D.
1	Pre- oviposition Period	4	13	7.92 \pm 2.45
2	Oviposition Period	13	26	21.60 \pm 3.39
3	Post- oviposition Period	4	10	7.16 \pm 1.77

Here SD stands for “Standard Deviation” and means are significantly different at 5% level of significance

Table 6: Incubation period, hatching percentage and fecundity of *C. septempunctata* on mustard aphid, *Lipaphis erysimi*

Sr. No.	Particulars	Minimum	Maximum	Mean \pm S.D.
1	Fecundity eggs/female	405	803	582.44 \pm 93.15
2	Incubation period of egg (days)	3	6	4.40 \pm 0.77
3	Hatching percentage (%)	66.67	80	873.3 \pm 5.27

Here SD stands for “Standard Deviation” and means are significantly different at 5% level of significance

Table 7: Developmental period of different instar grubs, total grub period, pre-pupal and pupal period of *C. septempunctata* on mustard aphid, *Lipaphis erysimi*

Sr. No.	Particulars	Minimum	Maximum	Mean \pm S.D.
1	First instar (days)	3	5	3.73 \pm 0.7
2	Second instar (days)	2	4	2.80 \pm 0.76
3	Third instar (days)	2	5	3.50 \pm 0.78
4	Fourth instar (days)	2	5	3.63 \pm 0.85
5	Total larval period (days)	9	19	13.67 \pm 1.77
6	Pupal Period (days)	5	9	6.73 \pm 1.11

Here SD stands for "Standard Deviation" and means are significantly different at 5% level of significance

Table 8: Adult longevity, total life cycle, adult emergence and sex ratio of *C. septempunctata* on mustard aphid, *Lipaphis erysimi*

Sr. No.	Particulars	Minimum	Maximum	Av. \pm S.D.
1	Adult longevity (days)			
	Male	26	39	31.33 \pm 3.28
	Female	30	45	37.30 \pm 3.44
2	Sex ratio (male: female)	1.0: 1.22	1.0:1.50	1.0: 1.39

Here SD stands for "Standard Deviation" and means are significantly different at 5% level of significance

Table 9: Predatory potential of *Coccinella transversalis* on mustard aphids

Sr. No.	Instar/adult	Total consumption of aphids /instar
1	I instar	19.95±3.23
2	II instar	34.25±4.36
3	III instar	58.30±7.54
4	IV instar	65.67±8.23
5	Male	58.32±5.23
6	Female	62.17±5.76
7	Mean	49.77±5.24

Here SD stands for "Standard Deviation" and means are significantly different at 5% level of significance

Table 10: Predatory potential of *Coccinella septempunctata* on mustard aphids

Sr. No.	Instar/adult	Total consumption of aphids /instar
1	1st instar grub	15.86±0.34
2	2nd instar grub	45.1±0.45
3	3rd instar grub	124.62±0.88
4	4th instar grub	238.82±1.11
5	Total no. of aphids consumed during larval development	424.4±2.78
6	Average consumption of aphid/Adult male/day	103.2 ± 1.52
7	Average consumption of aphid/Adult female/day	116.6 ±1.46

Here SD stands for “Standard Deviation” and means are significantly different at 5% level of significance

Table 11: Mean Consumption of musturd aphid, *Lipaphis erysimi* by different stages of *Coccinella septempunctata* and *Coccinella transversalis*

Sr. No.	Instar/adult	Total consumption of aphids per instar	
		<i>Coccinella septempunctata</i>	<i>Coccinella transversalis</i>
1	1st instar grub	15.86±0.34	19.95±3.23
2	2nd instar grub	45.10±0.45	34.25±4.36
3	3rd instar grub	124.62±0.88	58.30±7.54
4	4th instar grub	238.82±1.11	65.67±8.23
5	Average consumption of aphid/Adult male/day	103.2 ± 1.52	58.32±5.23
6	Average consumption of aphid/Adult female/day	116.6 ±1.46	62.17±5.76

Here SD stands for “Standard Deviation” and means are significantly different at 5% level of significance

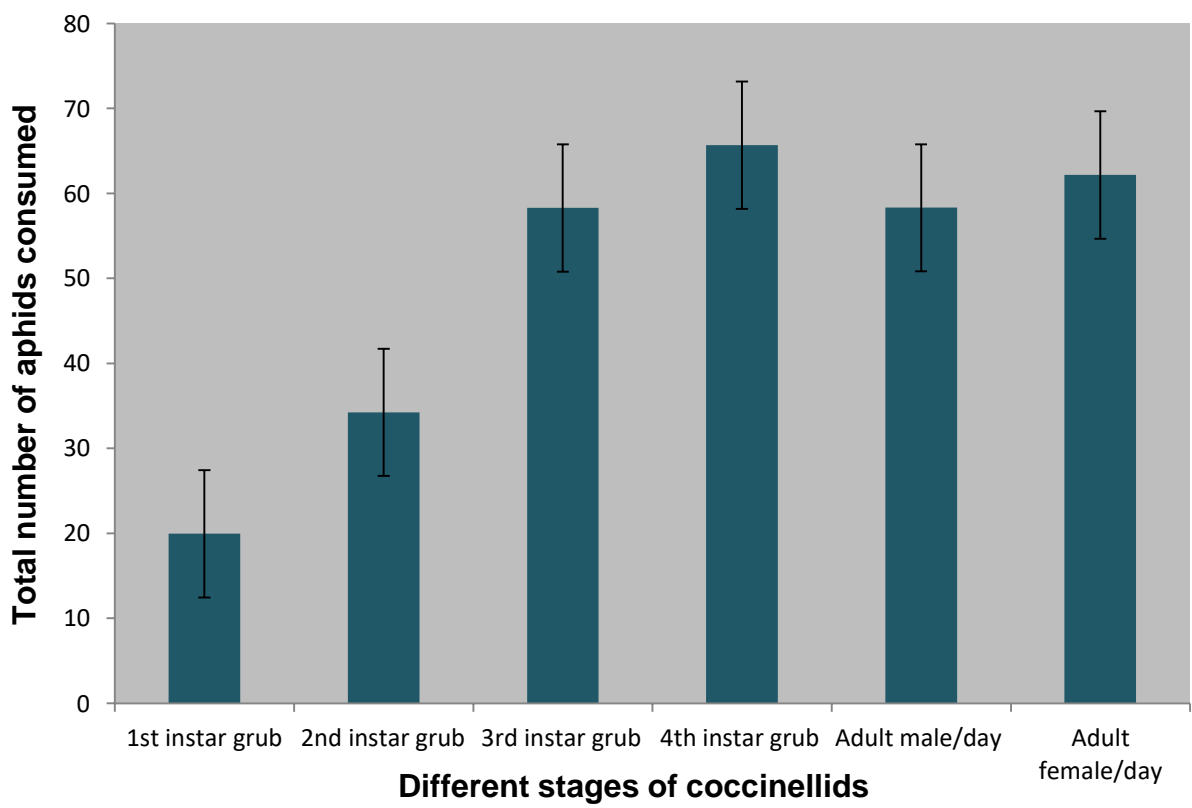


Fig 4.2 Predatory potential of different instars of *Coccinella transversalis* on different stages of mustard aphids

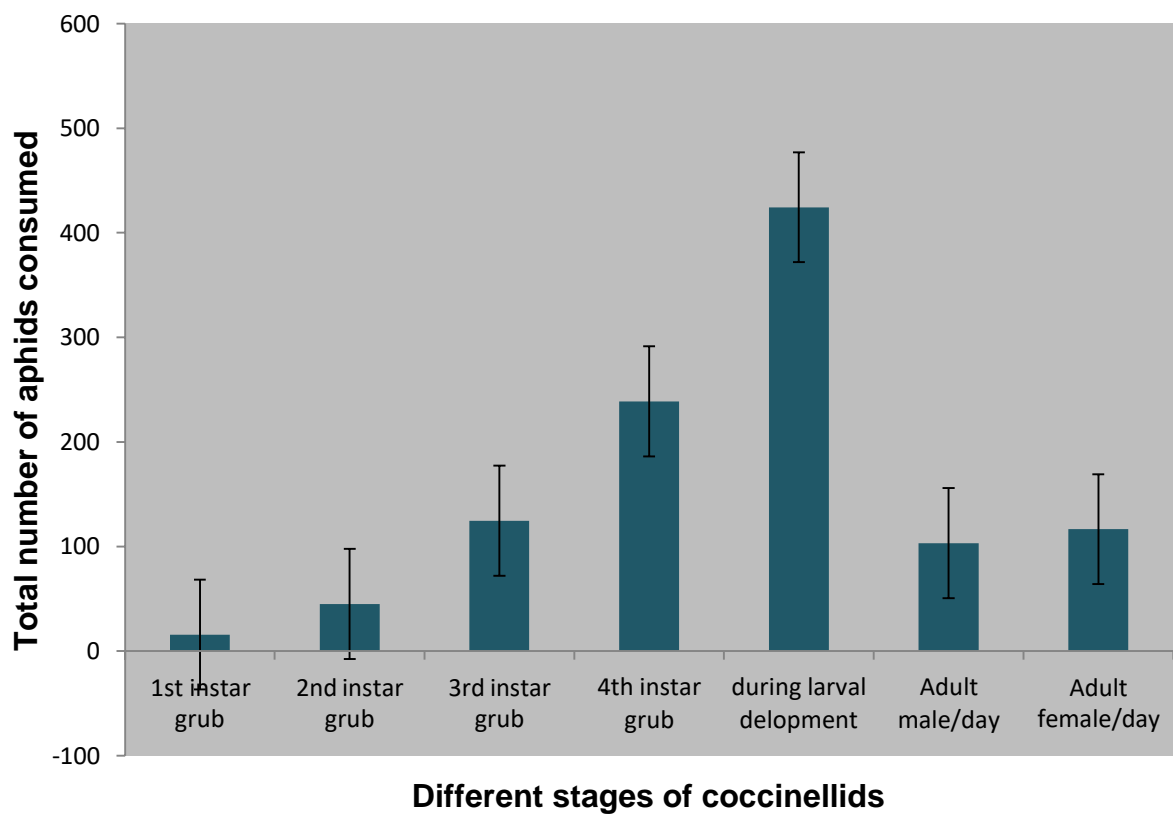


Fig 4.2 Predatory potential of different instars of *Coccinella septempunctata* on different stages of mustard aphids

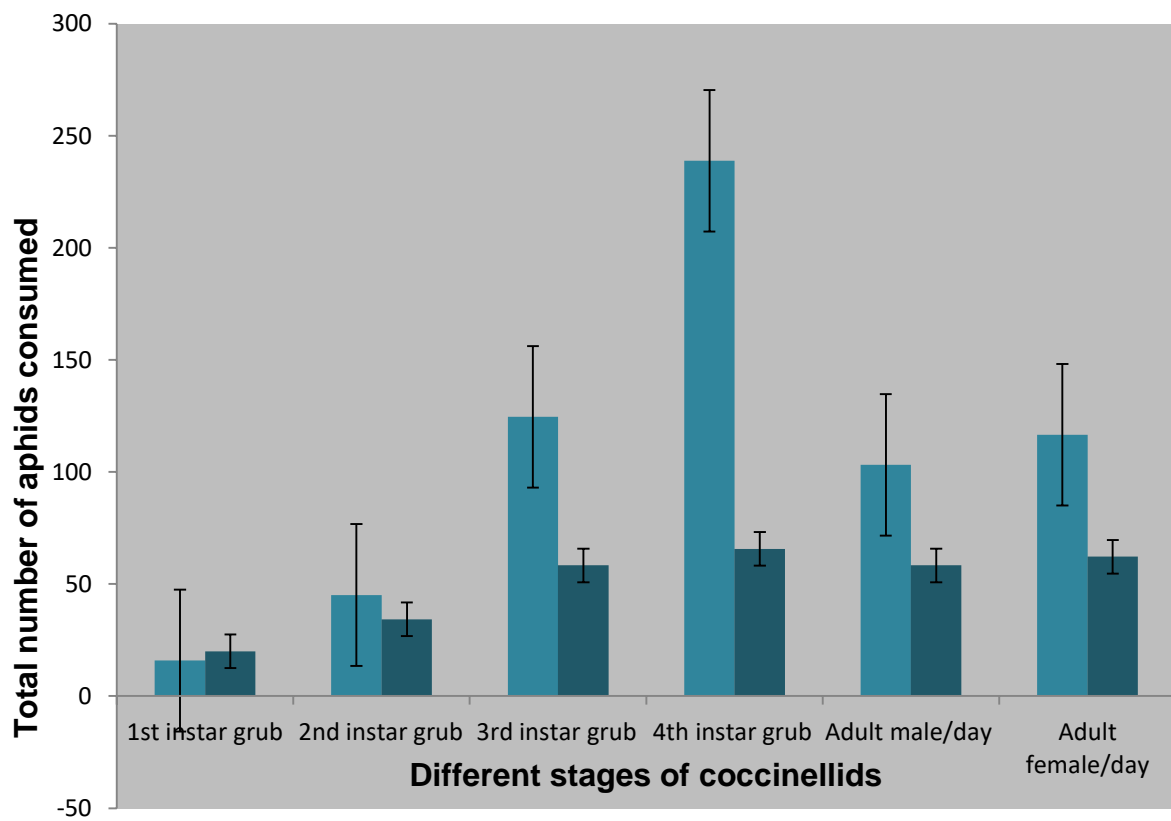


Fig. 4.3 Mean Consumption of mustard aphid, *Lipaphis erysimi* by different stages of *C. septempunctata* and *C. transversalis*



Plate 3.1 Experimental setup



Plate 4.1 Eggs of *C.transversalis*

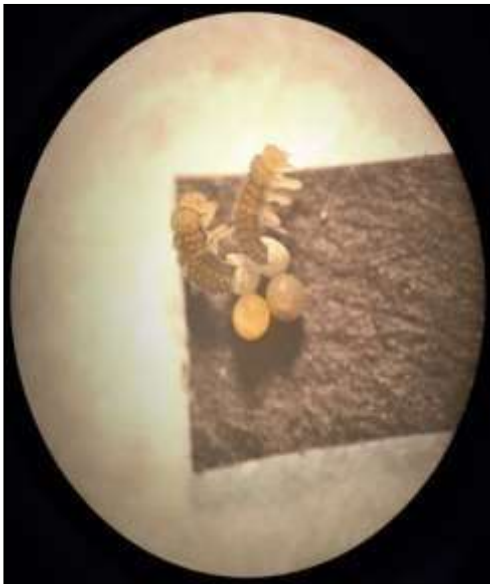


Plate 4.2 First instar grubs of *C.transversalis*



4.3.A.



4.3.B.

Plate 4.3 Grubs of *C.transversalis* (A) Second Instar (B) Third Instar



Plate 4.4 Emergence of fourth instar grub of *C.transversalis*



4.5.A.



4.5.B.

Plate 4.5 (A) Pre-Pupal, and (B) Pupal stage of *C. transversalis*



4.6.A.



4.6.B.

Plate 4.6 (A) Freshly emerged adult, and (B) Fully developed adult of *transversalis*

C.



4.7. A



4.7.B

Plate 4.7 (A) First Instar, and (B) Second Instar of *C. septempunctata*



4.8. A



4.8.B

Plate 4.8 (A) Third Instar, and (B) Fourth Instar of *C. septempunctata*



Plate 4.9 Pre-pupal and pupal stage of *C. septumpunctata*



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