EFFECT OF DIFFERENT TEMPERATURES AND PESTICIDES ON THE BIOLOGICAL ATTRIBUTES OF MAJOR COCCINELLID BEETLES PREDATING ON MUSTARD APHID, *Lipaphis erysimi* (KALTENBACH)

Thesis

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of

Doctor of Philosophy

in

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by

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The moral, spiritual support and examples of hard work provided by my mother and my father have been my inspiration

Affectionately Dedicated

to my loving Parents,

Empor Lytan & Francis Synnah

and my siblings

Orilanton,

Dalamki

&

Owandaroy

STUDENT'S DECLARATION

I, Mr. Damitre Lytan hereby declare that the subject matter of this Thesis is the record of work done by me, that the contents of this Thesis did not form the basis of the award of any previous Degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree to any other Universities/Institute.

This is submitted to SASRD, Nagaland University for the Degree of Doctor of Philosophy (Agriculture) in Entomology.

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CERTIFICATE - I

This is to certify that the Thesis entitled "Effect of different temperatures and pesticides on the biological attributes of major coccinellid beetles predating on mustard aphid, *Lipaphis erysimi* (Kaltenbach)" submitted to Nagaland University in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY (AGRICULTURE) in the discipline of Entomology is a record of research work carried out by **Mr. Damitre Lytan**, Registration No. 653/2015 under my personal supervision and guidance.

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This is to certify that the Thesis entitled "Effect of different temperatures and pesticides on the biological attributes of major coccinellid beetles predating on mustard aphid, *Lipaphis erysimi* (Kaltenbach)" submitted by **Mr. Damitre Lytan**, Admission No. Ph-145/13, Registration No. 653/2015 to Nagaland University in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY (AGRICULTURE) in the discipline of Entomology has been examined and approved by the student Advisory Committee and the External Examiner, after viva voce.

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ABSTRACT

Field experiments were conducted to study the species composition of coccinellid beetles in mustard crop in the states of Meghalaya and Nagaland during 2014-2016. The results revealed that about seven (7) species of coccinellid beetles viz., *Coccinella septempunctata*, *C. transversalis*, *Micraspis discolor*, *Harmonia dimidiata*, *Menochilus sexmaculata*, *Oenopia sexareata* and *O. kirbyi* were observed in Entomology experimental field at ICAR Research Complex for NEH Region, Meghalaya whereas only three (3) species viz., *C. septempunctata*, *C. transversalis* and *M. discolor* were found in Entomology farm at NU: SASRD throughout the study period.

Laboratory experimental studies on the effect of four different temperature levels (20ºC, 25ºC, 30ºC and 35ºC) on the biology and feeding potential of *C. septempunctata* and *C. transversalis* predating on *Lipaphis erysimi* during 2014-2016 revealed that with increasing temperature, developmental period and consumption rate decreases significantly. The mean ovipositional period, incubation period, larval period, pre-pupal, pupal period, total developmental period and adult longevity was found longest at 20ºC with 40.58±1.71 and 24.33±1.32, 4.73±0.24 and 3.65±0.29, 20.03±1.14 and 14.98±1.28, 2.33±0.28 and 1.68±0.30, 6.53±0.28 and 3.85±0.31, 33.60±1.94 and 24.15±2.18, 60.10±2.90 and 36.38±3.69 days on *C. septempunctata* and *C. transversalis* respectively; while the mean fecundity, size of egg cluster, percentage of grub emergence and percentage of adult emergence was found maximum at 25ºC with 377.82±26.41 and 305.53±19.14 eggs/female, 36.99±3.49 and 31.58±3.40 eggs/cluster, 84.60±0.50% and 87.38±0.86%, 90.08±0.71% and 83.28±0.89% on *C. septempunctata* and *C. transversalis*, respectively. The average aphid consumption of 1st, 2nd, 3rd and 4th instars was recorded maximum at 25°C with 11.53±0.72 and 10.48±0.62, 21.38±0.90 and 15.48±0.83, 36.38±0.86 and 26.38±0.78 and 43.90±0.94 and 35.88±0.89 aphids/individual/day on *C. septempunctata* and *C. transversalis*, respectively. Among the adult, the average aphid consumption was recorded maximum at 25°C with 47.53±1.24 and 39.76±1.11 aphids/beetle/day on *C. septempunctata* and *C. transversalis*, respectively.

Laboratory experimental studies on the toxicity effect of different pesticides on *C. septempunctata* and *C. transversalis* revealed that among pesticides, maximum mortality was observed in Deltamethrin 2.5 EC to *C. septempunctata* and *C. transversalis* followed by Imidacloprid 17.8 SL, Acetamiprid 20 SP and Neem 0.03 EC while *Bt* var. *kurstaki* 8 SP treatment was found to be safer, having least mortality rate as compared to other pesticides. It can be concluded that, all five commonly used pesticides against *L. erysimi* are harmful to its predators and therefore the use of these pesticides should be avoided during peak activity of natural enemies. However, *Bt* var. *kurstaki* 8 SP is comparatively safe pesticide for coccinellids, therefore it could be used during severe infestation of mustard aphid.

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LIST OF ABBREVIATIONS

@	-	at a rate of
BOD	-	Biological Oxygen Demand
cm	-	Centimetre
CIH	-	Central Institute of Horticulture
CRD	-	Completely Randomized Design
CUTS	-	Consumer Unity and Trust Society
DAS	-	Days after Spraying
df	-	Degree of freedom
ºC	-	Degree Celsius
et al.	-	*et allia* (and others/co-workers)
Fig.	-	Figure
F-test	-	Fisher’s test
gm	-	Gram
ha	-	Hectare
HSD	-	Honestly Significant Difference
IBM	-	International Business Machines
ICAR	-	Indian Council of Agricultural Research
i.e.	-	Id est (that is)
IPM	-	Integrated Pest Management
kg	-	Kilogram
lt	-	Litre
Max.	-	Maximum
m	-	Metre
m^2	-	Metre square
msl	-	Mean sea level
MT	-	Metric Tonnes
mg	-	Milligram
mm	-	Millimetre
Min.	-	Minimum
NEH	-	North Eastern Hill
NKSE	-	Neem Kernel Seed Extract
NU	-	Nagaland University

No.	-	Number
$^{-1}$ or /	-	Per
%	-	Per cent
ppm	-	Parts per million
SASRD	-	School of Agricultural Sciences and Rural Development
Sl. No.	-	Serial number
SEm±	-	Standard error of mean
SPSS	-	Statistical Package for the Social Sciences
var.	-	Variety
viz.	-	Videlicet (Namely)

CHAPTER - I

INTRODUCTION

INTRODUCTION

India is the third largest mustard seed producer in the world with an annual production of 6.80 million tonnes from 6.52 million hectares of land during 2014-2015 (Anon., 2015). India contributes about 28.60 per cent in the total oilseeds production and mustard alone accounts about 27.80 per cent in oilseed economy which is the second most important edible oil after groundnut (Shekhawat *et al*., 2012). In Nagaland and Meghalaya, the annual productions of mustard seed were 27.42 and 104.96 tonnes from 27.17 and 98.54 thousand hectares of land, respectively (Anon., 2014; Anon., 2017). Mustard (*Brassica* spp.) is a major group of oilseed crop of the world being grown in 53 countries across the six continents (Hedge, 2005). When compared to other edible oils, the mustard oil has the lowest amount of harmful saturated fatty acids and contains adequate amounts of two essential fatty acids, linoleic and linolenic, which are not present in many of the other edible oils (Anon., 2009).

Due to their similar genetic make-up, rapeseed and mustard seed share the same growing areas throughout India. A large number of species and sub-species of mustard are cultivated in the country under the name mustard seed, including Rai, Torai, Brown Sarson, Yellow Sarson, Swedi, Karan Rai and Taramira. Some of these are hybrids and some locally grown seed varieties. In a drive for further crop diversification, government agencies are currently promoting the cultivation of a hybrid variety called “Hyola”, a strain which gives both higher yields and oil content (Pahariya *et al.*, 2007).

Traditionally, mustard seed grown in India contains a high amount of euric acid and glucosinolates, and as such does not conform to the international standard, “Canola quality” (Pahariya *et al.*, 2007). The mustard seed produced in India is mainly for domestic consumption, and is mostly consumed in the Northern, Central and Eastern parts of the country. A study by Consumer Unity and Trust Society (CUTS) on the mustard seed sector in Rajasthan found that 82 per cent of rural consumers use the oil as their staple edible oil, with monthly consumption varying between two and four kilograms per family in the state (Pahariya, 2006). Mustard seed accounts for 65 per cent of India’s total winter or Rabi oil crop, which is made up of mustard seed, sunflower, castor seed, linseed and safflower (Damodaran and Hegde, 2005). Mustard oil content typically varies between 36 and 42 per cent; of this, average oil recovery is approximately 34 to 35 per cent (Srinivasan, 2004). Once the oil is extracted, the remaining part of the seed is used to produce mustard meal which is an important source of cattle and poultry feeds. This represents a significant source of oil meal in the country, supplying on average about 3.0 to 3.2 million tonnes of meal/cake annually (Pahariya *et al.*, 2007).

The productivity of mustard seed has been increased in India from 935 kg/ha in 2000-2001 to 1257 kg/ha in 2011-2012 (Bhardwaj, 2013). It is estimated that the production of mustard in India will reach from 7.00 million tonnes to 7.10 million tonnes in 2016-2017 (Anon., 2017). Such a remarkable performance in production and yield of rapeseed and mustard leading which is commonly being “Yellow Revolution” visible in all rapeseed-mustard growing states as well as in non-traditional areas of the country.

Mustard oil, used primarily in cooking, is a rich source of monosaturated fatty acids, making it a healthier option than most other cooking oils. Over the years, its health advantages have continued to improve, especially with the recent, limited introduction of the “Canola” strain of the seeds. Two varieties of the oil are popular in India, Kaccha Ghani (preferred by most consumers due to its characteristic colour and pungency) and Pakki Ghani (refined mustard oil preferred mostly by health conscious people). Other than its culinary advantages, mustard seed and its oil also hold a number of diverse applications, from fertilizers to lubricants to massage oils (Pahariya *et al.*, 2007).

More than three dozens of pests are known to be associated with various phenological stages of rapeseed and mustard crops in India (Bakhetia *et al.*, 1989). Among the insect pests attacking rapeseed and mustard, the “Mustard Aphid”, *Lipaphis erysimi* (Kalt.) is a serious insect pest, infesting the crop from seedling stage to maturity that ravages the crop during the reproductive phase and acts as a limiting factor in the production (Dixon, 1998). The losses in yield caused by mustard aphid ranged from 24% to 96% (Phadke, 1985), 35.40% to 72.30% (Bakhetia *et al*., 1986), up to 96% (Verma, 2000) at different places in India such as Haryana, Delhi, and Kanpur respectively. The infestation by pests not only results in reduced yield of the seeds but also reduces the oil content by 15% (Verma and Singh, 1987) and 66.87% (Singhvi *et al*., 1973) respectively.

Morphologically, mustard aphid adults are very small, soft body, oblong in shape and light green or slightly yellowish in colour. They have a pair of short tubes or cornicles; the special morphological features in which honey dew is excreted out. They breed parthenogenetically and the females give birth to 26 to 133 nymphs. They grow very fast and mature in 7 to 10 days. There are about 45 generations in one year (Atwal and Dhaliwal, 2003). Both the nymphs and adults have the potential to cause damage by sucking the plant sap which results the plant to become weak, pale, exhausted and incapable of producing seeds. They infest the crop right from vegetative stage to pod stage results to huge crop losses. However, flowering stage is the most vulnerable to aphid attack and weather conditions prevailing at this stage make the aphid more serious (Saharia, 1984).

The biocontrol agents like coccinellids and chrysopids have been reported to be effective for controlling the aphids, *L. erysimi* population (Shukla *et al*., 1990; Singh and Singh, 2013). In the field, mustard aphid population is naturally controlled to a large extent by its predator, *Coccinella septempunctata* and plays a vital role in lowering the population of mustard aphid (Kalra, 1988).

Global warming has cautioned us and the unpleasant consequences of insecticides use are always alarming and also increasing pest outbreak because of pest resistance. These entomological backlashes have forced scientists to think about entomologically eco-friendly pest management programmes (Hodek, 1970). Therefore, utilization of natural enemies in biological control is an excellent pest management tactic to reduce the population level of invasive pests (Delfoss, 2005). Exploration of the potential employment of predatory insects or mites to control aphid pests received more attention or decline of chemical damages to the environment (Jafari, 2011).

Alternative control measures that are simple and inexpensive to implement have not been properly developed with the consequence that farmers continue to use chemical pesticides, thereby exacerbating problems of resistance, environmental pollution, degradation of important ecosystem services such as control by natural enemies, and creating significant hazards to human health (Corriols *et al*., 2009).

Nevertheless, vegetable and oilseed cultivations are very important in the agricultural economy of Meghalaya and Nagaland. Farmers of Meghalaya and Nagaland are marginal and mostly depend on hill farming for their subsistence. Besides costly and health hazards, synthetic chemicals have significant impact on the biodiversity of the region. Thus, several efforts are being made to reduce the use of synthetic pesticides and to increase the productivity of vegetables as well as oilseeds without affecting the ecosystem by using supplementary natural enemies and biopesticides as biological approaches. With the concept of biological control emerging as an eco-friendly source of pest management, it encourages the producers to adopt it as a supplement for chemical pesticides. This biological control involves the natural enemies such as predators, parasitoids, parasites, pathogens etc., which are used as the bio-control agents to suppress the pest population density.

Keeping these points in mind and considering *Lipaphis erysimi* as a serious pest on mustard particularly in NEH region, the present studies were conducted with the following objectives:

1. To study the species composition of coccinellid beetles in mustard crop in the states of Meghalaya and Nagaland.
2. To study the biological attributes of major coccinellid beetles on mustard aphid, *Lipaphis erysimi* (Kalt.) under the influence of different temperatures.
3. To study the impact of commonly used pesticides on major coccinellid beetles predators of mustard aphid, *Lipaphis erysimi* (Kalt.).

CHAPTER - II

LITERATURE REVIEW

LITERATURE REVIEW

Studies on “Effect of different temperatures and pesticides on the biological attributes of major coccinellid beetles predating on mustard aphid, *Lipaphis erysimi* (Kaltenbach)” are reviewed under the following heads:

2.1. Importance of coccinellid beetles

The coccinellid beetles or ladybird beetles have been associated with good fortune in many myths and legends. The first successful case of biological control by introducing Australian ladybird, *Rodolia cardinalis* (Mulsant) in 1888 in Carlifornia, USA for the suppression of cottony cushion scale, *Icerya purchasi* Maskell resulted in worldwide spread of coccinellids and has been referred to as the ‘Ladybird Fantasy’ period (Lounsbury, 1940).

Coccinellid beetles have been respected through the centuries, as the vernacular indicates, for the term “lady” is in reference to biblical “Mother Mary” (Roache, 1960). Coccinellids appear to be distasteful to birds, and their conspicuous appearance is an example of warning coloration (Moreton, 1969).

There are a number of reasons for the popularity of ladybird beetles. Firstly, many ladybirds have bright contrasting colour patterns. Secondly, about 70 per cent of them i.e. approximately 4200 coccinellid species are considered beneficial because of their predatory activity mainly against homopterous insects (aphids and scale insects) and phytophagous mites, which are harmful to various agricultural and forest plants (Shah, 1985).

The larvae and adults of predatory coccinellid species feed on almost 39 species such as scale insects, aphids, thrips, leafhoppers, whiteflies, mealy bugs, mites as well as other small soft-bodied species and their eggs (Gautam, 1989; Iperti and Paoletti, 1999). When their normal prey insects are scarce, predatory coccinellids can survive on some alternative food sources like flower nectar, pollen, honeydew and secretions of extra floral nectaries (Pemberton and Vandenberg, 1993).

The coccinellid beetles are considered economically very important in agro-ecosystem as they have been successfully employed in the biological control of many injurious insects (Agarwala and Dixon, 1992). Morphologically, they are small to medium size beetles with an oval, oblong or hemispherical body shape and comparatively well known by the general public as a result of their showy aposematic coloration, their economically benificial aspects, innocuous and pleasing nature (Majerus, 1994).

Coccinellids play their important role as biocontrol for those crops that are especially susceptible to aphid attack viz., maize, alfalfa, canola, wheat, flax, forage crop, canary seed (or canary grass), peas, apples and potatoes (Wise *et al*., 1995). They are also regarded as bioindicators (Iperti and Paoletti, 1999) and provide more general information about the ecosystem in which they occur (Andersen, 1999).

2.2. Species composition and distribution of coccinellid beetles, *Coccinella* spp. in agro-ecosystem

Linnaeus (1758) had described about 36 species of coccinellid beetles from Europe under the genus *Coccinella*. The first meaningful internal classifications of Coccinellidae were attempted and divided the family into two groups: aphidophagous and phytophagous (Redtenbacher, 1843).

The ladybird beetles (Coleoptera: Coccinellidae) are enormously diverse in their habits (Moreton, 1969; Anon., 2000). The family to which these insects belong, the Coccinellidae is extremely diverse in their habits, i.e. they live in all terrestrial ecosystems: tundra, forest, grassland, agro-ecosystems and from the plains to mountains (Skaife, 1979).

In Northeast India about 8 species were reported from Nagaland, 38 species from Manipur, 16 species from Mizoram, 49 species from Meghalaya, 35 species from Arunachal Pradesh and 24 species from Tripura, respectively (Shantibala and Singh, 1991; Singh and Singh, 1991; Chakraborty and Biswas, 2000; Chakraborty, 2004; Hemcahandra *et al*., 2010; Majumder *et al.*, 2013).

Omkar and Bind (1993) have reported 6 species of coccinellids from Lucknow region of Central Uttar Pradesh, to this Omkar and Bind (1996) added 17 new species, whilst Omkar and Pervez (2002) further added 17 more species from the same region. Vandenberg (2000) described that about 6000 species of coccinellids are known worldwide. In India, about 400 species under 79 genera belong to 22 tribes and five subfamilies were reported from Uttar Pradesh and Uttarakhand (Poorani, 2002).

Zahoor *et al.* (2003) reported from the cropped area of Faisalabad about 19 species of coccinellids with highest population of *Coccinella septempunctata*, *Brumus* *suturalis*, following the species *Menochilus sexmaculata* and *Coccinella septempunctata* var. *Divaricata*, respectively.

Singh and Brar (2004) from India also reported about 77 species of coccinellids which are widely distributed throughout the country. But according to Omkar and Pervez (2004), about 261 species of predaceous coccinellid beetles belonging to 57 genera are widely distributed throughout India.

Joshi and Sharma (2008) have reported 31 species of lady beetles with 19 new records from the district of Haridwar, India. Recently, Sharma and Joshi (2010a) have also reported 25 species of lady beetles with 14 new records from the district of Dehradun, India.

Rahatullah *et al*. (2010) documented about 4,000 predatory species of coccinellid beetles, of which more than 300 species are from Indo-Pakistan subcontinent while 71 species are found only in Pakistan (Irshad, 2001; Khan *et al*., 2006).

Anbalagan *et al.* (2013) from Tamil Nadu, India studied the diversity of predatory ladybird beetles in four different crops viz., brinjal, cowpea, groundnut and okra during 2007-2008 and reported that about 10 different species were recorded and all the 10 species occurred in all the four crops.

Biranvand *et al.* (2014) studied the diversity and distribution of Coccinellidae (Coleoptera) in five regions of Lorestan Province, Iran during April to September 2012 and reported that a total of 22 species were recorded from different agro-ecosystem.

2.3. Biological parameters of major coccinellid beetles under the influence of variable temperatures

2.3.1. Biology of major coccinellid beetles, *Coccinella* spp. at different temperatures

Sethi and Atwal (1964) studied on the influence of temperatures and humidity on the development of different stages of ladybird beetle, *Coccinella septempunctata* and observed that the average larval duration at 20, 30 and 35ºC was 16.80, 6.80 and 6.40 days, respectively. However, adult longevity was reduced to 69.20 days at 20ºC to 10.40 days at 35ºC.

Wratten (1973) reported that the ladybird beetles have a common tendency to stay and lay their eggs only in areas where the aphid population density is high. That means they attack aphids only when aphid population was sufficiently high in number to support a generation of larvae.

Kawauchi (1979) evaluated the effects of temperatures on the aphidophagous coccinellids and observed that temperature not only influenced the rate of development but also influenced the adult weight in coccinellids. However, the larvae reared at higher temperatures produced smaller adults than larvae reared at lower temperatures.

Singh *et al.* (1994) conducted an experiment to determine the fecundity potential of *Coccinella septempunctata* predation on mustard aphid, *Lipaphis erysimi*. They observed that the pre-oviposition period in *C. septempunctata* takes about 19 days and the female deposited the first batch of eggs on the 20th day of emergence. The female laid eggs till the 47th day and the last female died on the 49th day. They also observed that the net reproductive rate and mean length generation under laboratory and field conditions were 95.88 and 54.18 and 28.88 and 28.68 days, respectively.

Katsoyannos *et al.* (1997) studied the phenology of *Coccinella septempunctata* in central Greece and reported that the average fecundity of 1780 eggs per female for the first generation of adults of *C. septempunctata* reared in outdoor cages. They also reported that the average fecundities of 925, 182 and 85 eggs per female were recorded in the second, third and fourth generations, respectively. The relatively low fecundities of third and fourth generation females might be attributed to the combination of limited feeding time available, late emergence in the season, low average temperatures (below 15ºC) and high energy needs for accumulation of reserves for survival during winter. However, the maximum average fecundity of 1788 ± 576.40 eggs per female was observed in those reared in the laboratory.

Suhail *et al.* (1999) evaluated the biology of *Coccinella septempunctata* on cotton aphid, *Aphis gossypii* in laboratory conditions at 21 ± 1°C and 70 ± 5% relative humidity and reported that the average duration of egg, first, second, third, fourth instar grubs and pupa were about 3.53, 3.50, 1.54, 2.21, 4.32 and 3.64 days, respectively.

Phoofolo and Obrycki (2000) conducted studies on the reproduction of *Coccinella septempunctata* and *Propylea quatuordecimpunctata* populations in Nearctic and Palearctic and observed that 47 to 61% of *C. septempunctata* females laid their first batch of eggs within the first two weeks of their adult life. Similarly, for *P. quatuordecimpunctata* populations, 56 to 83% of females initiated oviposition within two weeks. However, the remaining females either had pre-oviposition periods of more than two weeks or never laid eggs during a 60 days observation period. Analysis on daily fecundity revealed differences in oviposition strategies among females within each population.

Ozder and Saglam (2002) evaluated the effects of aphid prey on larval development and mortaliy of *Adalia bipunctata* and *Coccinella septempunctata* on five aphid species viz., *Metopolophium dirhodum*, *Sitobion avenae*, *Rhopalosiphum padi*, *Hyalopterus pruni* and *Myzus cerasi*. They found that the developmental period varied from 16.79 ± 0.76 to 20.79 ± 1.03 days and 17.51 ± 0.84 to 20.84 ± 1.60 days for *A. bipunctata* and *C. septempunctata*, respectively. However, mortality rate of *A. bipunctata* and *C. septempunctata* were found highest at 50% and 63%, respectively on *H. pruni.*

Omkar and Srivastava (2003a) conducted an experiment to evaluate the functional response of six aphid species on pre-imaginal development, immature survival and reproduction of *Coccinella septempunctata*. The results revealed that pre-adult developmental period was shortest (13.93 ± 0.12 days) when fed on *Lipaphis erysimi* and longest (22.85 ± 0.10 days) on *Aphis nerii*. The immature survival, adult emergence, growth index, relative growth rate, development rate, male and female longevity, oviposition period, fecundity and hatching percentage were maximal, i.e. 73.47 ± 0.89, 90.07 ± 1.43%, 8.62 ± 0.23, 1.52 ± 0.02, 81.10 ± 1.26 days, 85.70 ± 1.45 days, 69.80 ± 1.32 days, 1764.10 ± 8.46 and 87.88 ± 1.05, respectively when *C. septempunctata* were fed on *L. erysimi.*

Katsarou *et al.* (2005) did observations on the growth, development and feeding response of *Coccinella septempunctata* and *Hippodamia convergens* on tobacco aphid, *Myzus persicae* under four constant temperatures at 14, 17, 20 and 23ºC, respectively. They observed that the egg, larval and pupal mortality was highest at 14ºC reaching 85.00, 73.80, 29.40% in *H. convergens* and 49.30, 75.40 and 58.80% in *C. septempunctata*, respectively. However, the total pre-imaginal development ranged from 57.20 to 70.40 days at 14ºC and 16.90 to 22.10 days at 23ºC in *H. convergens* and *C. septempunctata*, respectively.

Khursheed *et al.* (2006) studied the different developmental stages of *Coccinella septempunctata* reared on mustard aphid, *Lipaphis erysimi* and observed that the egg, larval, pre-pupal and adult stages occupied more duration in first generation as compared to second. The total larval period of 16.00 ± 1.73 days and pupal period of 7.50 ± 0.87

days was more in first generation in contrast to second of 13.50 ± 0.87 days and 6.50 ± 0.87 days, respectively. However, with respect to adult longevity, mean adult male and female was 15.24 ± 8.10 and 20.18 ± 8.40 days in first generation and 12.53 ± 6.07 days and 18.40 ± 8.68 days in second generation, respectively.

Ali and Rizvi (2007a) investigated the development and predatory performance of *Coccinella septempunctata* on five different aphid species viz., *Lipaphis erysimi*, *Aphis craccivora*, *Hyadaphis coriandri*, *Rhopalosiphum nymphae and Myzus rosae* under laboratory conditions at 25 ± 1ºC, 65 ± 5% RH and 12:12 hours (Light:Dark) photoperiod. The overall developmental period and adult longevity of *C. septempunctata* were observed longer on *L. erysimi* of 62.75 ± 1.43 and 31.78 ± 0.68 days, respectively and shorter on *M. rosae* of 47.55 ± 0.67 and 18.65 ± 0.29 days, respectively. Both the total grub and total pupal period, however, required significantly longer developmental period on *H. coriandri* of 17.00 ± 0.55 and 13.30 ± 0.14 days, respectively and shorter on *M. rosae* of 15.70 ± 0.18 and 9.40 ± 0.15 days, respectively. Between the sexes, the female required longer period for its development than male with respect to all the species and moreover, females of *C. septempunctata* devour more aphids than male due to her egg bearing capacity.

Ali and Rizvi (2007b) conducted an experiment to determine the age specific and survival fecundity of *Coccinella septempunctata* for two successive generations with respect to different aphid species viz., *Lipaphis erysimi*, *Aphis craccivora*, *Hyadaphis coriandri*, *Rhopalosiphum nymphae and Myzus rosae* under laboratory condition at 25 ± 1ºC, 65 ± 5% RH and 12:12 hours (Light: Dark) photoperiod. They found that the highest potential fecundity and net reproductive rate of *C. septempunctata* was observed on *L. erysimi* with 129.43 eggs per female and 40.14 females per female per generation, respectively and the lowest was on *M. rosae* with 39.62 eggs per female and 7.13 females per female per generation, respectively.

Ali and Rizvi (2008) studied the effect of varying temperature on the survival and fecundity of *Coccinella septempunctata* fed on mustard aphid, *Lipaphis erysimi* under laboratory condition at 18 ± 1°C, 24 ± 1°C and 28 ± 1°C, respectively coupled with 65 ± 5% RH and 12:12 hours (Light: Dark) photoperiod. They observed that the highest potential fecundity and net reproductive rate of *C. septempunctata* was obtained at 24 ± 1°C with 165.67 eggs per female and 41.09 females per female per generation, respectively and the lowest was at 28 ± 1ºC with 146.63 eggs per female and 29.70

females per female per generation, respectively.

Sattar *et al.* (2008) conducted an experiment to evaluate the predatory potential and biology of *Coccinella septempunctata* feeding on cotton aphid, *Aphis gossypii* under laboratory conditions at 26 ± 2 ºC and 65 ± 5% RH and observed that a single female can lay about 177.00 ± 23.03 eggs during her entire life. The egg hatching percentage was 98.30 ± 2.79 per cent while only 82.20 ± 6.20 per cent grub survived upto pupal stage. They also observed that the total larval and pupal period was 18.30 ± 0.53 and 4.90 ± 0.58 days, respectively whereas the mean per cent emergence in male and female was 36.60 ± 2.98 and 56.60 ± 4.21, respectively with male to female sex ratio of 1:1.5.

Ali and Rizvi (2009) evaluated the age and stage specific life-table of *Coccinella transversalis* with regards to various temperatures in the laboratory conditions and reported that the *C. transversalis* fed on mustard aphid, *Lipaphis erysimi* required a maximum period of 60, 56 and 50 days to complete one generation at 20 ± 1°C, 24 ± 1°C and 28 ± 1°C, respectively. Further, they reported that the apparent mortality rate at egg stage was observed minimum (8%) at 20 ± 1°C as well as 24 ± 1°C and maximum (9%) at 28 ± 1°C. While comparing larval instars, the lowest mortality (1.35%) was recorded at fourth instar stage at 24 ± 1°C, whereas first instar showed highest mortality (13.19%) at 28 ± 1°C. On the other hand, pre-pupal and pupal mortality was found minimum (1.37 and 3.13%) at 24 ± 1°C and 20 ± 1°C, respectively. Similarly, the corresponding values of maximum mortality (3.39 and 3.51%, respectively) were recorded at 28 ± 1°C.

Singh *et al.* (2009) studied the biology and feeding potential of *Coccinella septempunctata* on mustard aphid, *L. erysimi* in the laboratory at 27 ± 2°C and reported that the mean fecundity was 357.45 ± 22.41 eggs per female while the oviposition period, incubation period, larval period pupal period, total developmental period, and adult longevity were 4.32 ± 0.26, 4.40 ± 0.22, 10.95 ± 0.35, 5.35 ± 0.15, 20.70 ± 0.72, and 122.90 ± 3.12 days, respectively.

Ali and Rizvi (2010) evaluated the age and stage specific life-table of *Coccinella* s*eptempunctata* at varying temperatures in the laboratory and reported that the *C. septempunctata* fed on mustard aphid, *Lipaphis erysimi* required maximum period of 68 days to complete the entire generation at 20 ± 1°C, followed by 61 days at 24 ± 1°C and 53 days at 28 ± 1°C. Further, they reported that the apparent mortality rate at egg stage was observed maximum (10.00%) at 28 ± 1°C and minimum (6.00%) at 24 ± 1°C. When a comparison was made between larval instars, the highest mortality (12.66%) was observed at 28 ± 1°C at second instar, whereas lowest mortality (1.23%) was recorded at fourth instar at 24 ± 1°C. Similarly, the apparent mortality at pre-pupal and pupal stages remained maximum (3.39 and 5.26%, respectively) at 28 ± 1°C and minimum (1.25 and 1.27%, respectively) at 24 ± 1°C.

Kumar *et al.* (2012) conducted a laboratory experiment to evaluate the biology of *Coccinella septempunctata* and observed that the incubation period of eggs was 3.67 ± 0.33 days and the average developmental period of first, second, third and fourth instar grubs were 2.33 ± 0.33, 2.67 ± 0.33, 2.67 ± 0.33 and 5.00 ± 0.58 days, respectively. The pupal period was 5.00 ± 0.58 days and the adult longevity of male and female was 29.33 ± 0.88 and 33.33 ± 0.88 days, respectively.

Mahyoub *et al.* (2013) studied the method for mass production of the seven spotted lady beetle, *Coccinella septempunctata* in laboratory conditions at 23 ± 2ºC and relative humidity at 60 ± 5% and observed that the *C. septempunctata* females laid their eggs in clusters with the total number of clusters per female ranging from 1 to 25. The incubation period ranged from 2 to 3 days with adult longevity of females ranging from 21 to 26 days, while that of males ranged from 24 to 29 days. They further observed that the durations of the first, second, third and fourth instar grubs were 1 to 2, 2 to 4, 2 to 4, and 2 to 4 days, respectively and the pupal stages lasted from 5 to 8 days.

Bukero *et al.* (2014) conducted studies on developmental period of *Coccinella transversalis* on *Lipaphis erysimi* and observed that the average duration of first, second, third and fourth instar grubs were 2, 3, 3 and 5 days, respectively at 26 ± 2°C. Further, they reported that the average adult longevity of male and female were 32 and 35 days, respectively.

Shukla and Jadhav (2014) conducted an experiment to study the biology of *Coccinella transversalis* reared on three different aphid species viz., *Aphis craccivora*, *Lipaphis erysimi* and *Myzus persicae* under laboratory conditions at 23.27 ± 1.04°C and relative humidity 52.84 ± 13.78%. They recorded that the total life cycle of male and female *C. transversalis* 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 on *A. craccivora*, *L. erysimi* and *M. Persicae*, respectively. They also recorded that the mean fecundity of *C. transversalis* fed on *A. craccivora*, *L. erysimi* and *M. persicae* were 376.46 ± 47.32, 364.88 ± 27.44 and 377.36

± 28.96 eggs per female, respectively.

Singh and Singh (2014) studied the biology and devouring propensity of *Coccinella septempunctata* on mustard aphid, *Lipaphis erysimi* in the laboratory at 25 ± 1°C and relative humidity 65 ± 5% and observed that the females started oviposition after 6.30 ± 0.36 days of mating and eggs are laid in clusters of 8 to 100 eggs per cluster. The adult females laid an average of 360.75 ± 25.71 and 395.25 ± 27.31 eggs during 2009-2010 and 2010-2011, respectively, with mean fecundity of 378.00 ± 26.51 eggs.

Singh and Singh (2014) also observed that the average incubation period of *Coccinella septempunctata* were 4.60 ± 0.31 and 4.40 ± 0.26 days during 2009-2010 and 2010-2011, respectively with mean period of 4.50 ± 0.29 days. The total larval period were recorded as 10.00 ± 0.47 and 12.30 ± 0.53 days, respectively with mean period of first, second, third and fourth instars being 2.86 ± 0.12, 2.43 ± 0.11, 2.30 ± 0.13 and 3.55 ± 0.14 days and total grub period was as 11.15 ± 0.50 days. The average pupal period was recorded as 6.50 ± 0.20 and 4.70 ± 0.15 days during 2009-2010 and 2010-2011, respectively with mean period of 5.60 ± 0.18 days. The total life cycle of *C. septempunctata* completed were 25.38 ± 1.14 and 25.75 ± 1.25 days during 2009-2010 and 2010-2011, respectively with mean period of 25.57 ± 1.20. They also observed that the average longevity of *C. septempunctata* adult were 120.25 ± 3.75 and 125.60 ± 4.35 days during 2009-2010 and 2010-2011, respectively with mean longevity of 122.93 ± 4.05 days.

Bukero *et al.* (2015a) conducted an experiment to determine the life table studies of *Coccinella septempunctata* on fresh, frozen and dried mustard aphid, *Lipaphis erysimi* and observed that the highest apparent mortality was observed in all life stages of the predator on dried and minimum on fresh aphids. The highest number of the survivor, i.e. 36 adults was recorded on fresh aphid followed by 26 and 18 on frozen and dried aphids, respectively. The minimum total generation mortality was recorded as 0.14 on fresh aphid followed by 0.28 and 0.44 on frozen and dried aphids, respectively. It was concluded that dried aphids are not fit for mass rearing of *C. septempunctata*; however, during the period of natural diets scarcity frozen aphids are better for mass rearing.

2.3.2. Feeding potential of major coccinellid beetles, *Coccinella* spp.

Singh and Singh (1994) conducted laboratory experiment on the predatory potentiality of coccinellids, *Coccinella septempunctata* over mustard aphid, *Lipaphis erysimi* and reported that the first, second, third and fourth instar of *C. septempunctata* consumed an average of 22.78, 66.00, 172.50 and 333.11 mustard aphids, respectively whereas the adult male and female consumed about 119.80 and 140.68, respectively. They also reported that the consumption of aphid by an individual predator larva increased in age and ranges between 25 to 100 nymphs aphid per day, whereas an adult was found consuming on an average of 78.00 to 80.50 nymphs aphid per day.

Akram *et al*. (1996) evaluated the predatory efficacy of *Coccinella septempunctata* and reported that the predator *C. septempunctata* has high potential of predation both in the immature as well as adult stages. Both the larvae and adults fed voraciously on aphids and consumed an average of 1203.55 aphids in the entire life, which is completed in 17.91 days.

Kumari and Singh (1999) studied the predatory potentiality of *Coccinella septempunctata* on mustard aphid, *Lipaphis erysimi* infesting mustard crop and recorded that the larvae of *C. septempunctata* consumed about 11.61 and 141 aphids, respectively whereas the adult consumed about 580 and 528 aphids, respectively.

Suhail *et al.* (1999) evaluated the predatory efficacy of *Coccinella septempunctata* on cotton aphid, *Aphis gossypii* in laboratory conditions at 21 ± 1°C and 70 ± 5% relative humidity and reported that the average feeding potential of first, second, third, fourth instar grubs and adult were 15.23, 36.40, 42.23, 47.15 and 60.56 aphids per day per individual, respectively.

Devi *et al.* (2002) studied the role of natural enemies in the management of mustard aphid, *Lipaphis erysimi* and reported that during the development of *Coccinella septempunctata* through four instars, an individual grub consumed an average of 50 aphids per day.

Gautam *et al.* (2002) evaluated the feeding potential and preference of larval *Coccinella septempunctata* preying on aphids in the laboratory condition and observed that the grubs of *C. septempunctata* consumed an average of 281 aphids (mixed population of *Lipaphis erysimi* and *Myzus persicae*) during its larval period of nine days.

Lekha and Jat (2002) studied the feeding potential of two coccinellids viz., *Coccinella septempunctata* and *Menochilus sexmaculata* on coriander aphid, *Hyadaphis coriandari* and observed that the first, second, third and fourth instar grubs of *C. septempunctata* consumed about 16.70, 25.30, 44.00 and 63.30 aphids per day, respectively. They also observed that during 24 hours starved adults of *C. septempunctata* consumed more aphids (76.30) than unstarved *M. sexmaculata* (53.00) and *C. septempunctata* (53.30).

Gour and Pareek (2003) conducted laboratory experiment on the predation potential of *Coccinella septempunctata* on mustard aphid, *Lipaphis erysimi* and observed that the first, second, third and fourth instar grubs of *C. septempunctata* consumed about 22.86 - 24.53, 71.13 - 71.67, 178.66 - 185.48 and 333.44 - 338.70 mustard aphids per day, respectively. They further observed that the total consumption rate of an individual during the entire larval stage was about 612.91 - 613.56 mustard aphids. However, male adult consumed about 120.14 - 144.29 mustard aphids per day with an average of 132.32, whereas the female adult consumed about 151.18 - 179.33 mustard aphids per day with an average of 165.27.

Omkar and Srivastava (2003a) studied the functional response of fourth instar grubs and adult *Coccinella septempunctata* at different densities of aphid, *L. erysimi* and reported that the maximum prey consumption was recorded at the highest prey density of 800, whereas the minimum was recorded for the male adult at the lowest prey density of 25. It was concluded that prey consumed by the predatory stage was directly proportional to prey density, whereas the percent prey consumption was inversely proportional to prey density.

Omkar and Srivastava (2003b) evaluated the efficiency of fourth instar grubs of *Coccinella septempunctata* and *Coccinella transversalis* against three aphid species viz., *Myzus persicae*, *Rhopalosiphum maidis* and *Macrosiphum rosae* and observed that the grubs of *C. septempunctata* consumed a maximum number of *M. persicae* (245.60 ± 1.92) and a minimum number of *R. maidis* (18.80 ± 0.88), whereas *C. transversalis* also consumed maximum number of *Myzus persicae* (244.60 ± 1.93) but a minimum number of *M. rosae* (17.40 ± 0.58) at the prey densities of 800 and 25 aphids, respectively.

Jindal and Malik (2006) studied the feeding potential of *Coccinella septempunctata* on mustard aphid, *Lipaphis erysimi* and potato peach aphid, *Myzus* *persicae* and observed that the fourth larval instar of the predator *C. septempunctata* consumed about 69.40 and 61.50 aphids per day of *L. erysimi* and *M. Persicae*, respectively.

Khursheed *et al.* (2006) evaluated the feeding potential of *Coccinella septempunctata* reared on mustard aphid, *Lipaphis erysimi* and observed that the number of aphid consumed per day per individual increased with the advancement of its age. The predation potential of first, second, third and fourth instar grubs during first and second generation consumed 10.00 ± 1.73, 29.00 ± 2.89, 39.00 ± 1.16 and 52.30 ± 7.23 aphids per day per individual and 11.50 ± 2.02, 27.00 ± 2.89, 51.00 ± 5.78 and 60.30 ± 9.54, respectively. In contrast with the adult, the feeding potential during first and second generation consumed 72.00 ± 5.20 and 77.50 ± 3.76 aphids per day per individual, respectively.

Bilashini *et al.* (2007) studied the feeding potential of *Coccinella septempunctata* on three aphid species viz., *Lipaphis erysimi*, *Myzus persicae* and *Brevicoryne brassicae* and reported that the feeding potential of *C. septempunctata* on three aphid species increased with an increase in the age of the larva. Among the larval stages, i.e. second, third and fourth instar, the highest voracity was observed in fourth instar larvae with 40.50 ± 0.26, 35.27 ± 0.56 and 20.59 ± 0.17 on *L. erysimi*, *M. persicae* and *B. brassicae*, respectively while the lowest was recorded in second instar larvae with 15.17 ± 0.25, 13.29 ± 0.10 and 7.35 ± 0.12, respectively. In terms of adults, females fed more aphids with 45.50 ± 0.35, 40.50 ± 0.22 and 25.29 ± 0.34 on *L. erysimi*, *M. persicae* and *B. brassicae*, respectively as compared to males with 30.20 ± 0.49, 28.42 ± 0.24 and 19.24 ± 0.40, respectively.

Shantibala *et al.* (2007) evaluated the comparative prey composition and searching efficiency of fourth instar grubs of *Coccinella septempunctata* against two aphid species viz., *Acyrthosiphon pisum* and *Aphis craccivora* and observed that *C. septempunctata* consumed a maximum number (238.00 ± 7.38) of *A. pisum* at prey density of 600 and a minimum (19.20 ± 0.86) of *A. craccivora* at prey density of 25. They further observed that the area of discovery of this predator was more at lower predator (1) and prey density (25) and lesser at the highest predator (8) and prey density (600) of *A. pisum*. It was concluded that the preying composition of coccinellid beetles increased but their searching efficiency decreased with increase of either prey or predator density.

Solangi *et al*. (2007) studied the searching ability and feeding potential of seven-spotted beetle, *Coccinella septempunctata* under laboratory and field conditions and observed that aphid consumption of the first, second, third and fourth instar grubs of *C. septempunctata* was affected significantly ($P<0.05$) by their host density. The aphid consumed under host density of 10 was 1.10 ± 0.10, 1.65 ± 0.96, 1.95 ± 0.09 and 2.8 ± 0.14 per grub in laboratory conditions and 0.92 ± 0.09, 1.35 ± 0.09, 1.75 ± 0.09 and 2.55 ± 0.15 per grub under field conditions by first, second, third and fourth instar grubs, respectively. They further indicated that aphid consumption increased significantly with increasing host density which was 1.65 ± 0.05, 2.0 ± 0.11, 2.65 ± 0.18 and 3.95 ± 0.20 per grub under laboratory conditions and 1.40 ± 0.00, 1.95 ± 0.23, 1.30 ± 0.19, 3.67 ± 0.30 per grub under field conditions by the first, second, third and fourth instar grubs under the host density of 30 aphids, respectively.

Solangi *et al*. (2007) also observed that the searching distance covered by the first, second, third and fourth instar grubs of *Coccinella septempunctata* under host density of 10 was 15.56 ± 1.54, 21.69 ± 1.05, 28.35 ± 0.98 and 37.91 ± 1.96 cm per grub in laboratory conditions and 24.56 ± 1.33, 31.64 ± 1.34, 38.68 ± 1.11 and 46.39 ± 1.19 cm per grub under field conditions, respectively. They further observed that the searching distance decreased with increasing host density and under host density of 30 searching distance was 10.26 ± 0.80, 16.92 ± 1.04, 22.43 ± 0.99 and 33.41 ± 1.84 cm per grub in laboratory conditions and 19.91 ± 1.37, 27.02 ± 1.24, 33.58 ± 1.40 and 41.51 ± 1.67 cm per grub in the field conditions by first, second, third and fourth instar grubs, respectively. They concluded that ladybird beetles had long and free searching distance of food under field conditions as compared to those under laboratory conditions.

Brar *et al.* (2008) studied the feeding potential of second instar grub and adult of *Coccinella septempunctata* under laboratory conditions at various densities of *Lipaphis erysimi* (10, 20, 30, 40, 50, 60, 70, 80, 90 and 100) and reported that the highest feeding rate of 2.68 aphids per hour by second instar grub was recorded in population level of 90 aphids and adult beetle showed highest feeding rate of 4.57 aphids per hour at population level of 100 aphids.

Sattar *et al.* (2008) evaluated that the predatory potential and biology of *Coccinella septempunctata* feeding on cotton aphid, *Aphis gossypii* under laboratory conditions at 26 ± 2 ºC and 65 ± 5% RH and observed that the mean consumption of aphids by a single grub during first, second, third and fourth instar grubs were 21.90, 55.90, 107.40 and 227.30 aphids, respectively whereas the adult consumed about 77.80 ± 5.15 aphids.

Soni *et al*. (2008) studied the feeding potential of *Coccinella septempunctata* (Linn.) on wheat aphid complex in response to level intensity of food and reported that the two-day-old grub, second, third, fourth instar and adult of *C. septempunctata* consumed 14.50, 15.75, 26.50, 51.25 and 40.75 aphids, respectively within 24 hours of release when 100 aphids were provided as food source.

Bunker and Ameta (2009) conducted studies on the predation efficiency of different stages of two coccinellids, viz., *Coccinella septempunctata* and *Cheilomenes sexmaculata* on four aphid species, viz., *Lipaphis erysimi*, *Myzus persicae*, *Rhopalosiphum maidis* and *Hyadaphis coriandri* and revealed that *L. erysimi* was most suitable and preferred prey for *C. septempunctata*, *H. coriandri* was least preferred. During two years, i.e. 2004 and 2005, the first, second, third, fourth instar grubs and adults of *C. septempunctata* consumed a maximum of 23.67 and 25.33, 50.80 and 54.00, 73.13 and 75.40, 82.80 and 84.33 and 60.13 and 63.07 aphids per day, respectively on *L. erysimi*.

Singh *et al.* (2009) evaluated the biology and feeding potential of *Coccinella septempunctata* on mustard aphid, *L. erysimi* in the laboratory at 27 ± 2°C and reported that the mean feeding potential of first, second, third, fourth instar grubs and adults of *C. septempunctata* were 19.68 ± 1.05, 38.10 ± 1.98, 57.68 ± 1.80, 86.05 ± 1.42 and 83.54 ± 1.15 per day per individual, respectively.

Xue *et al.* (2009) studied the predation by *Coccinella septempunctata* on soybean aphids, *Aphis glycines* and found that the type II functional response of *C. septempunctata* third instars and adult females consumed significantly more aphids than adult males at prey densities of 150 and 180 aphids per arena at 26°C in laboratory conditions. They also observed that the maximum daily predation rate of adult aphids by *C. septempunctata* was predicted to be 204 per third instar, 277 per adult female and 166 per adult male, respectively.

Prabhakar and Roy (2010) evaluated the consumption rates of *Coccinella septempunctata* and *C. transversalis* on four aphids species, viz., *Aphis craccivora*, *Aphis gossypii*, *Lipaphis erysimi* and *Myzus persicae* and observed that the consumption rate on number of prey per 24 hours by both *C. septempunctata* females and males were highly preferred on *A. craccivora* (65.60 ± 3.01, 52.00 ± 4.20 and 58.42 ± 2.10, 47.20 ± 2.00) on nymphs and adults, respectively followed by *M. persicae* (61.40 ± 0.85, 49.60 ± 1.22 and 50.80 ± 2.00, 41.00 ± 1.26 on adults), *L. erysimi* (63.70 ± 0.65, 51.00 ± 2.80 on nymphs, 56.00 ± 2.20, 48.20 ± 0.78 on adults) and *A. gossypii* (59.20 ± 2.30, 46.00 ± 4.50 on nymphs, 47.30 ± 1.21, 39.00 ±3.20 on adults). In terms of *C. transversalis*, both females and males preferred *L. erysimi* (57.00 ± 4.40, 41.25 ± 1.70 on nymphs, 47.00 ± 2.10, 39.30 ± 0.65 on adults) followed by *M. persicae* (52.00 ± 2.10, 43.40 ± 1.66 on nymphs, 42 ± 1.20, 36.40 ± 0.63 on adults), *A. gossypii* (42.00 ± 2.20, 33.60 ± 0.80 on nymphs, 37.20 ± 0.70, 29.00 ± 2.10 on adults) and *A. craccivora* (38.50 ± 0.50, 31.00 ± 1.20 on nymphs and 33.00 ± 2.30, 28.30 ± 0.62 on adults).

Rai *et al.* (2010) studied the functional response of grub and adult of *Coccinella septempunctata* and *C. transversalis* on mustard aphid, *Lipaphis erysimi* and reported that the feeding efficiency of fourth instar grub on average consumed 19.90 ± 0.04 and 19.90 ± 0.03 aphids when the aphid density was 20, which is 99.9 and 99.8% of the total aphid population in the case of *C. septempunctata* and *C. transversalis*, respectively. The average consumption of an individual fourth instar grub of both *C. septempunctata* and *C. transversalis* on *L. erysimi* when the corresponding prey densities was maintained at 40, 80, 100, 200, 400 and 800 aphids were 39.40 ± 0.22 and 39.10 ± 0.30, 71.9 ± 0.70 and 68.40 ± 1.20, 78.80 ± 1.10 and 72.70 ± 2.20, 143.50 ± 3.26 and 111.60 ± 3.05, 192.60 ± 2.02 and 166.30 ± 0.32, 287.70 ± 2.73 and 187.70 ± 2.56, respectively.

Sharma and Joshi (2010b) evaluated the feeding potential of *Coccinella septempunctata* on *Lipaphis erysimi* and reported that fourth instar grubs consumed the highest number of aphids and the hourly consumption was 6.50 ± 0.80, 6.10 ± 0.73 and 6.40 ± 0.96 for first, second and third hours respectively in unstarved condition, while in starved condition the hourly consumption was 11.20 ± 0.91, 8.30 ± 0.94 and 8.00 ± 1.05 for first, second and third hours, respectively.

Singh *et al.* (2011) conducted studies on the predatory potentiality of *Coccinella septempunctata* against mustard aphid, *Lipaphis erysimi* and recorded that a single grub of *C. septempunctata* was found to consume a total of 549.11 mustard aphids in its total developmental period, whereas male and female adults consumed on an average of 107.15 and 120.62 aphids per day per individual, respectively.

Gupta *et al.* (2012) studied the stage-specific functional response of an aphidophagous ladybird, *Coccinella septempunctata* to two aphid species viz., *Lipaphis erysimi* and *Brevicoryne brassicae* and observed that type II feeding response of *C. septempunctata* towards both on *L. erysimi* and *B. brassicae.* The attack rate was highest (0.0192) with the lowest handling time (7.90 min) when the adult female consumed *L. erysimi.* However, there was a significant difference in the predicted values of consumption of *L. erysimi* by fourth instars, adult males and females compared with those of *B. brassicae*, indicating that the former prey is preferred over the latter one.

Kumar *et al.* (2012) evaluated the feeding potential of *Coccinella septempunctata* on *Aphis craccivora* and *Lipaphis erysimi* in laboratory conditions and observed that the first, second, third and fourth instar grubs consumed an average of 20.33 ± 1.33 and 11.67 ± 1.33, 33.00 ± 7.23 and 28.67 ± 0.33, 28.33 ± 4.41 and 33.00 ± 2.52 and 28.00 ± 6.66 and 36.33 ± 2.19 on *A. craccivora* and *L. erysimi*, respectively. They also observed that the female beetles consumed more number of aphids, i.e. 922.00 ± 8.62 and 843.33 ± 3.38 than the male with 749.33 ± 6.36 and 725.33 ± 11.85 on *A. craccivora* and *L. erysimi*, respectively.

Singh *et al.* (2012) evaluated the preying potential of lady bird beetle in relation to mustard aphid and reported that the first, second, third and fourth instar grubs consumed about 17.03 and 18.32, 44.50 and 47.30, 64.66 and 73.33 and 91.60 and 93.28 aphids per day per individual during 2007-2008 and 2008-2009, respectively. Further, they reported that the male adult fed about 1925.50 and 1951.50 aphids, whereas the female adult fed about 2770.20 and 2787.50 aphids during the life-span of thirty days in both the years.

Mahyoub *et al.* (2013) studied on the method for mass production of the seven spotted lady beetle, *Coccinella septempunctata* in laboratory conditions at 23 ± 2ºC and relative humidity at 60 ± 5% and observed that the average number of aphids consumed by first, second, third and fourth instar grubs are about 35, 63, 96, and 290, respectively.

Rauf *et al.* (2013) conducted laboratory experiment on the predatory potential of *Coccinella septempunctata* on *Schizaphis graminum* under controlled conditions and observed that the predatory response of different immature stages of *C. septempunctata* exhibited significant difference with respect to temperatures. The predatory potential of first, second, third and fourth instar grubs was from 21.00 to 37.00, 40.50 to 79.00, 73.80

to 124.80 and 342.10 to 481.50 aphids, respectively at different temperatures with total larval predatory potential ranging from 573.50 to 667.87 aphids.

Singh and Singh (2013) evaluated the preying capacity of *Coccinella septempunctata* on mustard aphid, *Lipaphis erysimi* (Kaltenbach) infesting mustard crop in laboratory conditions and reported that *C. septempunctata* of first, second, third and fourth instar grubs efficiently consumed 17.83, 43.70, 66.29 and 91.20 aphids per day, respectively during 2010-2011. They further reported that the corresponding consumption rates during 2011-2012 were 17.20, 46.30, 69.33 and 96.28 aphids per day, respectively. The average feeding capability of the grubs during their different instars was observed to be 54.76 to 57.28 aphids per day.

Singh and Singh (2013) also reported that *Coccinella septempunctata* of first, second, third and fourth instar grubs efficiently consumed 21.43, 46.90, 72.61, and 102.60 aphids per day, respectively during 2009-2010. They further reported that the corresponding consumption rates during 2010-2011 were 21.80, 49.15, 74.13, and 102.68 aphids per day, respectively. The average feeding capability of the grubs during their different instars was observed to be 60.89 to 61.94 aphids per day.

Bukero *et al.* (2014) conducted an experiment on voracity rate of *Coccinella transversalis* on *Lipaphis erysimi* and observed that the first, second, third and fourth instar grubs consumed about 4.00 ± 0.37, 9.34 ± 0.72, 17.80 ± 0.79 and 31.96 ± 1.13 aphids per grub per day, respectively at 26 ± 2°C. Further, they reported that the average of male and female adult consumed about 42.99 ± 0.41 and 56.56 ± 0.53 aphids per grub per day, respectively.

Pareek *et al.* (2014) studied the feeding potential of *Coccinella septempunctata* under laboratory condition on *Hyadaphis coriandri* and observed that the total consumption rate of the first, second, third and fourth instar grubs of *C. septempunctata* were 27.00 ± 5.35, 34.22 ± 4.29, 91.44 ± 25.13 and 237.37 ± 88.37 aphids, respectively. The individual grub consumed about 380.62 ± 81.66 aphids during its total life span and the adult male and female beetles consumed about 1345.00 ± 227.66 and 1948.00 ± 123.40 aphids during their adult longevity with daily ability to consume 52.50 ± 4.74 and 63.50 ± 10.87 aphids, respectively.

Singh and Singh (2014) conducted an experiment to study the devouring propensity of ladybird beetle, *Coccinella septempunctata* on mustard aphid, *Lipaphis* *erysimi* and reported that the overall mean consumption of first, second, third and fourth instars of *C. septempunctata* during 2009-2010 and 2010-2011 was 51.58 ± 1.28 and 54.64 ± 1.63 aphids per grub per day and total consumption by a single grub was 206.30 ± 5.11 and 218.55 ± 6.52 aphids, respectively.

Singh and Singh (2014) also reported that the male adults of *Coccinella septempunctata* consumed 84.62 ± 1.41 and 85.10 ± 1.20 aphids per day during 2009-2010 and 2010-2011, respectively with a mean of 84.86 ± 1.31 aphids per day. They also recorded that the female adults consumed about 87.33 ± 1.35 and 87.75 ± 1.37 aphids per day during 2009-2010 and 2010-2011, respectively with mean female adult consumption of 87.54 ± 1.36 aphids per day. The average consumption of adults was 85.98 ± 1.38 and 86.43 ± 1.29 aphids per day during 2009-2010 and 2010-2011, respectively with a mean of 86.20 ± 1.34 aphids per day.

Jadhav and Shukla (2015) conducted an experiment to study the feeding potential of *Coccinella transversalis* on three aphid species viz., *Aphis craccivora*, *Lipaphis erysimi* and *Myzus persicae* under laboratory conditions at 23.27 ± 1.04°C and relative humidity 52.84 ± 13.78%. They recorded that the first, second, third and fourth instar grubs consumed an average of 10.64 ± 2.46, 23.98 ± 6.81 and 14.80 ± 3.96, 13.22 ± 3.88, 22.76 ± 6.28 and 23.52 ± 4.77, 31.46 ± 4.94, 92.88 ± 10.42 and 84.68 ± 13.45 and 64.92 ± 8.43, 127.44 ± 35.88 and 127.18 ± 17.47 on *A. craccivora*, *L. erysimi* and *M. Persicae*, respectively. They also observed that the adult beetles consumed an average of 3229.50 ± 675.72, 2529.80 ± 494.68 and 2299.40 ± 562.17 on *A. craccivora*, *L. erysimi* and *M. Persicae*, respectively.

2.4. Impact of certain pesticides on major coccinellid beetles, *Coccinella* spp.

Hurej and Dutcher (1994) studied the toxicity of response from insecticides with an Ethyl fatty ester-base adjuvant and reported that Carbaryl and Phosmet showed slow acting insecticides that caused the greatest mortality, whereas Methomyl did not cause 100% mortality of ladybird beetles fed on insecticides treated aphids.

Vincent *et al*. (2000) conducted a laboratory experiment to evaluate the effects of Imidacloprid on *Harmonia axyridis* and reported that after 24 hours of treatment, the larval mortality was 4.60%, 13.10%, 53.30% and 68.00% on treated Imidacloprid of 0.0015, 0.015, 0.15 and 0.3 g/litre, respectively. They further reported that after 48 hours of treatment, the larval mortality was 6.80%, 14.70%, 78.30% and 73.00% on treated Imidacloprid of 0.0015, 0.015, 0.15 and 0.3 g/litre, respectively.

Youn *et al*. (2003) evaluated the toxicity of pesticides to multicolored Asian lady beetles, *Harmonia axyridis* and found that some of the ladybird beetles were susceptible to chemical insecticides like Chlorpyrifos and Pirmicarb at the recommended doses. They also found that the first and second instars of ladybird beetles were very sensitive to Thiamethoxam and Abamectin but these chemicals were very effective against aphids.

Bozsik (2006) studied the susceptibility of adult *Coccinella septempunctata* to insecticides with different modes of action and reported that the effect of several pesticides including imidacloprid and deltamethrin on the lady beetle *C. septempunctata* (L.) in the laboratory. In his study, he found that Imidacloprid and Deltamethrin were relatively harmful insecticides for the predator.

Solangi *et al.* (2007) evaluated the toxicity of different insecticides at two individual doses against fourth instar grub of *Coccinella septempunctata* and found that after 96 hours of spraying, Danitol proved to be more toxic among the insecticides and reduced maximum population of predators upto 90% mortality, followed by Talstar, Sumilpha, Confidor, Polo, Proclaim, Steward of 76%, 74%, 64%, 62%, 54% and 48% mortality, respectively while Tracer found to be less toxic of 38% mortality.

Mehmet *et al.* (2008) conducted an experiment by treating the adults *Coccinella septempunctata* with eight entomopathogenic fungi viz., *Paecilomyces farinosus* (ARSEF-4045), *P. farinosus* (ARSEF-4010), *Paecilomyces fumosoroseus* (ARSEF-3458), *Beauveria bassiana* (ARSEF-1151), *Lecanicillium lecanii* (ARSEF-5132), *Metarhizium anisopliae* (ARSEF-3329) and *M. anisopliae* (CSIRO-F1-23) with an appropriate conidial suspension of 105 conidia ml^{-1} for a period of 10 seconds. The results revealed that the mortality rate was observed highest in *L. lecanii* of 50.93 ± 3.28% followed by *P. farinosus*, *B. bassiana* (ARSEF-1151), *M. anisopliae* (ARSEF-3329), *M. anisopliae* (CSIRO-F1-23), *B. bassiana* (HRI-215) and *P. farinosus* (ARSEF-4045) of 49.02 ± 0.98%, 48.89 ± 1.11%, 47.61 ± 1.32%, 39.49 ± 0.51%, 38.33 ± 0.83%, 36.94 ± 1.94% and 27.41 ± 3.88%, respectively.

Ahmad and Ahmad (2009) evaluated the toxicity of two pesticides viz., Fenazaquin @ 0.016, 0.008, 0.004, 0.002 and 0.001 and Quinalphos @ 0.100, 0.050, 0.025, 0.0125 and 0.0062% against *Coccinella septempunctata* adults. The results revealed that the highest mortality rate (67.28%) was obtained in Quinalphos @ 0.100%

followed by Quinalphos @ 0.050%, Fenazaquin @ 0.016, Fenazaquin @ 0.008, Quinalphos @ 0.025, Fenazaquin @ 0.004, Quinalphos @ 0.0125 and Quinalphos @ 0.0062% of 56.37, 54.54, 44.54, 38.16, 27.27, 18.21, 17.26 and 4.58%, respectively while the lowest mortality rate was on Fenazaquin @ 0.001 of 2.72%.

Chatterjee and Senapati (2010) conducted a field experiment to evaluate the effect of some microbial insecticides viz., Avermectin 1.8% w/v @ 0.1%, *Btk*-32000 IU/mg @ 0.1%, *Btk*-55000 SU/mg @ 0.1% and *Beauvaria bassiana* 1 x 107 spores/ml @ 0.2% against coccinellids. They reported that among the four microbials, Avermectin-1.8% w/v was found to be the most toxic to coccinellid beetles causing 37.11% reduction in beetle population followed by *Btk*-32000 IU/mg (34.62%), *Btk*-55000 SU/mg (28.8%) and *B. bassiana* (25.61%) to coccinellid beetles such as *Menochilus* spp., *Micraspis* spp. and *Harmonia* spp.

Maula *et al.* (2010) studied the effectiveness of three insecticides against mustard aphid and predator under field condition and reported that the percent reduction of *Coccinella septempunctata* after first spray ranged from 60.92 to 85.74%, 49.27 to 86.72 % and 29.81 to 76.28% at 1, 4 and 7 days after spraying (DAS), respectively. At 1 DAS, the highest percent reduction (85.74%) was observed in the Fenetrothion @ 0.05% followed by Oxydemeton methyl @ 0.05% and Dimethoate @ 0.05% of 78.5 and 62.41%, respectively. However, at 4 and 7 DAS, the highest percent reduction of the *C. septempunctata* was observed in the Fenetrothion @ 0.05% of 86.72% and 76.28%, respectively and the lowest percent reduction was found in Dimethoate @ 0.05% 49.27% and 29.81%, respectively. The findings thus concluded that Fenetrothion @ 0.05% was found to be the most toxic to the grub and adult of *C. septempunctata*.

Swaminathan *et al*. (2010) evaluated the side effects of a few botanicals on the aphidophagous coccinellid, *Adonia variegate* and reported that the highest mortality of was recorded in NSKE @ 10% of 73.33% followed by for neem oil @ 5% of 65.00% mortality, and the post treatment effect (one day after spraying) evinced maximum reduction in NSKE @ 10% of 72.00% followed by neem oil @ 5% of 68.00% mortality.

Sohail *et al*. (2011) conducted a field experiment to determine the effect of different chemical pesticides on mustard aphid, *L. erysimi* and their adverse effects on ladybird beetles. They recorded that nine days after spraying, the lowest population density of ladybird beetles was observed on Methomyl @ 200 ml/100 lt and

Thiamethoxam 25 WG @ 15g/100 litre, i.e. 1.00 and 1.00 per 5 plants followed by Imidacloprid 20 SL @ 100 ml/100 litre, i.e. 1.33 ladybird beetle per 5 plants. Data recorded twelve days after spraying found lowest population on Fastkil (0.30 ladybird beetle per 5 plants) followed by Imidacloprid 20 SL @ 120 ml/100 litre (2.33 ladybird beetle per 5 plants) and Thiamethoxam 25 WG @ 5g/100 litre (4.00 ladybird beetle per 5 plants). Data recorded fifteen days after spraying indicated the lowest population of 2.00 ladybird beetle per 5 plants on Thiamethoxam 25 WG @ 10g/100 litre which was at par with all the treatments as compared to the control where the highest number of ladybird beetle per 5 plants was recorded, i.e. 13.33.

Mollah *et al.* (2012) conducted a field experiment to evaluate the effect of some insecticides on the abundance and mortality of predacious lady bird beetles in country bean, *Lablab purpureus* ecosystem. Among the insecticides, Neem oil @ 2.5 ml/lt water, Curtap 50 SP @ 2.0 g/lt water and Emamectin benzoate 5 SG @ 1.0 g/lt water ensure highest number of lady bird beetle resulting in 22.45, 17.97 and 15.63 adult lady bird beetles per plot area respectively. On the contrary, lowest number of lady bird beetle was found in Fenvalerate 20 EC @ 1 ml/lt water, Cypermethrin 10 EC @ 1.0 ml/lt water and Fenvalerate 5 EC @ 1.0 ml/lt water treated resulting in 10.67, 11.43 and 12.72 adult lady bird beetles per plot area respectively. In terms of mortality, Neem oil @ 2.5 ml/lt water and Emamectin benzoate 5 SG @ 1.0 g/lt water were found to be least toxic to lady bird beetles confirming 9.37 and 19.04 % mortality, respectively whereas Fenvalerate 5 EC @ 1.0 ml/lt water, Cypermethrin 10 EC @ 1.0 ml/lt water and Deltamethrin 2.5 EC @ 1.0 ml/lt water were found to be highly toxic to lady bird beetle resulting 33.78, 31.76 and 28.42 % mortality, respectively.

Awasthi *et al.* (2013) conducted a laboratory experiment to evaluate relative toxicity of six insecticides viz., Spinosad 45 SC, Indoxacarb 15.8 EC, Emamectin benzoate 5 SG, Acephate 75 SP, Acetamiprid 20 SP and Imidacloprid 17.8 SL against cotton aphid *Aphis gossypii* and different stages of predatory coccinellids. On the basis of LC_{50} values, they reported that Spinosad was the safest insecticide for the different stages of the predatory coccinellids and Acetamiprid was the most toxic followed by Imidacloprid, Indoxacarb, Emamectin benzoate and Acephate. They further reported that the relative toxicity of Acetamiprid was 27.83 and 6.08 times, imidacloprid 21.78 and 3.51 times, Indoxacarb 14.31 and 5.96 times, Emamectin benzoate 9.11 and 2.21 times and Acephate 5.11 and 0.92 times more toxic than Spinosad against late instar grubs and adults coccinellids, respectively.

Frah *et al.* (2013) studied the comparative effects between flavonoids extracted from leaves of Faba bean and Acetamiprid on the first instar grubs of *Coccinella septempunctata* fed on *Aphis craccivora* under laboratory conditions. After 144 hours of treatment, the larval mortality of *C. septempunctata* was 1.99%, 2.00%, 1.95%, 1.89% and 1.89% on those treated with flavonoids extract of 50, 100, 150, 200 and 250 ppm, respectively. Whereas, on those treated with Acetamiprid the larval mortality of *C. septempunctata* was 16.66%, 26.60%, 50.00%, 66.66% and 100.00% on those treated with flavonoids extract of 50, 100, 150, 200 and 250ppm, respectively.

Meena *et al.* (2013) reported that among the treatments *Verticillium lecanii* @ 5 g/litre of water, *Beauveria bassiana* @ 5 g/litre of water, *Metarhizium anisopliae* @ 5 g/litre of water, Cow urine @ 50 litre/ha, Tobacco extract @ 5%, Onion extract @ 5%, Neem seed kernel extract (NSKE) @ 5%, Dimethoate 30 EC @ 300 g a.i/ha had no significant difference in the population of the coccinellids at 3, 7 and 10 days after spraying (DAS). The population of coccinellids per plant at 10 DAS was found lowest on Dimethoate 30 EC @ 300 g a.i/ha (0.60 adult and grub per plant) in comparison to control (0.83 adult and grub per plant) and in case of syrphid fly 0.35 and 0.65 adult per plant, respectively.

Amin *et al.* (2014) conducted an experiment to evaluate the effect of different insecticides against insect pests and predators complex on *Brassica napus* L. under field conditions. Among the insecticides, the results revealed that Diafenthuron was found highly toxic to *C. septempunctata* as it showed maximum percent reduction (78.93%) after seven days of spraying, whereas imidacloprid was safe and showed minimum percent reduction (57.34%) after seven days of spraying. However, moderately toxic to *C. septempunctata* population was found on Dimethoate and Bifenthrin with 72.87% and 65.55% reduction after seven days of spraying, respectively.

Bana *et al.* (2014) conducted a field experiment to evaluate the effect of different insecticides on *Coccinella septempunctata* during 2008-2009 and 2009-2010. They found that the minimum population (2.67 and 2.10/10 plants) was recorded in Imidacloprid followed by Malathion (2.77 and 2.17/10 plants) and Lufenuron (2.83 and 2.50/10 plants) which proved toxic and statistically at par, whereas the maximum population was recorded in NSKE (4.10 and 3.90/10 plants) followed by Azadirachtin (4.00 and 3.67/10 plants), *Bt. kurstaki* (3.97 and 3.60/10 plants), Spinosad (3.90 and 3.57/10 plants), Indoxacarb (3.87 and 3.57/10 plants) and Endosulfan (3.80 and 3.53/10 plants) and proved least toxic.

Sabry *et al.* (2014) studied the toxicity effect of three modern insecticides viz., Spinetoram @ 25 ppm, Thiamethoxam @ 25 ppm and Chlorantraniliprole @ 25 ppm on second instar larvae of *Coccinella septempunctata* and reported that the highest mortality was recorded on Thiamethoxam with 88.30% followed by Chlorantraniliprole and Spinetoram with 86.7% and 58.30%, respectively.

Khan *et al.* (2015) conducted studies on the toxicity effect of four commonly used insecticides viz., Cypermethrin, Emamectin benzoate, Spinosad, and Neem oil against different stages of *Menochilus sexmaculatus* under laboratory condition during 2010. The results showed that among the selected insecticides, Cypermethrin exhibited high level of toxicity by causing maximum egg, larva, pupa, and adult (66.67%, 83.33%, 76.67% and 86%) mortality, respectively whereas Emamectin benzoate proved to be the best one with significantly least level of toxicity against egg, larva, pupa, and adult (26.67%, 20%, 20% and 30%) mortality, respectively. The results further revealed that Neem oil was highly toxic by causing maximum egg and pupa (80% and 86.67%) mortality, respectively.

CHAPTER - III

MATERIALS AND METHODS

MATERIALS AND METHODS

Studies on “Effect of different temperatures and pesticides on the biological attributes of major coccinellid beetles predating on mustard aphid, *Lipaphis erysimi* (Kaltenbach)” were carried out in the experimental cum research farm, Department of Entomology at School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema campus, Nagaland and Division of Crop Protection (Entomology) at ICAR Research Complex for NEH Region, Umiam, Meghalaya during the year 2014-2015 and 2015-2016. All the laboratory experiments were carried out in the Biological Control laboratory and Integrated Pest Management (IPM) laboratory at ICAR Research Complex for NEH Region, Division of Crop Protection (Entomology), Umiam, Meghalaya. The details on materials used and the methodologies studied in the experiments are as follows:

3.1. Geographical location, experimental site and climatic condition of the study area

3.1.1. Geographical location and experimental site of School of Agricultural Sciences and Rural Development, Nagaland University

The institute is situated at Medziphema, Nagaland, 25º45’53” North latitude and 93º53’ 04” East longitude having an elevation of 310 meters above mean sea level (msl).

3.1.2. Climatic condition of School of Agricultural Sciences and Rural Development, Nagaland University

The experimental farm is situated in the humid and sub-tropical region with an average rainfall ranging from 2000 to 2500 mm annually. The mean temperature ranges from 21ºC to 32ºC during summer and rarely goes below 8ºC in winter.

3.1.3. Geographical location and experimental site of ICAR Research Complex for NEH Region, Umiam, Meghalaya

The institute is situated at Umiam (Barapani), Meghalaya, 25º41’21” North latitude and 91º55’25” East longitude having an elevation of 1010 meters above mean sea level (msl).

3.1.4. Climatic condition of ICAR Research Complex for NEH Region, Umiam, Meghalaya

The experimental area is situated in the mid-tropical region with an average annual rainfall of about 2000 to 2500 mm. The maximum temperature of the region

Plate 1a: **SASRD, Nagaland University, Nagaland**

Plate 1b: **ICAR Research Complex for NEH Region, Meghalaya**

Plate 1: Google earth showing the location of the study areas

Plate 2a: **Entomology experimental field at SASRD, Nagaland University, Nagaland**

Plate 2b: **Entomology experimental field at ICAR Research Complex for NEH Region, Meghalaya**

Plate 2: Experimental fields in both the study areas

ranges between 20.9ºC to 27.4ºC and minimum temperature between 6.7ºC to 18.10ºC.

3.2. Experimental details

3.2.1. Field experimental details

In both areas of studies, i.e. at School of Agricultural Sciences and Rural Development, Nagaland University, Nagaland and ICAR Research Complex for NEH Region, Umiam, Meghalaya, three ecological plots of (6 x 4) m^2 were maintained and mustard seeds were broadcasted. The plots were separated from each other by a passage, i.e. 1 meter in width. The detailed layout is presented below:

Ecological plot	:	(6 x 4) m^2
No of plots	:	3
Crop	:	Mustard
Variety	:	Varuna (T-59)

From these ecological plots, coccinellid beetles were observed and recorded at two weeks interval and collected directly by hand or sweeping net. The collected adult beetles were dry preserved and the larval stages were preserved in 70% ethyl alcohol solution. Later, the collected beetles were identified with the help of identification guides and published literatures collected. Further, comparative studies on the composition of different coccinellid species in mustard crop, were recorded between Meghalaya and Nagaland.

3.2.2. Laboratory experimental details

3.2.2.1. Studies on the effect of different temperatures on the biology of major coccinellid beetles, *Coccinella septempunctata* and *C. transversalis* predating on mustard aphid, *Lipaphis erysimi* (Kalt.)

The experiments on the biological parameters of both the predators, i.e. *Coccinella septempunctata* and *C. transversalis* were studied at four different temperature levels (20ºC, 25ºC, 30ºC and 35ºC) in Biological Control laboratory, Division of Crop Protection (Entomology) at ICAR Research Complex for NEH Region, Umiam, Meghalaya. The experiments were designed to study the biology of *C. septempunctata* and *C. transversalis* on mustard aphid, *L. erysimi* at four different temperatures.

The experiment was started with initial cultures of the two predators, i.e. *C. septempunctata* and *C. transversalis* collected from the Indian mustard variety Varuna

***Plate 3a:* BOD incubator maintained at 20ºC and 30ºC**

***Plate 3b:* BOD incubator maintained at 35ºC**

***Plate 3c:* First instar larvae of coccinellids maintained at 25ºC**

***Plate 3d:* Second instar larvae of coccinellids maintained at 25ºC**

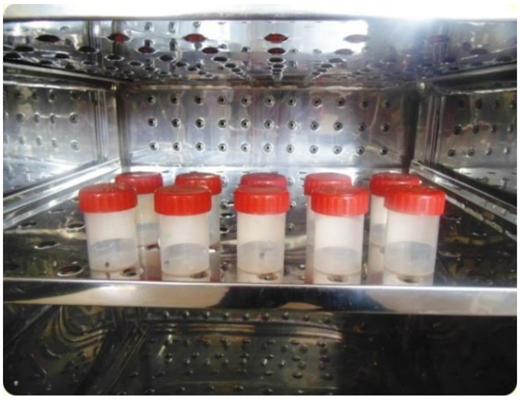

***Plate 3e:* First instar larvae of coccinellids inside BOD incubator**

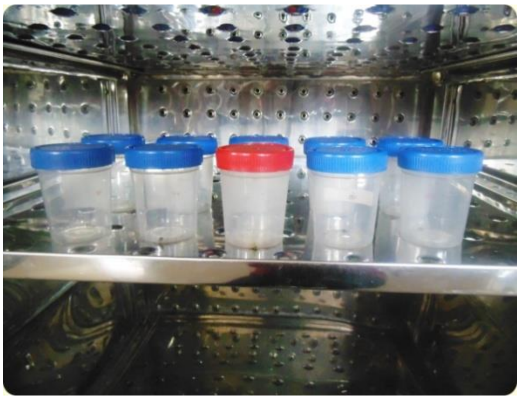

***Plate 3f:* Second instar larvae of coccinellids inside BOD incubator**

Plate 3: Studies on biological attributes of Coccinellid beetles maintained at different temperatures

(T-59) grown in the entomological field of ICAR, Umiam, Meghalaya. Ten pairs of adults *C. septempunctata* and *C. transversalis* were selected and reared in the laboratory at different temperatures, i.e. at 20ºC, 25ºC, 30ºC and 35ºC respectively and 75 ± 5% relative humidity. The collected adult beetles from the field were then released in pairs and kept separately in plastic containers of 12 x 8 cm, secured by muslin cloth and kept in BOD incubator for obtaining eggs. Each plastic container was provided daily with fresh twigs along with sufficient amount of fresh mustard aphids as food source and substrate (paper strip) for egg laying. The mated females were allowed to oviposit and kept separately in plastic containers and observations on fecundity and ovipositional period were recorded. Eggs laid by each female during 24 hours were removed daily, counted and transferred to petri dishes of 5 cm diameter lined with slightly dampened filter paper at the bottom and observed twice daily, i.e. 10 a.m and 4 p.m, for recording the incubation period. Soon after hatching, the larvae were collected with a fine point camel hair brush and reared individually on mustard aphids in a plastic container of 6 x 3.5 cm till third instar. Soon after they moulted to fourth instars, they were shifted to another big plastic container of 7 x 5.5 cm. First and second instar nymphs of aphid along with fresh twigs were provided as food to first instar predator larvae, whereas subsequent instar of predators were provided with third, fourth and well developed nymphs.

The duration of all the larval instars were recorded continuously from first to fourth instars. The larvae were observed daily until pupation and when the larvae were completely transformed to pupae they were kept in petridishes and observations on pupal period and adult emergence were recorded. After the adult emergence, male and female beetles were differentiated on the basis of body size and the characters present on the 9^{th} and 10^{th} abdominal segments. The emerged adult beetles were collected and reared individually in plastic containers of 7 x 5.5 cm with sufficient amount of mustard aphids, and observations on adult longevity was recorded.

The experiments were conducted in Completely Randomized Design (CRD) with ten replications. Observations on the different developmental parameters, i.e. ovipositional period, fecundity, size of egg cluster, incubation period, percentage of grub emergence, larval period, pre-pupal period, pupal period, percentage of adult emergence and adult longevity of *C. septempunctata* and *C. transversalis* were recorded.

3.2.2.2. Studies on the feeding potential of major coccinellid beetles, *Coccinella septempunctata* and *C. transversalis* predating on mustard aphid, *Lipaphis erysimi* (Kalt.) at different temperatures

The experiments on the feeding potential of both the predators, i.e. *Coccinella septempunctata* and *C. transversalis* were studied at four different temperature levels, (20ºC, 25ºC, 30ºC and 35ºC) in Biological Control laboratory, Division of Crop Protection (Entomology) at ICAR Research Complex for NEH Region, Umiam, Meghalaya. The experiments were designed to study the feeding response of *C. septempunctata* and *C. transversalis* on mustard aphid, *L. erysimi* at four different temperatures.

The experiment was started with males and ovipositing females of coccinellid beetles. Ten pairs of adults *C. septempunctata* and *C. transversalis* were collected from the Indian mustard var. "Varuna", grown in experimental field infested with mustard aphid, *L. erysimi* and reared in the laboratory under different temperatures, i.e. at 20ºC, 25ºC, 30ºC and 35ºC respectively and 75 ± 5% relative humidity. The collected adult beetles from the field were then released in pairs and kept separately in plastic containers of 12 x 8 cm. These beetles were then reared in the laboratory and kept in BOD incubator by providing sufficient numbers of mustard aphid, *L. erysimi* as a food source and substrate (paper strip) for egg laying. The eggs laid by adult females were allowed to hatch in 5 cm petri dishes lined with slightly dampened filter paper at the bottom. Soon after hatching, individual larvae were separated to avoid cannibalism among them. To determine the feeding efficiency of different larval stages, viz., first, second, third and fourth instar grubs, different prey densities of mustard aphid, *L. erysimi,* i.e. 20, 30, 40 and 50 were provided individually and kept separately in a plastic container of 6 x 3.5 cm. Thereafter, individual larva was allowed to feed for 24 hours and after feeding the left over aphids were counted, and it continued till pupation. After pupation, freshly emerged adults of *C. septempunctata* and *C. transversalis* were transferred to another big plastic container of 7 x 5.5 cm and individual male and female adult was kept separately provided with aphids of constant prey density, i.e. 60 aphids/day and observations on the predatory potential were recorded till death.

At each aphid population, one treatment (n = 10) was done for both larvae and adults. After the completion of 24 hours of experiment, predators were withdrawn and the total number of unconsumed aphids in each treatment was counted. When the counting was over, the containers were cleaned and larvae were replaced in a container along with fresh known number of aphids and fresh mustard twigs for 24 hours. During the larval period, these were maintained till it metamorphosed (turn into pupa) and for adult, observation continued till death.

The actual number of aphids consumed by the predators was calculated by using the formula given by Bunker and Ameta (2009) and these corrected values were analyzed statistically.

$$X = R - (T + C)$$

Where,

X = Actual number of aphids consumed by predator
R = Total number of aphids released in treatment
T = Number of live aphids left in treatment
C = Number of dead aphids in control

The "X" values so obtained were used for evaluating mean and standard error of mean.

The experiments were conducted in Completely Randomized Design (CRD) with ten replications. Observations on the feeding potential of different stages, i.e. first, second, third, fourth and adults of *C. septempunctata* and *C. transversalis* were recorded.

3.2.2.3. Studies on the toxicity of different pesticides on major coccinellid beetles, *Coccinella septempunctata* and *C. transversalis* predating on mustard aphid, *Lipaphis erysimi* (Kalt.)

On the basis of Pesticide Use Database, 2012 of Central Insecticide Board, India, five (5) widely used pesticides against mustard aphid, *Lipaphis erysimi* and its effect on predators, *Coccinella* species were selected for this study. The details on pesticides used, doses and mode of action are indicated in Table 1. In order to find out the highest possible effects, the pesticides with their recommended field doses were selected for the experiments.

Table 1: Details of pesticides used during the study

Sl. No.	Common Name	Dose	Mode of action
1.	Neem 1500 ppm	4 ml/lt of water	Antifeedant and growth regulator characters.
2.	Imidacloprid 17.8 SL	0.25 ml/lt of water	Nicotinic acetylcholine receptor, channel agonists (Allosteric) effect with direct contact and stomach action.
3.	Deltamethrin 2.5 EC	1 ml/lt of water	Sodium channel modulators with direct contact.
4.	*Bacillus thuringiensis* var. *kurstaki* 8 SP	2gm/lt of water	Disruption of midgut epithelial membrane, gut paralysis etc.
5.	Acetamiprid 20 SP	2 gm/lt of water	Nicotinic acetylcholine receptor, channel agonists (Allosteric) effect with direct contact and stomach action.

3.2.2.3.1. Studies on the toxicity of different pesticides on major coccinellid beetles, *Coccinella septempunctata* and *C. transversalis* by residual film method

Pesticide solutions with required concentrations were prepared in the IPM laboratory, Division of Crop Protection (Entomology) at ICAR Research Complex for NEH Region, Umiam, Meghalaya in clean and sterilized glass jars with the help of micropipette (Tarsons®). Distilled water along with 0.1% Triton X was used for preparation of pesticide solutions (viz., Neem 0.4 EC, Imidacloprid 17.8 SL, Deltamethrin 2.5 EC, *Bacillus thuringiensis* var. *kurstaki* 8 SP and Acetamiprid 20 SP). Only 0.1% Triton X-100 solution was used in control. New well sterilized plastic petri dishes (Tarsons® size 1.5 cm height and 5 cm diameter) were used for the bioassay experiment.

The bioassay experiment was conducted in Biological Control laboratory, Division of Crop Protection (Entomology) at ICAR Research Complex for NEH Region, Umiam, Meghalaya under ambient conditions, i.e. Average temperature 21 ± 1ºC and 75 ± 5% relative humidity and 14:10 hours in a light : dark conditions. Initially, plastic petri

Plate 4a: **Neem oil**

Plate 4b: **Imidacloprid 17.8 SL**

Plate 4c: **Deltamethrin 2.5 EC**

Plate 4d: Bt **var.** ***kurstaki*** **8 SP**

Plate 4e: **Acetamiprid 20 SP**

Plate 4: **Pesticides used for the efficacy study of** ***Coccinella septempunctata*** **and** ***C. transversalis***

dishes (5 x 1.5 cm) were uniformly surface coated (except lid) with pesticides. Further, after drying of container surface, i.e. after 1 hour, five numbers each of fourth instar grubs and adults *Coccinella septempunctata* and *C. transversalis*, respectively were released separately into each petri dishes and covered with lids.

The experiment was conducted in Completely Randomized Design (CRD) with three replications. Overall experiments were also repeated three times. Observations on mortality of predators were recorded after 6, 12, 24, 48, 72, 96 and 120 hours of treatment. The data recorded on mortality were converted into percentage basis and used for further analysis.

3.2.2.3.2. Studies on the toxicity of different pesticides on major coccinellid beetles, *Coccinella septempunctata* and *C. transversalis* by diet contamination method

Diet contamination experiment was conducted in the same laboratory of ICAR Research Complex for NEH Region, Umiam, Meghalaya. Pesticide solutions with required concentrations were prepared in clean and sterilized glass jars with the help of micropipette (Tarsons®). Distilled water along with 0.1% Triton X was used for preparation of pesticide solutions (viz., Neem 0.4 EC, Imidacloprid 17.8 SL, Deltamethrin 2.5 EC, *Bacillus thuringiensis* var. *kurstaki* 8 SP and Acetamiprid 20 SP). Only 0.1% Triton X-100 solution was used in control. New well sterilized plastic petri dishes (Tarsons® size 1.5 cm height and 5 cm diameter) were used for the bioassay experiment.

The bioassay experiment was conducted in Biological Control laboratory, Division of Crop Protection (Entomology) at ICAR Research Complex for NEH Region, Umiam, Meghalaya under ambient conditions, i.e. Average temperature 21 ± 1ºC and 75 ± 5% relative humidity and 14:10 hours in a light : dark conditions. Initially, aphids were treated with pesticides along with infested part (twig) by leaf dip method for about two minutes and kept in plastic petri dishes of 5 x 1.5 cm. Thereafter, five numbers each of fourth instar grubs and adults *Coccinella septempunctata* and *C. transversalis*, respectively were released separately into each petri dishes and covered with lids.

The experiment was conducted in Completely Randomized Design (CRD) with three replications. Overall experiments were also repeated three times. Observations on mortality of predators were recorded after 6, 12, 24, 48, 72, 96 and 120 hours of treatment. The data recorded on mortality were converted into percentage basis and used for further analysis.

3.3. Statistical analysis:

All the data collected were subjected to statistical analysis by using statistical software IBM SPSS 16.0 (2007). Data obtained during the experiments were analyzed by using one-way analysis of variance (ANOVA). For toxicity studies against coccinellid beetles, different parameters were measured by utilizing the formula given by Abbott (1925) and these corrected values were analyzed statistically.

$$\text{Percent mortality} = \frac{\text{Number of coccinellids died}}{\text{Total number of coccinellids present}} \text{ x } 100$$

Further, differences between treatments were analyzed by using ANOVA at a significance level of 0.05 and after conducting ‘F-test”, the homogeneity of variances between different treatments was tested by application of Tukey's Honestly Significant Difference (Tukey’s HSD) test to find out the significant differences between mean values.

Table 2: Meteorological data recorded during the period of investigation (November 2014 to February 2015 and November 2015 to February 2016) at SASRD, Nagaland University, Nagaland

Month	2014-2015				2015-2016			
	Temperature (°C)		Mean Relative Humidity (%)	Rainfall (cm)	Temperature (°C)		Mean Relative Humidity (%)	Rainfall (cm)
	Maximum	Minimum			Maximum	Minimum		
November	26.50	12.30	44.00	0.30	27.60	12.00	47.00	0.32
December	24.30	8.65	40.75	0.25	24.70	9.10	45.60	0.24
January	24.38	10.05	39.50	1.83	24.30	10.00	40.20	0.72
February	26.68	11.18	40.50	0.00	26.20	11.20	46.50	1.70

Source: CIH meteorological observatory, Nagaland

Table 3: Meteorological data recorded during the period of investigation (November 2014 to February 2015 and November 2015 to February 2016) at ICAR Research Complex for NEH Region, Meghalaya

Month	2014-2015				2015-2016			
	Temperature (°C)		Mean Relative Humidity (%)	Rainfall (cm)	Temperature (°C)		Mean Relative Humidity (%)	Rainfall (cm)
	Maximum	Minimum			Maximum	Minimum		
November	24.10	10.90	72.10	2.80	27.40	14.70	72.80	94.50
December	22.40	7.10	68.85	2.80	24.50	9.70	69.55	0.20
January	21.60	6.50	67.90	37.60	20.70	5.60	68.25	3.20
February	22.80	7.60	60.80	13.80	21.00	6.90	62.75	42.50

Source: ICAR meteorological observatory, Meghalaya

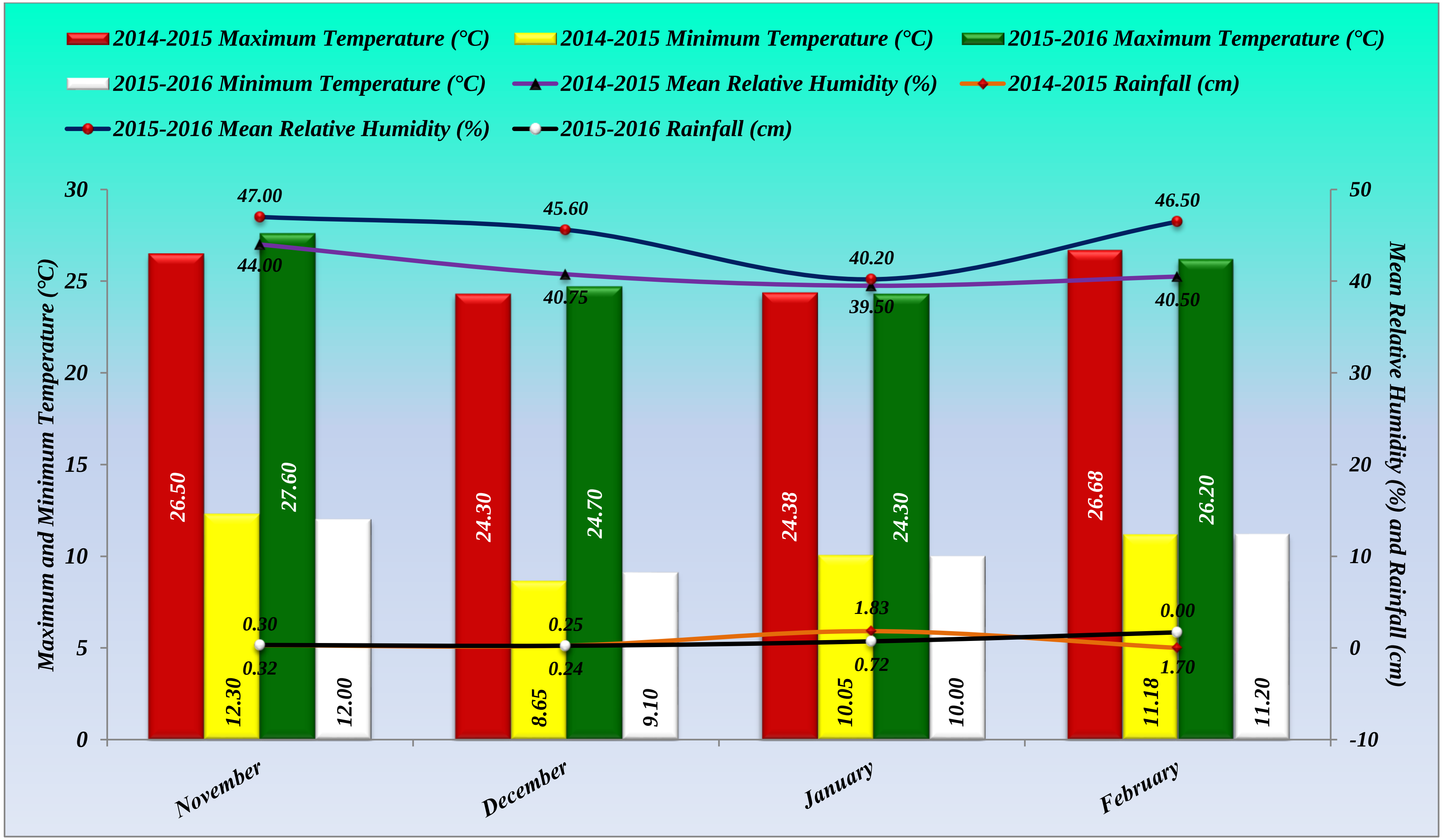

Fig 1: Graphical presentation of meteorological data during the period of investigation (November 2014 to February 2015 and November 2015 to February 2016) at SASRD, Nagaland University, Nagaland

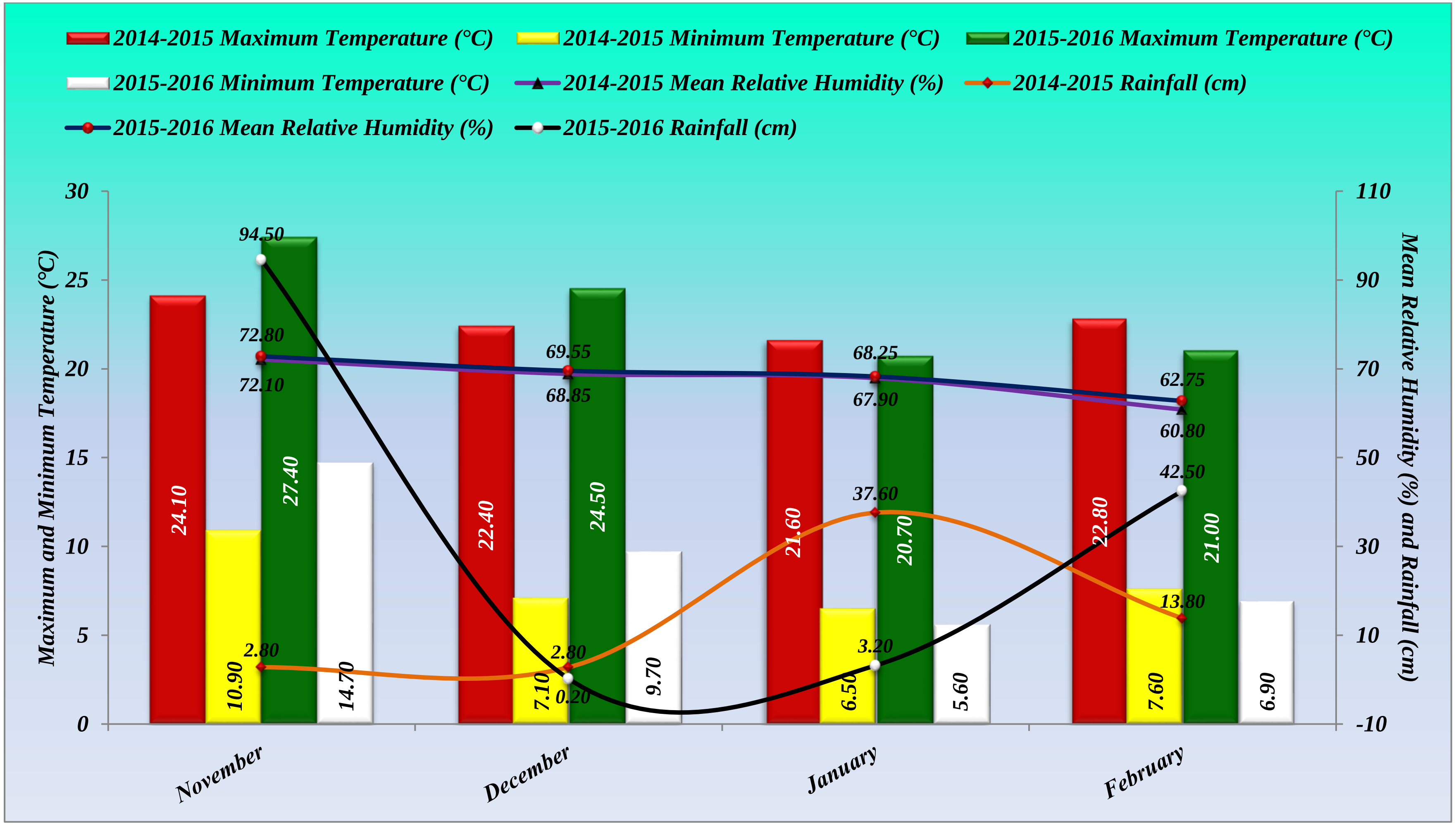

Fig 2: Graphical presentation of meteorological data during the period of investigation (November 2014 to February 2015 and November 2015 to February 2016) at ICAR Research Complex for NEH Region, Meghalaya

CHAPTER - IV

RESULTS AND DISCUSSIONS

RESULTS AND DISCUSSIONS

The findings of present investigation on "Effect of different temperatures and pesticides on the biological attributes of major coccinellid beetles predating on mustard aphid, *Lipaphis erysimi* (Kaltenbach)" are discussed under the following heads:

4.1. Species composition of coccinellid beetles in mustard ecosystem in the states of Meghalaya and Nagaland

The species composition of coccinellid beetles recorded in mustard ecosystem in both the study areas during 2014-2015 and 2015-2016 are presented in Table 4 and Fig. 3a to 4b. The present findings indicated that about seven (7) species of coccinellid beetles viz., *Coccinella septempunctata*, *Coccinella transversalis*, *Micraspis discolor*, *Harmonia dimidiata*, *Menochilus sexmaculata*, *Oenopia sexareata* and *Oenopia kirbyi* were observed in Entomology experimental field at ICAR Research Complex for NEH Region, Meghalaya whereas in Experimental cum research farm at SASRD, Nagaland University only three (3) species viz., *Coccinella septempunctata*, *Coccinella transversalis* and *Micraspis discolor* were found throughout the study period. In Entomology experimental field at ICAR Research Complex for NEH Region, Meghalaya, *Coccinella septempunctata* complex (Plate 5a, 5b and 5c) were the most abundant species observed throughout the season with 50% and 52% during 2014-2015 and 2015-2016, respectively followed by *C. transversalis* (Plate 5d), *M. discolor* (Plate 5e), *H. dimidiata* (Plate 5f), *M. sexmaculata* (Plate 5g), *O. sexareata* (Plate 5h) and *O. kirbyi* (Plate 5i) with 7% and 8%, 2% and 4%, 3% and 3%, 2% and 2% and 2% and 2%, respectively. In Experimental cum research farm at SASRD, Nagaland University, Nagaland, *C. transversalis* (Plate 6a) was the most abundant species observed throughout the season with 53% and 50% during 2014-2015 and 2015-2016, respectively followed by *C. septempunctata* (Plate 6b) and *M. discolor* (Plate 6c) with 42% and 43% and 5% and 7%, respectively.

Interestingly, in *C. septempunctata* complex about three different types of polymorphic and polychromic elytral patterns were observed in Entomology experimental field at ICAR Research Complex for NEH Region, Meghalaya whereas in Experimental cum research farm at SASRD, Nagaland University, only one type of polymorphic and polychromic elytral patterns were found throughout the season.

Similar findings were reported by Firake *et al.* (2012) who observed about six (6)

Table 4: Species composition of coccinellid beetles in mustard ecosystem in the states of Meghalaya and Nagaland

Sl. No.	Location	Number of coccinellid beetles species identified	Species composition of coccinellid beetles in mustard crop	Per cent of coccinellid species composition in mustard ecosystem	
				2014-2015	2015-2016
1.	ICAR Research Complex for NEH Region, Meghalaya	7	*Coccinella septempunctata* (Linnaeus)	50	52
			Coccinella transversalis (Fabricius)	34	29
			Micraspis discolor (Fabricius)	7	8
			Harmonia dimidiata (Fabricius)	2	4
			Menochilus sexmaculata (Fabricius)	3	3
			Oenopia sexareata (Mulsant)	2	2
			Oenopia kirbyi (Mulsant)	2	2
2.	SASRD, Nagaland University, Nagaland	3	*Coccinella septempunctata* (Linnaeus)	42	43
			Coccinella transversalis (Fabricius)	53	50
			Micraspis discolor (Fabricius)	5	7

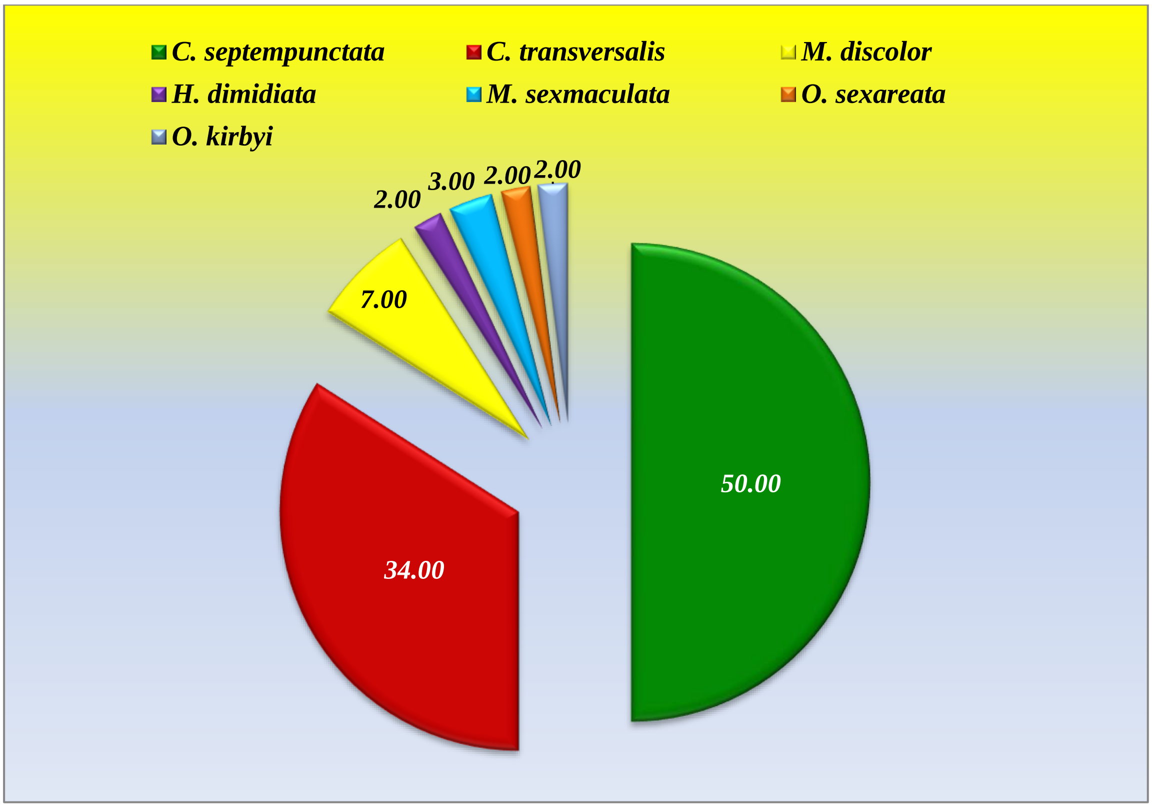

Fig 3a: Species composition of coccinellids at ICAR Research Complex for NEH Region, Meghalaya during 2014-2015

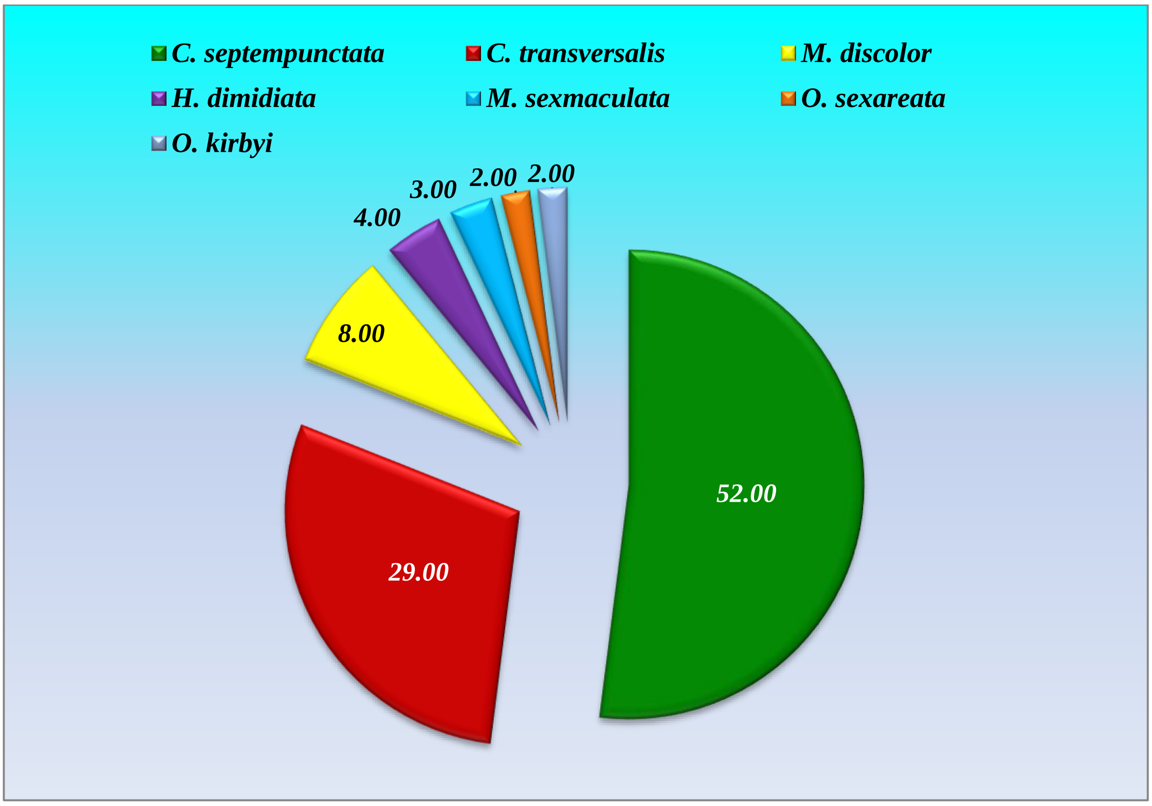

Fig 3b: Species composition of coccinellids at ICAR Research Complex for NEH Region, Meghalaya during 2015-2016

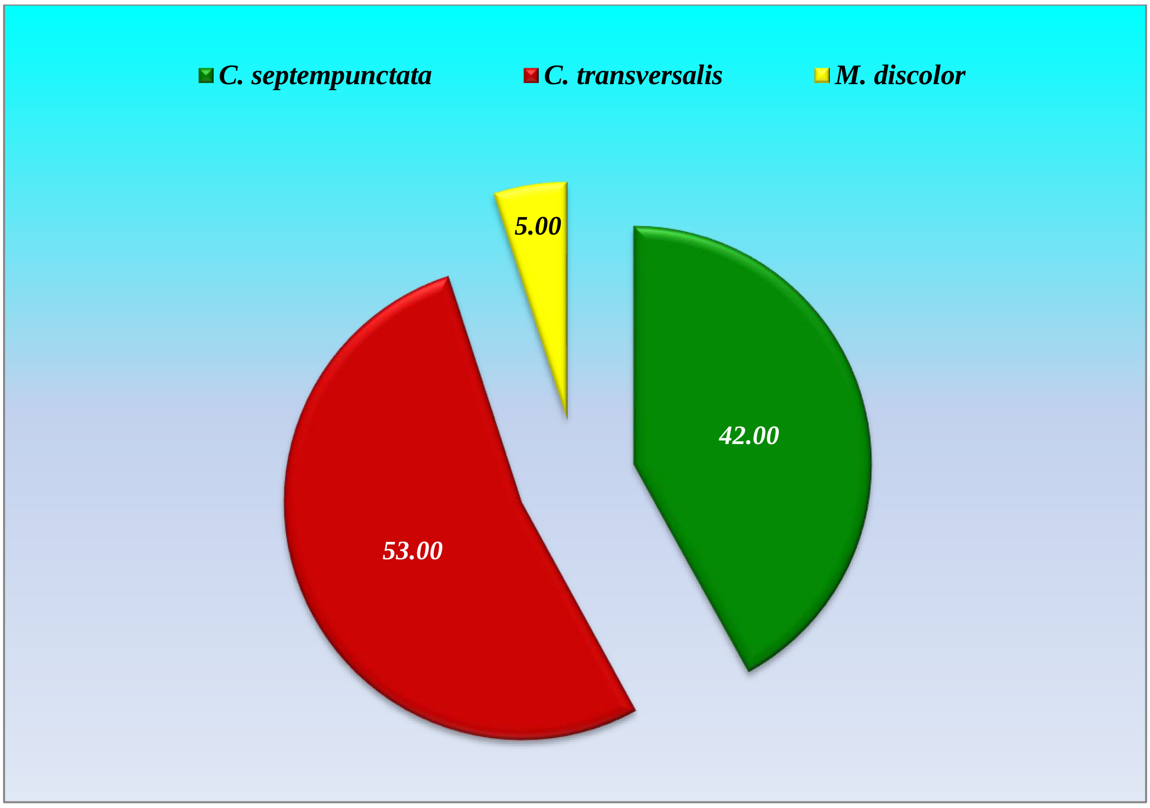

Fig 4a: Species composition of coccinellids at SASRD, Nagaland University, Nagaland during 2014-2015

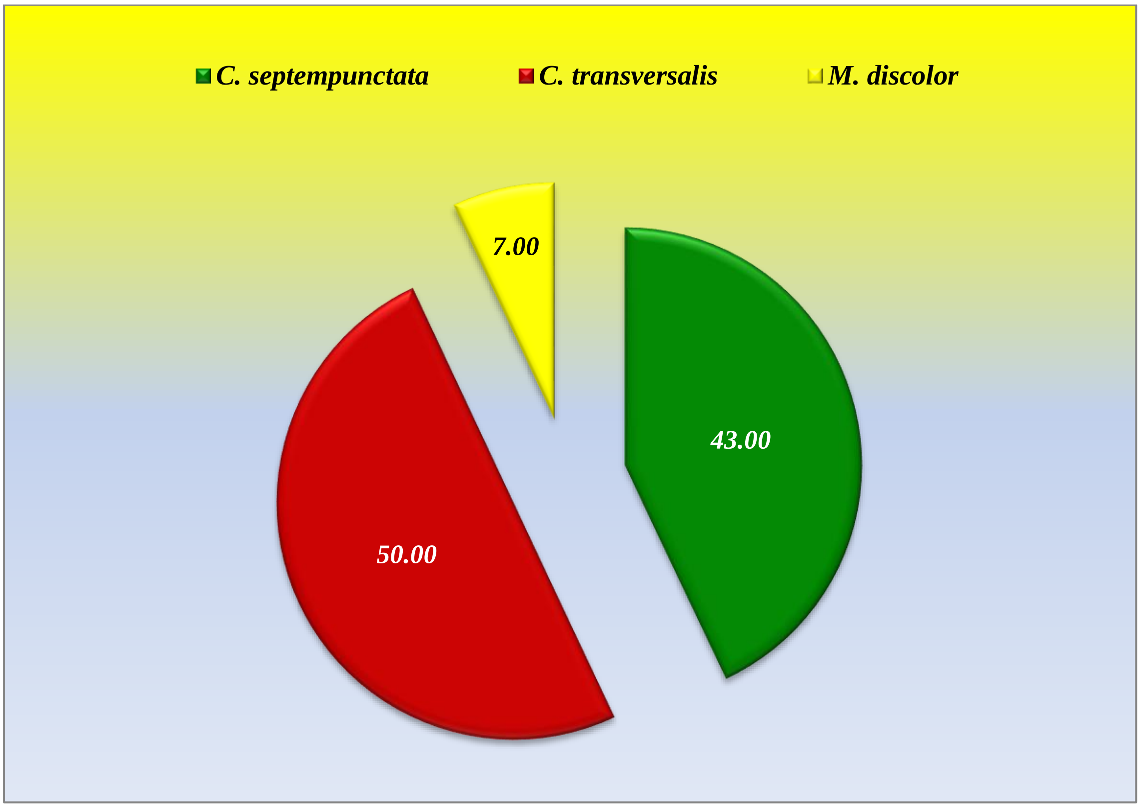

Fig 4b: Species composition of coccinellids at SASRD, Nagaland University, Nagaland during 2015-2016

Plate 5a: ***Coccinella septempunctata***

Plate 5b: ***Coccinella septempunctata***

Plate 5c: ***Coccinella septempunctata***

Plate 5d: ***Coccinella transversalis***

Plate 5e: ***Micraspis discolor***

Plate 5f: ***Harmonia dimidiate***

Plate 5g: ***Menochilus sexmaculata***

Plate 5h: ***Oenopia sexareata***

Plate 5i: ***Oenopia Kirbyi***

Plate 5: Different Coccinellid beetles species observed in mustard ecosystem in Meghalaya

Plate 6a: ***Coccinella transversalis***

Plate 6b: ***Coccinella septempunctata***

Plate 6c: ***Micraspis discolor***

Plate 6: Different Coccinellid beetles species observed in mustard ecosystem in Nagaland

species of coccinellid beetles in the brassicaceous ecosystem of which *Coccinella septempunctata* was the most abundant species throughout the season. In Nagaland so far, no literature or citations were available regarding the species abundance of coccinellid beetles in mustard or brassicaceous ecosystem.

4.2. Biological parameters of major coccinellid beetles reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

4.2.1. Biology of *Coccinella septempunctata* reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

The results during the course of investigations revealed that temperature had a significant effect on all the biological parameters of *C. septempunctata* reared on *L. erysimi*. The details of the results pertaining on the biology of *C. septempunctata* are emphasized under the following heads:

4.2.1.1. Ovipositional period

The data indicated that the ovipositional period of *C. septempunctata* decreased significantly with the increase in temperature from 38.50 ± 1.95 and 42.65 ± 1.47 days at 20°C to 30.45 ± 1.44 and 31.60 ± 1.79 at 35°C during 2014-2015 and 2015-2016, respectively with mean as 40.58 ± 1.71 days at 20°C to 31.03 ± 1.62 days at 35°C (Table 5, 6 and 7). The longest ovipositional period were recorded about 38.50 ± 1.95 and 42.65 ± 1.47 days with mean as 40.58 ± 1.71 days at 20°C followed by 38.35 ± 1.55 and 40.30 ± 1.87, 32.60 ± 1.59 and 35.25 ± 1.74 and 30.45 ± 1.44 and 31.60 ± 1.79 days with means as 39.28 ± 1.71, 33.93 ± 1.67 and 31.03 ± 1.62 days at 25°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively. The significant delay in the oviposition of *C. septempunctata* as the temperature decreases may be due to lower metabolic rate resulting slower maturation of the gonads.

Similar findings was reported by Ali and Rizvi (2008) indicating the ovipositional period of *C. septempunctata* when reared on *L. erysimi* decreased from 43.50 to 51.50 days at 24 ± 1°C to 38.50 to 44 days at 28 ± 1°C. The results are further supported by Hemchandra *et al.* (2010) who found that the oviposition period of *Micraspis discolor* when reared on *Rophalosiphum maidis* decreased from 53.00 ± 0.84 days at 20°C to 38.00 ± 2.92 days at 30°C.

4.2.1.2. Fecundity (Eggs per female)

There was an undulating pattern on fecundity of *C. septempunctata* with respect

Table 5: Biology of *C. septempunctata* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 (n=10)

Sl. No.	Parameters	Biology of *C. septempunctata* under the influence of different temperatures (Mean ± SEm)						
		2014-2015						
		20ºC	25ºC	30ºC	35ºC	F value	P value	$HSD_{P=0.05}$
1.	Ovipositional period (in days)	38.50 ± 1.95[a]	38.35 ± 1.55[a]	32.60 ± 1.59[b]	30.45 ± 1.44[c]	16.63	<0.01	3.43
2.	Fecundity (Eggs/female)	332.70 ± 20.67[b]	365.25 ± 25.30[a]	265.65 ± 15.87[c]	220.30 ± 12.45[d]	107.32	<0.01	24.01
3.	Size of egg cluster (Number of eggs/cluster)	30.70 ± 3.11[b]	35.52 ± 3.62[a]	26.57 ± 2.64[b]	22.25 ± 2.44[c]	26.74	<0.01	4.18
4.	Incubation period (in days)	4.75 ± 0.25[a]	4.20 ± 0.24[b]	3.85 ± 0.19[bc]	3.50 ± 0.19[c]	19.49	<0.01	0.46
5.	Percentage of grub emergence	82.70 ± 0.55[b]	84.20 ± 0.53[a]	82.50 ± 0.78[b]	75.00 ± 0.54[c]	155.64	<0.01	1.27
6.	Total larval period (in days)	19.85 ± 1.28[a]	16.65 ± 0.83[b]	12.95 ± 0.84[c]	9.50 ± 0.65[d]	251.98	<0.01	1.08
i.	I instar	3.75 ± 0.31[a]	3.00 ± 0.14[b]	2.75 ± 0.15[b]	2.10 ± 0.12[c]	40.34	<0.01	0.41
ii.	II instar	4.40 ± 0.30[a]	3.70 ± 0.34[b]	2.80 ± 0.20[c]	2.15 ± 0.14[d]	49.46	<0.01	0.54
iii.	III instar	5.20 ± 0.37[a]	4.75 ± 0.20[a]	3.20 ± 0.15[b]	2.50 ± 0.24[c]	85.48	<0.01	0.52
iv.	IV instar	6.50 ± 0.30[a]	5.20 ± 0.15[b]	4.20 ± 0.34[c]	2.75 ± 0.15[d]	132.52	<0.01	0.52
7.	Pre-pupal period (in days)	2.30 ± 0.28[a]	2.10 ± 0.12[a]	2.00 ± 0.19[a]	2.00 ± 0.19[a]	1.60	NS	NS
8.	Pupal period (in days)	6.60 ± 0.27[a]	5.50 ± 0.24[b]	4.25 ± 0.25[c]	3.25 ± 0.25[d]	115.40	<0.01	0.52
9.	Total developmental period; egg to adult emergence (in days)	33.50 ± 2.07[a]	28.45 ± 1.43[b]	23.05 ± 1.47[c]	18.25 ± 1.28[d]	337.20	<0.01	1.37
10.	Percentage of adult emergence	86.50 ± 0.91[b]	89.70 ± 0.55[a]	78.30 ± 0.90[c]	75.60 ± 0.49[d]	255.61	<0.01	1.54
11.	Adult longevity (in days)							
i.	Males (in days)	52.80 ± 2.66[a]	50.40 ± 2.30[b]	46.50 ± 2.68[c]	40.20 ± 2.60[d]	301.79	<0.01	1.21
ii.	Females (in days)	65.90 ± 3.14[a]	61.70 ± 3.86[b]	54.20 ± 2.85[c]	47.70 ± 2.67[d]	269.99	<0.01	1.87
12.	Total life cycle; egg to death of adult (in days)							
i.	Males (in days)	86.30 ± 4.73[a]	78.85 ± 3.73[b]	69.55 ± 4.15[c]	58.45 ± 3.88[d]	595.22	<0.01	1.88
ii.	Females (in days)	99.40 ± 5.21[a]	90.15 ± 5.29[b]	77.25 ± 4.32[c]	65.95 ± 3.95[d]	631.73	<0.01	2.22

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.

Means within rows were separated by Tukey's Honestly Significant Difference.

Table 6: Biology of *C. septempunctata* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2015-2016 (n=10)

Sl. No.	Parameters	Biology of *C. septempunctata* under the influence of different temperatures (Mean ± SEm)						
		2015-2016						
		20°C	25°C	30°C	35°C	F value	P value	$HSD_{P=0.05}$
1.	Ovipositional period (in days)	42.65 ± 1.47[a]	40.30 ± 1.87[a]	35.25 ± 1.74[b]	31.60 ± 1.79[c]	21.49	<0.01	3.59
2.	Fecundity (Eggs/female)	350.25 ± 22.48[b]	390.40 ± 27.52[a]	290.20 ± 18.56[c]	232.65 ± 15.96[d]	995.31	<0.01	8.34
3.	Size of egg cluster (Number of eggs/cluster)	32.45 ± 3.14[b]	38.35 ± 3.37[a]	27.78 ± 2.35[c]	24.62 ± 2.39[c]	34.57	<0.01	3.90
4.	Incubation period (in days)	4.70 ± 0.24[a]	4.55 ± 0.29[a]	3.70 ± 0.24[b]	3.65 ± 0.14[b]	18.45	<0.01	0.49
5.	Percentage of grub emergence	83.20 ± 0.66[b]	85.00 ± 0.47[a]	83.70 ± 0.72[b]	75.20 ± 0.53[c]	179.75	<0.01	1.26
6.	Total larval period (in days)	20.20 ± 1.00[a]	17.25 ± 0.82[b]	13.55 ± 0.82[c]	9.90 ± 0.82[d]	278.60	<0.01	1.03
i.	I instar	3.30 ± 0.28[a]	3.25 ± 0.20[ab]	3.00 ± 0.19[b]	2.20 ± 0.15[c]	25.27	<0.01	0.42
ii.	II instar	4.60 ± 0.30[a]	3.45 ± 0.16[b]	2.90 ± 0.18[c]	2.35 ± 0.19[d]	60.61	<0.01	0.47
iii.	III instar	5.45 ± 0.29[a]	5.05 ± 0.21[a]	3.45 ± 0.21[b]	2.65 ± 0.27[c]	93.85	<0.01	0.52
iv.	IV instar	6.85 ± 0.14[a]	5.50 ± 0.24[b]	4.00 ± 0.24[c]	2.70 ± 0.20[d]	252.63	<0.01	0.43
7.	Pre-pupal period (in days)	2.35 ± 0.27[a]	2.25 ± 0.20[a]	2.00 ± 0.19[a]	2.00 ± 0.19[a]	2.21	NS	NS
8.	Pupal period (in days)	6.45 ± 0.29[a]	5.35 ± 0.24[b]	4.40 ± 0.27[c]	3.00 ± 0.19[d]	115.94	<0.01	0.52
9.	Total developmental period; egg to adult emergence (in days)	33.70 ± 1.81[a]	29.40 ± 1.55[b]	23.45 ± 1.52[c]	18.55 ± 1.34[d]	318.44	<0.01	1.42
10.	Percentage of adult emergence	88.20 ± 0.85[b]	90.45 ± 0.87[a]	77.65 ± 0.75[c]	76.45 ± 0.84[c]	242.80	<0.01	1.75
11.	Adult longevity (in days)							
i.	Males (in days)	54.60 ± 2.68[a]	52.30 ± 2.39[b]	48.30 ± 2.94[c]	41.80 ± 2.66[d]	216.85	<0.01	1.45
ii.	Females (in days)	67.10 ± 3.10[a]	64.00 ± 3.88[b]	55.70 ± 2.72[c]	49.20 ± 2.85[d]	272.29	<0.01	1.88
12.	Total life cycle; egg to death of adult (in days)							
i.	Males (in days)	88.30 ± 4.49[a]	81.70 ± 3.94[b]	71.75 ± 4.46[c]	60.35 ± 4.00[d]	425.14	<0.01	2.25
ii.	Females (in days)	100.80 ± 4.91[a]	93.50 ± 5.43[b]	79.15 ± 4.24[c]	67.75 ± 4.19[d]	503.36	<0.01	2.51

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.

Means within rows were separated by Tukey's Honestly Significant Difference.

Table 7: Biology of *C. septempunctata* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016 (Pooled) (n=10)

Sl. No.	Parameters	Biology of *C. septempunctata* under the influence of different temperatures (Mean ± SEm)						
		Pooled						
		20ºC	25ºC	30ºC	35ºC	F value	P value	$HSD_{P=0.05}$
1.	Ovipositional period (in days)	40.58 ± 1.71[a]	39.28 ± 1.71[a]	33.93 ± 1.67[b]	31.03 ± 1.62[b]	19.18	<0.01	3.45
2.	Fecundity (Eggs/female)	341.48 ± 21.58[b]	377.82 ± 26.41[a]	277.93 ± 17.22[c]	226.48 ± 14.21[d]	202.95	<0.01	17.63
3.	Size of egg cluster (Number of eggs/cluster)	31.58 ± 3.13[b]	36.99 ± 3.49[a]	27.18 ± 2.50[c]	23.43 ± 2.41[c]	30.38	<0.01	3.97
4.	Incubation period (in days)	4.73 ± 0.24[a]	4.38 ± 0.27[a]	3.78 ± 0.22[b]	3.58 ± 0.17[b]	18.94	<0.01	0.47
5.	Percentage of grub emergence	82.95 ± 0.61[b]	84.60 ± 0.50[a]	78.60 ± 0.75[c]	75.10 ± 0.54[d]	167.56	<0.01	1.24
6.	Total larval period (in days)	20.03 ± 1.14[a]	16.95 ± 0.83[b]	13.15 ± 0.83[c]	9.70 ± 0.74[d]	264.65	<0.01	1.03
i.	I instar	3.53 ± 0.30[a]	3.23 ± 0.17[ab]	2.88 ± 0.17[b]	2.15 ± 0.14[c]	32.56	<0.01	0.41
ii.	II instar	4.50 ± 0.30[a]	3.48 ± 0.25[b]	2.85 ± 0.19[c]	2.25 ± 0.17[d]	54.29	<0.01	0.49
iii.	III instar	5.33 ± 0.33[a]	4.90 ± 0.21[a]	3.33 ± 0.18[b]	2.58 ± 0.26[c]	89.63	<0.01	0.51
iv.	IV instar	6.68 ± 0.22[a]	5.35 ± 0.20[b]	4.10 ± 0.29[c]	2.73 ± 0.18[d]	181.03	<0.01	0.47
7.	Pre-pupal period (in days)	2.33 ± 0.28[a]	2.18 ± 0.16[a]	2.00 ± 0.19[a]	2.00 ± 0.19[a]	1.93	NS	NS
8.	Pupal period (in days)	6.53 ± 0.28[a]	5.43 ± 0.24[b]	4.33 ± 0.26[c]	3.13 ± 0.22[d]	115.67	<0.01	0.51
9.	Total developmental period; egg to adult emergence (in days)	33.60 ± 1.94[a]	28.93 ± 1.49[b]	23.25 ± 1.50[c]	18.40 ± 1.31[d]	327.50	<0.01	1.37
10.	Percentage of adult emergence	87.35 ± 0.88[b]	90.08 ± 0.71[a]	77.98 ± 0.83[c]	76.03 ± 0.67[d]	248.40	<0.01	1.62
11.	Adult longevity (in days)							
i.	Males (in days)	53.70 ± 2.67[a]	51.35 ± 2.35[b]	47.40 ± 2.81[c]	41.00 ± 2.63[d]	251.58	<0.01	1.31
ii.	Females (in days)	66.50 ± 3.12[a]	62.90 ± 3.87[b]	54.95 ± 2.79[c]	48.45 ± 2.76[d]	271.15	<0.01	1.84
12.	Total life cycle; egg to death of adult (in days)							
i.	Males (in days)	87.30 ± 4.61[a]	80.28 ± 3.84[b]	70.65 ± 4.31[c]	59.40 ± 3.94[d]	494.93	<0.01	2.03
ii.	Females (in days)	100.10 ± 5.06[a]	91.83 ± 5.36[b]	78.20 ± 4.28[c]	66.85 ± 4.07[d]	559.82	<0.01	2.32

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.

Means within rows were separated by Tukey's Honestly Significant Difference.

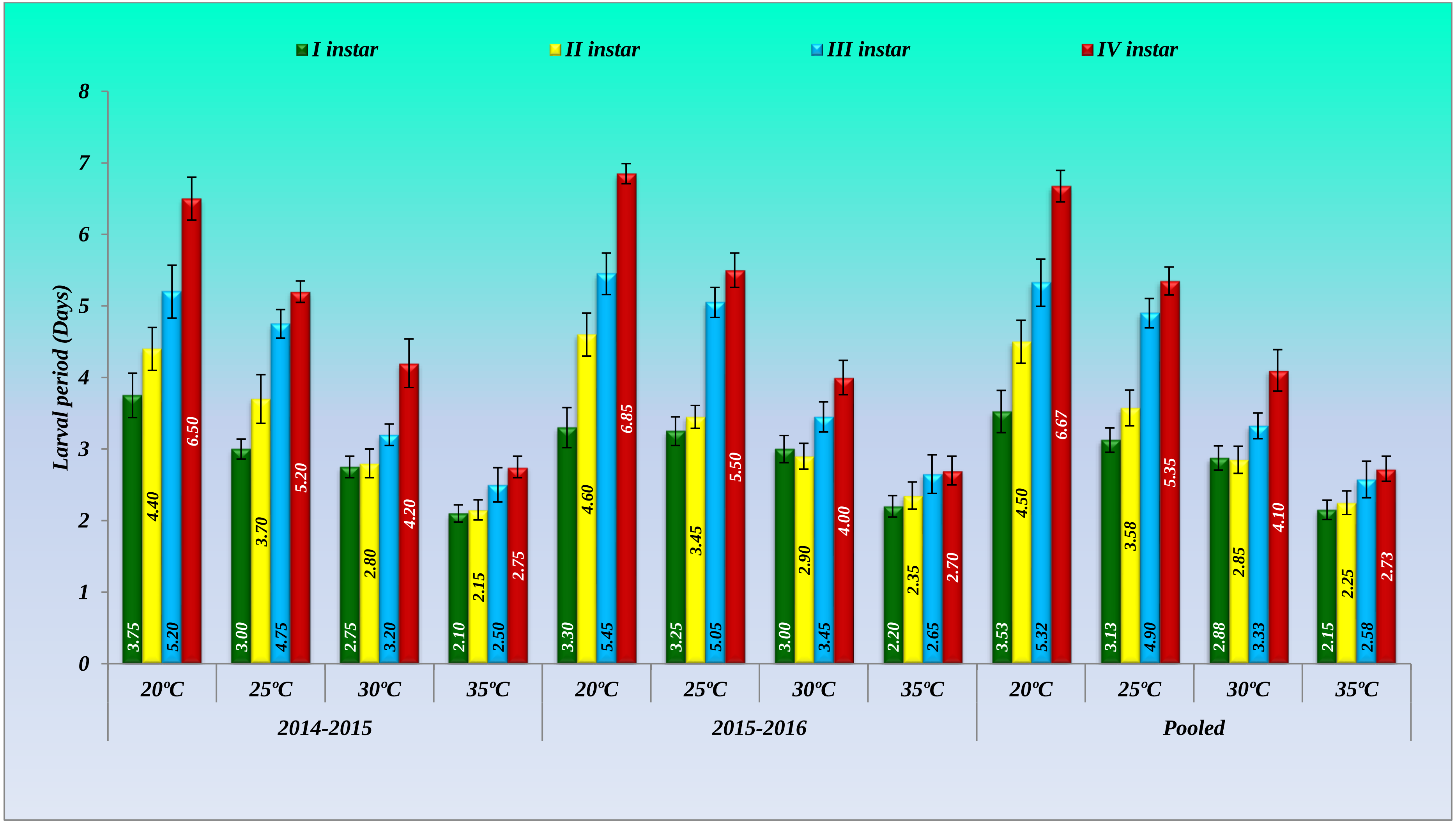

Fig 5a: Duration of larval development of *C. septempunctata* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

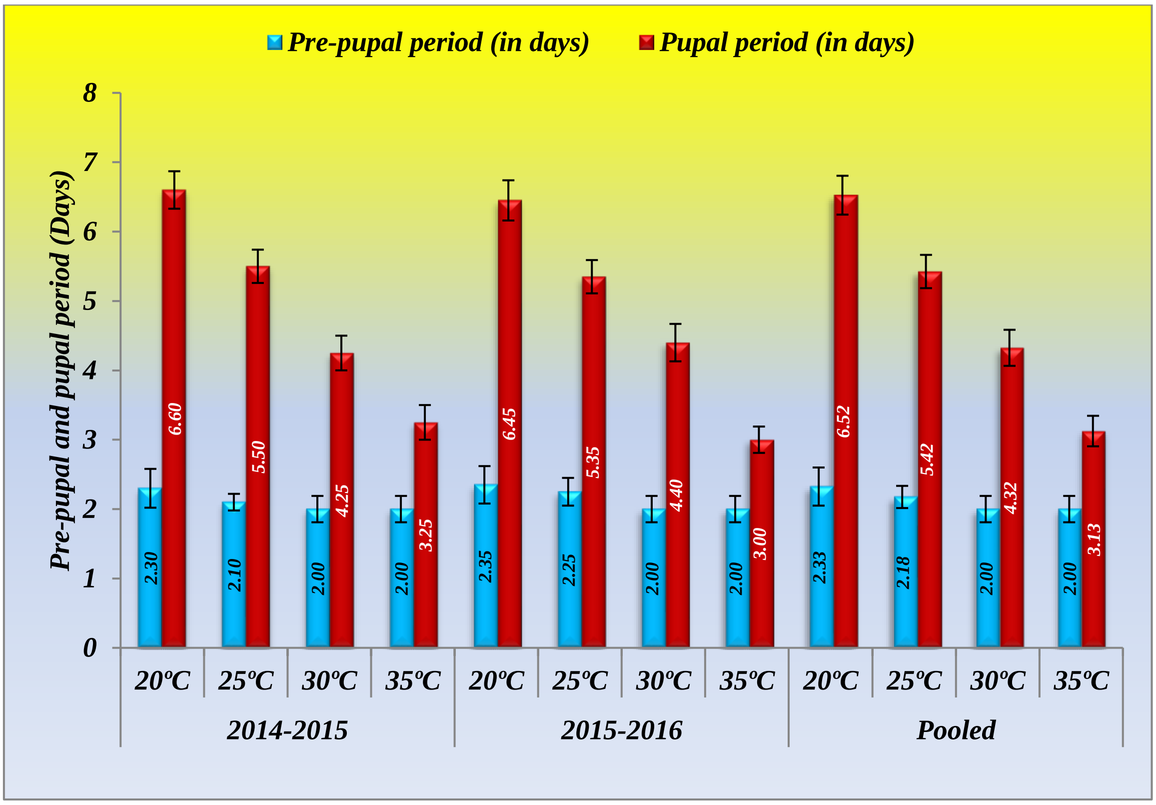

Fig 5b: Duration of pre-pupal and pupal development of *C. septempunctata* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

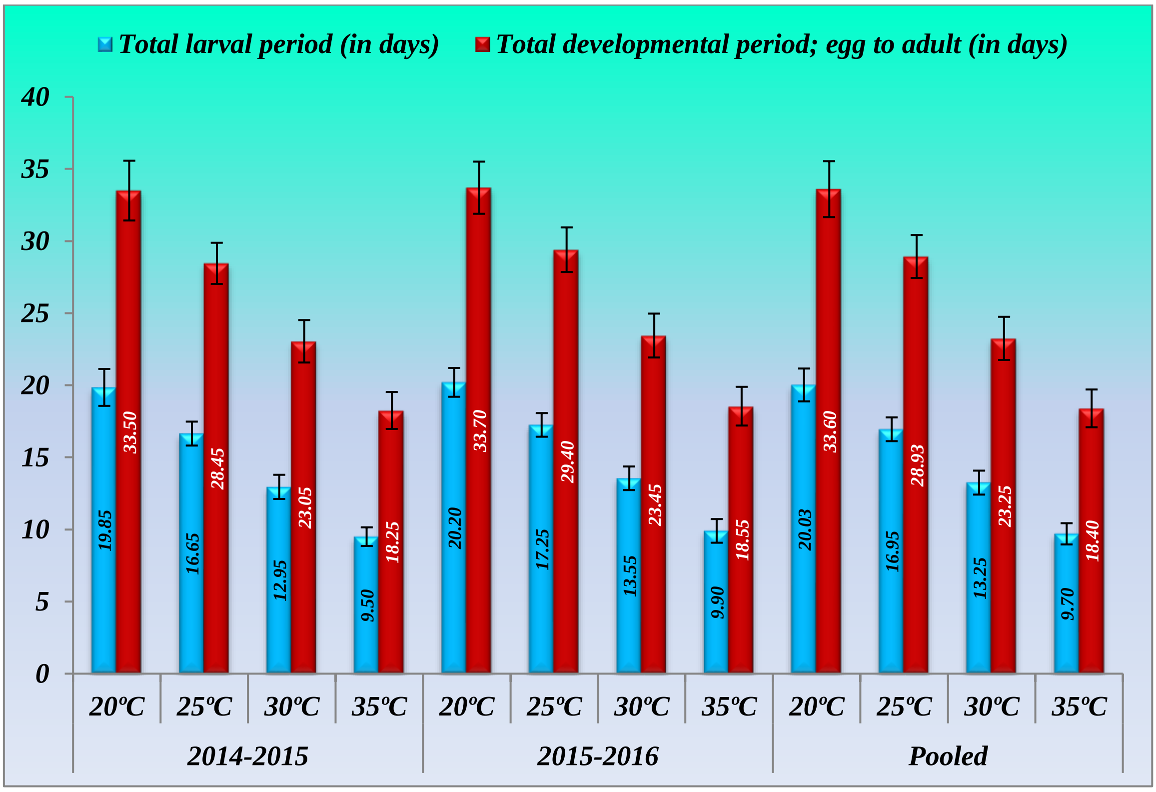

Fig 5c: Duration of total larval and total development period; egg to adult of *C. septempunctata* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

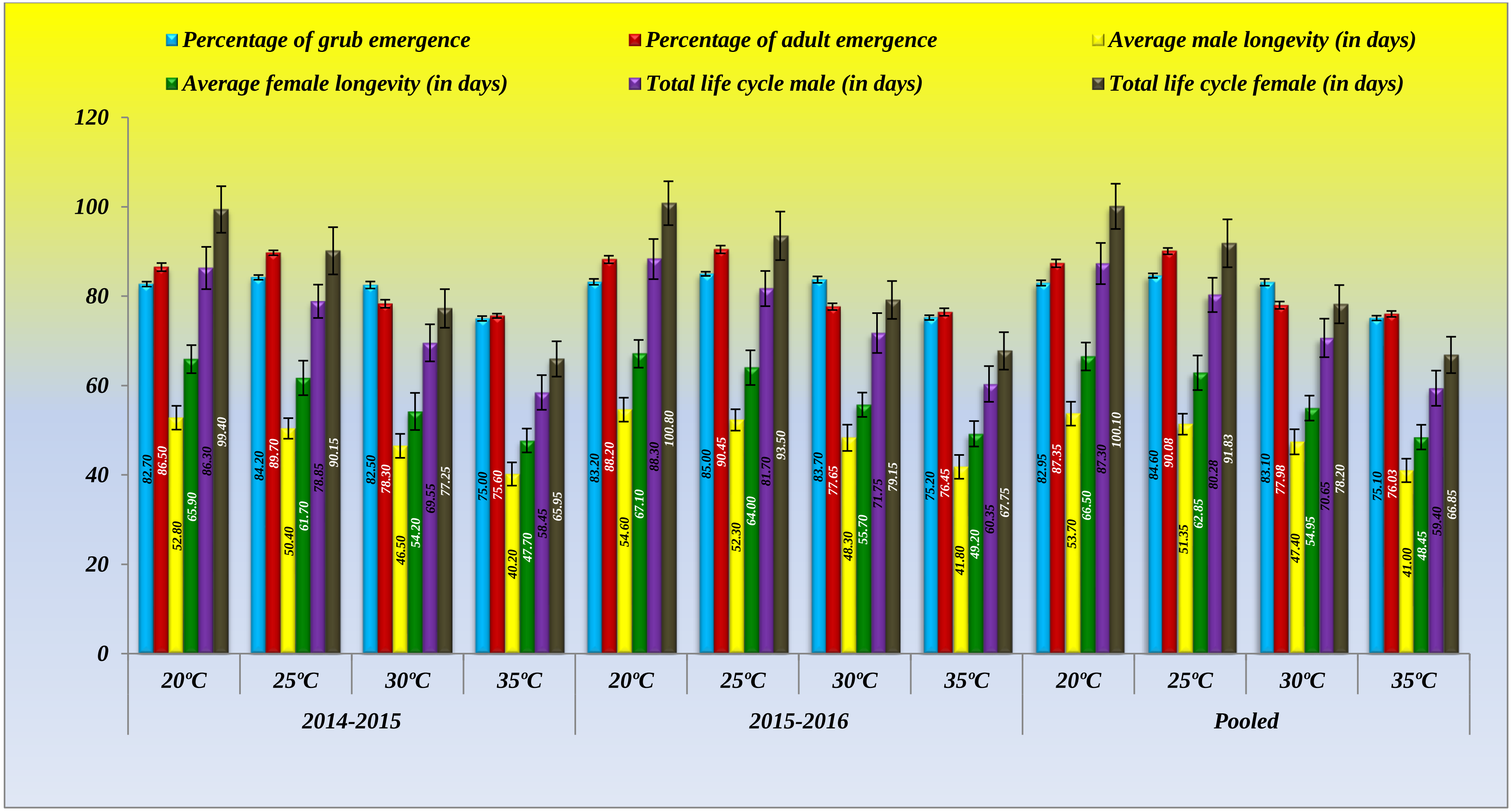

Fig 5d: Percentage of grub emergence, percentage of adult emergence, average male longevity and female longevity and total life cycle of male longevity and female of *C. septempunctata* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

to different temperatures. From table 5, 6 and 7, the results showed that the mean fecundity of female *C. septempunctata* reared on *L. erysimi* increased from 332.70 ± 20.67 and 350.25 ± 22.48 eggs/female at 20°C to 365.25 ± 25.30 and 390.40 ± 27.52 eggs/female at 25°C, then fell down to (265.65 ± 15.87 and 290.20 ± 18.56) and (220.30 ± 12.45 and 232.65 ± 15.96) eggs/female at 30°C and 35°C during 2014-2015 and 2015-2016, respectively. However, the highest fecundity of *C. septempunctata* was recorded 365.25 ± 25.30 and 390.40 ± 27.52 eggs/female at 25°C followed by 332.70 ± 20.67 and 350.25 ± 22.48, 265.65 ± 15.87 and 290.20 ± 18.56 and 220.30 ± 12.45 and 232.65 ± 15.96 eggs/female at 20°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively with means as 377.82 ± 26.41, 341.48 ± 21.58, 277.93 ± 17.22 and 226.48 ± 14.21, respectively. The significant decrease on the fecundity of *C. septempunctata* as the temperature increases may be due to the maturation of the gonads and faster metabolic activities which are responsible for the lower fecundity rate beyond optimal temperature.

The present investigations are in agreement with the findings of Hemchandra *et al.* (2010) who reported that the highest fecundity of *Micraspis discolor* when reared on *Rophalosiphum maidis* was 385.70 ± 49.28 eggs/female at 20°C to 750.60 ± 25.71 eggs at 27°C, then reduced to 601.60 ± 38.49 eggs/female at 30°C. Few researchers have also reported that the adult females of *C. septempunctata* when reared on *L. erysimi* laid an average of 378.00 ± 26.51 and 357.45 ± 22.41 eggs/female at 25°C and 27°C, respectively (Singh *et al.*, 2012; Singh and Singh, 2014).

4.2.1.3. Size of the egg cluster (Number of eggs per cluster)

From table 5, 6 and 7 presented, the data showed that the number of eggs laid by *C. septempunctata* female reared on *L. erysimi* ranged from 22.25 ± 2.44 to 35.52 ± 3.62 and 24.62 ± 2.39 to 38.35 ± 3.37 eggs/cluster during 2014-2015 and 2015-2016, respectively with means as 23.43 ± 2.41 to 36.99 ± 3.49 eggs/cluster at four different temperatures. However, the number of eggs laid by *C. septempunctata* female was recorded highest at 25°C with 30.70 ± 3.11 and 32.45 ± 3.14 eggs/cluster while mean was 36.99 ± 3.49 eggs/cluster followed by 35.52 ± 3.62 and 38.35 ± 3.37, 26.57 ± 2.64 and 27.78 ± 2.35 and 22.25 ± 2.44 and 24.62 ± 2.39 eggs/cluster with means as 31.58 ± 3.13, 27.18 ± 2.50 and 23.43 ± 2.41 eggs/cluster at 20°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively. Nevertheless, there was a variation on the number of eggs laid by *C. septempunctata* but few researchers reported that *C. septempunctata* laid around 6 to 60 eggs/cluster (Rai *et al*., 2002; Sirvi and Singh, 2014).

4.2.1.4. Incubation period

The data indicated that with the increase in temperature the egg incubation period of *C. septempunctata* reduced significantly from 4.75 ± 0.25 and 4.70 ± 0.24 days at 20°C to 3.50 ± 0.19 and 3.65 ± 0.14 days at 35°C during 2014-2015 and 2015-2016, respectively with means as 4.73 ± 0.24 and 3.58 ± 0.17 days (Table 5, 6 and 7). It is clearly documented from the tables that the incubation period was recorded longest at 20°C with 4.75 ± 0.25 and 4.70 ± 0.24 days while mean was 4.73 ± 0.24 days followed by 4.20 ± 0.24 and 4.55 ± 0.29, 3.85 ± 0.19 and 3.70 ± 0.24 and 3.50 ± 0.19 and 3.65 ± 0.14 days with means as 4.38 ± 0.27, 3.78 ± 0.22 and 3.58 ± 0.17 days at 25°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively.

Similar findings were recorded by Rauf *et al.* (2013) who reported that the egg incubation period of *C. septempunctata* were 5.12 ± 0.08, 3.62 ± 0.12 and 3.20 ± 0.25 days when reared on *Schizaphis graminum* at 20°C, 25°C and 30°C, respectively. The present findings are further in conformity with the findings of Singh and Singh (2014) who reported that the incubation period of *C. septempunctata* when reared on *L. erysimi* was 4.28 ± 0.16 and 4.35 ± 0.31 days with mean as 4.32 ± 0.26 days at 25°C days during 2009-2010 and 2010-2011, respectively.

4.2.1.5. Percentage of grub emergence

From table 5, 6 and 7 and fig. 5d presented, the data showed that the percentage of grub emergence of *C. septempunctata* was highest at 25°C with 84.20 ± 0.53% and 85.00 ± 0.47% during 2014-2015 and 2015-2016, respectively while mean was 84.60 ± 0.50%. These were followed by 82.70 ± 0.55% and 83.20 ± 0.66%, 82.50 ± 0.78% and 83.70 ± 0.72% and 75.00 ± 0.54% and 75.20 ± 0.53% with means as 82.95 ± 0.61%, 78.60 ± 0.75% and 75.10 ± 0.54% at 20°C, 30°C and 35°C, respectively.

The results obtained are in agreement with the findings of Omkar and Srivastava (2003a) who indicated that the percentage of adult emergence of *C. septempunctata* reared on *L. erysimi* was about 87.88 ± 1.05% at 25°C. Similar results were found by Rauf *et al.* (2013) where the percentage of grub emergence of *C. septempunctata* when reared on *Schizaphis graminum* was highest at 25°C with 82.00 ± 1.41% followed by 75.60 ± 0.74% and 71.20 ± 0.48% at 20°C and 30°C, respectively.

4.2.1.6. Larval period

The data indicated that with the increase in temperature, the developmental period of all the larval stages of *C. septempunctata* decreased significantly (Table 5, 6 and 7 and Fig. 5a). The mean developmental period of first, second, third and fourth instar grubs ranged from 2.15 ± 0.14 to 3.53 ± 0.30, 2.25 ± 0.17 to 4.50 ± 0.30, 2.58 ± 0.26 to 5.33 ± 0.33 and 2.73 ± 0.18 to 6.68 ± 0.22 days, respectively at four different temperatures feeding on *L. erysimi* and total larval duration was 9.70 ± 0.74 to 20.03 ± 1.14 days.

The duration of first, second, third and fourth instar grubs were (3.75 ± 0.31 and 3.30 ± 0.28, 3.00 ± 0.14 and 3.25 ± 0.20, 2.75 ± 0.15 and 3.00 ± 0.19, and 2.10 ± 0.12 and 2.20 ± 0.15), (4.40 ± 0.30 and 4.60 ± 0.30, 3.70 ± 0.34 and 3.45 ± 0.16, 2.80 ± 0.20 and 2.90 ± 0.18, and 2.15 ± 0.14 and 2.35 ± 0.19), (5.20 ± 0.37 and 5.45 ± 0.29, 4.75 ± 0.20 and 5.05 ± 0.21, 3.20 ± 0.15 and 3.45 ± 0.11, and 2.50 ± 0.24 and 2.65 ± 0.27) and (6.60 ± 0.27 and 6.85 ± 0.14, 5.20 ± 0.15 and 5.50 ± 0.24, 4.20 ± 0.34 and 4.00 ± 0.24, and 2.75 ± 0.15 and 2.70 ± 0.20) days during 2014-2015 and 2015-2016 at 20°C, 25°C, 30°C and 35°C. The mean larval duration of first, second, third and fourth instar grubs were (3.53 ± 0.30, 3.23 ± 0.17, 2.88 ± 0.17 and 2.15 ± 0.14), (4.50 ± 0.30, 3.48 ± 0.17, 2.85 ± 0.19 and 2.25 ± 0.17), (5.33 ± 0.33, 4.90 ± 0.21, 3.33 ± 0.18 and 2.58 ± 0.26) and (6.68 ± 0.22, 5.35 ± 0.20, 4.10 ± 0.29 and 2.73 ± 0.18) days, respectively at 20°C, 25°C, 30°C and 35°C.

The total larval period of *C. septempunctata* was recorded longest at 20°C with 19.85 ± 1.28 and 20.20 ± 1.00 days during 2014-2015 and 2015-2016 respectively while mean was 20.03 ± 1.14 followed by 16.65 ± 0.83 and 17.25 ± 0.82, 12.95 ± 0.84 and 13.55 ± 0.82 and 9.50 ± 0.65 and 9.90 ± 0.82 days during 2014-2015 and 2015-2016 respectively with means as 16.95 ± 0.83, 13.15 ± 0.83 and 9.70 ± 0.74 days at 25°C, 30°C and 35°C (Table 5 and 6 and Fig. 5c). The present results are quite similar with the findings of few researchers who have reported that the mean total larval period of *C. septempunctata* were 19.30 ± 0.30, 17.00 ± 0.53 and 10.95 ± 0.35 days at 25°C and 27°C respectively (Xia *et al.*, 1999; Ali and Rizvi, 2007a and Singh *et al.*, 2009).

4.2.1.7. Pre-pupal and pupal period

From table 5, 6 and 7 and fig. 5b presented, the data showed that the mean pre-pupal and pupal period of *C. septempunctata* ranged from 2.00 ± 0.19 to 2.33 ± 0.28 and 3.13 ± 0.22 to 6.53 ± 0.28 days respectively at four different temperatures. The pre-pupal period of *C. septempunctata* showed longest at 20°C with 2.30 ± 0.28 and 2.35 ± 0.27 days while mean was 2.33 ± 0.28 days followed by 2.10 ± 0.12 and 2.25 ± 0.20, 2.00 ± 0.19 and 2.00 ± 0.19 and 2.00 ± 0.19 and 2.00 ± 0.19 days with means as 2.18 ± 0.16, 2.00 ± 0.19 and 2.00 ± 0.19 days at 25°C, 30°C and 35°C during 2014-2015 and 2015-2016 respectively. There was little information regarding the pre-pupal period of *C. septempunctata* but the present results obtained are quite close with the findings of Khursheed *et al.* (2006) who reported that the average pre-pupal period was 1.50 days at 25°C.

The pupal period of *C. septempunctata* showed about 6.60 ± 0.27 and 6.45 ± 0.29, 5.50 ± 0.24 and 5.35 ± 0.24, 4.25 ± 0.25 and 4.40 ± 0.27 and 3.25 ± 0.25 and 3.00 ± 0.19 days at 20°C, 25°C, 30°C and 35°C during 2014-2015 and 2015-2016 respectively with means as 6.53 ± 0.28, 5.43 ± 0.24, 4.33 ± 0.26 and 3.13 ± 0.22 days (Table 5 and 6 and Fig. 5b). However, few researchers reported that the pupal stage may last from 3-12 days depending upon availability of food and temperature (Debaraj and Singh, 1990 and Rauf *et al.*, 2013). Nevertheless, the present investigations are quite similar with the findings of Xia *et al.* (1999) who also reported that the average pupal period of *C. septempunctata* was 5.70 ± 0.11, 3.80 ± 0.08 and 3.60 ± 0.07 days at 25°C, 30°C and 35°C, respectively.

4.2.1.8. Total developmental period; egg to adult

The data indicated that with the increase in temperature the total developmental period of *C. septempunctata* from egg to adult emergence decreased significantly from 33.50 ± 2.07 and 33.70 ± 1.81 days at 20°C to 18.25 ± 1.28 and 18.55 ± 1.34 days at 35°C during 2014-2015 and 2015-2016 respectively with means as 33.60 ± 1.94 and 18.40 ± 1.31 days (Table 5, 6 and 7 and Fig. 5c). The total developmental period were recorded about 33.50 ± 2.07 and 33.70 ± 1.81, 28.45 ± 1.43 and 29.40 ± 1.55, 23.05 ± 1.47 and 23.45 ± 1.52 and 18.25 ± 1.28 and 18.55 ± 1.34 days at 20°C, 25°C, 30°C and 35°C during 2014-2015 and 2015-2016 respectively with means as 33.60 ± 1.94, 28.93 ± 1.49, 23.25 ± 1.50 and 18.40 ± 1.31 days.

The present results obtained are in agreement with the findings of Singh and Singh (2014) who reported that the total developmental period of *C. septempunctata* feeding on *L. erysimi* was 25.38 ± 1.14 and 25.75 ± 1.25 days with mean as 25.57 ± 1.20 days at 25°C during 2009-2010 and 2010-2011 respectively. The present findings are further supported with the findings of Singh *et al.* (2009) who have observed that the developmental period of *C. septempunctata* when reared on *L. erysimi* was 20.90 ± 0.71 and 20.50 ± 0.72 days with mean as 20.70 ± 0.72 days at 27°C during 2005-2006 and 2006-2007 respectively.

4.2.1.9. Percentage of adult emergence

From table 5, 6 and 7 and fig. 5d presented, the data showed that the percentage of adult emergence of *C. septempunctata* was highest at 25°C with 89.70 ± 0.55% and 90.45 ± 0.87% while mean was 90.08 ± 0.71% during 2014-2015 and 2015-2016, respectively followed by 86.50 ± 0.91% and 88.20 ± 0.85%, 78.30 ± 0.90% and 77.65 ± 0.75% and 75.60 ± 0.49% and 76.45 ± 0.84% at 20°C, 30°C and 35°C, respectively with means as 87.35 ± 0.88%, 77.98 ± 0.83% and 76.03 ± 0.67%. The present investigations are similar with the findings of Omkar and Srivastava (2003a) who reported that the percentage of adult emergence of *C. septempunctata* was about 90.07 ± 1.43% at 25°C.

4.2.1.10. Adult longevity

The data indicated that with the increase in temperature the average longevity of *C. septempunctata* adult reduced significantly (Table 5, 6 and 7 and Fig. 5d). The longevity of adult male ranged from 40.20 ± 2.60 to 52.80 ± 2.66 and 41.80 ± 2.66 to 54.60 ± 2.68 days during 2014-2015 and 2015-2016, respectively with means as 41.00 ± 2.63 to 53.70 ± 2.67 days at four different temperatures. The mean longevity of adult female ranging from 47.70 ± 2.67 to 65.90 ± 3.14 and 49.20 ± 2.85 to 67.10 ± 3.10 days, respectively during 2014-2015 and 2015-2016 at different temperature regimes indicating that female took more days to complete its development than male.

The average longevity of adult female showed longer in comparison to adult male with 65.90 ± 3.14 and 67.10 ± 3.10, 61.70 ± 3.86 and 64.00 ± 3.88, 54.20 ± 2.85 and 55.70 ± 2.72 and 47.70 ± 2.67 and 49.20 ± 2.85 days during 2014-2015 and 2015-2016, respectively with means as 66.50 ± 3.12, 62.90 ± 3.87, 54.95 ± 2.79 and 48.45 ± 2.76 days at 20°C, 25°C, 30°C and 35°C while the longevity of adult male were recorded about 52.80 ± 2.66 and 54.60 ± 2.68, 50.40 ± 2.30 and 52.30 ± 2.39, 46.50 ± 2.68 and 48.30 ± 2.94 and 40.20 ± 2.60 and 41.80 ± 2.66 days during 2014-2015 and 2015-2016, respectively with means as 53.70 ± 2.67, 51.35 ± 2.35, 47.40 ± 2.81 and 41.00 ± 2.76 days at 20°C, 25°C, 30°C and 35°C.

The present results obtained are similar with the findings of Kalushkov and Hodek (2004) who reported that the mean longevity of male and female *C. septempunctata* reared on *Aphis craccivora* were 52 and 68 days, respectively at 25°C. The present findings are further supported by Mari *et al.* (2005) who reported that the longevity of female *C. undecimpunctata* was longer than male with 56.70 ± 5.80 and 50.70 ± 4.20 days, respectively at 25°C.

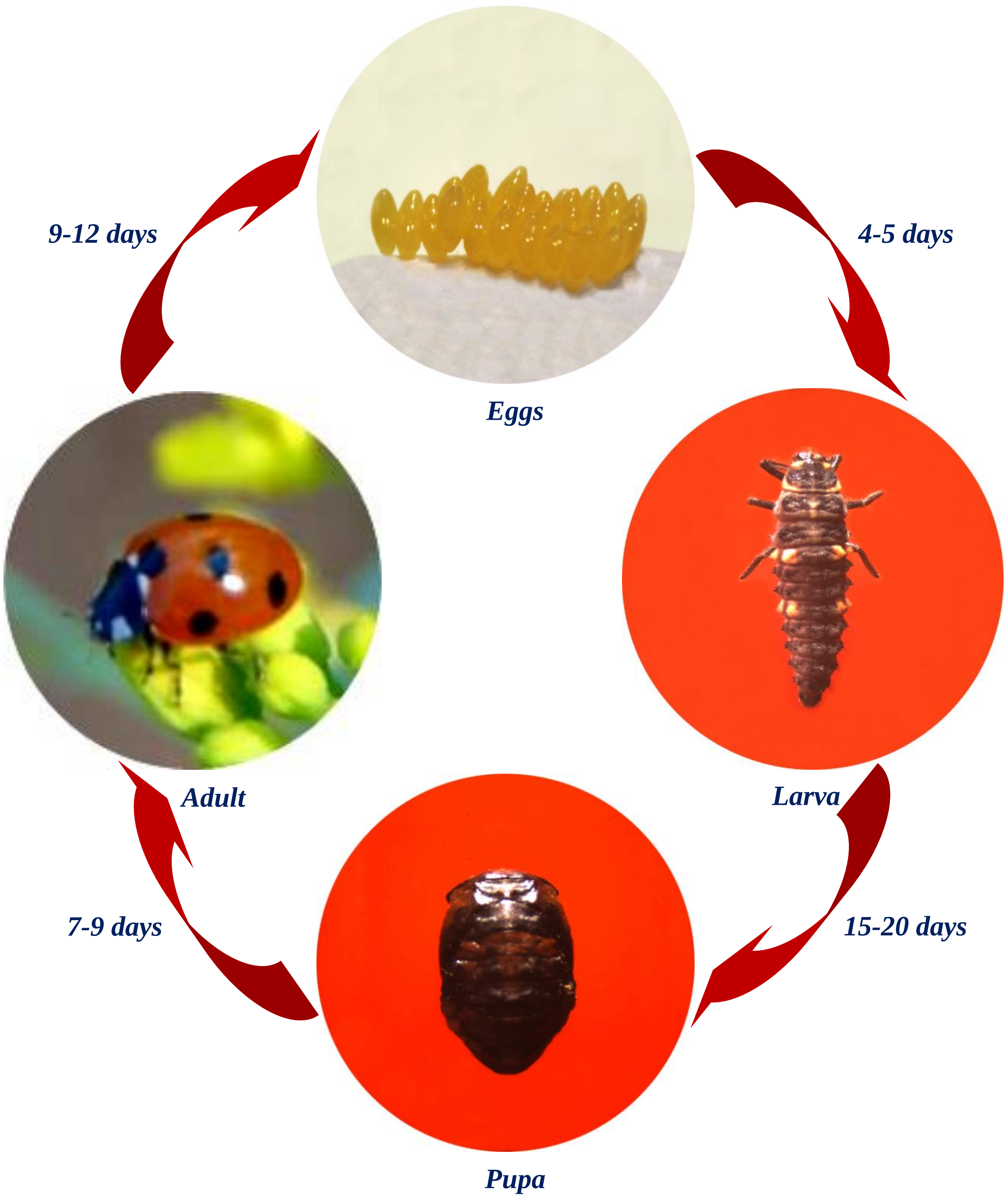

Plate 7: Life cycle of *Coccinella septempunctata*

Plate 8a: Newly hatched grubs of *C. septempunctata*

Plate 8b: First instar grub of *C. septempunctata*

Plate 8c: Second instar grub of *C. septempunctata*

Plate 8d: Third instar grub of *C. septempunctata*

Plate 8e: Fourth instar grub of *C. septempunctata*

Plate 8: Different stages of *Coccinella septempunctata*

Plate 9a: Male *Coccinella septempunctata*

Plate 9b: Female *Coccinella septempunctata*

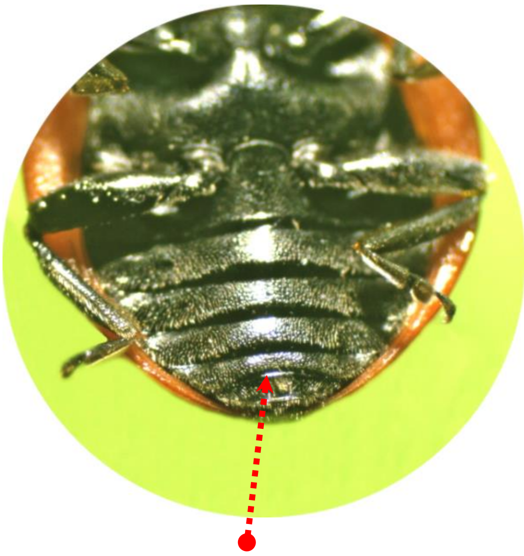

Plate 9c: Male; Distal margin of 5th visible abdominal sternite (convex)

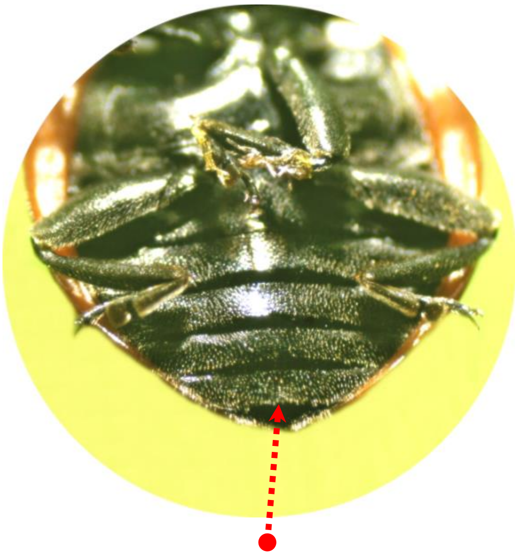

Plate 9d: Female; Distal margin of 5th visible abdominal sternite (parallel)

Plate 9: Differentiation of male and female *Coccinella septempunctata*

4.2.1.11. Total life cycle

From Table 5, 6 and 7 presented and fig. 5d, the data showed that the total life cycle of male *C. septempunctata* when reared on *L. erysimi* ranged from 58.45 ± 3.88 to 86.30 ± 4.73 and 60.35 ± 4.00 and 88.30 ± 4.49 days during 2014-2015 and 2015-2016, respectively with means as 59.40 ± 3.94 to 87.30 ± 4.61 days at four different temperatures. The total life cycle of adult female ranging from 65.95 ± 3.95 to 99.40 ± 5.21 and 67.75 ± 4.19 to 100.80 ± 4.91 days during 2014-2015 and 2015-2016, respectively with means as 66.85 ± 4.07 to 100.10 ± 5.06 days at different temperature regimes indicating that female took more days to complete its life cycle than male.

The total life cycle of *C. septempunctata* of adult male were recorded about 86.30 ± 4.73 and 88.30 ± 4.49, 78.85 ± 3.73 and 81.70 ± 3.94, 69.55 ± 4.15 and 71.75 ± 4.46, 58.45 ± 3.88 and 60.35 ± 4.00 days during 2014-2015 and 2015-2016, respectively with means as 87.30 ± 4.61, 80.28 ± 3.84, 70.65 ± 4.31 and 59.40 ± 3.94 days at 20°C, 25°C, 30°C and 35°C while the total life cycle of adult female were recorded about 99.40 ± 5.21 and 100.80 ± 4.91, 90.15 ± 5.29 and 93.50 ± 5.43, 77.25 ± 4.32 and 79.15 ± 4.24, 65.95 ± 3.95 and 67.75 ± 4.19 days during 2014-2015 and 2015-2016, respectively with means as 100.10 ± 5.06, 91.83 ± 5.36[b], 78.20 ± 4.28 and 66.85 ± 4.07 days at 20°C, 25°C, 30°C and 35°C. The results clearly showed that the longest life cycle of *C. septempunctata* was recorded at low temperature and shortest at high temperature.

The present findings are in conformity with the findings of Ali and Rizvi (2010) who reported that *C. septempunctata* reared on *L. erysimi* showed about 68 days to complete the entire generation at 20 ± 1°C followed by 61 and 53 days at 24 ± 1°C and 28 ± 1°C, respectively. Slight variation on life cycle of *C. septempunctata* could be due to variation of geographical as well as ecological conditions.

4.2.2. Measurement of various life stages of *Coccinella septempunctata* reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

4.2.2.1. Egg size

The size of the eggs of *C. septempunctata* reared on *L. erysimi* decreased significantly from 1.54 ± 0.02 and 1.57 ± 0.02 to 1.30 ± 0.01 and 1.32 ± 0.02 mm in length and 0.62 ± 0.02 and 0.64 ± 0.02 to 0.53 ± 0.02 and 0.54 ± 0.02 mm in width as the temperature increase from 20°C to 35°C during 2014-2015 and 2015-2016 (Table 8 and 9 and Fig. 6). The largest egg size was recorded at 20°C with 1.54 ± 0.02 and 1.57 ± 0.02 mm in length and 0.62 ± 0.02 and 0.64 ± 0.02 mm in width while mean was 1.56 ± 0.02

Table 8: Measurement of various life stages of *C. septempunctata* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016 (n=10)

Sl. No.	Parameters	Measurement of various stages of *C. septempunctata* under the influence of different temperatures (Mean ± SEm)													
		2014-2015							2015-2016						
		20ºC	25ºC	30ºC	35ºC	F value	P value	HSD p=0.05	20ºC	25ºC	30ºC	35ºC	F value	P value	HSD p=0.05
1.	**Egg**														
	Length (mm)	1.54 ± 0.02[a]	1.50 ± 0.02[a]	1.42 ± 0.02[b]	1.30 ± 0.01[c]	107.98	<0.01	0.04	1.57 ± 0.02[a]	1.53 ± 0.02[b]	1.45 ± 0.01[c]	1.32 ± 0.02[d]	153.80	<0.01	0.04
	Width (mm)	0.62 ± 0.02[a]	0.60 ± 0.02[a]	0.54 ± 0.02[b]	0.53 ± 0.02[b]	26.08	<0.01	0.05	0.64 ± 0.02[a]	0.62 ± 0.02[a]	0.55 ± 0.02[b]	0.54 ± 0.01[b]	32.99	<0.01	0.04
2.	**Larva**														
i.	**I instar**														
	Length (mm)	2.62 ± 0.02[a]	2.53 ± 0.02[b]	2.00 ± 0.01[c]	1.85 ± 0.02[d]	1317.13	<0.01	0.04	2.65 ± 0.02[a]	2.55 ± 0.02[b]	2.02 ± 0.02[c]	1.87 ± 0.02[d]	963.21	<0.01	0.05
	Width (mm)	0.85 ± 0.02[a]	0.81 ± 0.02[b]	0.74 ± 0.02[c]	0.68 ± 0.01[d]	76.74	<0.01	0.04	0.87 ± 0.02[a]	0.82 ± 0.01[b]	0.75 ± 0.02[c]	0.69 ± 0.01[d]	117.00	<0.01	0.04
ii.	**II instar**														
	Length (mm)	5.75 ± 0.03[a]	5.66 ± 0.02[b]	5.57 ± 0.02[c]	4.82 ± 0.03[d]	1133.53	<0.01	0.05	5.78 ± 0.02[a]	5.70 ± 0.02[b]	5.60 ± 0.02[c]	4.85 ± 0.03[d]	1243.21	<0.01	0.05
	Width (mm)	1.84 ± 0.02[a]	1.76 ± 0.02[b]	1.68 ± 0.02[c]	1.52 ± 0.02[d]	163.84	<0.01	0.04	1.86 ± 0.02[a]	1.80 ± 0.02[b]	1.70 ± 0.02[c]	1.56 ± 0.02[d]	190.36	<0.01	0.05
iii.	**III instar**														
	Length (mm)	8.22 ± 0.03[a]	8.12 ± 0.02[b]	7.95 ± 0.02[c]	6.75 ± 0.02[d]	2381.03	<0.01	0.05	8.25 ± 0.02[a]	8.17 ± 0.02[b]	7.99 ± 0.02[c]	6.78 ± 0.02[d]	2828.68	<0.01	0.05
	Width (mm)	2.52 ± 0.02[a]	2.45 ± 0.02[b]	2.39 ± 0.02[c]	2.27 ± 0.03[d]	74.53	<0.01	0.05	2.54 ± 0.02[a]	2.48 ± 0.02[b]	2.42 ± 0.02[c]	2.29 ± 0.02[d]	82.68	<0.01	0.05
iv.	**IV instar**														
	Length (mm)	10.12 ± 0.02[a]	10.07 ± 0.02[b]	9.72 ± 0.02[c]	8.70 ± 0.02[d]	2203.60	<0.01	0.05	10.15 ± 0.02[a]	10.10 ± 0.02[b]	9.75 ± 0.02[c]	8.72 ± 0.03[d]	2512.12	<0.01	0.04
	Width (mm)	2.79 ± 0.02[a]	2.72 ± 0.02[b]	2.67 ± 0.02[c]	2.65 ± 0.02[c]	44.14	<0.01	0.05	2.82 ± 0.02[a]	2.77 ± 0.02[b]	2.70 ± 0.02[c]	2.68 ± 0.02[c]	49.55	<0.01	0.05
3.	**Pupa**														
	Length (mm)	5.33 ± 0.02[a]	5.30 ± 0.02[a]	5.20 ± 0.02[b]	4.82 ± 0.03[c]	414.84	<0.01	0.05	5.37 ± 0.02[a]	5.32 ± 0.01[b]	5.22 ± 0.02[c]	4.85 ± 0.02[d]	589.67	<0.01	0.04
	Width (mm)	3.57 ± 0.02[a]	3.51 ± 0.01[b]	3.49 ± 0.02[b]	3.30 ± 0.01[c]	227.12	<0.01	0.04	3.60 ± 0.02[a]	3.55 ± 0.02[b]	3.52 ± 0.02[b]	3.34 ± 0.02[c]	153.62	<0.01	0.05
4.	**Adult male**														
	Length (mm)	6.95 ± 0.03[a]	6.72 ± 0.02[b]	6.48 ± 0.02[c]	5.92 ± 0.02[d]	1596.13	<0.01	0.05	6.98 ± 0.02[a]	6.75 ± 0.02[b]	6.50 ± 0.02[c]	5.95 ± 0.02[d]	1886.27	<0.01	0.05
	Width (mm)	5.46 ± 0.02[a]	5.35 ± 0.02[b]	5.12 ± 0.02[c]	3.96 ± 0.02[d]	5732.18	<0.01	0.05	5.48 ± 0.02[a]	5.37 ± 0.02[b]	5.16 ± 0.02[c]	3.98 ± 0.02[d]	6126.61	<0.01	0.05
5.	**Adult female**														
	Length (mm)	7.45 ± 0.02[a]	7.22 ± 0.02[b]	7.00 ± 0.03[c]	6.43 ± 0.02[d]	1379.95	<0.01	0.05	7.48 ± 0.02[a]	7.25 ± 0.02[b]	7.03 ± 0.02[c]	6.47 ± 0.02[d]	1871.57	<0.01	0.05
	Width (mm)	5.94 ± 0.02[a]	5.82 ± 0.03[b]	5.70 ± 0.02[c]	4.90 ± 0.02[d]	1583.54	<0.01	0.05	5.96 ± 0.02[a]	5.84 ± 0.03[b]	5.72 ± 0.02[c]	4.94 ± 0.02[d]	1558.78	<0.01	0.05

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.
Means within rows were separated by Tukey's Honestly Significant Difference.

Table 9: Measurement of various life stages of *C. septempunctata* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016 (Pooled) (n=10)

Sl. No.	Parameters	Measurement of various stages of *C. septempunctata* under the influence of different temperatures (Mean ± SEm)						
		Pooled						
		20ºC	25ºC	30ºC	35ºC	F value	P value	$HSD_{p=0.05}$
1.	**Egg**							
	Length (mm)	1.56 ± 0.02[a]	1.52 ± 0.02[a]	1.44 ± 0.01[b]	1.31 ± 0.02[c]	128.36	<0.01	0.04
	Width (mm)	0.63 ± 0.02[a]	0.61 ± 0.02[a]	0.55 ± 0.02[b]	0.54 ± 0.01[b]	29.73	<0.01	0.04
2.	**Larva**							
i.	**I instar**							
	Length (mm)	2.64 ± 0.01[a]	2.54 ± 0.02[b]	2.01 ± 0.01[c]	1.86 ± 0.02[d]	1108.89	<0.01	0.04
	Width (mm)	0.86 ± 0.02[a]	0.82 ± 0.01[b]	0.75 ± 0.02[c]	0.69 ± 0.01[d]	93.61	<0.01	0.04
ii.	**II instar**							
	Length (mm)	5.77 ± 0.02[a]	5.68 ± 0.02[b]	5.59 ± 0.02[c]	4.84 ± 0.03[d]	1185.79	<0.01	0.05
	Width (mm)	1.85 ± 0.02[a]	1.78 ± 0.02[b]	1.69 ± 0.02[c]	1.54 ± 0.02[d]	175.23	<0.01	0.05
iii.	**III instar**							
	Length (mm)	8.24 ± 0.02[a]	8.15 ± 0.02[b]	7.97 ± 0.02[c]	6.77 ± 0.02[d]	2586.46	<0.01	0.05
	Width (mm)	2.53 ± 0.02[a]	2.47 ± 0.02[b]	2.41 ± 0.02[c]	2.28 ± 0.02[d]	78.45	<0.01	0.05
iv.	**IV instar**							
	Length (mm)	10.14 ± 0.02[a]	10.09 ± 0.02[b]	9.74 ± 0.02[c]	8.71 ± 0.02[d]	2348.41	<0.01	0.05
	Width (mm)	2.81 ± 0.02[a]	2.75 ± 0.02[b]	2.69 ± 0.02[c]	2.67 ± 0.02[c]	46.90	<0.01	0.05
3.	**Pupa**							
	Length (mm)	5.35 ± 0.02[a]	5.31 ± 0.01[b]	5.21 ± 0.02[c]	4.84 ± 0.03[d]	486.01	<0.01	0.04
	Width (mm)	3.59 ± 0.02[a]	3.53 ± 0.01[b]	3.51 ± 0.02[b]	3.32 ± 0.01[c]	184.48	<0.01	0.04
4.	**Adult male**							
	Length (mm)	6.97 ± 0.02[a]	6.74 ± 0.01[b]	6.49 ± 0.02[c]	5.94 ± 0.02[d]	1729.61	<0.01	0.04
	Width (mm)	5.47 ± 0.01[a]	5.36 ± 0.02[b]	5.14 ± 0.02[c]	3.97 ± 0.02[d]	5923.23	<0.01	0.04
5.	**Adult female**							
	Length (mm)	7.47 ± 0.02[a]	7.24 ± 0.02[b]	7.02 ± 0.02[c]	6.45 ± 0.02[d]	1585.19	<0.01	0.05
	Width (mm)	5.95 ± 0.02[a]	5.83 ± 0.03[b]	5.71 ± 0.02[c]	4.92 ± 0.02[d]	1571.42	<0.01	0.05

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.
Means within rows were separated by Tukey's Honestly Significant Difference.

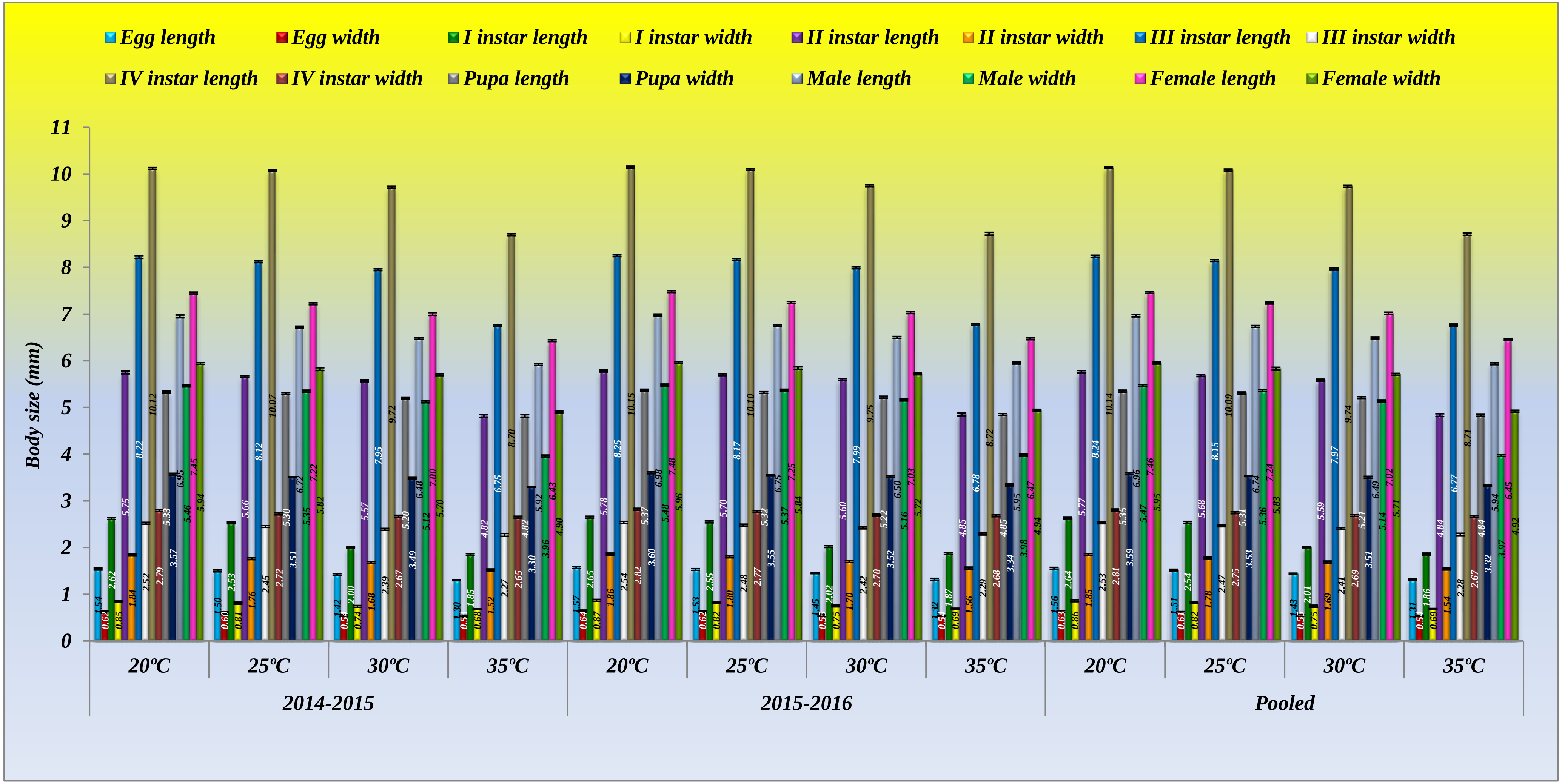

Fig 6: Measurement of various life stages of *C. septempunctata* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

mm in length and 0.63 ± 0.02 mm in width during 2014-2015 and 2015-2016, respectively followed by 1.50 ± 0.02 and 1.53 ± 0.02 mm, 1.42 ± 0.02 and 1.45 ± 0.01 mm and 1.30 ± 0.01 and 1.32 ± 0.02 mm in length and 0.60 ± 0.02 and 0.62 ± 0.02 mm, 0.54 ± 0.02 and 0.55 ± 0.02 mm and 0.53 ± 0.02 and 0.54 ± 0.02 mm in width while means was 1.52 ± 0.02, 1.44 ± 0.01 and 1.31 ± 0.02 mm in length and 0.61 ± 0.02, 0.55 ± 0.02 and 0.54 ± 0.01 mm in width at 25°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively.

Since no specific literature or citations were available regarding the egg size of *C. septempunctata*, therefore no further comparison could be conducted with the present findings.

4.2.2.2. Larva size

The data indicated that with the increase in temperature the size of all the larval stages of *C. septempunctata* reduced significantly (Table 8 and 9 and Fig. 6). There was significant difference in length and width among different larval instars. The mean length and width of first, second, third and fourth instar grubs ranged from (1.86 ± 0.02 to 2.64 ± 0.01 mm and 0.69 ± 0.01 to 0.86 ± 0.02 mm), (4.84 ± 0.03 to 5.77 ± 0.02 mm and 1.54 ± 0.02 to 1.85 ± 0.02 mm), (6.77 ± 0.02 to 8.24 ± 0.02 mm and 2.28 ± 0.02 to 2.53 ± 0.02 mm and (8.71 ± 0.02 to 10.14 ± 0.02 mm and 2.67 ± 0.02 to 2.81 ± 0.02 mm, respectively at 35°C to 20°C.

The length of first, second, third and fourth instar grubs showed longest at 20°C with 2.62 ± 0.02 and 2.65 ± 0.02 mm, 5.75 ± 0.03 and 5.78 ± 0.02 mm, 8.22 ± 0.03 and 8.25 ± 0.02 mm and 10.12 ± 0.02 and 10.15 ± 0.02 mm while means was 2.64 ± 0.01, 5.77 ± 0.02, 8.24 ± 0.02 and 10.14 ± 0.02 mm during 2014-2015 and 2015-2016, respectively whereas the shortest length was recorded at 35°C with 1.85 ± 0.02 and 1.87 ± 0.02 mm, 4.82 ± 0.03 and 4.85 ± 0.03 mm, 6.75 ± 0.02 and 6.78 ± 0.02 mm and 8.70 ± 0.02 and 8.72 ± 0.03 mm while means was 1.86 ± 0.02, 4.84 ± 0.03, 6.77 ± 0.02 and 8.71 ± 0.02 mm, respectively. In contrast with the width of the first, second, third and fourth instar grubs among different temperature regimes, the longest was also recorded at 20°C with 0.85 ± 0.02 and 0.87 ± 0.02 mm, 1.84 ± 0.02 and 1.86 ± 0.02 mm, 2.52 ± 0.02 and 2.54 ± 0.02 mm and 2.79 ± 0.02 and 2.82 ± 0.02 mm while means was 0.86 ± 0.02, 1.85 ± 0.02, 2.53 ± 0.02 and 2.81 ± 0.02 mm during 2014-2015 and 2015-2016, respectively whereas the shortest width was recorded at 35°C with 0.68 ± 0.02 and 0.69 ± 0.01 mm, 1.52 ± 0.02 and 1.56 ± 0.02 mm, 2.27 ± 0.03 and 2.29 ± 0.02 mm and 2.65 ± 0.02 and

2.68 ± 0.02 mm while means was 0.69 ± 0.01, 1.54 ± 0.02, 2.28 ± 0.02 and 2.67 ± 0.02 mm, respectively.

The present results are in contradiction with the findings of Bukero *et al.* (2015a) who reported that the average length and width of first, second, third and fourth instar grubs were 2.25 ± 0.11 and 0.55 ± 0.03 mm; 5.54 ± 0.14 and 0.93 ± 0.04 mm; 7.15 ± 0.10 and 1.41 ± 0.12 mm and 8.38 ± 0.14 and 1.82 ± 0.07 mm when reared on *Myzus persicae* at 26 ± 2°C. The variation on the length and width of *C. septempunctata* grubs with their findings might be due to the rearing conditions at different temperature and on different prey species.

4.2.2.3. Pupa size

From table 8 and 9 and fig. 6 presented, the data showed that as the temperature increased the pupa size of *C. septempunctata* reduced significantly from 5.33 ± 0.02 and 5.37 ± 0.02 mm to 4.82 ± 0.03 and 4.85 ± 0.02 mm in length and 3.57 ± 0.02 and 3.60 ± 0.02 mm to 3.30 ± 0.01 and 3.34 ± 0.02 mm in width at 20°C to 35°C during 2014-2015 and 2015-2016, respectively. The longest pupa length was recorded at 20°C with 5.33 ± 0.02 and 5.37 ± 0.02 mm in with mean as 5.35 ± 0.02 mm during 2014-2015 and 2015-2016, respectively followed by 5.30 ± 0.02 and 5.32 ± 0.01 mm, 5.20 ± 0.02 and 5.22 ± 0.02 mm and 4.82 ± 0.03 and 4.85 ± 0.02 mm with means as 5.31 ± 0.01, 5.21 ± 0.02 and 4.84 ± 0.03 mm at 25°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively. Similarly, the width of the pupa was also recorded longest at 20°C with 3.57 ± 0.02 and 3.60 ± 0.02 mm in with mean as 3.59 ± 0.02 mm during 2014-2015 and 2015-2016, respectively followed by 3.51 ± 0.01 and 3.55 ± 0.02 mm, 3.49 ± 0.02 and 3.52 ± 0.02 mm and 3.30 ± 0.01 and 3.34 ± 0.02 mm with means as 3.53 ± 0.01, 3.51 ± 0.02 and 3.32 ± 0.01 mm at 25°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively.

The present results obtained are in contradiction with the findings of Bukero *et al.* (2015a) who reported that the average length and width of pupa was 5.13 ± 0.12 and 3.71 ± 0.18 mm when reared on *Myzus persicae* at 26 ± 2°C. The variation on the body length and width of *C. septempunctata* pupa with their findings might be due to the rearing at different temperature and on different prey species.

4.2.2.4. Adult size

The data indicated that with the increase in temperature the average size of *C. septempunctata* adult feeding on *L. erysimi* reduced significantly (Table 8 and 9 and Fig.

6). The mean size of male adult reduced from 6.97 ± 0.02 to 5.94 ± 0.02 mm in length and 5.47 ± 0.01 to 3.97 ± 0.02 mm in width at 20°C to 35°C, respectively whereas mean size of female adult reduced from 7.47 ± 0.02 to 6.45 ± 0.02 mm in length and 5.95 ± 0.02 to 4.92 ± 0.02 mm in width at 20°C to 35°C, respectively.

In contrast between male and female, the results revealed that female size was recorded bigger than male in all the four different temperature regimes. The length and width of the female was recorded longest at 20°C with 7.45 ± 0.02 and 7.48 ± 0.02 mm and 5.94 ± 0.02 and 5.96 ± 0.02 mm while mean was 7.47 ± 0.02 and 5.95 ± 0.02 mm during 2014-2015 and 2015-2016, respectively whereas the shortest was recorded at 35°C with 6.43 ± 0.02 and 6.47 ± 0.02 mm and 4.90 ± 0.02 and 4.94 ± 0.02 mm while mean was 6.45 ± 0.02 and 4.92 ± 0.02 mm, respectively. Similar trends was also observed that the length and width of the male recorded longest at 20°C with 6.95 ± 0.03 and 6.98 ± 0.02 mm and 5.46 ± 0.02 and 5.48 ± 0.02 mm while mean was 6.97 ± 0.02 and 5.47 ± 0.01 mm during 2014-2015 and 2015-2016, respectively, whereas the shortest was recorded at 35°C with 5.92 ± 0.02 and 5.95 ± 0.02 mm and 3.96 ± 0.02 and 3.98 ± 0.02 mm while mean was 5.94 ± 0.02 and 3.97 ± 0.02 mm, respectively.

The present results are quite similar with the findings of Obrycki and Orr (1990) who reported that female *C. septempunctata* measured about 7.65 ± 0.25 and 6.71 ± 0.11 mm in length and 5.91 ± 0.13 and 5.19 ± 0.10 mm in width whereas the male measured about 7.13 ± 0.30 and 6.22 ± 0.17 mm in length and 5.56 ± 0.11 and 4.93 ± 0.05 mm in width when reared on *Aphis pisum* and *Rhopalosiphum maidis*, respectively at 23°C. Slight variation on the body length and width of *C. septempunctata* adults with their findings might be due to the rearing at different temperature and on different prey species.

4.2.3. Measurement of head capsule of *Coccinella septempunctata* reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

4.2.3.1. Larva

The results revealed that with the advancement of growth, the average head capsule size between the larval instars of *C. septempunctata* increased significantly (Table 10 and 11 and Fig. 7). There was significant difference in length and width of head capsule among different larval instars at four different temperature regimes. The mean head capsule length and width of first, second, third and fourth instar grubs ranged from (0.316 ± 0.01 to 0.347 ± 0.01 mm and 0.489 ± 0.01 to 0.524 ± 0.01 mm), (0.624 ±

Table 10: Measurement of head capsule of *C. septempunctata* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016 (n=10)

Sl. No.	Parameters	Measurement of head capsule of *C. septempunctata* under the influence of different temperatures (Mean ± SEm)													
		2014-2015							2015-2016						
		20°C	25°C	30°C	35°C	F value	P value	HSD p=0.05	20°C	25°C	30°C	35°C	F value	P value	HSD p=0.05
1.	**Larva**														
i.	**I instar**														
	Length (mm)	0.345 ± 0.01^{a}	0.339 ± 0.01^{a}	0.320 ± 0.01^{b}	0.314 ± 0.01^{c}	28.50	<0.01	0.03	0.348 ± 0.01^{a}	0.332 ± 0.01^{b}	0.323 ± 0.01^{c}	0.317 ± 0.01^{d}	25.45	<0.01	0.03
	Width (mm)	0.522 ± 0.01^{a}	0.515 ± 0.01^{a}	0.509 ± 0.01^{b}	0.487 ± 0.01^{c}	58.98	<0.01	0.03	0.525 ± 0.01^{a}	0.517 ± 0.01^{a}	0.511 ± 0.01^{b}	0.490 ± 0.01^{c}	68.43	<0.01	0.03
ii.	**II instar**														
	Length (mm)	0.664 ± 0.02^{a}	0.652 ± 0.01^{a}	0.637 ± 0.01^{b}	0.622 ± 0.01^{b}	18.61	<0.01	0.03	0.660 ± 0.02^{a}	0.655 ± 0.02^{a}	0.639 ± 0.01^{b}	0.625 ± 0.01^{b}	16.61	<0.01	0.03
	Width (mm)	1.15 ± 0.02^{a}	1.04 ± 0.02^{b}	0.972 ± 0.01^{c}	0.958 ± 0.01^{c}	178.32	<0.01	0.04	1.11 ± 0.02^{a}	1.07 ± 0.01^{b}	0.977 ± 0.01^{c}	0.960 ± 0.01^{c}	221.96	<0.01	0.03
iii.	**III instar**														
	Length (mm)	0.872 ± 0.01^{a}	0.865 ± 0.02^{a}	0.843 ± 0.01^{b}	0.830 ± 0.01^{b}	20.06	<0.01	0.03	0.875 ± 0.01^{a}	0.869 ± 0.01^{a}	0.845 ± 0.01^{b}	0.832 ± 0.01^{b}	25.40	<0.01	0.03
	Width (mm)	1.26 ± 0.02^{a}	1.17 ± 0.01^{b}	1.12 ± 0.01^{c}	1.02 ± 0.01^{d}	124.53	<0.01	0.03	1.30 ± 0.02^{a}	1.20 ± 0.01^{b}	1.16 ± 0.02^{c}	1.05 ± 0.01^{d}	153.04	<0.01	0.04
iv.	**IV instar**														
	Length (mm)	1.25 ± 0.02^{a}	1.20 ± 0.02^{b}	1.14 ± 0.01^{c}	1.04 ± 0.01^{d}	103.57	<0.01	0.03	1.27 ± 0.02^{a}	1.23 ± 0.02^{b}	1.17 ± 0.02^{c}	1.07 ± 0.01^{d}	81.78	<0.01	0.04
	Width (mm)	2.12 ± 0.02^{a}	2.07 ± 0.03^{b}	1.96 ± 0.02^{c}	1.90 ± 0.02^{d}	73.81	<0.01	0.05	2.16 ± 0.02^{a}	2.10 ± 0.03^{b}	1.98 ± 0.02^{c}	1.93 ± 0.02^{d}	87.56	<0.01	0.05
2.	**Adult male**														
	Length (mm)	1.35 ± 0.02^{a}	1.33 ± 0.02^{a}	1.27 ± 0.01^{b}	1.20 ± 0.02^{c}	67.84	<0.01	0.04	1.37 ± 0.02^{a}	1.35 ± 0.01^{a}	1.30 ± 0.01^{b}	1.24 ± 0.02^{c}	69.89	<0.01	0.04
	Width (mm)	2.90 ± 0.02^{a}	2.82 ± 0.02^{b}	2.78 ± 0.02^{c}	2.57 ± 0.02^{d}	158.20	<0.01	0.05	2.94 ± 0.02^{a}	2.85 ± 0.02^{b}	2.80 ± 0.02^{c}	2.60 ± 0.02^{d}	151.06	<0.01	0.05
3.	**Adult female**														
	Length (mm)	1.47 ± 0.02^{a}	1.42 ± 0.02^{b}	1.35 ± 0.02^{c}	1.25 ± 0.02^{d}	123.52	<0.01	0.05	1.44 ± 0.01^{a}	1.45 ± 0.02^{a}	1.37 ± 0.02^{b}	1.28 ± 0.02^{c}	81.92	<0.01	0.04
	Width (mm)	2.96 ± 0.02^{a}	2.90 ± 0.02^{b}	2.85 ± 0.02^{c}	2.63 ± 0.02^{d}	161.96	<0.01	0.05	2.98 ± 0.02^{a}	2.93 ± 0.02^{b}	2.89 ± 0.02^{b}	2.66 ± 0.02^{c}	182.23	<0.01	0.05

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance. Means within rows were separated by Tukey's Honestly Significant Difference.

Table 11: Measurement of head capsule of *C. septempunctata* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016 (Pooled) (n=10)

Sl. No.	Parameters	Measurement of head capsule of *C. septempunctata* under the influence of different temperatures (Mean ± SEm)						
		Pooled						
		20°C	25°C	30°C	35°C	F value	P value	$HSD_{p=0.05}$
1.	**Larva**							
i.	**I instar**							
	Length (mm)	0.347 ± 0.01[a]	0.336 ± 0.01[a]	0.322 ± 0.01[b]	0.316 ± 0.01[c]	27.05	<0.01	0.03
	Width (mm)	0.524 ± 0.01[a]	0.516 ± 0.01[a]	0.510 ± 0.01[b]	0.489 ± 0.01[c]	63.34	<0.01	0.03
ii.	**II instar**							
	Length (mm)	0.662 ± 0.02[a]	0.654 ± 0.01[a]	0.638 ± 0.01[b]	0.624 ± 0.01[b]	17.70	<0.01	0.03
	Width (mm)	1.13 ± 0.02[a]	1.06 ± 0.01[b]	0.975 ± 0.01[c]	0.959 ± 0.01[c]	193.58	<0.01	0.03
iii.	**III instar**							
	Length (mm)	0.874 ± 0.01[a]	0.867 ± 0.01[a]	0.844 ± 0.01[b]	0.831 ± 0.01[b]	22.51	<0.01	0.03
	Width (mm)	1.28 ± 0.02[a]	1.19 ± 0.01[b]	1.14 ± 0.01[c]	1.04 ± 0.01[d]	137.97	<0.01	0.03
iv.	**IV instar**							
	Length (mm)	1.26 ± 0.02[a]	1.22 ± 0.02[b]	1.16 ± 0.01[c]	1.06 ± 0.01[d]	91.67	<0.01	0.04
	Width (mm)	2.14 ± 0.02[a]	2.09 ± 0.02[b]	1.97 ± 0.02[c]	1.92 ± 0.02[d]	80.18	<0.01	0.05
2.	**Adult male**							
	Length (mm)	1.36 ± 0.02[a]	1.34 ± 0.01[a]	1.29 ± 0.01[b]	1.22 ± 0.02[c]	68.77	<0.01	0.04
	Width (mm)	2.92 ± 0.02[a]	2.84 ± 0.02[b]	2.79 ± 0.02[c]	2.59 ± 0.02[d]	154.44	<0.01	0.05
3.	**Adult female**							
	Length (mm)	1.46 ± 0.01[a]	1.44 ± 0.02[a]	1.36 ± 0.02[b]	1.27 ± 0.02[c]	101.94	<0.01	0.04
	Width (mm)	2.97 ± 0.02[a]	2.92 ± 0.02[b]	2.87 ± 0.02[c]	2.65 ± 0.02[d]	171.28	<0.01	0.05

(Tukey’s HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance. Means within rows were separated by Tukey’s Honestly Significant Difference.

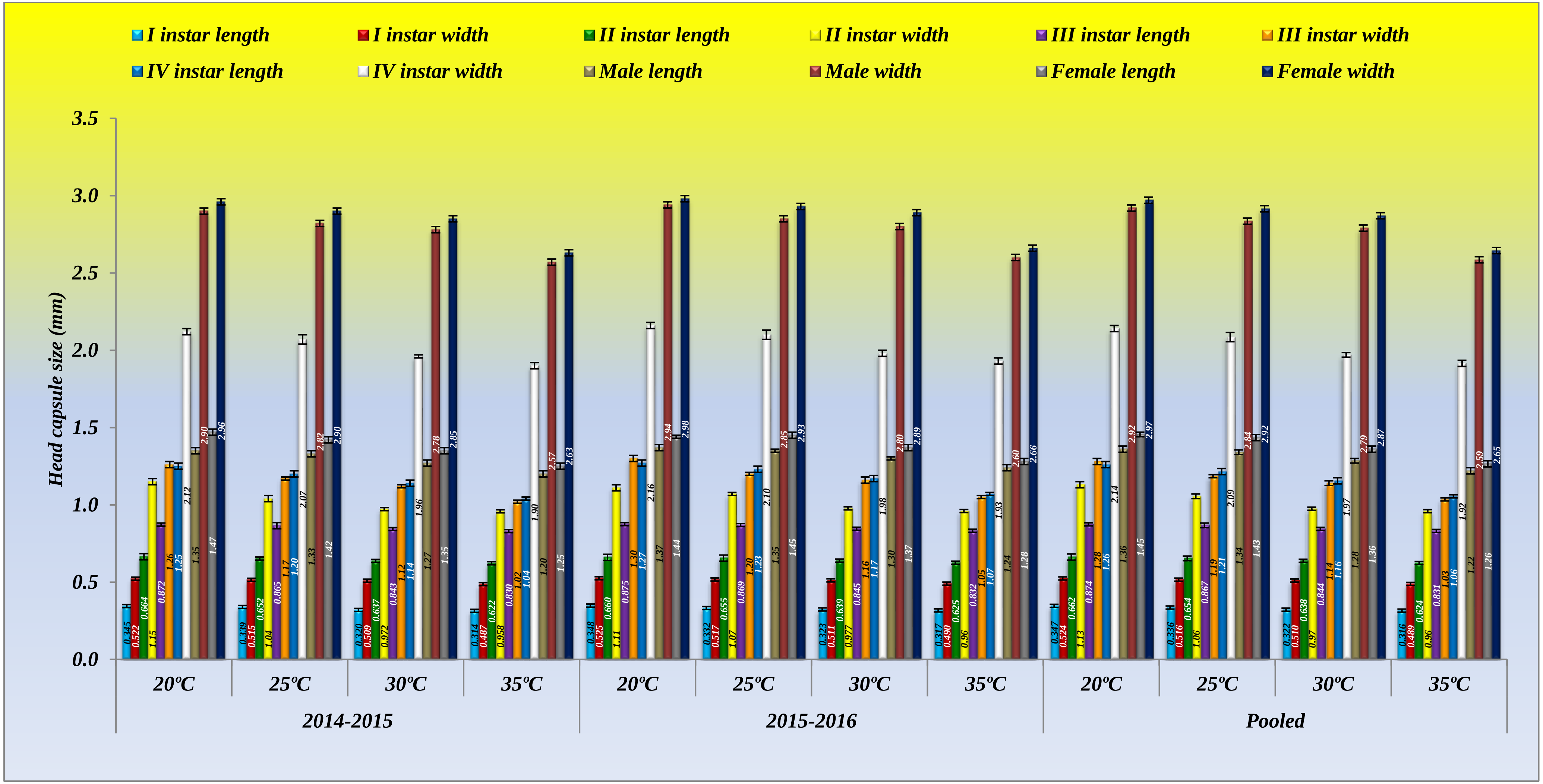

Fig 7: Measurement of head capsule of *C. septempunctata* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

0.01 to 0.662 ± 0.02 mm and 0.959 ± 0.01 to 1.13 ± 0.02 mm), (0.831 ± 0.01 to 0.874 ± 0.01 mm and 1.04 ± 0.01 to 1.28 ± 0.02 mm) and (1.06 ± 0.01 to 1.26 ± 0.02 mm and 1.92 ± 0.02 to 2.14 ± 0.02 mm), respectively at 35°C to 20°C.

The head capsule length of first, second, third and fourth instar grubs showed longest at 20°C with 0.345 ± 0.01 and 0.348 ± 0.01 mm, 0.664 ± 0.02 and 0.660 ± 0.02 mm, 0.872 ± 0.01 and 0.875 ± 0.01 mm and 1.25 ± 0.02 and 1.27 ± 0.02 mm while means was 0.347 ± 0.01, 0.662 ± 0.02, 0.874 ± 0.01 and 1.26 ± 0.02 mm during 2014-2015 and 2015-2016, respectively whereas the shortest length was recorded at 35°C with 0.314 ± 0.01 and 0.317 ± 0.01 mm, 0.622 ± 0.01 and 0.625 ± 0.01 mm, 0.830 ± 0.01 and 0.832 ± 0.01 mm and 1.04 ± 0.01 and 1.07 ± 0.01 mm while means was 0.316 ± 0.01, 0.624 ± 0.01, 0.831 ± 0.01 and 1.06 ± 0.01 mm, respectively. In contrast with the width of the first, second, third and fourth instar grubs among different temperatures, the longest was also recorded at 20°C with 0.522 ± 0.01 and 0.525 ± 0.01 mm, 1.15 ± 0.02 and 1.11 ± 0.02 mm, 1.26 ± 0.02 and 1.30 ± 0.02 mm and 2.12 ± 0.02 and 2.16 ± 0.02 mm while means was 0.524 ± 0.01, 1.13 ± 0.02, 1.28 ± 0.02 and 2.14 ± 0.02 mm during 2014-2015 and 2015-2016, respectively, whereas the shortest length was recorded at 35°C with 0.487 ± 0.01 and 0.490 ± 0.01 mm, 0.958 ± 0.01 and 0.960 ± 0.01 mm, 1.02 ± 0.01 and 1.05 ± 0.01 mm and 1.90 ± 0.02 and 1.93 ± 0.02 mm while means was 0.489 ± 0.01, 0.959 ± 0.01, 1.04 ± 0.01 and 1.92 ± 0.02 mm, respectively. Since no specific literature or citations were available regarding the head capsule size of *C. septempunctata* larva, therefore no further comparison could be done with the present findings.

4.2.3.2. Adult

The data pertained in table 10 and 11 and fig. 7 showed that with the increase in temperature the average head capsule size of *C. septempunctata* adult feeding on *L. erysimi* reduced significantly from 1.36 ± 0.02 to 1.22 ± 0.02 mm in length and 2.92 ± 0.02 to 2.59 ± 0.02 mm in width in case of male and 1.46 ± 0.01 to 1.27 ± 0.02 mm in length and 2.97 ± 0.02 to 2.65 ± 0.02 mm in width in case of female at 20°C to 35°C, respectively.

In contrast between male and female, the results revealed that female head capsule size was recorded bigger than male in all the four different temperature regimes. The length and width of the female head capsule was recorded longest at 20°C with 1.47 ± 0.02 and 1.44 ± 0.01 mm and 2.96 ± 0.02 and 2.98 ± 0.02 mm while mean was 1.46 ± 0.01 and 2.97 ± 0.02 mm during 2014-2015 and 2015-2016, respectively, whereas the shortest was recorded at 35°C with 1.25 ± 0.02 and 1.28 ± 0.02 mm and 2.63 ± 0.02 and 2.66 ± 0.02 mm while mean was 1.27 ± 0.02 and 2.65 ± 0.02 mm, respectively. Similar trends was also observed on male head capsule that the length and width recorded longest at 20°C with 1.35 ± 0.02 and 1.37 ± 0.02 mm and 2.90 ± 0.02 and 2.94 ± 0.02 mm while mean was 1.36 ± 0.02 and 2.92 ± 0.02 mm during 2014-2015 and 2015-2016, respectively whereas the shortest was recorded at 35°C with 1.20 ± 0.02 and 1.24 ± 0.02 mm and 2.57 ± 0.02 and 2.60 ± 0.02 mm while mean was 1.22 ± 0.02 and 2.59 ± 0.02 mm, respectively. Since no specific literature or citations were available regarding the head capsule size of *C. septempunctata* adult, therefore no further comparison could be conducted with the present findings.

4.3.1. Biology of *Coccinella transversalis* reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

The results during the course of investigations revealed that temperature had a significant effect on all the biological parameters of *C. transversalis* feeding on *L. erysimi*. The details of the results pertaining on the biology of *C. transversalis* are emphasized under the following heads:

4.3.1.1. Ovipositional period

The ovipositional period of *C. transversalis* ranged from 17.75 ± 1.24 to 23.45 ± 1.40 during 2014-2015 and 18.50 ± 1.31 to 25.20 ± 1.24 days during 2015-2016 with means of 18.13 ± 1.28 and 24.58 ± 1.32 days at four different temperatures (Table 12, 13 and 14). The longest ovipositional period were recorded about 23.45 ± 1.40 and 25.20 ± 1.24 days with mean as 24.58 ± 1.32 days at 20°C followed by 22.75 ± 1.54 and 23.70 ± 1.31, 20.45 ± 1.57 and 21.30 ± 1.39 and 17.75 ± 1.24 and 18.50 ± 1.31 days with means as 23.23 ± 1.42, 20.88 ± 1.48 and 18.13 ± 1.28 days at 25°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively. The present results are similar with the findings of Shukla and Jadhav (2014) who reported that the ovipositional period of *C. transversalis* when reared on *L. erysimi* took about 24.08 ± 1.83 days at 23.27 ± 1°C.

4.3.1.2. Fecundity (Eggs per female)

There was an undulating pattern on fecundity of *C. transversalis* with respect to different temperatures. From table 12, 13 and 14, the results showed that the fecundity of female *C. transversalis* reared on *L. erysimi* increased from 275.60 ± 17.54 and 290.45 ± 19.25 eggs/female at 20°C to 290.70 ± 17.85 and 320.35 ± 20.42 eggs/female at 25°C, then fell down to 225.70 ± 12.37 and 250.35 ± 15.72 to 180.40 ± 10.75 and 210.20 ±

Table 12: Biology of *C. transversalis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 (n=10)

Sl. No.	Parameters	Biology of *C. transversalis* under the influence of different temperatures (Mean ± SEm)						
		2014-2015						
		20ºC	25ºC	30ºC	35ºC	F value	P value	$HSD_{P=0.05}$
1.	Ovipositional period (in days)	23.45 ± 1.40[a]	22.75 ± 1.54[a]	20.45 ± 1.57[ab]	17.75 ± 1.24[b]	10.62	<0.01	3.01
2.	Fecundity (Eggs/female)	275.60 ± 17.54[a]	290.70 ± 17.85[a]	225.70 ± 12.37[b]	180.40 ± 10.75[c]	60.00	<0.01	24.68
3.	Size of egg cluster (Number of eggs/cluster)	27.80 ± 2.80[ab]	30.70 ± 3.02[a]	24.70 ± 2.25[b]	20.80 ± 2.44[c]	21.96	<0.01	3.45
4.	Incubation period (in days)	3.80 ± 0.31[a]	3.20 ± 0.15[b]	2.75 ± 0.25[bc]	2.50 ± 0.19[c]	20.12	<0.01	0.48
5.	Percentage of grub emergence	84.25 ± 0.78[b]	86.75 ± 0.89[a]	80.70 ± 0.55[c]	75.50 ± 0.56[d]	156.22	<0.01	1.49
6.	Total larval period (in days)	14.55 ± 1.32[a]	12.75 ± 1.11[b]	11.20 ± 0.80[c]	9.05 ± 0.92[d]	72.23	<0.01	1.05
i.	I instar	2.70 ± 0.28[a]	2.40 ± 0.27[ab]	2.15 ± 0.14[b]	2.00 ± 0.19 [b]	6.12	<0.01	0.47
ii.	II instar	3.30 ± 0.28[a]	2.85 ± 0.33[ab]	2.50 ± 0.24[bc]	2.10 ± 0.23[c]	11.69	<0.01	0.57
iii.	III instar	4.00 ± 0.47[a]	3.50 ± 0.27[ab]	3.00 ± 0.14[b]	2.35 ± 0.24[c]	17.86	<0.01	0.64
iv.	IV instar	4.55 ± 0.29[a]	4.00 ± 0.24[ab]	3.55 ± 0.29[b]	2.60 ± 0.27[c]	31.22	<0.01	0.56
7.	Pre-pupal period (in days)	1.75 ± 0.31[a]	1.45 ± 0.25[ab]	1.20 ± 0.15[b]	1.00 ± 0.19[b]	6.35	<0.01	0.49
8.	Pupal period (in days)	3.55 ± 0.21[a]	3.20 ± 0.20[ab]	2.75 ± 0.34[b]	2.20 ± 0.15[c]	20.28	<0.01	0.49
9.	Total developmental period; egg to adult emergence (in days)	23.65 ± 2.15[a]	20.60 ± 1.71[b]	17.90 ± 1.53[c]	14.75 ± 1.46[d]	119.45	<0.01	1.32
10.	Percentage of adult emergence	79.65 ± 0.79[b]	82.20 ± 0.85[a]	77.50 ± 0.73[c]	74.60 ± 0.49[d]	65.13	<0.01	1.52
11.	Adult longevity (in days)							
i.	Males (in days)	33.60 ± 3.87[a]	32.10 ± 3.57[b]	30.45 ± 3.75[c]	26.25 ± 2.63[d]	65.70	<0.01	1.49
ii.	Females (in days)	37.80 ± 3.81[a]	36.50 ± 3.91[ab]	35.20 ± 3.71[b]	30.50 ± 3.72[c]	53.85	<0.01	1.65
12.	Total life cycle; egg to death of adult (in days)							
i.	Males (in days)	57.25 ± 6.02[a]	52.70 ± 5.28[b]	48.35 ± 5.28[c]	41.00 ± 4.09[d]	595.22	<0.01	2.29
ii.	Females (in days)	61.45 ± 5.96[a]	57.10 ± 5.62[b]	53.10 ± 5.24[c]	45.25 ± 5.18[d]	631.73	<0.01	2.58

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.

Means within rows were separated by Tukey's Honestly Significant Difference.

Table 13: Biology of *C. transversalis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2015-2016 (n=10)

Sl. No.	Parameters	Biology of *C. transversalis* under the influence of different temperatures (Mean ± SEm)						
		2015-2016						
		20ºC	25ºC	30ºC	35ºC	F value	P value	$HSD_{P=0.05}$
1.	Ovipositional period (in days)	25.20 ± 1.24[a]	23.70 ± 1.31[ab]	21.30 ± 1.39[b]	18.50 ± 1.31[c]	16.58	<0.01	2.74
2.	Fecundity (Eggs/female)	290.45 ± 19.25[b]	320.35 ± 20.42[a]	250.35 ± 15.72[c]	210.20 ± 12.20[d]	526.51	<0.01	7.96
3.	Size of egg cluster (Number of eggs/cluster)	30.25 ± 2.46[a]	32.45 ± 3.77[a]	26.35 ± 2.09[b]	22.20 ± 2.41[c]	32.23	<0.01	3.03
4.	Incubation period (in days)	3.50 ± 0.27[a]	3.00 ± 0.33[ab]	2.50 ± 0.19[bc]	2.25 ± 0.15[c]	16.70	<0.01	0.52
5.	Percentage of grub emergence	85.20 ± 0.89[b]	88.00 ± 0.82[a]	82.25 ± 0.85[c]	77.25 ± 0.66[d]	156.94	<0.01	1.67
6.	Total larval period (in days)	15.40 ± 1.23[a]	13.10 ± 1.02[b]	11.95 ± 1.14[c]	9.25 ± 0.93[d]	79.38	<0.01	1.09
i.	I instar	2.85 ± 0.19[a]	2.25 ± 0.20[b]	2.30 ± 0.20[b]	2.00 ± 0.19[b]	10.87	<0.01	0.41
ii.	II instar	3.65 ± 0.36[a]	2.90 ± 0.33[b]	2.85 ± 0.33[b]	2.00 ± 0.19[c]	15.67	<0.01	0.65
iii.	III instar	4.20 ± 0.43[a]	3.70 ± 0.34[ab]	3.20 ± 0.28[b]	2.50 ± 0.24[c]	16.07	<0.01	0.69
iv.	IV instar	4.70 ± 0.24[a]	4.25 ± 0.15[a]	3.60 ± 0.33[b]	2.75 ± 0.31[c]	33.33	<0.01	0.56
7.	Pre-pupal period (in days)	1.60 ± 0.30[a]	1.50 ± 0.24[a]	1.35 ± 0.19[ab]	1.00 ± 0.19[b]	4.19	<0.05	0.49
8.	Pupal period (in days)	4.15 ± 0.41[a]	3.50 ± 0.19[b]	2.90 ± 0.30[c]	2.00 ± 0.14[d]	35.71	<0.01	0.58
9.	Total developmental period; egg to adult emergence (in days)	24.65 ± 2.21[a]	21.10 ± 1.78[b]	18.70 ± 1.83[c]	14.50 ± 1.41[d]	124.50	<0.01	1.45
10.	Percentage of adult emergence	81.00 ± 0.61[b]	84.35 ± 0.92[a]	75.75 ± 0.63[c]	75.25 ± 0.84[c]	93.68	<0.01	1.59
11.	Adult longevity (in days)							
i.	Males (in days)	35.20 ± 3.66[a]	32.00 ± 3.54[b]	30.20 ± 3.60[c]	27.20 ± 2.60[d]	104.01	<0.01	1.25
ii.	Females (in days)	38.90 ± 3.74[a]	37.20 ± 3.85[b]	35.50 ± 3.68[c]	32.25 ± 3.82[d]	44.51	<0.01	1.62
12.	Total life cycle; egg to death of adult (in days)							
i.	Males (in days)	59.85 ± 5.87[a]	53.10 ± 5.32[b]	48.90 ± 5.43[c]	41.70 ± 4.01[d]	425.14	<0.01	2.03
ii.	Females (in days)	63.55 ± 5.95[a]	58.30 ± 5.63[b]	54.20 ± 5.51[c]	46.75 ± 5.23[d]	503.36	<0.01	2.27

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.

Means within rows were separated by Tukey's Honestly Significant Difference.

Table 14: Biology of *C. transversalis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016 (Pooled) (n=10)

Sl. No.	Parameters	Biology of *C. transversalis* under the influence of different temperatures (Mean ± SEm)						
		Pooled						
		20ºC	25ºC	30ºC	35ºC	F value	P value	$HSD_{P=0.05}$
1.	Ovipositional period (in days)	24.33 ± 1.32[a]	23.23 ± 1.42[ab]	20.88 ± 1.48[bc]	18.13 ± 1.28[c]	13.32	<0.01	2.82
2.	Fecundity (Eggs/female)	283.03 ± 18.40[b]	305.53 ± 19.14[a]	238.03 ± 14.05[c]	195.30 ± 11.48[d]	103.96	<0.01	17.99
3.	Size of egg cluster (Number of eggs/cluster)	29.03 ± 2.63[a]	31.58 ± 3.40[a]	25.53 ± 2.17[b]	21.50 ± 2.43[c]	26.43	<0.01	3.18
4.	Incubation period (in days)	3.65 ± 0.29[a]	3.10 ± 0.24[b]	2.63 ± 0.22[bc]	2.38 ± 0.17[c]	18.30	<0.01	0.49
5.	Percentage of grub emergence	84.73 ± 0.84[b]	87.38 ± 0.86[a]	81.48 ± 0.70[c]	76.38 ± 0.61[d]	156.62	<0.01	1.55
6.	Total larval period (in days)	14.98 ± 1.28[a]	12.93 ± 1.07[b]	11.58 ± 0.97[c]	9.15 ± 0.93[d]	75.96	<0.01	1.05
i.	I instar	2.78 ± 0.24[a]	2.33 ± 0.24[b]	2.23 ± 0.17[b]	2.00 ± 0.19[b]	8.19	<0.01	0.44
ii.	II instar	3.48 ± 0.32[a]	2.88 ± 0.33[b]	2.68 ± 0.29[b]	2.05 ± 0.21[c]	13.94	<0.01	0.60
iii.	III instar	4.10 ± 0.45[a]	3.60 ± 0.31[ab]	3.10 ± 0.21[b]	2.43 ± 0.24[c]	16.89	<0.01	0.65
iv.	IV instar	4.63 ± 0.27[a]	4.13 ± 0.20[ab]	3.58 ± 0.31[b]	2.68 ± 0.29[c]	32.27	<0.01	0.55
7.	Pre-pupal period (in days)	1.68 ± 0.30[a]	1.48 ± 0.25[ab]	1.28 ± 0.17[ab]	1.00 ± 0.19[b]	5.27	<0.01	0.48
8.	Pupal period (in days)	3.85 ± 0.31[a]	3.35 ± 0.20[ab]	2.83 ± 0.32[b]	2.10 ± 0.15[c]	29.26	<0.01	0.53
9.	Total developmental period; egg to adult emergence (in days)	24.15 ± 2.18[a]	20.85 ± 1.75[b]	18.30 ± 1.68[c]	14.63 ± 1.44[d]	122.22	<0.01	1.36
10.	Percentage of adult emergence	80.33 ± 0.70[b]	83.28 ± 0.89[a]	76.63 ± 0.68[c]	74.93 ± 0.67[c]	80.04	<0.01	1.53
11.	Adult longevity (in days)							
i.	Males (in days)	34.40 ± 3.77[a]	32.05 ± 3.56[b]	30.33 ± 3.68[c]	26.73 ± 2.62[d]	81.52	<0.01	1.35
ii.	Females (in days)	38.35 ± 3.78[a]	36.85 ± 3.88[ab]	35.35 ± 3.70[b]	31.38 ± 3.77[c]	49.27	<0.01	1.61
12.	Total life cycle; egg to death of adult (in days)							
i.	Males (in days)	58.55 ± 5.95[a]	52.90 ± 5.30[b]	48.63 ± 5.36[c]	41.35 ± 4.05[d]	494.93	<0.01	2.12
ii.	Females (in days)	62.50 ± 5.96[a]	57.70 ± 5.63[b]	53.65 ± 5.38[c]	46.00 ± 5.21[d]	559.82	<0.01	2.38

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.

Means within rows were separated by Tukey's Honestly Significant Difference.

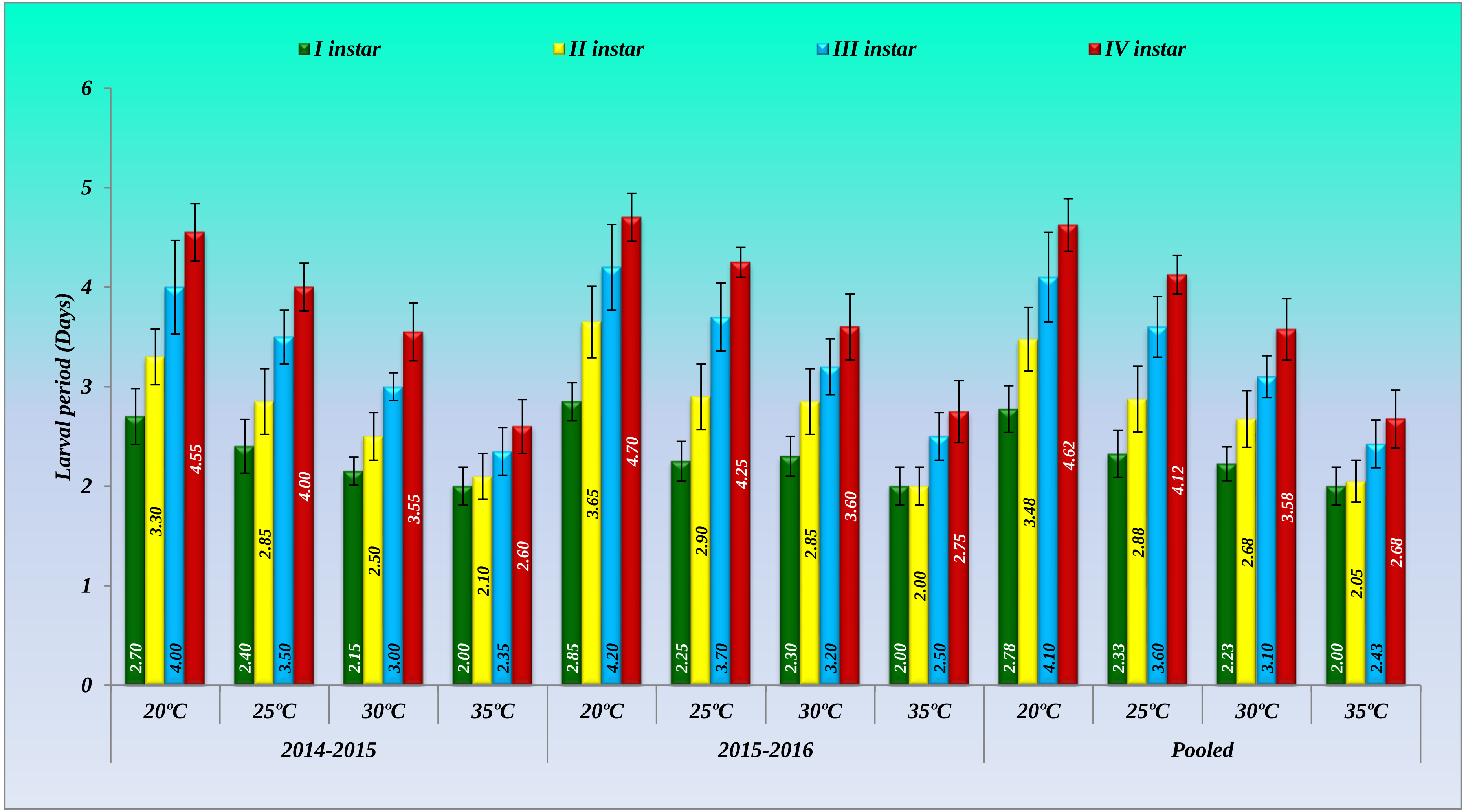

Fig 8a: Duration of larval development of *C. transversalis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

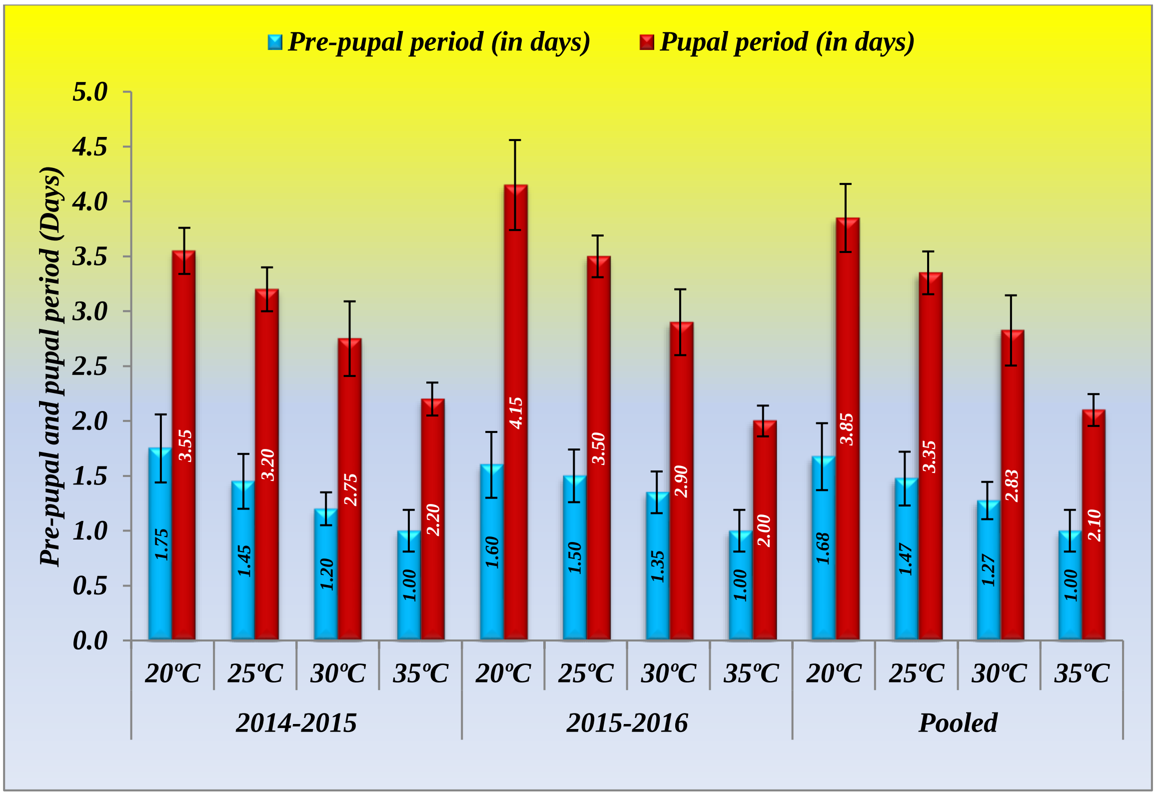

Fig 8b: Duration of larval development of *C. transversalis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

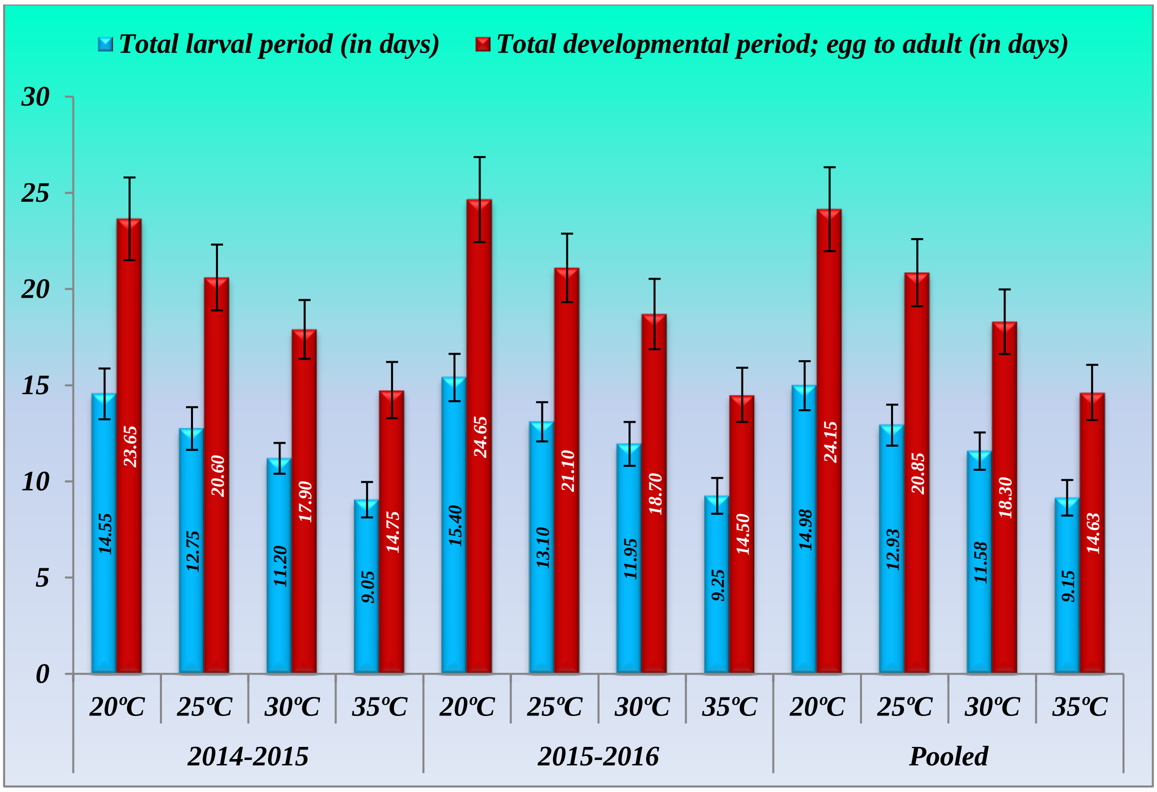

Fig 8c: Duration of total larval development and total development period; egg to adult of *C. transversalis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

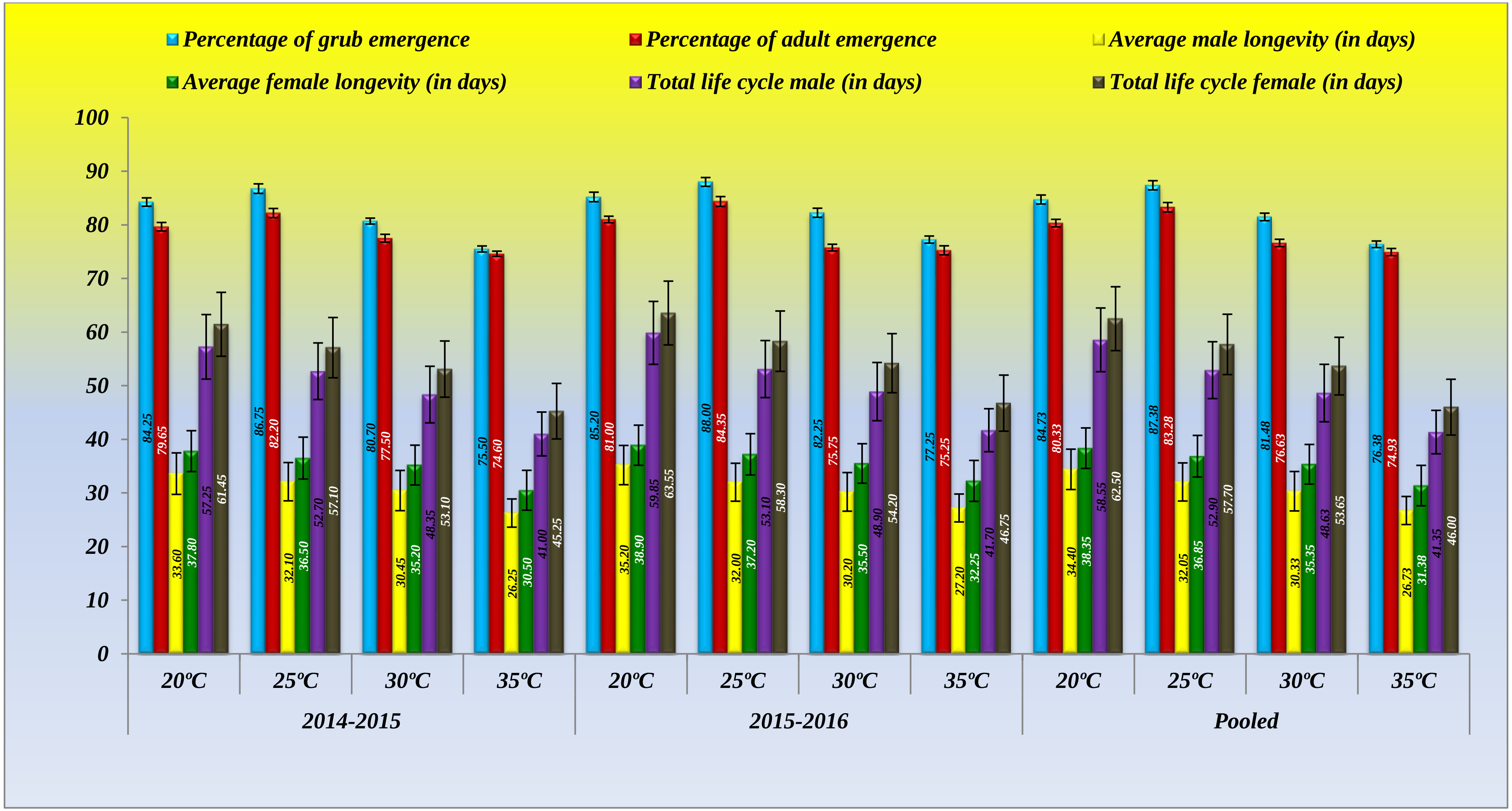

Fig 8d: Percentage of grub emergence, percentage of adult emergence, average male longevity and female longevity and total life cycle of male longevity and female of *C. transverslis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

12.20 at 30°C and 35°C during 2014-2015 and 2015-2016, respectively. However, the highest fecundity of *C. transversalis* were recorded about 290.70 ± 17.85 and 320.35 ± 20.42 eggs/female at 25°C followed by 275.60 ± 17.54 and 290.45 ± 19.25, 225.70 ± 12.37 and 250.35 ± 15.72 and 180.40 ± 10.75 and 210.20 ± 12.20 eggs/female at 20°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively. The present results are quite similar with the findings of Chakraborty and Korat (2014) who reported that the adult females of *C. transversalis* when reared on *Aphis gossypii* laid an average of 253.85 ± 38.76 eggs/female at 25°C. Slight variation on fecundity of *C. transversalis* could be due to rearing at different temperature and on different prey species.

4.3.1.3. Size of the egg cluster (Number of eggs per cluster)

From table 12, 13 and 14 presented, the data showed that the mean number of eggs laid by *C. transversalis* female reared on *L. erysimi* ranged from 20.80 ± 2.44 and 22.20 ± 2.41 to 30.70 ± 3.02 and 32.45 ± 3.77 eggs/cluster during 2014-2015 and 2015-2016, respectively with mean ranging from 21.50 ± 2.43 to 31.58 ± 3.40 eggs/cluster at four different temperatures. However, the number of eggs laid by *C. transversalis* female was recorded highest at 25°C with 30.70 ± 3.02 and 32.45 ± 3.77 eggs/cluster while mean was 31.58 ± 3.40 eggs/cluster followed by 27.80 ± 2.80 and 30.25 ± 2.46, 24.70 ± 2.25 and 26.35 ± 2.09 and 20.80 ± 2.44 and 22.20 ± 2.41 eggs/cluster during 2014-2015 and 2015-2016, respectively with means as 29.03 ± 2.63, 25.53 ± 2.17 and 21.50 ± 2.43 eggs/cluster at 20°C, 30°C and 35°C. The present results are quite similar with the findings of Shukla and Jadhav (2014) who reported that the *C. transversalis* female when reared on *L. erysimi* laid upto 31 eggs/cluster at 23.27 ± 1°C.

4.3.1.4. Incubation period

The data indicated that with the increase in temperature the egg incubation period of *C. transversalis* reduced significantly from 3.80 ± 0.31 and 3.50 ± 0.27 days at 20°C to 2.50 ± 0.19 and 2.25 ± 0.15 days at 35°C with means ranging from 3.65 ± 0.29 at 20°C to 2.38 ± 0.17 days at 35°C (Table 12, 13 and 14). The longest incubation period was recorded longest at 20°C with 3.80 ± 0.31 and 3.50 ± 0.27 days while the shortest incubation period was exhibited when kept at 35°C recording 2.50 ± 0.19 and 2.50 ± 0.19 for two years 2014-2015 and 2015-2016.

The present results obtained are in conformity with the findings of Shukla and Jadhav (2014) who reported that the incubation period of *C. transversalis* female was about 2.70 ± 0.77 days when reared on *L. erysimi* at 23.27 ± 1°C. Since no literature were available regarding the incubation period of *C. transversalis* eggs reared at different temperature regimes, therefore no further comparison could be conducted to corroborate or contradict with the present findings.

4.3.1.5. Percentage of grub emergence

From table 12, 13 and 14 presented and fig. 8d, the data showed that the percentage of grub emergence of *C. transversalis* was highest at 25°C with 86.75 ± 0.89% and 88.00 ± 0.82% during 2014-2015 and 2015-2016, respectively. The highest mean of 87.38 ± 0.86% and lowest mean of 76.38 ± 0.61% was recorded at 25°C and 25°C, respectively.

The present results are similar with the findings of Shukla and Jadhav (2014) who reported that the percentage of grub emergence of *C. transversalis* when reared on *L. erysimi* was 84.73% at 23.27 ± 1°C. In other studies by Bukero *et al.* (2015b) reported that the percentage of grub emergence of *C. transversalis* when reared on fresh *Aphis nerii* was 68.00 ± 2.29% at 26 ± 2°C which are in contradiction with the present findings.

4.3.1.6. Larval period

The data indicated that with the increase in temperature the developmental period of all the larval stages of *C. transversalis* decreased significantly (Table 12, 13 and 14 and Fig. 8a). The mean developmental period of first, second, third and fourth instar grubs feeding on *L. erysimi* ranged from 2.00 ± 0.19 to 2.78 ± 0.24, 2.05 ± 0.21 to 3.48 ± 0.32, 2.43 ± 0.24 to 4.10 ± 0.45 and 2.68 ± 0.29 to 4.63 ± 0.27 days, respectively at four different temperatures and total larval duration was ranging from 9.15 ± 0.93 to 14.98 ± 1.28 days.

The duration of first, second, third and fourth instar grubs were (2.70 ± 0.28 and 2.85 ± 0.19, 2.40 ± 0.27 and 2.25 ± 0.20, 2.15 ± 0.14 and 2.30 ± 0.20, and 2.00 ± 0.19 and 2.00 ± 0.19), (3.30 ± 0.28 and 3.65 ± 0.36, 2.85 ± 0.33 and 2.90 ± 0.33, 2.50 ± 0.24 and 2.85 ± 0.33, and 2.10 ± 0.23 and 2.00 ± 0.19), (4.00 ± 0.47 and 4.20 ± 0.43, 3.50 ± 0.27 and 3.70 ± 0.34, 3.00 ± 0.14 and 3.20 ± 0.28, and 2.35 ± 0.24 and 2.50 ± 0.24) and (4.55 ± 0.29 and 4.70 ± 0.24, 4.00 ± 0.24 and 4.25 ± 0.15, 3.55 ± 0.29 and 3.60 ± 0.33, and 2.60 ± 0.27 and 2.75 ± 0.31) days at 20°C, 25°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively with means as (2.78 ± 0.24, 2.33 ± 0.24, 2.23 ± 0.17 and 2.00 ± 0.14), (3.48 ± 0.32, 2.88 ± 0.33, 2.68 ± 0.29 and 2.05 ± 0.21), (4.10 ± 0.45, 3.60 ± 0.31, 3.10 ± 0.21 and 2.43 ± 0.24) and (4.63 ± 0.32, 4.13 ± 0.33, 3.58 ± 0.29 and 2.68 ±

0.21) days for first, second, third and fourth instar respectively at four different sets of temperature i.e., 20°C, 25°C, 30°C and 35°C.

The total larval period of *C. transversalis* were recorded about 14.55 ± 1.32 and 15.40 ± 1.23, 12.75 ± 1.11 and 13.10 ± 1.02, 11.20 ± 0.80 and 11.95 ± 1.14 and 9.05 ± 0.92 and 9.25 ± 0.93 days with means as 14.98 ± 1.28, 12.93 ± 1.07, 11.58 ± 0.97 and 9.70 ± 0.93 days at 20°C, 25°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively (Table 9 and 10 and Fig. 8c). The present results are quite similar with the findings of Shukla and Jadhav (2014) who reported that the total larval period *C. transversalis* when reared on *L. erysimi* was about 12.68 ± 1.63 days at 23.27 ± 1°C.

4.3.1.7. Pre-pupal and pupal period

From table 12, 13 and 14 and fig. 8b presented, the data showed that the mean pre-pupal and pupal period of *C. transversalis* ranged from 1.00 ± 0.19 to 1.68 ± 0.30 and 2.10 ± 0.15 to 3.85 ± 0.31 days, respectively at four different sets of temperature. The longest pre-pupal period of *C. transversalis* was recorded at 20°C with 1.75 ± 0.31 and 1.60 ± 0.30 days during 2014-2015 and 2015-2016, respectively while highest mean pre-pupal was recorded as 1.68 ± 0.30 days at 20°C followed by 1.48 ± 0.25, 1.28 ± 0.17 and 1.00 ± 0.19 days at 25°C, 30°C and 35°C. The present results obtained are quite close with the findings of few researchers who have reported that the average pre-pupal period was about 1.00 ± 0.00 and 1.30 ± 0.15 days at 23.27 ± 1°C and 26 ± 1°C, respectively (Shukla and Jadhav 2014; Bukero *et al.*, 2015b).

The longest pupal period of 3.55 ± 0.21 and 4.15 ± 0.41 days were exhibited by *C. transversalis* at 20°C during 2014-2015 and 2015-2016, respectively with a maximum pupal mean of 3.85 ± 0.31 days and minimum of 2.10 ± 0.15 days at 20°C and 35°C (Table 9 and 10 and Fig. 8b). The present results are in agreement with the findings of Bukero *et al.* (2015b) who reported that the pupal period of *C. transversalis* when reared on fresh *A. nerii* was about 2.30 ± 0.21 days at 26 ± 1°C.

4.3.1.8. Total developmental period; egg to adult

The data indicated that with the increase in temperature the total developmental period of *C. transversalis* decreased significantly from 23.65 ± 2.15 and 24.65 ± 2.21 days at 20°C to 4.75 ± 1.46 and 14.50 ± 1.41 at 35°C during 2014-2015 and 2015-2016, respectively with means ranging from 24.15 ± 2.18 to 14.63 ± 1.44 days (Table 12, 13 and 14 and Fig. 8c). The total developmental period were recorded about 23.65 ± 2.15

and 24.65 ± 2.21, 20.60 ± 1.71 and 21.10 ± 1.78, 17.90 ± 1.53 and 18.70 ± 1.83, 14.75 ± 1.46 and 14.50 ± 1.41 days with means recording 24.15 ± 2.18, 20.85 ± 1.75, 18.30 ± 1.68 and 14.63 ± 1.44 days at 20°C, 25°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively.

The present results obtained are in agreement with the findings of Bukero *et al.* (2015b) who reported that the total developmental period of *C. transversalis* feeding on frozen *A. nerii* was 19.20 ± 1.57 days at 26 ± 1°C. In other studies by Chakraborty and Korat (2014) reported that the total developmental period of *C. transversalis* when reared on *A. gossypii* was 31.97 ± 0.67 days at 25°C which are in contradiction with the present findings.

4.3.1.9. Percentage of adult emergence

From table 12, 13 and 14 and fig. 8d presented, the data showed that the percentage of adult emergence of *C. transversalis* was highest at 25°C with 82.20 ± 0.85% and 84.35 ± 0.92% during 2014-2015 and 2015-2016, respectively and a maximum of 83.28 ± 0.89% at 25°C and a minimum of 74.93 ± 0.67% at 35°C was recorded followed by 79.65 ± 0.79% and 81.00 ± 0.61% (20°C), 77.50 ± 0.73% and 75.75 ± 0.63% (30°C), 74.60 ± 0.49% and 75.25 ± 0.84% (35°C). The present results obtained are similar with the findings of Shukla and Jadhav (2014) who reported that percentage of adult emergence of *C. transversalis* was about 80.36 ± 10.83% at 23.27 ± 1°C.

4.3.1.10. Adult longevity

The data indicated that with the increase in temperature the average longevity of *C. septempunctata* adult reduced significantly (Table 12, 13 and 14 and Fig. 8d). The longevity of adult male ranged from 26.25 ± 2.63 to 33.60 ± 3.87 and 27.20 ± 2.60 to 35.20 ± 3.66 days during 2014-2015 and 2015-2016, respectively with means as 26.73 ± 2.62 to 34.40 ± 3.77 days at four different temperatures. The mean longevity of adult female ranging from 30.50 ± 3.72 to 37.80 ± 3.81 and 32.25 ± 3.82 to 38.90 ± 3.74 days, respectively during 2014-2015 and 2015-2016 with means as 31.38 ± 3.77 to 38.35 ± 3.78 days at different temperature regimes indicating that female took more days to complete its development than male.

The average longevity of adult female showed longer in comparison to adult male with 37.80 ± 3.81 and 38.90 ± 3.74, 3.50 ± 3.91 and 37.20 ± 3.85, 35.20 ± 3.71 and 35.50

± 3.68 and 30.50 ± 3.72 and 32.25 ± 2.82 days during 2014-2015 and 2015-2016, respectively with means as 38.35 ± 3.78, 36.85 ± 3.88, 35.35 ± 3.70 and 31.38 ± 3.77 days at 20°C, 25°C, 30°C and 35°C while the longevity of adult male were recorded about 33.60 ± 3.87 and 35.20 ± 3.66, 32.10 ± 3.57 and 32.00 ± 3.54, 30.45 ± 3.75 and 30.20 ± 3.60, 26.25 ± 2.63 and 27.20 ± 2.60 days during 2014-2015 and 2015-2016, respectively with means as 34.40 ± 3.77, 32.05 ± 3.56, 30.33 ± 3.68 and 26.73 ± 2.62 days at 20°C, 25°C, 30°C and 35°C.

The results obtained are similar with the findings of Shukla and Jadhav (2014) who reported that the mean longevity of male and female *C. transversalis* reared on *L. erysimi* were 30.12 ± 4.49 and 33.88 ± 2.57 days, respectively at 23.27 ± 1°C. The present findings are further supported by Bukero *et al.* (2015b) who reported that the longevity of male and female *C. transversalis* were 35.80 ± 0.99 and 42.50 ± 1.01 days, respectively at 26 ± 2°C.

4.3.1.11. Total life cycle

From table 12, 13 and 14 and fig. 8d presented, the data indicated that with the increase in temperature the average longevity of *C. transversalis* adult reduced significantly (Table 12, 13 and 14 and Fig. 8d). The total life cycle of male *C. transversalis* when reared on *L. erysimi* ranged from 41.00 ± 4.09 to 57.25 ± 6.02 and 41.70 ± 4.01 to 59.85 ± 5.87 days during 2014-2015 and 2015-2016, respectively with means ranging from 41.35 ± 4.05 to 58.55 ± 5.95 days at four different sets of temperatures. The total life cycle of adult female ranging from 45.25 ± 5.18 to 61.45 ± 5.96 and 46.75 ± 5.23 to 63.55 ± 5.95 days during 2014-2015 and 2015-2016, respectively with means as 46.00 ± 5.21 to 62.50 ± 5.96 days at different temperature regimes indicating that female took more days to complete its life cycle than male.

The total life cycle of *C. transversalis* of adult male were recorded about 57.25 ± 6.02 and 59.85 ± 5.87, 52.70 ± 5.28 and 53.10 ± 5.32, 48.35 ± 5.28 and 48.90 ± 5.43, 41.00 ± 4.09 and 41.70 ± 4.01 days during 2014-2015 and 2015-2016, respectively with means as 58.55 ± 5.95, 52.90 ± 5.30, 48.63 ± 5.36 and 41.35 ± 4.05 days at 20°C, 25°C, 30°C and 35°C while the total life cycle of adult female were recorded about 61.45 ± 5.96 and 63.55 ± 5.95, 57.10 ± 5.62 and 58.30 ± 5.63, 53.10 ± 5.24 and 54.20 ± 5.51, 45.25 ± 5.18 and 46.75 ± 5.23 days during 2014-2015 and 2015-2016, respectively with means as 62.50 ± 5.96, 57.70 ± 5.63, 53.65 ± 5.38 and 46.00 ± 5.21 days at 20°C, 25°C, 30°C and 35°C. The results clearly showed that the longest life cycle of *C. transversalis*

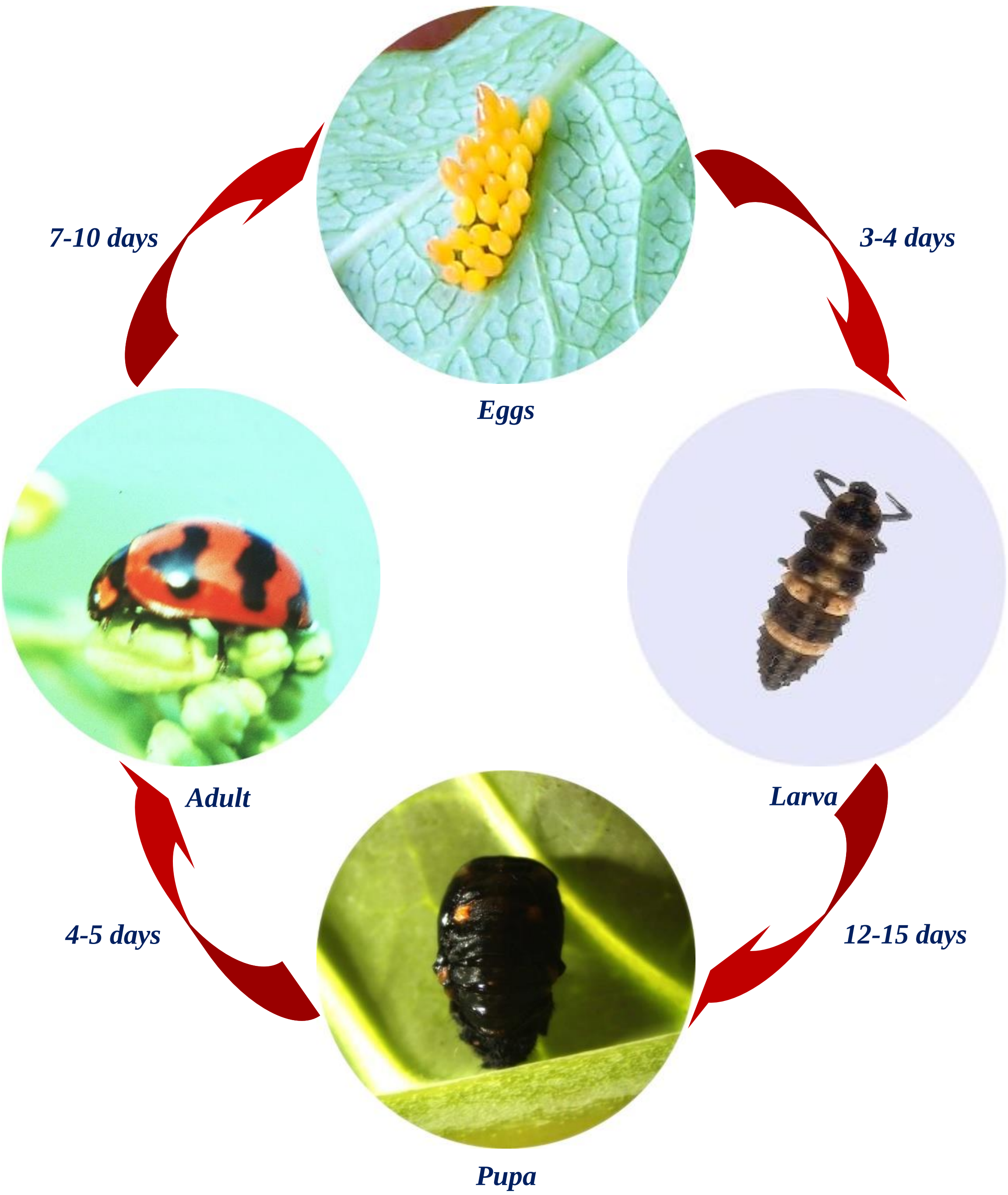

Plate 10: Life cycle of *Coccinella transversalis*

Plate 11a: Newly hatched grubs of *C. transversalis*

Plate 11b: First instar grub of *C. transversalis*

Plate 11c: Second instar grub of *C. transversalis*

Plate 11d: Third instar grub of *C. transversalis*

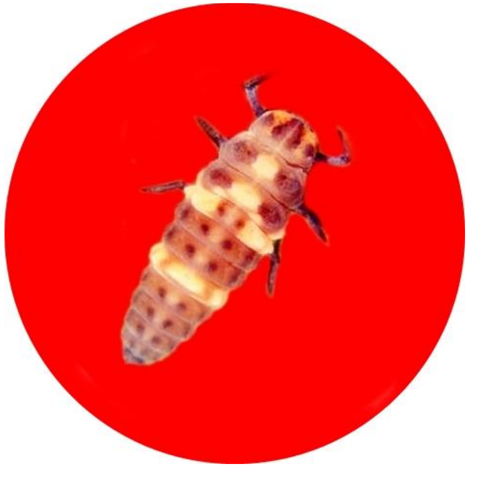

Plate 11e: Fourth instar grub of *C. transversalis*

Plate 11: Different stages of *Coccinella transversalis*

Plate 12a: Male *Coccinella Transversalis*

Plate 12b: Female *Coccinella transversalis*

Plate 12c: Male; Distal margin of 1st visible abdominal sternite (convex)

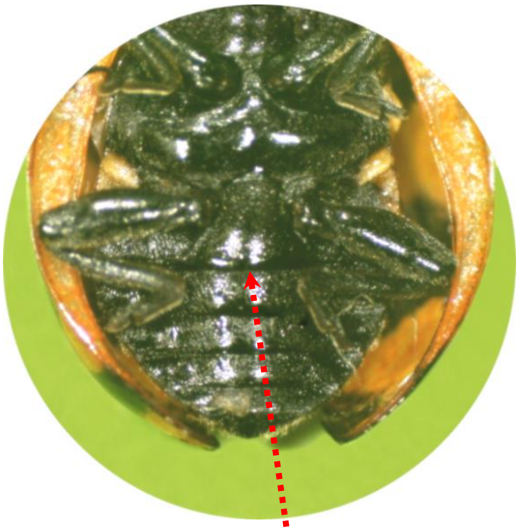

Plate 12d: Female; Distal margin of 1st visible abdominal sternite (concave)

Plate 12: Differentiation of male and female *Coccinella transversalis*

was recorded at low temperature and shortest at high temperature.

The present results are similar with the findings of Ali and Rizvi (2009) who reported that *C. transversalis* reared on *L. erysimi* at various temperatures revealed that it took maximum period of 60 days to complete a generation at 20 ± 1°C followed by 56 and 50 days at 24 ± 1°C and 28 ± 1°C, respectively.

4.3.2. Measurement of various life stages of *Coccinella transversalis* reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

4.3.2.1. Egg size

From the table 15 and 16 and fig. 9, the results revealed that with the increase in temperature the size of the eggs of *C. transversalis* reared on *L. erysimi* decreased significantly from 1.32 ± 0.01 and 1.30 ± 0.02 to 1.15 ± 0.02 and 1.17 ± 0.02 mm in length and 0.54 ± 0.02 and 0.53 ± 0.02 to 0.34 ± 0.02 and 0.36 ± 0.02 mm in width from 20°C to 35°C during 2014-2015 and 2015-2016, respectively. The largest egg size was recorded at 20°C with 1.32 ± 0.01 and 1.30 ± 0.02 mm in length and 0.54 ± 0.02 and 0.53 ± 0.02 mm in width while mean was 1.31 ± 0.02 mm in length and 0.54 ± 0.02 mm in width during 2014-2015 and 2015-2016, respectively followed by 1.26 ± 0.02 and 1.29 ± 0.02 mm, 1.20 ± 0.01 and 1.24 ± 0.01 mm and 1.15 ± 0.02 and 1.17 ± 0.02 mm in length and 0.48 ± 0.02 and 0.50 ± 0.02 mm, 0.39 ± 0.02 and 0.40 ± 0.02 mm and 0.34 ± 0.02 and 0.36 ± 0.02 mm in width while means was 1.28 ± 0.02, 1.22 ± 0.01 and 1.16 ± 0.02 mm in length and 0.49 ± 0.01, 0.40 ± 0.02 and 0.35 ± 0.02 mm in width at 25°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively.

The present results are in conformity with the findings of Chakraborty and Korat (2014) who reported that the average length and width of the *C. transversalis* eggs were 1.06 ± 0.01 and 0.47 ± 0.01 mm, respectively at 25°C.

4.3.2.2. Larva size

The data indicated that with the increase in temperature the size of all the larval stages of *C. transversalis* reduced significantly (Table 15 and 16 and Fig. 9). There was significant difference in length and width among different larval instars. The mean length and width of first, second, third and fourth instar grubs ranged from (1.50 ± 0.02 to 2.58 ± 0.02 mm and 0.59 ± 0.02 to 0.81 ± 0.02 mm), (3.02 ± 0.02 to 3.54 ± 0.02 mm and 0.95 ± 0.02 to 1.31 ± 0.02 mm), (4.34 ± 0.22 to 5.88 ± 0.02 mm and 1.21 ± 0.02 to 1.72 ± 0.02

Table 15: Measurement of various life stages of *C. transversalis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016 (n=10)

Sl. No.	Parameters	Measurement of various stages of *C. transversalis* under the influence of different temperatures (Mean ± SEm)													
		2014-2015							2015-2016						
		20ºC	25ºC	30ºC	35ºC	F value	P value	HSD p=0.05	20ºC	25ºC	30ºC	35ºC	F value	P value	HSD p=0.05
1.	**Egg**														
	Length (mm)	1.32 ± 0.01^{a}	1.26 ± 0.02^{b}	1.20 ± 0.01^{c}	1.15 ± 0.02^{d}	53.81	<0.01	0.05	1.30 ± 0.02^{a}	1.29 ± 0.02^{a}	1.24 ± 0.01^{b}	1.17 ± 0.02^{c}	51.49	<0.01	0.04
	Width (mm)	0.54 ± 0.02^{a}	0.48 ± 0.02^{b}	0.39 ± 0.02^{c}	0.34 ± 0.02^{d}	83.63	<0.01	0.05	0.53 ± 0.02^{a}	0.50 ± 0.01^{b}	0.40 ± 0.02^{c}	0.36 ± 0.02^{d}	102.51	<0.01	0.04
2.	**Larva**														
i.	**I instar**														
	Length (mm)	2.57 ± 0.02^{a}	2.49 ± 0.02^{b}	1.65 ± 0.02^{c}	1.50 ± 0.02^{d}	2073.81	<0.01	0.05	2.59 ± 0.03^{a}	2.52 ± 0.02^{b}	1.68 ± 0.02^{c}	1.49 ± 0.02^{d}	2153.25	<0.01	0.05
	Width (mm)	0.80 ± 0.02^{a}	0.75 ± 0.01^{b}	0.63 ± 0.01^{c}	0.57 ± 0.02^{d}	153.25	<0.01	0.04	0.82 ± 0.02^{a}	0.77 ± 0.02^{b}	0.64 ± 0.01^{c}	0.60 ± 0.02^{d}	190.20	<0.01	0.04
ii.	**II instar**														
	Length (mm)	3.52 ± 0.02^{a}	3.47 ± 0.01^{b}	3.22 ± 0.02^{c}	3.00 ± 0.02^{d}	908.03	<0.01	0.04	3.55 ± 0.02^{a}	3.50 ± 0.02^{b}	3.25 ± 0.01^{c}	3.04 ± 0.02^{d}	779.83	<0.01	0.04
	Width (mm)	1.29 ± 0.02^{a}	1.22 ± 0.02^{b}	1.10 ± 0.01^{c}	0.94 ± 0.02^{d}	289.54	<0.01	0.04	1.32 ± 0.02^{a}	1.27 ± 0.02^{b}	1.12 ± 0.02^{c}	0.96 ± 0.01^{d}	385.63	<0.01	0.05
iii.	**III instar**														
	Length (mm)	5.85 ± 0.02^{a}	5.72 ± 0.03^{b}	4.85 ± 0.02^{c}	4.32 ± 0.02^{d}	2721.91	<0.01	0.05	5.90 ± 0.02^{a}	5.77 ± 0.02^{b}	4.88 ± 0.03^{c}	4.35 ± 0.02^{d}	2908.36	<0.01	0.05
	Width (mm)	1.70 ± 0.02^{a}	1.64 ± 0.02^{b}	1.48 ± 0.02^{c}	1.19 ± 0.02^{d}	598.75	<0.01	0.05	1.74 ± 0.02^{a}	1.66 ± 0.02^{b}	1.50 ± 0.01^{c}	1.22 ± 0.02^{d}	585.97	<0.01	0.04
iv.	**IV instar**														
	Length (mm)	8.67 ± 0.02^{a}	8.60 ± 0.02^{b}	6.02 ± 0.02^{c}	5.76 ± 0.02^{d}	1658.68	<0.01	0.05	8.70 ± 0.02^{a}	8.65 ± 0.02^{b}	6.05 ± 0.02^{c}	5.80 ± 0.02^{d}	1643.32	<0.01	0.05
	Width (mm)	2.60 ± 0.02^{a}	2.55 ± 0.02^{b}	1.98 ± 0.01^{c}	1.87 ± 0.02^{d}	1585.11	<0.01	0.04	2.64 ± 0.02^{a}	2.59 ± 0.02^{b}	2.00 ± 0.02^{c}	1.90 ± 0.01^{d}	1409.31	<0.01	0.04
3.	**Pupa**														
	Length (mm)	4.96 ± 0.02^{a}	4.95 ± 0.03^{a}	4.12 ± 0.02^{b}	3.86 ± 0.02^{c}	1834.86	<0.01	0.05	5.00 ± 0.02^{a}	4.98 ± 0.02^{a}	4.17 ± 0.02^{b}	3.90 ± 0.02^{c}	1880.73	<0.01	0.05
	Width (mm)	3.22 ± 0.02^{a}	3.20 ± 0.02^{a}	3.00 ± 0.01^{b}	2.75 ± 0.02^{c}	651.99	<0.01	0.04	3.25 ± 0.02^{a}	3.24 ± 0.02^{a}	3.03 ± 0.01^{b}	2.78 ± 0.02^{c}	442.60	<0.01	0.04
4.	**Adult male**														
	Length (mm)	6.00 ± 0.03^{a}	5.94 ± 0.02^{b}	4.85 ± 0.02^{c}	4.32 ± 0.02^{d}	2494.46	<0.01	0.05	6.05 ± 0.02^{a}	5.97 ± 0.02^{b}	4.87 ± 0.02^{c}	4.35 ± 0.02^{d}	2669.49	<0.01	0.05
	Width (mm)	4.52 ± 0.02^{a}	4.45 ± 0.01^{b}	4.00 ± 0.02^{c}	3.76 ± 0.02^{d}	2153.95	<0.01	0.04	4.55 ± 0.02^{a}	4.47 ± 0.02^{b}	4.05 ± 0.02^{c}	3.78 ± 0.02^{d}	2144.07	<0.01	0.05
5.	**Adult female**														
	Length (mm)	6.17 ± 0.02^{a}	6.10 ± 0.02^{b}	5.37 ± 0.02^{c}	4.98 ± 0.02^{d}	2438.14	<0.01	0.05	6.20 ± 0.02^{a}	6.12 ± 0.02^{b}	5.40 ± 0.03^{c}	5.00 ± 0.02^{d}	2154.95	<0.01	0.05
	Width (mm)	4.77 ± 0.02^{a}	4.50 ± 0.02^{b}	4.20 ± 0.02^{c}	3.97 ± 0.02^{d}	972.03	<0.01	0.05	4.79 ± 0.03^{a}	4.53 ± 0.02^{b}	4.22 ± 0.02^{c}	4.00 ± 0.02^{d}	909.17	<0.01	0.05

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.
Means within rows were separated by Tukey's Honestly Significant Difference.

Table 16: Measurement of various life stages of *C. transversalis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016 (Pooled) (n=10)

Sl. No.	Parameters	Measurement of various stages of *C. transversalis* under the influence of different temperatures (Mean ± SEm)						
		Pooled						
		20°C	25°C	30°C	35°C	F value	P value	$HSD_{p=0.05}$
1.	**Egg**							
	Length (mm)	1.31 ± 0.02[a]	1.28 ± 0.02[a]	1.22 ± 0.01[b]	1.16 ± 0.02[c]	52.87	<0.01	0.04
	Width (mm)	0.54 ± 0.02[a]	0.49 ± 0.01[b]	0.40 ± 0.02[c]	0.35 ± 0.02[d]	91.31	<0.01	0.04
2.	**Larva**							
i.	**I instar**							
	Length (mm)	2.58 ± 0.02[a]	2.51 ± 0.02[b]	1.67 ± 0.02[c]	1.50 ± 0.02[d]	2113.37	<0.01	0.05
	Width (mm)	0.81 ± 0.02[a]	0.76 ± 0.02[b]	0.64 ± 0.01[c]	0.59 ± 0.02[d]	169.90	<0.01	0.04
ii.	**II instar**							
	Length (mm)	3.54 ± 0.02[a]	3.49 ± 0.02[b]	3.24 ± 0.01[c]	3.02 ± 0.02[d]	840.26	<0.01	0.04
	Width (mm)	1.31 ± 0.02[a]	1.25 ± 0.02[b]	1.11 ± 0.01[c]	0.95 ± 0.02[d]	333.96	<0.01	0.04
iii.	**III instar**							
	Length (mm)	5.88 ± 0.02[a]	5.75 ± 0.02[b]	4.87 ± 0.02[c]	4.34 ± 0.02[d]	2813.67	<0.01	0.05
	Width (mm)	1.72 ± 0.02[a]	1.65 ± 0.02[b]	1.49 ± 0.01[c]	1.21 ± 0.02[d]	592.29	<0.01	0.04
iv.	**IV instar**							
	Length (mm)	8.69 ± 0.02[a]	8.63 ± 0.02[b]	6.04 ± 0.02[c]	5.78 ± 0.02[d]	1650.97	<0.01	0.05
	Width (mm)	2.62 ± 0.02[a]	2.57 ± 0.02[b]	1.99 ± 0.01[c]	1.89 ± 0.02[d]	1490.49	<0.01	0.04
3.	**Pupa**							
	Length (mm)	4.98 ± 0.02[a]	4.97 ± 0.02[a]	4.15 ± 0.02[b]	3.88 ± 0.02[c]	1857.43	<0.01	0.05
	Width (mm)	3.24 ± 0.02[a]	3.22 ± 0.02[a]	3.02 ± 0.01[b]	2.77 ± 0.02[c]	524.43	<0.01	0.04
4.	**Adult male**							
	Length (mm)	6.03 ± 0.03[a]	5.96 ± 0.02[b]	4.86 ± 0.02[c]	4.34 ± 0.02[d]	2580.04	<0.01	0.05
	Width (mm)	4.54 ± 0.02[a]	4.46 ± 0.01[b]	4.03 ± 0.02[c]	3.77 ± 0.02[d]	2149.03	<0.01	0.04
5.	**Adult female**							
	Length (mm)	6.19 ± 0.02[a]	6.11 ± 0.02[b]	5.39 ± 0.02[c]	4.99 ± 0.02[d]	2287.33	<0.01	0.05
	Width (mm)	4.78 ± 0.02[a]	4.52 ± 0.02[b]	4.22 ± 0.02[c]	3.99 ± 0.02[d]	939.83	<0.01	0.05

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance. Means within rows were separated by Tukey's Honestly Significant Difference.

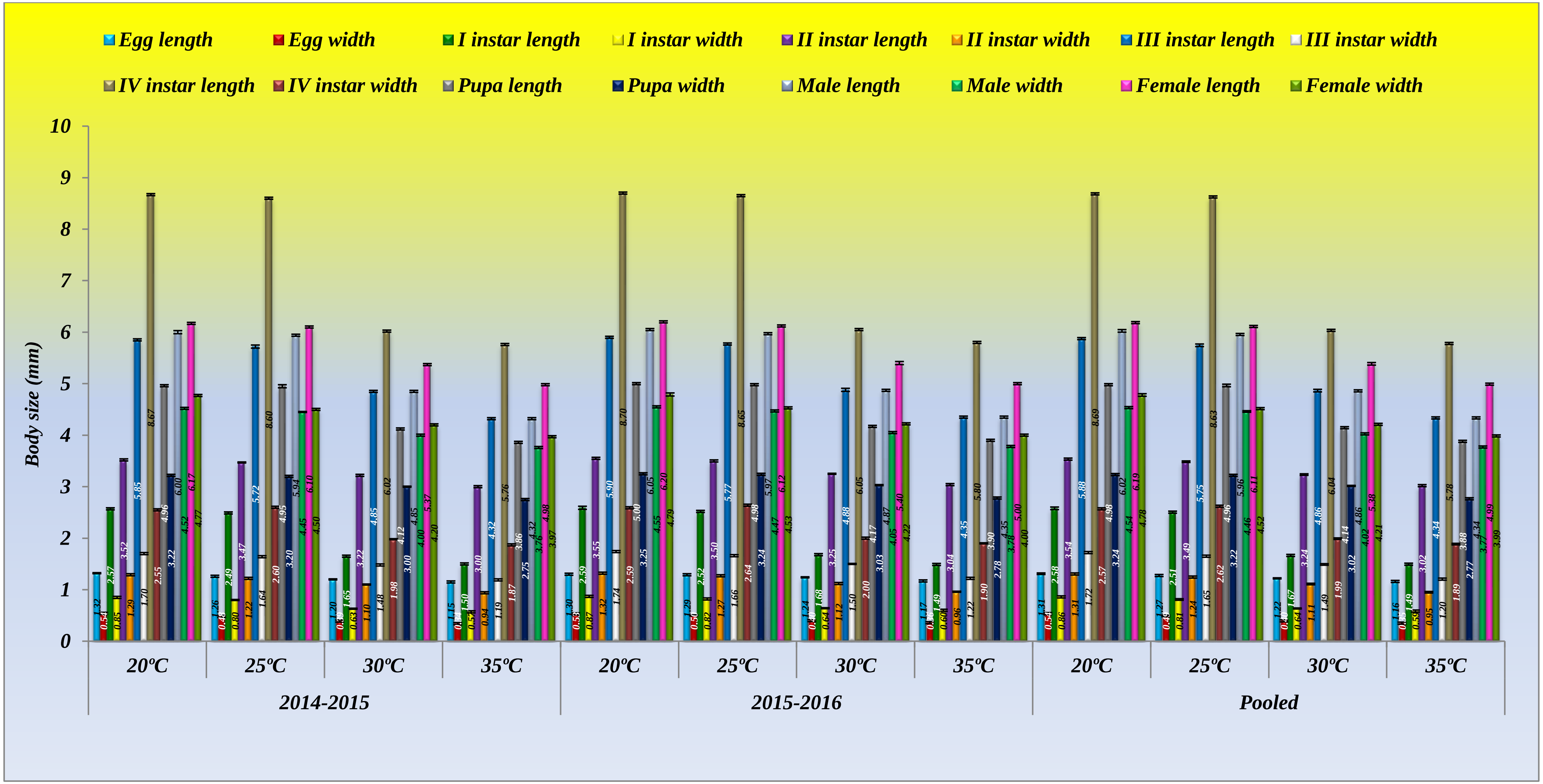

Fig 9: Measurement of various life stages of *C. transversalis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

mm and (5.78 ± 0.02 to 8.69 ± 0.02 mm and 1.89 ± 0.02 to 2.62 ± 0.02 mm), respectively at 35°C to 20°C.

The length of first, second, third and fourth instar grubs showed longest at 20°C with 2.57 ± 0.02 and 2.59 ± 0.03 mm, 3.52 ± 0.02 and 3.55 ± 0.02 mm, 5.85 ± 0.02 and 5.90 ± 0.02 mm and 8.67 ± 0.02 and 8.70 ± 0.02 mm while means was 2.58 ± 0.02, 3.54 ± 0.02, 5.88 ± 0.02 and 8.69 ± 0.02 mm during 2014-2015 and 2015-2016, respectively whereas the shortest length was recorded at 35°C with 1.50 ± 0.02 and 1.49 ± 0.02 mm, 3.00 ± 0.02 and 3.04 ± 0.02 mm, 4.32 ± 0.02 and 4.35 ± 0.02 mm and 5.76 ± 0.02 and 5.80 ± 0.02 mm while means was 1.50 ± 0.02, 3.02 ± 0.02, 4.34 ± 0.02 and 5.78 ± 0.02 mm, respectively. In contrast with the width of the first, second, third and fourth instar grubs among different temperature regimes, the longest was also recorded at 20°C with 0.80 ± 0.02 and 0.82 ± 0.02 mm, 1.29 ± 0.02 and 1.32 ± 0.02 mm, 1.70 ± 0.02 and 1.74 ± 0.02 mm and 2.60 ± 0.02 and 2.64 ± 0.02 mm while means was 0.81 ± 0.02, 1.31 ± 0.02, 1.72 ± 0.02 and 2.62 ± 0.02 mm during 2014-2015 and 2015-2016, respectively whereas the shortest length was recorded at 35°C with 0.57 ± 0.02 and 0.60 ± 0.02 mm, 0.94 ± 0.02 and 0.96 ± 0.01 mm, 1.19 ± 0.02 and 1.22 ± 0.02 mm and 1.87 ± 0.02 and 1.90 ± 0.01 mm while means was 0.59 ± 0.02, 0.95 ± 0.02, 1.21 ± 0.02 and 1.89 ± 0.02 mm, respectively.

The present results are in agreement with the findings of Chakraborty and Korat (2014) who reported that the average length and width of the first, second, third and fourth instar grubs of *C. transversalis* were 2.49 ± 0.02 and 0.76 ± 0.01 mm, 3.47 ± 0.02 and 1.03 ± 0.01 mm, 5.72 ± 0.02 and 1.47 ± 0.02 mm and 9.48 ± 0.06 and 2.49 ± 0.01 mm, respectively at 25°C.

4.3.2.3. Pupa size

From table 15 and 16 and fig. 9 presented, the data showed as the temperature increase the pupa size of *C. transversalis* reduced significantly from 4.96 ± 0.02 and 5.00 ± 0.02 to 3.86 ± 0.02 and 3.90 ± 0.02 mm in length and 3.22 ± 0.02 and 3.25 ± 0.02 to 2.75 ± 0.02 and 2.78 ± 0.02 mm in width at 20°C to 35°C during 2014-2015 and 2015-2016, respectively. The longest pupa length was recorded at 20°C with 4.96 ± 0.02 and 5.00 ± 0.02 mm during 2014-2015 and 2015-2016, respectively with mean as 4.98 ± 0.02 mm followed by 4.95 ± 0.03 and 4.98 ± 0.02 mm, 4.12 ± 0.02 and 4.17 ± 0.02 mm and 3.86 ± 0.02 and 3.90 ± 0.02 mm with means as 4.97 ± 0.02, 4.15 ± 0.02 and 3.88 ± 0.02 mm at 25°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively. Similarly, the width of the pupa was also recorded longest at 20°C with 3.22 ± 0.02 and 3.25 ± 0.02 mm in with mean as 3.24 ± 0.02 mm during 2014-2015 and 2015-2016, respectively followed by 3.20 ± 0.02 and 3.24 ± 0.02 mm, 3.00 ± 0.01 and 3.03 ± 0.01 mm and 2.75 ± 0.02 and 2.78 ± 0.02 mm with means as 3.22 ± 0.02, 3.02 ± 0.01 and 2.77 ± 0.02 mm at 25°C, 30°C and 35°C during 2014-2015 and 2015-2016, respectively.

The present results are quite similar with the findings of Chakraborty and Korat (2014) who reported that the average length and width of the *C. transversalis* pupa were 5.39 ± 0.02 and 3.46 ± 0.04 mm, respectively at 25°C.

4.3.2.4. Adult size

The data indicated that with the increase in temperature the average size of *C. transversalis* adult feeding on *L. erysimi* reduced significantly (Table 15 and 16 and Fig. 9). The mean size of male adult reduced from 6.03 ± 0.03 to 4.34 ± 0.02 mm in length and 4.54 ± 0.02 to 3.77 ± 0.02 mm in width at 20°C to 35°C, respectively whereas mean size of female adult reduced from 6.19 ± 0.02 to 4.99 ± 0.02 mm in length and 4.78 ± 0.02 to 3.99 ± 0.02 mm in width at 20°C to 35°C, respectively.

In contrast between male and female, the results revealed that female size was recorded bigger than male in all the four different temperature regimes. The length and width of the female was recorded longest at 20°C with 6.17 ± 0.02 and 6.20 ± 0.02 mm and 4.77 ± 0.02 and 4.79 ± 0.03 mm while mean was 6.19 ± 0.02 and 4.78 ± 0.02 mm during 2014-2015 and 2015-2016, respectively whereas the shortest was recorded at 35°C with 4.98 ± 0.02 and 5.00 ± 0.02 mm and 3.97 ± 0.02 and 4.00 ± 0.02 mm while mean was 4.99 ± 0.02 and 3.99 ± 0.02 mm, respectively. Similar trends was also observed that the length and width of the male recorded longest at 20°C with 6.00 ± 0.03 and 6.05 ± 0.02 mm and 4.52 ± 0.02 and 4.55 ± 0.02 mm while mean was 6.03 ± 0.03 and 4.54 ± 0.02 mm during 2014-2015 and 2015-2016, respectively, whereas the shortest was recorded at 35°C with 4.32 ± 0.02 and 4.35 ± 0.02 mm and 3.76 ± 0.02 and 3.78 ± 0.02 mm while mean was 4.34 ± 0.02 and 3.77 ± 0.02 mm, respectively.

The present results are in agreement with the findings of Chakraborty and Korat (2014) who reported that the average length and width of the *C. transversalis* male were 5.96 ± 0.02 and 4.53 ± 0.03 mm, respectively whereas female was 6.02 ± 0.01 mm in length and 4.62 ± 0.01 mm in width at 25°C.

4.3.3. Measurement of head capsule of *Coccinella transversalis* reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

4.3.3.1. Larva

The results revealed that with the advancement of growth, the average head capsule size between the larval instars of *C. transversalis* increased significantly (Table 17 and 18 and Fig. 10). There was significant difference in length and width of head capsule among different larval instars at four different temperature regimes. The mean head capsule length and width of first, second, third and fourth instar grubs ranged from (0.293 ± 0.01 to 0.320 ± 0.01 mm and 0.462 ± 0.01 to 0.510 ± 0.01 mm), (0.534 ± 0.01 to 0.569 ± 0.01 mm and 0.869 ± 0.02 to 1.04 ± 0.02 mm), (0.656 ± 0.01 to 0.677 ± 0.02 mm and 0.965 ± 0.01 to 1.19 ± 0.01 mm) and (0.967 ± 0.01 to 1.17 ± 0.01 mm and 1.83 ± 0.02 to 2.09 ± 0.02 mm), respectively at 35°C to 20°C.

The head capsule length of first, second, third and fourth instar grubs showed longest at 20°C with 0.320 ± 0.01 and 0.322 ± 0.01 mm, 0.567 ± 0.02 and 0.570 ± 0.01 mm, 0.675 ± 0.02 and 0.679 ± 0.02 mm and 1.16 ± 0.02 and 1.18 ± 0.01 mm while means was 0.321 ± 0.01, 0.569 ± 0.01, 0.677 ± 0.02 and 1.17 ± 0.01 mm during 2014-2015 and 2015-2016, respectively whereas the shortest length was recorded at 35°C with 0.286 ± 0.01 and 0.299 ± 0.01 mm, 0.532 ± 0.01 and 0.535 ± 0.01 mm, 0.654 ± 0.01 and 0.657 ± 0.02 mm and 0.965 ± 0.01 and 0.968 ± 0.01 mm while means was 0.293 ± 0.01, 0.534 ± 0.01, 0.656 ± 0.01 and 0.967 ± 0.01 mm, respectively. In contrast with the width of the first, second, third and fourth instar grubs among different temperatures, the longest was also recorded at 20°C with 0.509 ± 0.01 and 0.511 ± 0.01 mm, 1.06 ± 0.02 and 1.02 ± 0.02 mm, 1.17 ± 0.01 and 1.21 ± 0.02 mm and 2.07 ± 0.02 and 2.10 ± 0.02 mm while means was 0.510 ± 0.01, 1.04 ± 0.02, 1.17 ± 0.01 and 2.09 ± 0.02 mm during 2014-2015 and 2015-2016, respectively whereas the shortest length was recorded at 35°C with 0.460 ± 0.01 and 0.463 ± 0.01 mm, 0.868 ± 0.02 and 0.870 ± 0.02 mm, 0.963 ± 0.01 and 0.967 ± 0.01 mm and 1.81 ± 0.02 and 1.84 ± 0.02 mm while means was 0.462 ± 0.01, 0.869 ± 0.02, 0.965 ± 0.01 and 1.83 ± 0.02 mm, respectively.

Since no specific literature were available regarding the head capsule size of *C. septempunctata* larva, therefore no further comparison could be conducted with the present findings.

4.3.3.2. Adult

The data pertained in table 17 and 18 and fig. 10 showed that with the increase in

Table 17: Measurement of head capsule of *C. transversalis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016 (n=10)

Sl. No.	Parameters	Measurement of head capsule of *C. transversalis* under the influence of different temperatures (Mean ± SEm)													
		2014-2015							2015-2016						
		20°C	25°C	30°C	35°C	F value	P value	HSD p=0.05	20°C	25°C	30°C	35°C	F value	P value	HSD p=0.05
1.	**Larva**														
i.	**I instar**														
	Length (mm)	0.320 ± 0.01^{a}	0.314 ± 0.01^{a}	0.305 ± 0.01^{b}	0.286 ± 0.01^{c}	71.43	<0.01	0.03	0.322 ± 0.01^{a}	0.317 ± 0.01^{a}	0.307 ± 0.01^{b}	0.289 ± 0.01c	82.22	<0.01	0.03
	Width (mm)	0.509 ± 0.01^{a}	0.498 ± 0.01^{a}	0.488 ± 0.01^{b}	0.460 ± 0.01^{c}	153.26	<0.01	0.03	0.511 ± 0.01^{a}	0.502 ± 0.01^{a}	0.491 ± 0.01^{b}	0.463 ± 0.01^{c}	134.56	<0.01	0.03
ii.	**II instar**														
	Length (mm)	0.567 ± 0.02^{a}	0.562 ± 0.01^{a}	0.547 ± 0.01^{b}	0.532 ± 0.01^{c}	92.00	<0.01	0.03	0.570 ± 0.01^{a}	0.565 ± 0.02^{a}	0.549 ± 0.01^{b}	0.535 ± 0.01^{c}	97.62	<0.01	0.03
	Width (mm)	1.06 ± 0.02^{a}	0.976 ± 0.01^{b}	0.882 ± 0.01^{c}	0.868 ± 0.02^{d}	254.47	<0.01	0.04	1.02 ± 0.12^{a}	0.980 ± 0.01^{a}	0.887 ± 0.01^{b}	0.870 ± 0.02^{c}	209.35	<0.01	0.04
iii.	**III instar**														
	Length (mm)	0.675 ± 0.02^{a}	0.668 ± 0.01^{a}	0.651 ± 0.01^{b}	0.654 ± 0.01^{b}	8.48	<0.01	0.03	0.679 ± 0.02^{a}	0.672 ± 0.01^{a}	0.655 ± 0.01^{b}	0.657 ± 0.02$^{\mathbf{b}}$	10.53	<0.01	0.04
	Width (mm)	1.17 ± 0.01^{a}	1.08 ± 0.02^{b}	1.01 ± 0.01^{c}	0.963 ± 0.01^{d}	196.45	<0.01	0.03	1.21 ± 0.02^{a}	1.11 ± 0.02^{b}	1.05 ± 0.01^{c}	0.967 ± 0.01^{d}	146.45	<0.01	0.04
iv.	**IV instar**														
	Length (mm)	1.16 ± 0.02^{a}	1.11 ± 0.02^{b}	1.01 ± 0.01^{c}	0.965 ± 0.01^{d}	128.78	<0.01	0.04	1.18 ± 0.01^{a}	1.14 ± 0.02^{b}	1.05 ± 0.01^{c}	0.968 ± 0.01^{d}	157.36	<0.01	0.04
	Width (mm)	2.07 ± 0.02^{a}	1.99 ± 0.03^{b}	1.87 ± 0.02^{c}	1.81 ± 0.02^{d}	89.82	<0.01	0.05	2.10 ± 0.02^{a}	2.02 ± 0.02^{b}	1.89 ± 0.02^{c}	1.84 ± 0.02^{d}	91.30	<0.01	0.05
2.	**Adult male**														
	Length (mm)	1.26 ± 0.01^{a}	1.24 ± 0.02^{a}	1.18 ± 0.02^{b}	1.12 ± 0.02^{c}	49.15	<0.01	0.04	1.28 ± 0.01^{a}	1.26 ± 0.02^{a}	1.21 ± 0.02^{b}	1.15 ± 0.01^{c}	42.72	<0.01	0.04
	Width (mm)	2.80 ± 0.02^{a}	2.77 ± 0.02^{a}	2.70 ± 0.02^{b}	2.47 ± 0.02^{c}	184.09	<0.01	0.05	2.83 ± 0.02^{a}	2.80 ± 0.02^{a}	2.73 ± 0.02^{b}	2.50 ± 0.02^{c}	194.96	<0.01	0.05
3.	**Adult female**														
	Length (mm)	1.38 ± 0.02^{a}	1.33 ± 0.02^{a}	1.26 ± 0.02^{b}	1.19 ± 0.02^{c}	74.34	<0.01	0.05	1.35 ± 0.01^{a}	1.36 ± 0.02^{a}	1.28 ± 0.02^{b}	1.21 ± 0.02^{c}	62.81	<0.01	0.04
	Width (mm)	2.87 ± 0.02^{a}	2.81 ± 0.03^{b}	2.66 ± 0.02^{c}	2.58 ± 0.02^{d}	96.33	<0.01	0.05	2.89 ± 0.02^{a}	2.84 ± 0.02^{b}	2.70 ± 0.02^{c}	2.56 ± 0.02^{d}	107.19	<0.01	0.05

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.
Means within rows were separated by Tukey's Honestly Significant Difference.

Table 18: Measurement of head capsule of *C. transversalis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016 (Pooled) (n=10)

Sl. No.	Parameters	Measurement of head capsule of *C. transversalis* under the influence of different temperatures (Mean ± SEm)						
		Pooled						
		20ºC	25ºC	30ºC	35ºC	F value	P value	$HSD_{p=0.05}$
1.	**Larva**							
i.	**I instar**							
	Length (mm)	0.321 ± 0.01[a]	0.316 ± 0.01[a]	0.306 ± 0.01[b]	0.293 ± 0.01[c]	76.39	<0.01	0.03
	Width (mm)	0.510 ± 0.01[a]	0.500 ± 0.01[a]	0.490 ± 0.01[b]	0.462 ± 0.01[c]	143.43	<0.01	0.03
ii.	**II instar**							
	Length (mm)	0.569 ± 0.01[a]	0.564 ± 0.02[a]	0.548 ± 0.01[b]	0.534 ± 0.01[c]	94.74	<0.01	0.03
	Width (mm)	1.04 ± 0.02[a]	0.978 ± 0.01[b]	0.885 ± 0.01[c]	0.869 ± 0.02[d]	233.63	<0.01	0.03
iii.	**III instar**							
	Length (mm)	0.677 ± 0.02[a]	0.670 ± 0.01[a]	0.653 ± 0.01[b]	0.656 ± 0.01[b]	9.44	<0.01	0.03
	Width (mm)	1.19 ± 0.01[a]	1.10 ± 0.02[b]	1.03 ± 0.01[c]	0.965 ± 0.01[d]	165.00	<0.01	0.03
iv.	**IV instar**							
	Length (mm)	1.17 ± 0.01[a]	1.13 ± 0.02[b]	1.03 ± 0.01[c]	0.967 ± 0.01[d]	142.98	<0.01	0.04
	Width (mm)	2.09 ± 0.02[a]	2.01 ± 0.02[b]	1.88 ± 0.02[c]	1.83 ± 0.02[d]	90.54	<0.01	0.05
2.	**Adult male**							
	Length (mm)	1.27 ± 0.01[a]	1.25 ± 0.02[a]	1.20 ± 0.02[b]	1.14 ± 0.01[c]	46.21	<0.01	0.04
	Width (mm)	2.82 ± 0.02[a]	2.79 ± 0.02[a]	2.72 ± 0.02[b]	2.49 ± 0.02[c]	189.29	<0.01	0.05
3.	**Adult female**							
	Length (mm)	1.37 ± 0.01[a]	1.35 ± 0.02[a]	1.27 ± 0.02[b]	1.20 ± 0.02[c]	68.99	<0.01	0.04
	Width (mm)	2.88 ± 0.02[a]	2.83 ± 0.02[b]	2.68 ± 0.02[c]	2.57 ± 0.02[d]	101.79	<0.01	0.05

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance. Means within rows were separated by Tukey's Honestly Significant Difference.

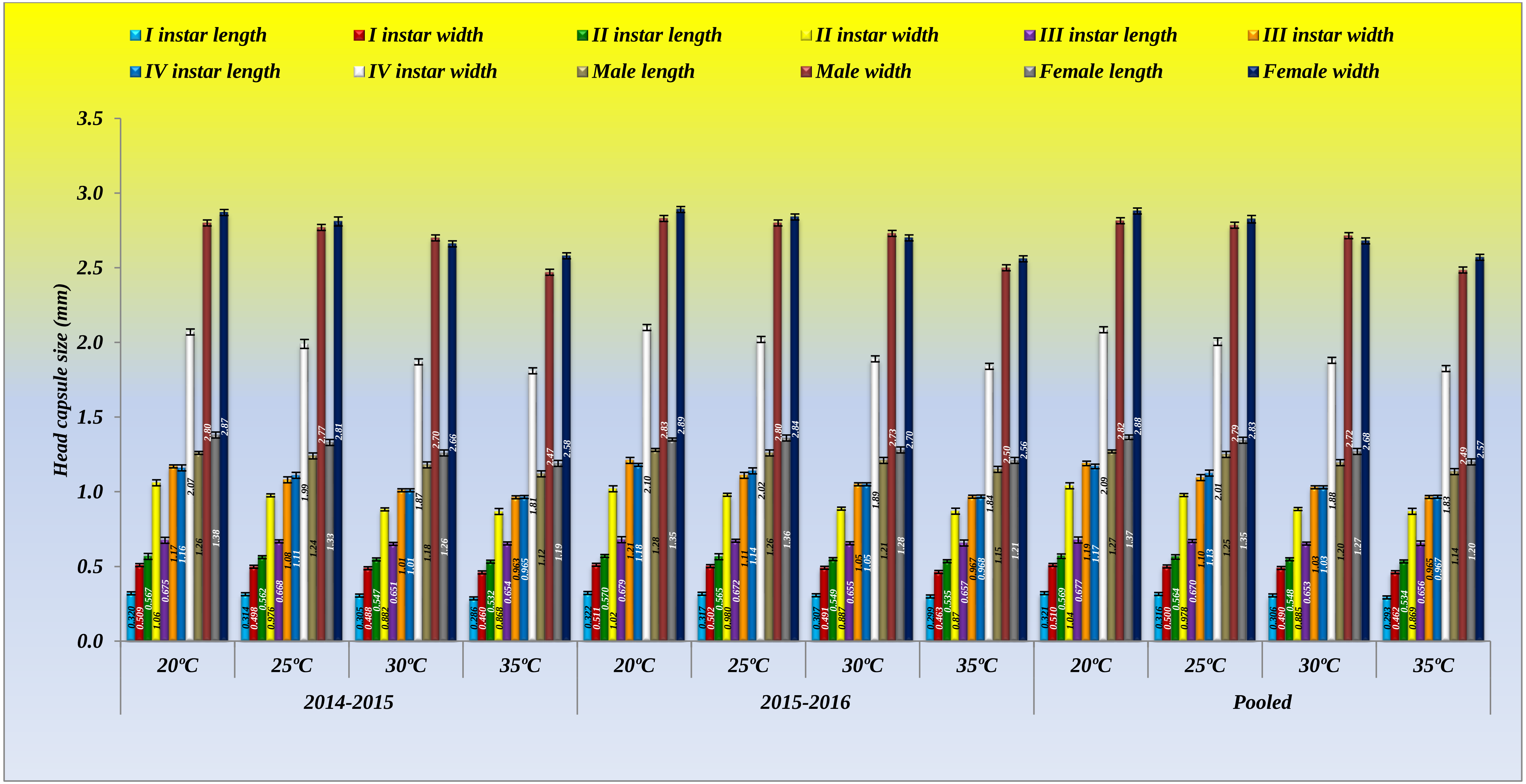

Fig 10: Measurement of head capsule of *C. transversalis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

temperature the average head capsule size of *C. transversalis* adult feeding on *L. erysimi* reduced significantly from 1.26 ± 0.01 and 1.28 ± 0.01 to 1.12 ± 0.02 and 1.15 ± 0.01 mm in length and 2.80 ± 0.02 and 2.83 ± 0.02 to 2.47 ± 0.02 and 2.50 ± 0.02 mm in width on male and 1.38 ± 0.02 and 1.35 ± 0.01 to 1.19 ± 0.02 and 1.21 ± 0.02 mm in length and 2.87 ± 0.02 and 2.89 ± 0.02 to 2.58 ± 0.02 and 2.56 ± 0.02 mm in width on female at 20°C to 35°C during 2014-2015 and 2015-2016, respectively.

In contrast between male and female, the results revealed that female head capsule size was recorded bigger than male in all the four different temperature regimes. The length and width of the female head capsule was recorded longest at 20°C with 1.38 ± 0.02 and 1.35 ± 0.01 mm and 2.87 ± 0.02 and 2.89 ± 0.02 mm while mean was 1.37 ± 0.01 and 2.88 ± 0.02 mm during 2014-2015 and 2015-2016, respectively whereas the shortest was recorded at 35°C with 1.19 ± 0.02 and 1.21 ± 0.02 mm and 2.58 ± 0.02 and 2.56 ± 0.02 mm while mean was 1.20 ± 0.02 and 2.57 ± 0.02 mm, respectively. Similar trends was also observed on male head capsule that the length and width recorded longest at 20°C with 1.26 ± 0.01 and 1.28 ± 0.01 mm and 2.80 ± 0.02 and 2.83 ± 0.02 mm while mean was 1.27 ± 0.01 and 2.82 ± 0.02 mm during 2014-2015 and 2015-2016, respectively whereas the shortest was recorded at 35°C with 1.12 ± 0.02 and 1.15 ± 0.01 mm and 2.47 ± 0.19 and 2.50 ± 0.17 mm while mean was 1.14 ± 0.01 and 2.49 ± 0.02 mm, respectively.

Since no specific literature were available regarding the head capsule size of *C. septempunctata* adult, therefore no further comparison could be conducted with the present findings.

4.4. Feeding potential of *Coccinella septempunctata* reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

4.4.1. Feeding potential of *Coccinella septempunctata* grubs reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

The feeding potential of different immature developmental stages of *C. septempunctata* reared on *L. erysimi* exhibited significant difference with respect to all temperatures. Initially with the increase in temperature the predation level increased up to a certain level beyond which the rate of predation goes decline. The results revealed that the mean feeding potential of first, second, third and fourth instars with prey density of 20, 30, 40 and 50 ranged from 5.28 ± 0.62 to 11.53 ± 0.72, 10.98 ± 0.66 to 21.38 ± 0.90, 19.08 ± 0.82 to 36.38 ± 0.86 and 23.53 ± 0.75 to 43.90 ± 0.94 aphids per grub per day at four different temperatures and total larval feeding potential ranged from 58.85 ± 2.86 to 113.18 ± 3.42 aphids per grub (Table 19, 20 and 21 and Fig. 11a). However, the highest feeding potential of first, second, third and fourth instars of *C. septempunctata* were recorded about 10.80 ± 0.81 and 12.25 ± 0.63, 22.30 ± 0.86 and 20.45 ± 0.94, 35.50 ± 0.97 and 37.25 ± 0.74 and 45.20 ± 0.87 and 42.60 ± 1.01 aphids per grub per day at 25°C during 2014-2015 and 2015-2016, respectively with means as 11.53 ± 0.72, 21.38 ± 0.90, 36.38 ± 0.86 and 43.90 ± 0.94 aphids per grub per day. As the temperature increase beyond 25°C, the feeding potential of first, second, third and fourth instars decreased significantly to (5.80 ± 0.65 and 7.35 ± 0.61 and 4.75 ± 0.56 and 5.80 ± 0.68), (14.25 ± 0.57 and 12.70 ± 0.56 and 10.50 ± 0.64 and 11.45 ± 0.68), (25.60 ± 0.96 and 27.20 ± 1.00 and 19.45 ± 0.82 and 18.70 ± 0.83) and (34.50 ± 1.02 and 35.75 ± 0.99 and 22.25 ± 0.71 and 24.80 ± 0.79) aphids per grub per day during 2014-2015 and 2015-2016 at 30°C and 35°C, respectively with means as 6.58 ± 0.63 and 5.28 ± 0.62, 13.48 ± 0.57 and 10.98 ± 0.66, 26.40 ± 0.98 and 19.08 ± 0.82 and 35.13 ± 1.01 and 23.53 ± 0.75 aphids per grub per day.

Regarding the total aphid consumption, the feeding potential of first, second, third and fourth instars of *C. septempunctata* ranged from 11.21 ± 2.20 to 37.20 ± 3.92, 24.64 ± 2.90 to 74.39 ± 7.77, 49.48 ± 7.37 to 178.29 ± 9.70 and 63.75 ± 3.94 to 234.63 ± 12.09 aphids per grub at four different temperature regimes and total larval feeding potential ranged from 149.08 ± 16.40 to 542.83 ± 41.36 aphids per grub (Table 22, 23 and 24 and Fig. 11b). The highest total aphid consumption of first, second, third and fourth instars was also recorded at 25°C with 32.40 ± 4.66 and 42.00 ± 3.17, 82.65 ± 9.91 and 66.13 ± 5.62, 168.85 ± 12.00 and 187.73 ± 7.40 and 235.20 ± 11.82 and 234.05 ± 12.37 aphids per grub during 2014-2015 and 2015-2016, respectively while means was 37.20 ± 3.92, 74.39 ± 7.77, 178.29 ± 9.70 and 234.63 ± 12.09 aphids per grub. The data indicated that as the temperature increase beyond 25°C, the feeding potential of first, second, third and fourth instars decreased significantly and revealed that the lowest total aphid consumption of first, second, third and fourth instars were recorded about 9.88 ± 1.98 and 12.55 ± 2.43, 22.35 ± 2.00 and 26.93 ± 3.80, 49.10 ± 7.31 and 49.85 ± 7.42 and 60.95 ± 3.48 and 66.55 ± 4.40 aphids per grub at 35°C during 2014-2015 and 2015-2016, respectively with means as 11.21 ± 2.20, 24.64 ± 2.90, 49.48 ± 7.37 and 63.75 ± 3.94 aphids per grub.

The present results are close with the findings of few researchers who have

Table 19: Average number of aphids consumed by *C. septempunctata* and *C. transversalis* per individual per day reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 (n=10)

Stages of coccinellid Beetles	No. of prey provided to coccinellid beetles per day	Average no. of aphids consumed per individual per day (Mean ± SEm)						
		2014-2015						
		20ºC	25ºC	30ºC	35ºC	F value	P value	$HSD_{P=0.05}$
C. septempunctata								
I instar	20	7.25 ± 0.73^{b}	10.80 ± 0.81^{a}	5.80 ± 0.65^{b}	4.75 ± 0.56^{b}	14.47	<0.01	2.64
II instar	30	15.70 ± 0.68^{b}	22.30 ± 0.86^{a}	14.25 ± 0.57^{b}	10.50 ± 0.64^{c}	50.05	<0.01	2.65
III instar	40	33.45 ± 0.81^{a}	35.50 ± 0.97^{a}	25.60 ± 0.96^{b}	19.45 ± 0.82^{c}	68.65	<0.01	3.40
IV instar	50	40.50 ± 1.07^{b}	45.20 ± 0.87^{a}	34.50 ± 1.02^{c}	22.25 ± 0.71^{d}	114.34	<0.01	3.54
Total instar		96.90 ± 3.29^{b}	113.80 ± 3.51^{a}	80.15 ± 3.20^{c}	56.95 ± 2.73^{d}	208.96	<0.01	6.39
Adult male	60	37.55 ± 0.83^{b}	42.70 ± 1.25^{a}	32.45 ± 0.87^{c}	20.80 ± 0.88^{d}	92.91	<0.01	3.70
Adult female	60	46.20 ± 1.00^{a}	50.35 ± 1.35^{a}	38.50 ± 1.16^{b}	25.25 ± 0.86^{c}	99.47	<0.01	4.21
Average adult	60	41.88 ± 0.91^{b}	46.53 ± 1.30^{a}	35.48 ± 1.01^{c}	23.03 ± 0.87^{d}	162.63	<0.01	3.05
C. transversalis								
I instar	20	6.30 ± 0.58^{b}	10.20 ± 0.59^{a}	4.70 ± 0.40^{bc}	3.50 ± 0.34^{c}	35.52	<0.01	1.86
II instar	30	11.75 ± 0.66^{b}	14.65 ± 0.93^{a}	10.25 ± 0.57^{b}	6.20 ± 0.51^{c}	26.40	<0.01	2.61
III instar	40	22.80 ± 0.77^{b}	27.25 ± 0.81^{a}	17.50 ± 0.76^{c}	12.65 ± 0.62^{d}	72.13	<0.01	2.84
IV instar	50	30.45 ± 1.07^{b}	36.40 ± 0.93^{a}	22.65 ± 0.67^{c}	18.40 ± 0.78^{d}	83.96	<0.01	3.34
Total instar		71.30 ± 3.08^{b}	88.50 ± 3.26^{a}	55.10 ± 2.40^{c}	40.75 ± 2.25^{d}	157.82	<0.01	6.25
Adult male	60	30.20 ± 1.02^{b}	34.70 ± 1.07^{c}	21.80 ± 1.03^{c}	16.70 ± 0.96^{d}	63.43	<0.01	3.88
Adult female	60	37.55 ± 1.31^{b}	43.25 ± 1.16^{a}	30.75 ± 1.15^{c}	22.60 ± 0.95^{d}	60.23	<0.01	4.37
Average adult	60	33.88 ± 1.16^{b}	38.98 ± 1.11^{a}	26.28 ± 1.09^{c}	19.65 ± 0.95^{d}	102.42	<0.01	3.20

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance. Means within rows were separated by Tukey's Honestly Significant Difference.

Table 20: Average number of aphids consumed by *C. septempunctata* and *C. transversalis* per individual per day reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2015-2016 (n=10)

Stages of coccinellid Beetles	No. of prey provided to coccinellid beetles per day	Average no. of aphids consumed per individual per day (Mean ± SEm)						
		2015-2016						
		20ºC	25ºC	30ºC	35ºC	F value	P value	HSD$_{P=0.05}$
C. septempunctata								
I instar	20	8.50 ± 0.82^{b}	12.25 ± 0.63^{a}	7.35 ± 0.61^{bc}	5.80 ± 0.68^{c}	15.93	<0.01	2.62
II instar	30	17.45 ± 0.79^{b}	20.45 ± 0.94^{a}	12.70 ± 0.56^{c}	11.45 ± 0.68^{c}	30.50	<0.01	2.89
III instar	40	30.70 ± 0.79^{b}	37.25 ± 0.74^{a}	27.20 ± 1.00^{c}	18.70 ± 0.83^{d}	83.50	<0.01	3.22
IV instar	50	40.50 ± 1.15^{a}	42.60 ± 1.01^{a}	35.75 ± 0.99^{b}	24.80 ± 0.79^{c}	64.14	<0.01	3.78
Total instar		97.15 ± 3.55^{b}	112.55 ± 3.33^{a}	83.00 ± 3.15^{c}	60.75 ± 2.98^{d}	157.93	<0.01	6.67
Adult male	60	38.70 ± 1.02^{b}	44.35 ± 1.27^{a}	34.40 ± 0.70^{c}	22.20 ± 0.70^{d}	97.02	<0.01	3.64
Adult female	60	45.35 ± 0.97^{b}	52.70 ± 1.11^{a}	40.20 ± 1.00^{c}	26.70 ± 0.56^{d}	138.82	<0.01	3.54
Average adult	60	42.03 ± 0.99^{b}	48.53 ± 1.19^{a}	37.30 ± 0.85^{c}	24.45 ± 0.63^{d}	289.49	<0.01	2.28
C. transversalis								
I instar	20	7.45 ± 0.68	10.75 ± 0.65^{a}b	5.35 ± 0.41^{c}	4.00 ± 0.33^{c}	29.96	<0.01	2.05
II instar	30	13.20 ± 0.55^{b}	16.30 ± 0.73^{a}	11.60 ± 0.54^{b}	6.75 ± 0.58^{c}	43.08	<0.01	2.31
III instar	40	24.25 ± 1.01^{a}	25.50 ± 0.75^{a}	19.25 ± 0.71^{b}	14.50 ± 0.73^{c}	38.63	<0.01	3.09
IV instar	50	31.70 ± 1.04^{b}	35.35 ± 0.85^{a}	24.20 ± 0.74^{c}	20.20 ± 0.79^{d}	63.92	<0.01	3.29
Total instar		76.60 ± 3.28^{b}	87.90 ± 2.98^{a}	60.40 ± 2.40^{c}	45.45 ± 2.44^{d}	136.64	<0.01	6.05
Adult male	60	28.80 ± 1.04^{b}	36.50 ± 1.02^{a}	23.40 ± 0.97^{c}	18.25 ± 0.69^{d}	68.71	<0.01	3.59
Adult female	60	38.20 ± 1.02^{b}	44.60 ± 1.18^{a}	33.45 ± 1.04^{c}	24.30 ± 0.79^{d}	70.84	<0.01	3.87
Average adult	60	33.50 ± 1.03^{b}	40.55 ± 1.10^{a}	28.43 ± 1.00^{c}	21.28 ± 0.74^{d}	102.40	<0.01	3.06

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance. Means within rows were separated by Tukey's Honestly Significant Difference.

Table 21: Average number of aphids consumed by *C. septempunctata* and *C. transversalis* per individual per day reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016 (Pooled) (n=10)

Stages of coccinellid Beetles	No. of prey provided to coccinellid beetles per day	Average no. of aphids consumed per individual per day (Mean ± SEm)						
		Pooled						
		20ºC	25ºC	30ºC	35ºC	F value	P value	$HSD_{P=0.05}$
C. septempunctata								
I instar	20	7.88 ± 0.77^{b}	11.53 ± 0.72^{a}	6.58 ± 0.63^{bc}	5.28 ± 0.62^{c}	15.20	<0.01	2.58
II instar	30	16.58 ± 0.74^{b}	21.38 ± 0.90^{a}	13.48 ± 0.57^{c}	10.98 ± 0.66^{c}	39.44	<0.01	2.72
III instar	40	32.08 ± 0.80^{b}	36.38 ± 0.86^{a}	26.40 ± 0.98^{c}	19.08 ± 0.82^{d}	75.68	<0.01	3.25
IV instar	50	40.50 ± 1.11^{a}	43.90 ± 0.94^{a}	35.13 ± 1.01^{b}	23.53 ± 0.75^{c}	87.58	<0.01	3.59
Total instar		97.03 ± 3.42^{b}	113.18 ± 3.42^{a}	81.58 ± 3.18^{c}	58.85 ± 2.86^{d}	182.36	<0.01	6.41
Adult male	60	38.13 ± 0.93^{b}	43.53 ± 1.26^{a}	33.43 ± 0.79^{c}	21.50 ± 0.79^{d}	94.93	<0.01	3.60
Adult female	60	45.78 ± 0.98^{b}	51.53 ± 1.23^{a}	39.35 ± 1.08^{c}	25.98 ± 0.71^{d}	115.77	<0.01	3.82
Average adult	60	41.95 ± 0.95^{b}	47.53 ± 1.24^{a}	36.39 ± 0.93^{c}	23.74 ± 0.75^{d}	208.19	<0.01	2.64
C. transversalis								
I instar	20	6.88 ± 0.63^{b}	10.48 ± 0.62^{a}	5.03 ± 0.40^{bc}	3.75 ± 0.34^{c}	32.49	<0.01	1.92
II instar	30	12.48 ± 0.60^{b}	15.48 ± 0.83^{a}	10.93 ± 0.56^{b}	6.48 ± 0.55^{c}	33.74	<0.01	2.42
III instar	40	23.53 ± 0.89^{a}	26.38 ± 0.78^{a}	18.38 ± 0.74^{b}	13.58 ± 0.68^{c}	54.02	<0.01	2.91
IV instar	50	31.08 ± 1.06^{b}	35.88 ± 0.89^{a}	23.43 ± 0.70^{c}	19.30 ± 0.78^{d}	74.08	<0.01	3.25
Total instar		73.95 ± 3.18^{b}	88.20 ± 3.12^{a}	57.75 ± 2.40^{c}	43.10 ± 2.35^{d}	147.56	<0.01	6.03
Adult male	60	29.50 ± 1.03^{b}	35.60 ± 1.04^{a}	22.60 ± 1.00^{c}	17.48 ± 0.82^{d}	65.86	<0.01	3.67
Adult female	60	37.88 ± 1.16^{b}	43.93 ± 1.17^{a}	32.10 ± 1.09^{c}	23.45 ± 0.87^{d}	64.89	<0.01	4.05
Average adult	60	33.69 ± 1.10^{b}	39.76 ± 1.11^{a}	27.35 ± 1.05^{c}	20.46 ± 0.84^{d}	102.41	<0.01	3.07

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.
Means within rows were separated by Tukey's Honestly Significant Difference.

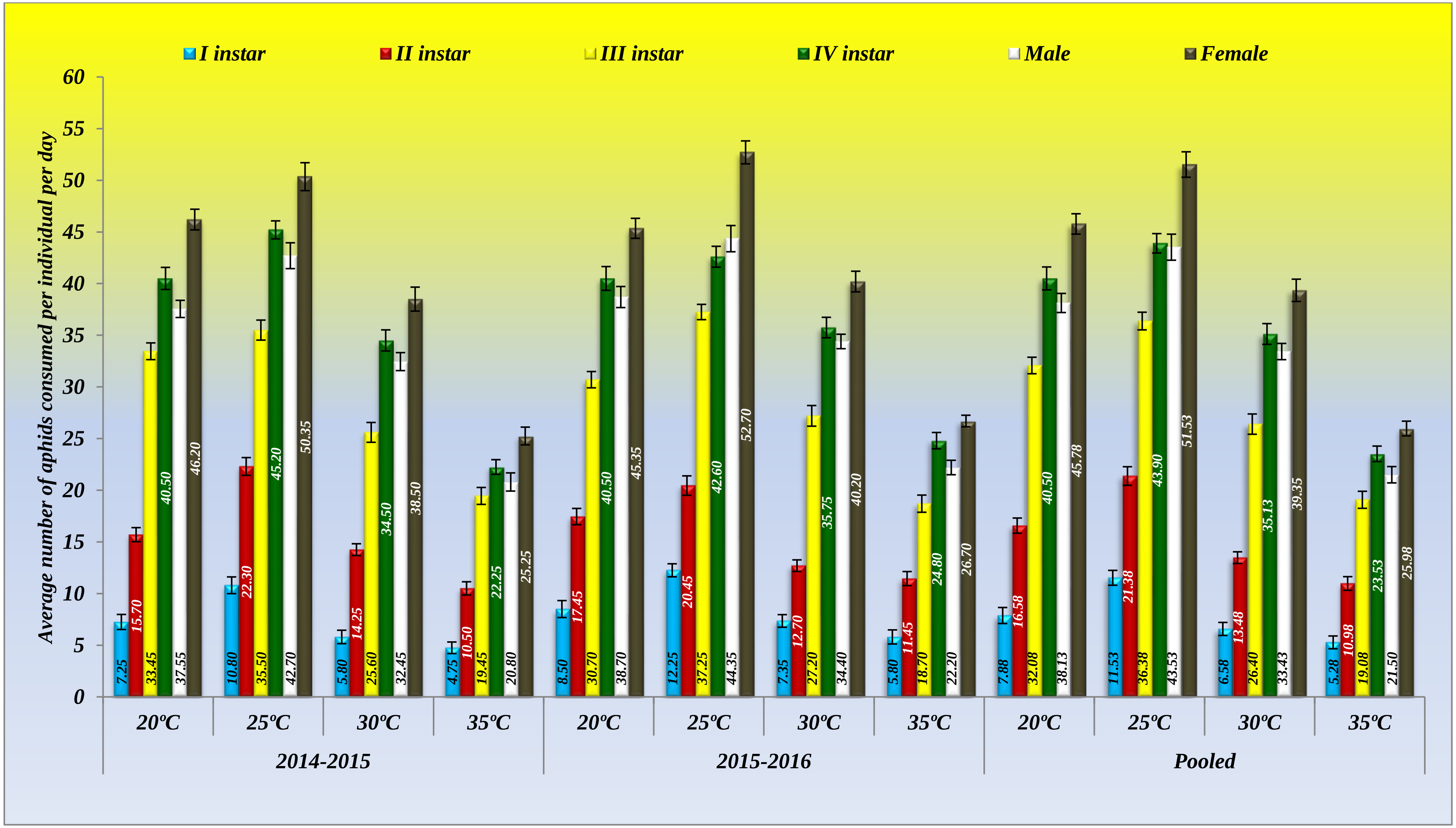

Fig 11a: Average number of aphids consumed by *C. septempunctata* per individual per day reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

reported that the average feeding potential of first, second, third and fourth instars of *C. septempunctata* reared on *L. erysimi* were 11.67 ± 1.33; 28.67 ± 0.33 and 15.17 ± 0.25; 33.00 ± 2.52 and 30.70 ± 0.16 and 36.33 ± 2.19 and 40.50 ± 0.26 aphids per grub per day, respectively at 25°C and 26 ± 3°C (Bilashini *et al.*, 2007; Kumar *et al*., 2012). Nevertheless, the feeding potential by different life stages of *C. septempunctata* showed a high degree of variation but these results are in accordance with the findings of several researchers who have reported that the feeding potential of *C. septempunctata* increased with an increase in age of the larva (Lekha and Jat 2002; Soni *et al*., 2008; Singh *et al*., 2009; Rai *et al*., 2010; Singh and Singh, 2013). The present results showed that the total larval consumption were at close range between 20°C and 25°C and these findings are in conformity with the findings of Tomar and Yadav (2009) who reported that the total larval consumption of *C. septempunctata* grubs on *L. erysimi* was 549.10, 579.40 and 493.80 aphids during three consecutive years under laboratory conditions at 22 ± 2°C. Since no literature were available regarding the feeding potential of *C. septempunctata* grubs reared at temperature beyond 30°C, therefore no further comparison could be conducted with the present findings.

4.4.2. Feeding potential of *Coccinella septempunctata* adults reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

The data pertained in table 19, 20 and 21 and fig. 11c showed that the average feeding potential of *C. septempunctata* adult with prey density of 60 increased from 41.88 ± 0.91 and 42.03 ± 0.99 aphids per beetle per day at 20°C to 46.53 ± 1.30 and 48.53 ± 1.19 aphids per beetle per day at 25°C during 2014-2015 and 2015-2016, then fell down to 36.39 ± 0.93 and 23.74 ± 0.75 per beetle per day at 30°C and 35°C, respectively. In comparison with the adult, the mean feeding potential of female ranged from 25.98 ± 0.71 to 51.53 ± 1.23 aphids per beetle per day and was greater than the adult male (21.50 ± 0.79 to 43.53 ± 1.26 aphids per beetle per day) at four constant temperatures (Table 19, 20 and 21 and Fig. 11c). The highest aphid consumption per beetle per day by *C. septempunctata* beetles was recorded at 25°C with 50.35 ± 1.35 and 52.70 ± 1.11 aphids per beetle per day in female and 42.70 ± 1.25 and 44.35 ± 1.27 aphids per beetle per day in male during 2014-2015 and 2015-2016, respectively whereas the lowest consumption was recorded at 35°C with 25.25 ± 0.86 and 26.70 ± 0.56 aphids per beetle per day in female and 20.80 ± 0.88 and 22.20 ± 0.70 aphids per beetle per day in male during 2014-2015 and 2015-2016, respectively.

Table 22: Total number of aphids consumed by *C. septempunctata* and *C. transversalis* per individual reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 (n=10)

Stages of coccinellid Beetles	Total no. of aphids consumed per individual (Mean ± SEm)						
	2014-2015						
	20ºC	25ºC	30ºC	35ºC	F value	P value	$HSD_{P=0.05}$
C. septempunctata							
I instar	26.90 ± 4.76[a]	32.40 ± 4.66[a]	16.35 ± 4.05[b]	9.88 ± 1.98[b]	21.27	<0.01	8.39
II instar	69.10 ± 7.08[a]	82.65 ± 9.91[a]	40.05 ± 4.59[b]	22.35 ± 2.00[c]	57.48	<0.01	13.74
III instar	173.75 ± 13.43[a]	168.85 ± 12.00[a]	82.40 ± 8.78[b]	49.10 ± 7.31[c]	114.37	<0.01	22.25
IV instar	263.60 ± 19.60[a]	235.20 ± 11.82[b]	144.75 ± 13.47[c]	60.95 ± 3.48[d]	157.30	<0.01	27.94
Total instar	533.35 ± 44.88[a]	519.10 ± 38.39[a]	283.55 ± 30.89[b]	142.28 ± 14.76[c]	331.76	<0.01	39.72
Adult male	1982.50 ± 83.03[a]	2152.10 ± 116.92[a]	1510.50 ± 89.38[b]	836.80 ± 69.74[c]	138.30	<0.01	190.69
Adult female	3044.20 ± 124.77[a]	3106.20 ± 155.85[a]	2089.20 ± 137.95[b]	1203.75 ± 71.97[c]	168.93	<0.01	264.04
Average adult	2513.35 ± 103.90[a]	2629.15 ± 136.39[a]	1799.85 ± 113.67[b]	1020.28 ± 70.86[c]	273.19	<0.01	171.37
C. transversalis							
I instar	16.95 ± 2.91[b]	24.65 ± 4.36[a]	10.05 ± 1.52[c]	6.95 ± 1.47[c]	25.82	<0.01	5.90
II instar	38.65 ± 4.52[a]	41.98 ± 7.32[a]	25.73 ± 3.99[b]	12.80 ± 2.15[c]	25.03	<0.01	10.14
III instar	91.40 ± 12.02[a]	95.68 ± 10.27[a]	52.60 ± 5.26[b]	29.60 ± 3.53[c]	46.36	<0.01	17.76
IV instar	138.88 ± 13.79[a]	145.40 ± 9.78[a]	80.23 ± 6.83[b]	47.65 ± 5.51[c]	81.66	<0.01	19.87
Total instar	285.88 ± 33.24[a]	307.70 ± 31.72[a]	168.60 ± 17.60[b]	97.00 ± 12.66[c]	177.84	<0.01	28.42
Adult male	1016.20 ± 75.78[a]	1113.60 ± 62.69[a]	660.40 ± 43.87[b]	436.80 ± 40.53[c]	99.47	<0.01	120.03
Adult female	1419.75 ± 99.34[a]	1579.15 ± 88.34[a]	1084.10 ± 84.91[b]	688.85 ± 52.85[c]	74.93	<0.01	173.53
Average adult	1217.98 ± 87.56[b]	1346.38 ± 75.52[a]	872.25 ± 64.39[c]	562.83 ± 46.69[d]	127.83	<0.01	119.10

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.

Means within rows were separated by Tukey's Honestly Significant Difference.

Table 23: Total number of aphids consumed by *C. septempunctata* and *C. transversalis* per individual reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2015-2016 (n=10)

Stages of coccinellid beetles	Total no. of aphids consumed per individual (Mean ± SEm)						
	2015-2016						
	20ºC	25ºC	30ºC	35ºC	F value	P value	$HSD_{P=0.05}$
C. septempunctata							
I instar	27.70 ± 4.57[b]	42.00 ± 3.17[a]	21.98 ± 3.44[b]	12.55 ± 2.43[c]	41.59	<0.01	7.28
II instar	79.85 ± 6.22[b]	66.13 ± 5.62[a]	37.15 ± 4.72[c]	26.93 ± 3.80[c]	75.79	<0.01	10.79
III instar	167.35 ± 11.76[b]	187.73 ± 7.40[a]	93.90 ± 8.59[c]	49.85 ± 7.42[d]	170.44	<0.01	18.71
IV instar	277.40 ± 15.29[a]	234.05 ± 12.37[b]	143.25 ± 12.22[c]	66.55 ± 4.40[d]	213.08	<0.01	24.58
Total instar	552.30 ± 37.84[a]	529.90 ± 28.55[a]	296.28 ± 28.97[b]	155.88 ± 18.05[c]	392.05	<0.01	36.73
Adult male	2113.20 ± 106.31[b]	2320.40 ± 130.91[a]	1663.00 ± 82.86[c]	929.00 ± 61.68[d]	129.41	<0.01	206.29
Adult female	3044.95 ± 144.10[b]	3376.90 ± 126.88[a]	2239.50 ± 106.73[c]	1314.30 ± 60.16[d]	217.57	<0.01	237.59
Average adult	2579.08 ± 125.20[b]	2848.65 ± 128.90[a]	1951.25 ± 94.80[c]	1121.65 ± 60.92[d]	472.25	<0.01	134.51
C. transversalis							
I instar	21.63 ± 4.47[a]	24.15 ± 3.15[a]	12.25 ± 1.81[b]	7.90 ± 1.29[b]	22.55	<0.01	6.16
II instar	47.90 ± 4.77[a]	47.60 ± 7.71[a]	33.15 ± 5.01[b]	13.35 ± 2.51[c]	31.15	<0.01	11.12
III instar	100.88 ± 10.16[a]	93.80 ± 7.75[a]	62.15 ± 8.89[b]	36.05 ± 3.93[c]	46.44	<0.01	16.75
IV instar	149.15 ± 12.62[a]	149.98 ± 6.72[a]	86.90 ± 8.54[b]	55.55 ± 7.04[c]	90.12	<0.01	18.86
Total instar	319.55 ± 32.02[a]	315.53 ± 25.33[a]	194.45 ± 24.26[b]	112.85 ± 14.77[c]	227.07	<0.01	25.36
Adult male	1012.80 ± 63.68[b]	1167.50 ± 58.60[a]	706.00 ± 51.29[c]	495.80 ± 32.04[d]	109.02	<0.01	110.13
Adult female	1486.50 ± 82.38[b]	1658.00 ± 79.72[a]	1188.35 ± 78.18[c]	783.85 ± 52.00[d]	89.08	<0.01	154.58
Average adult	1249.65 ± 73.03[b]	1412.75 ± 69.16[a]	947.18 ± 64.73[c]	639.83 ± 42.02[d]	149.19	<0.01	106.46

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.

Means within rows were separated by Tukey's Honestly Significant Difference.

Table 24: Total number of aphids consumed by *C. septempunctata* and *C. transversalis* per individual reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016 (Pooled) (n=10)

Stages of coccinellid beetles	Total no. of aphids consumed per individual (Mean ± SEm)						
	Pooled						
	20ºC	25ºC	30ºC	35ºC	F value	P value	$HSD_{P=0.05}$
C. septempunctata							
I instar	27.30 ± 4.67[b]	37.20 ± 3.92[a]	19.16 ± 3.75[c]	11.21 ± 2.20[d]	30.00	<0.01	7.71
II instar	74.48 ± 6.65[a]	74.39 ± 7.77[a]	38.60 ± 4.65[b]	24.64 ± 2.90[c]	64.46	<0.01	12.12
III instar	170.55 ± 12.60[a]	178.29 ± 9.70[a]	88.15 ± 8.69[b]	49.48 ± 7.37[c]	137.60	<0.01	20.17
IV instar	270.50 ± 17.45[a]	234.63 ± 12.09[b]	144.00 ± 12.85[c]	63.75 ± 3.94[d]	181.64	<0.01	25.82
Total instar	542.83 ± 41.36[a]	524.50 ± 33.47[a]	289.91 ± 29.93[b]	149.08 ± 16.40[c]	359.55	<0.01	37.53
Adult male	2047.85 ± 94.67[a]	2236.25 ± 123.92[a]	1586.75 ± 86.12[b]	882.90 ± 65.71[c]	133.51	<0.01	194.89
Adult female	3044.58 ± 134.44[a]	3241.55 ± 141.37[a]	2164.35 ± 122.34[b]	1259.03 ± 66.07[c]	190.69	<0.01	246.41
Average adult	2546.21 ± 114.55[b]	2738.90 ± 132.64[a]	1875.55 ± 104.23[c]	1070.96 ± 65.89[d]	349.08	<0.01	151.13
C. transversalis							
I instar	19.29 ± 3.69[a]	24.40 ± 3.75[a]	11.15 ± 1.67[b]	7.43 ± 1.38[b]	24.12	<0.01	5.92
II instar	43.28 ± 4.64[a]	44.79 ± 7.51[a]	29.44 ± 4.50[b]	13.08 ± 2.33[c]	28.37	<0.01	10.44
III instar	96.14 ± 11.09[a]	94.74 ± 9.01[a]	57.38 ± 7.07[b]	32.83 ± 3.73[c]	46.40	<0.01	16.93
IV instar	144.01 ± 13.21[a]	147.69 ± 8.25[a]	83.56 ± 7.68[b]	51.60 ± 6.28[c]	85.67	<0.01	19.01
Total instar	302.71 ± 32.63[a]	311.61 ± 28.52[a]	181.53 ± 20.93[b]	104.93 ± 13.71[c]	199.67	<0.01	26.42
Adult male	1014.50 ± 69.73[b]	1140.55 ± 60.64[a]	683.20 ± 47.58[c]	466.30 ± 36.28[d]	103.83	<0.01	113.01
Adult female	1453.13 ± 90.86[b]	1618.58 ± 84.03[a]	1136.23 ± 81.54[c]	736.35 ± 52.42[d]	81.19	<0.01	161.22
Average adult	1233.81 ± 80.30[b]	1379.56 ± 72.34[a]	909.71 ± 64.56[c]	601.33 ± 44.35[d]	137.31	<0.01	110.82

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance. Means within rows were separated by Tukey's Honestly Significant Difference.

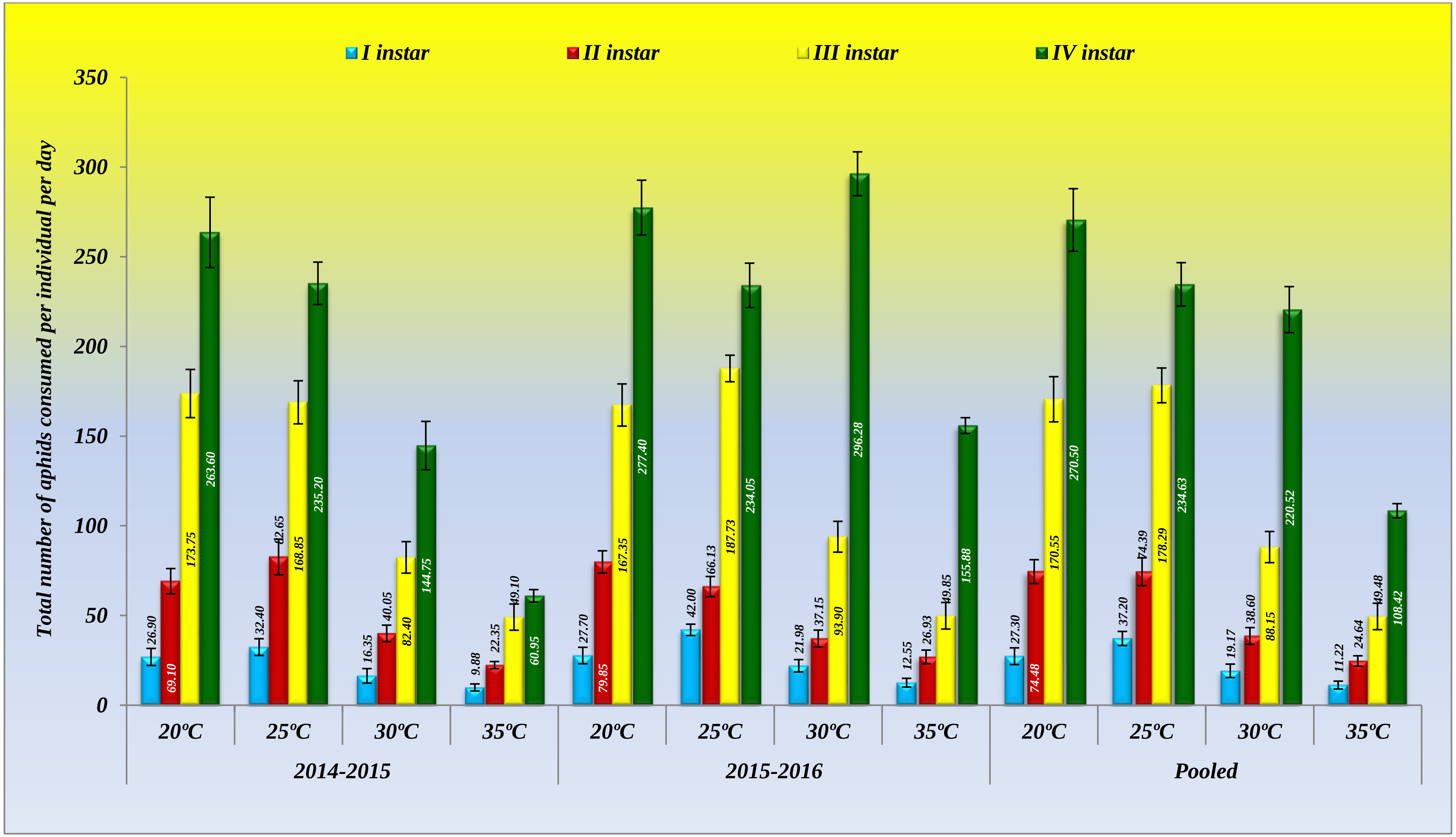

Fig 11b: Total number of aphids consumed by *C. septempunctata* grubs per individual reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

The total consumption per beetle during the entire stage by *C. septempunctata* beetles was recorded highest at 25°C with 3106.20 ± 155.85 and 3376.90 ± 126.88 aphids per beetle during 2014-2015 and 2015-2016, respectively with mean as 3241.55 ± 141.37 in female and 2152.10 ± 116.92 and 2320.40 ± 130.91 aphids per beetle with mean as 2236.25 ± 123.92 in male, whereas the lowest consumption was recorded at 35°C with 1203.75 ± 71.97 and 1314.30 ± 60.16 aphids per beetle during 2014-2015 and 2015-2016, respectively with mean as 1259.03 ± 66.07 in female and 836.80 ± 69.74 and 929.00 ± 61.68 aphids per beetle with mean as 882.90 ± 65.71 in male (Table 22, 23 and 24 and Fig. 11c). The results revealed that female beetles consumed more aphids as compared to male as this could be due to higher nutrition requirement for reproduction.

The present results are in conformity with the findings of Rauf *et al.* (2013) who reported that the feeding potential of *C. septempunctata* female adult reared on *Schizaphis graminum* consumed about 3262 and 2276.80 aphids and were greater than male i.e., 2571.70 and 1890.60 aphids at 20°C and 30°C, respectively. Several researchers have also reported that the feeding potential of *C. septempunctata* female adult consumed more aphids than male adult because they required higher nutrition for reproduction (Lekha and Jat 2002; Bilashini *et al.*, 2007; Soni *et al*., 2008; Singh *et al*., 2009; Singh and Singh, 2013; Pareek *et al.*, 2014; Singh and Singh, 2014). Since no literature were available regarding the feeding potential of *C. septempunctata* adults reared at temperature beyond 30°C, therefore no further comparison could be conducted with the present findings.

4.4.3. Total consumption of aphids by *Coccinella septempunctata* during the entire stage reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

The data pertained in table 25 and fig. 11d showed that the total consumption of aphids by *C. septempunctata* during the entire stage reared on *L. erysimi* ranged from 1162.55 ± 85.62 to 3148.25 ± 174.77 and 1277.53 ± 78.97 to 3378.55 ± 157.45 aphids during 2014-2015 and 2015-2016, respectively at four temperature regimes. The results revealed that the highest consumption of aphid during the entire stage were recorded about 3148.25 ± 174.77 and 3378.55 ± 157.45 aphids at 25°C during 2014-2015 and 2015-2016, respectively with mean as 3263.40 ± 166.11. These were followed by 3046.70 ± 148.78 and 3131.38 ± 163.04, 2083.40 ± 144.56 and 2247.53 ± 123.77 and 1162.55 ± 85.62 and 1277.53 ± 78.97 aphids at 20°C, 30°C and 35°C, respectively with means as 3089.04 ± 155.91, 2165.46 ± 134.16 and 1220.04 ± 82.29, respectively.

Table 25: Total number of aphids consumed during the entire stage by *C. septempunctata* and *C. transversalis* reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016 (n=10)

Coccinellid species	Total number of aphids consumed during the entire stage (Mean ± SEm)																				
	2014-2015							2015-2016							Pooled						
	20ºC	25ºC	30ºC	35ºC	F value	P value	HSD P=0.05	20ºC	25ºC	30ºC	35ºC	F value	P value	HSD P=0.05	20ºC	25ºC	30ºC	35ºC	F value	P value	HSD P=0.05
C. septempunctata	3046.70 ± 148.78^{a}	3148.25 ± 174.77^{a}	2083.40 ± 144.56^{b}	1162.55 ± 85.62^{c}	405.33	<0.01	176.24	3131.38 ± 163.04^{b}	3378.55 ± 157.45^{a}	2247.53 ± 123.77^{c}	1277.53 ± 78.97^{d}	684.67	<0.01	138.82	3089.04 ± 155.91^{b}	3263.40 ± 166.11^{a}	2165.46 ± 134.16^{c}	1220.04 ± 82.29^{d}	512.29	<0.01	155.64
C. transversalis	1503.85 ± 120.80^{b}	1654.08 ± 107.24^{a}	1040.85 ± 81.99^{c}	659.83 ± 59.35^{d}	171.13	<0.01	131.81	1569.20 ± 105.05^{b}	1728.28 ± 94.49^{a}	1141.61 ± 88.99^{c}	752.68 ± 56.79^{d}	197.41	<0.01	119.25	1536.53 ± 112.93^{b}	1691.18 ± 100.86^{a}	1091.24 ± 85.49^{c}	706.25 ± 58.07^{d}	182.96	<0.01	123.31

(Tukey's HSD, P = 0.05)

Note: Different small letters within the rows after mean values indicate significant differences among treatments at 5% level of significance.

Means within rows were separated by Tukey's Honestly Significant Difference.

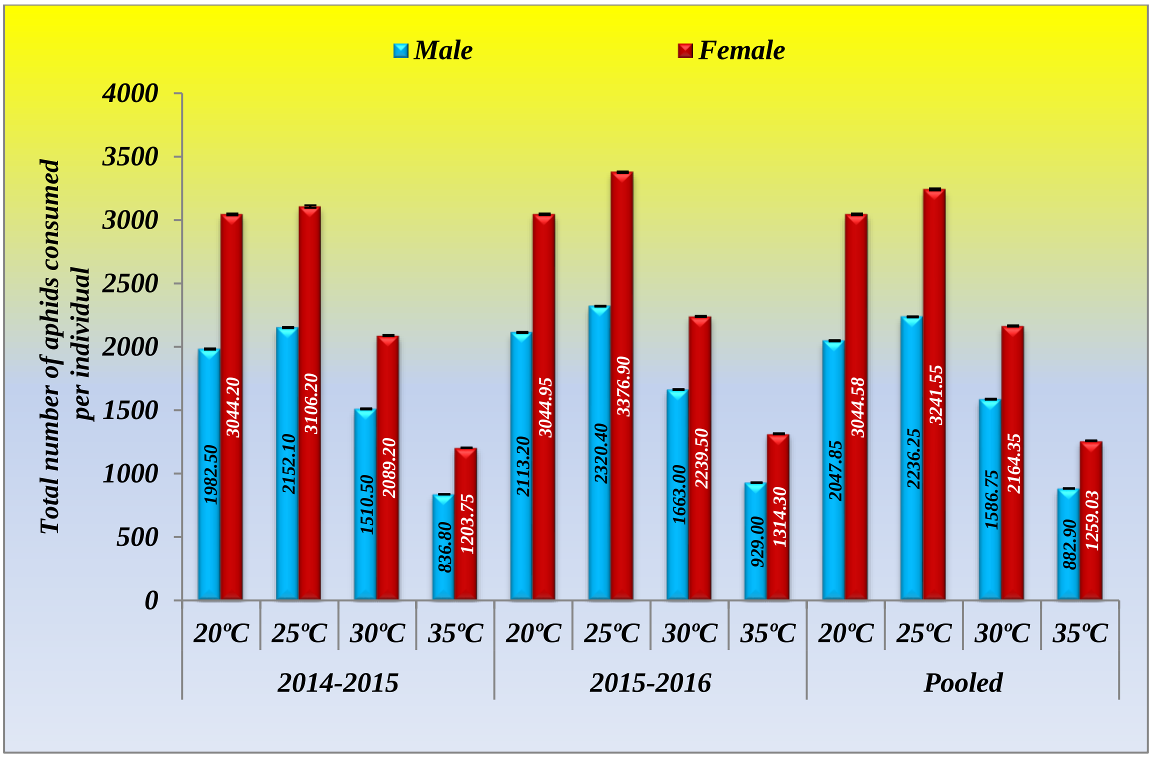

Fig 11c: Total number of aphids consumed by *C. septempunctata* adults per individual reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

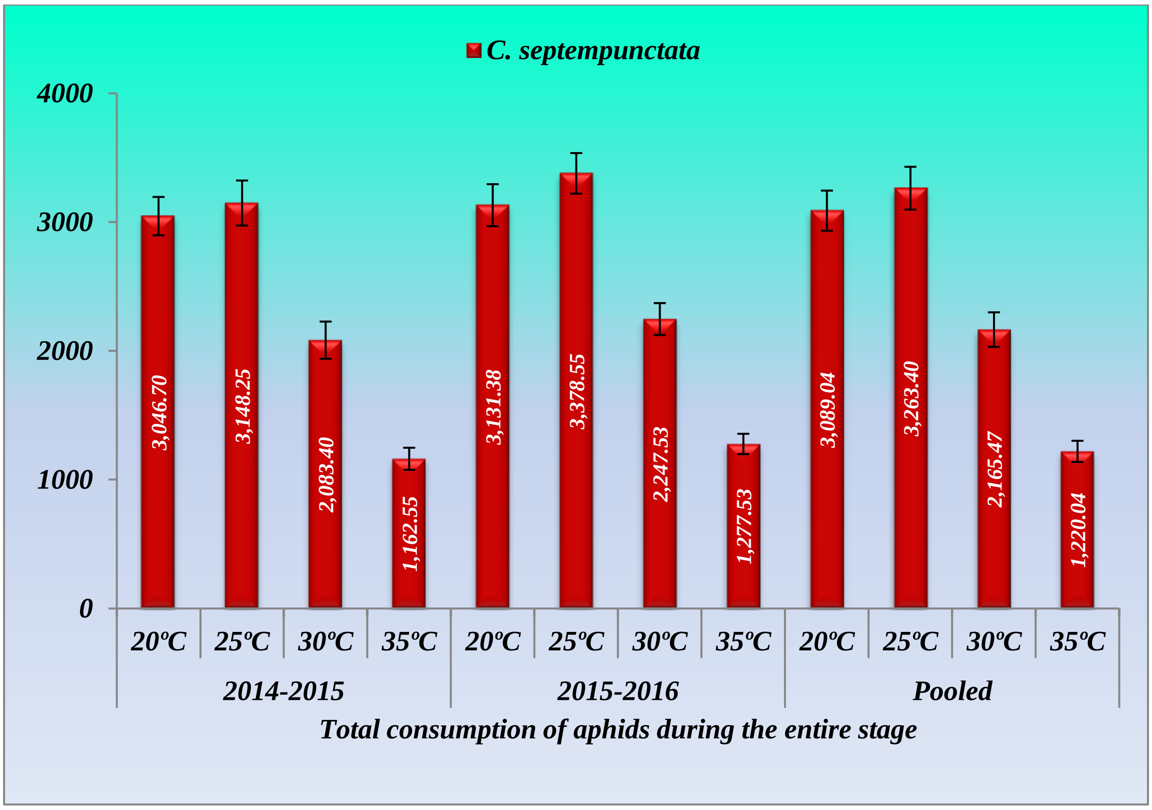

Fig 11d: Total number of aphids consumed by *C. septempunctata* during the entire stage reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

The present results are in agreement with the findings of Rauf *et al.* (2013) who found that the feeding potential of *C. septempunctata* reared on *Schizaphis graminum* to complete one generation consumed more aphids at 20°C as compared to 30°C. However, there was a variation on the consumption rate of *C. septempunctata* during the entire stage reported from location to location; this could be due to the rearing conditions at different temperature or on different prey species.

4.5. Feeding potential of *Coccinella transversalis* reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

4.5.1. Feeding potential of *Coccinella transversalis* grubs reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

The feeding potential of *C. transversalis* reared on *L. erysimi* is not only related to the prey density but also dependent on temperature. Initially with the increase in temperature the predation level increased up to a certain level beyond which the rate of predation goes decline. The results revealed that the mean feeding potential of first, second, third and fourth instars with prey density of 20, 30, 40 and 50 ranged from 3.75 ± 0.34 to 10.48 ± 0.62, 6.48 ± 0.55 to 15.48 ± 0.83, 13.58 ± 0.68 to 26.38 ± 0.78 and 19.30 ± 0.78 to 35.88 ± 0.89 aphids per grub per day at four different temperatures and total larval feeding potential ranged from 43.10 ± 2.35 to 88.20 ± 3.12 aphids per grub (Table 19, 20 and 21 and Fig. 12a). However, the highest feeding potential of first, second, third and fourth instars of *C. transversalis* were recorded about 10.20 ± 0.59 and 10.75 ± 0.65, 14.65 ± 0.93 and 16.30 ± 0.73, 27.25 ± 0.81 and 25.50 ± 0.75 and 36.40 ± 0.93 and 35.35 ± 0.85 aphids per grub per day at 25°C during 2014-2015 and 2015-2016, respectively with means as 10.48 ± 0.62, 15.48 ± 0.83, 26.38 ± 0.78 and 35.88 ± 0.89 aphids per grub per day. As the temperature increase beyond 25°C, the feeding potential of first, second, third and fourth instars decreased significantly to (4.70 ± 0.40 and 5.35 ± 0.41 and 3.50 ± 0.34 and 4.00 ± 0.33), (10.25 ± 0.57 and 11.60 ± 0.54 and 6.20 ± 0.51 and 6.75 ± 0.58), (17.50 ± 0.76 and 19.25 ± 0.71 and 12.65 ± 0.62 and 14.50 ± 0.73) and (22.65 ± 0.67 and 24.20 ± 0.74 and 18.40 ± 0.78 and 20.20 ± 0.79) aphids per grub per day during 2014-2015 and 2015-2016 at 30°C and 35°C, respectively with means as 5.03 ± 0.40 and 3.75 ± 0.34, 10.93 ± 0.56 and 6.48 ± 0.55, 18.38 ± 0.74 and 13.58 ± 0.68 and 23.43 ± 0.70 and 19.30 ± 0.78 aphids per grub per day.

Regarding the total aphid consumption, the feeding potential of first, second, third and fourth instars of *C. transversalis* ranged from 7.43 ± 1.38 to 24.40 ± 3.75, 13.08 ±

2.33 to 44.79 ± 7.51, 32.83 ± 3.73 to 94.74 ± 9.01 and 51.60 ± 6.28 to 147.69 ± 8.25 aphids per grub at four different temperature regimes and total larval feeding potential ranged from 104.93 ± 13.71 to 311.61 ± 28.52 aphids per grub (Table 22, 23 and 24 and Fig. 12b). The highest total aphid consumption of first, second, third and fourth instars was also recorded at 25°C with 24.65 ± 4.36 and 24.15 ± 3.15, 41.98 ± 7.32 and 47.60 ± 7.71, 95.68 ± 10.27 and 93.80 ± 7.75 and 145.40 ± 9.78 and 149.98 ± 6.72 aphids per grub during 2014-2015 and 2015-2016, respectively while means was 24.40 ± 3.75, 24.40 ± 3.75, 94.74 ± 9.01 and 147.69 ± 8.25 aphids per grub. The data indicated that as the temperature increase beyond 25°C, the feeding potential of first, second, third and fourth instars decreased significantly and revealed that the lowest total aphid consumption of first, second, third and fourth instars were recorded about 6.95 ± 1.47 and 7.90 ± 1.29, 12.80 ± 2.15 and 13.35 ± 2.51, 29.60 ± 3.53 and 36.05 ± 3.93 and 47.65 ± 5.51 and 55.55 ± 7.04 aphids per grub at 35°C during 2014-2015 and 2015-2016, respectively with means as 7.43 ± 1.38, 13.08 ± 2.33, 32.83 ± 3.73 and 51.60 ± 6.28 aphids per grub.

Similar findings were recorded by Bukero *et al.* (2014) where the first, second, third and fourth instars of *C. transversalis* reared on *L. erysimi* consumed about 4.0 ± 0.37, 9.34 ± 0.72, 17.80 ± 0.79 and 31.96 ± 1.13 aphids per grub per day, respectively at 26 ± 2°C. In other studies by Jadhav and Shukla (2015) reported that the larval consumption of first, second, third and fourth instars of *C. transversalis* reared on *L. erysimi* to developed to next instar were 23.98 ± 6.81, 22.76 ± 6.28, 92.88 ± 10.42 and 127.44 ± 35.89 with a total of 265.86 ± 43.706 aphids per grubs at 23.27 ± 1.04°C which was in agreement with the present findings. Since no literature were available regarding the feeding potential of *C. transversalis* grubs reared at temperature beyond 30°C, therefore no further comparison could be conducted with the present findings.

4.5.2. Feeding potential of *Coccinella transversalis* adults reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

The average feeding potential of *C. transversalis* adult with prey density of 60 increased from 33.88 ± 1.16 and 33.50 ± 1.03 aphids per beetle per day at 20°C to 38.98 ± 1.11 and 40.55 ± 1.10 aphids per beetle per day at 25°C during 2014-2015 and 2015-2016, then fell down to 26.28 ± 1.00 and 28.43 ± 1.00 and 19.65 ± 0.95 and 21.28 ± 0.74 per beetle per day at 30°C and 35°C, respectively. In comparison with the adult, the mean feeding potential of female ranged from 23.45 ± 0.87 to 43.93 ± 1.17 aphids per beetle per day and was greater than the adult male (17.48 ± 0.82 to 29.50 ± 1.03 aphids per beetle per day) at four constant temperatures (Table 19, 20 and 21 and Fig. 12c). The highest aphid consumption per beetle per day by *C. transversalis* beetles was recorded at 25°C with 43.25 ± 1.16 and 44.60 ± 1.18 aphids per beetle per day during 2014-2015 and 2015-2016, respectively in female with mean as 43.93 ± 1.17. However, highest consumption in male per beetle per day was found at 25°C recording 34.70 ± 1.07 and 36.50 ± 1.02 aphids per beetle per day in male with mean as 35.60 ± 1.04, whereas the lowest consumption was recorded at 35°C with 22.60 ± 0.95 and 24.30 ± 0.79 aphids per beetle per day in female during 2014-2015 and 2015-2016, respectively with mean as 23.45 ± 0.87 and 16.70 ± 0.96 and 18.25 ± 0.69 aphids per beetle per day in male with mean as 17.48 ± 0.82.

The total consumption per beetle during the entire stage by *C. transversalis* beetles was recorded highest at 25°C with 1579.15 ± 88.34 and 1658.00 ± 79.72 aphids per beetle in female during 2014-2015 and 2015-2016, respectively with mean as 1618.58 ± 84.03 and 1113.60 ± 62.69 and 1167.50 ± 58.60 aphids per beetle in male with mean as 1140.55 ± 60.64, whereas the lowest consumption was recorded at 35°C with 688.85 ± 52.85 and 783.85 ± 52.00 aphids per beetle in female during 2014-2015 and 2015-2016, respectively with mean as 736.35 ± 52.42 aphids per beetle per day and 436.80 ± 40.53 and 495.80 ± 32.04 aphids per beetle in male with mean as 466.30 ± 36.28 aphids per beetle per day (Table 22, 23 and 24 and Fig. 12c). The results revealed that female beetles consumed more aphids as compared to male as this may be due to higher nutrition requirement for reproduction.

The present results are similar with the findings of Bukero *et al.* (2014) who reported that the feeding potential of *C. transversalis* female adult reared on *L. erysimi* consumed about 56.56 ± 0.53 aphids per day and were greater than male i.e., 42.99 ± 0.41 aphids per day at 26 ± 2°C. Few researchers have also reported that the feeding potential of *C. transversalis* female adult consumed more aphids than male adult (Omkar and James, 2004; Borah and Dutta 2010). Since no literature were available regarding the feeding potential of *C. transversalis* adults reared at temperature beyond 30°C, therefore no further comparison could be conducted with the present findings.

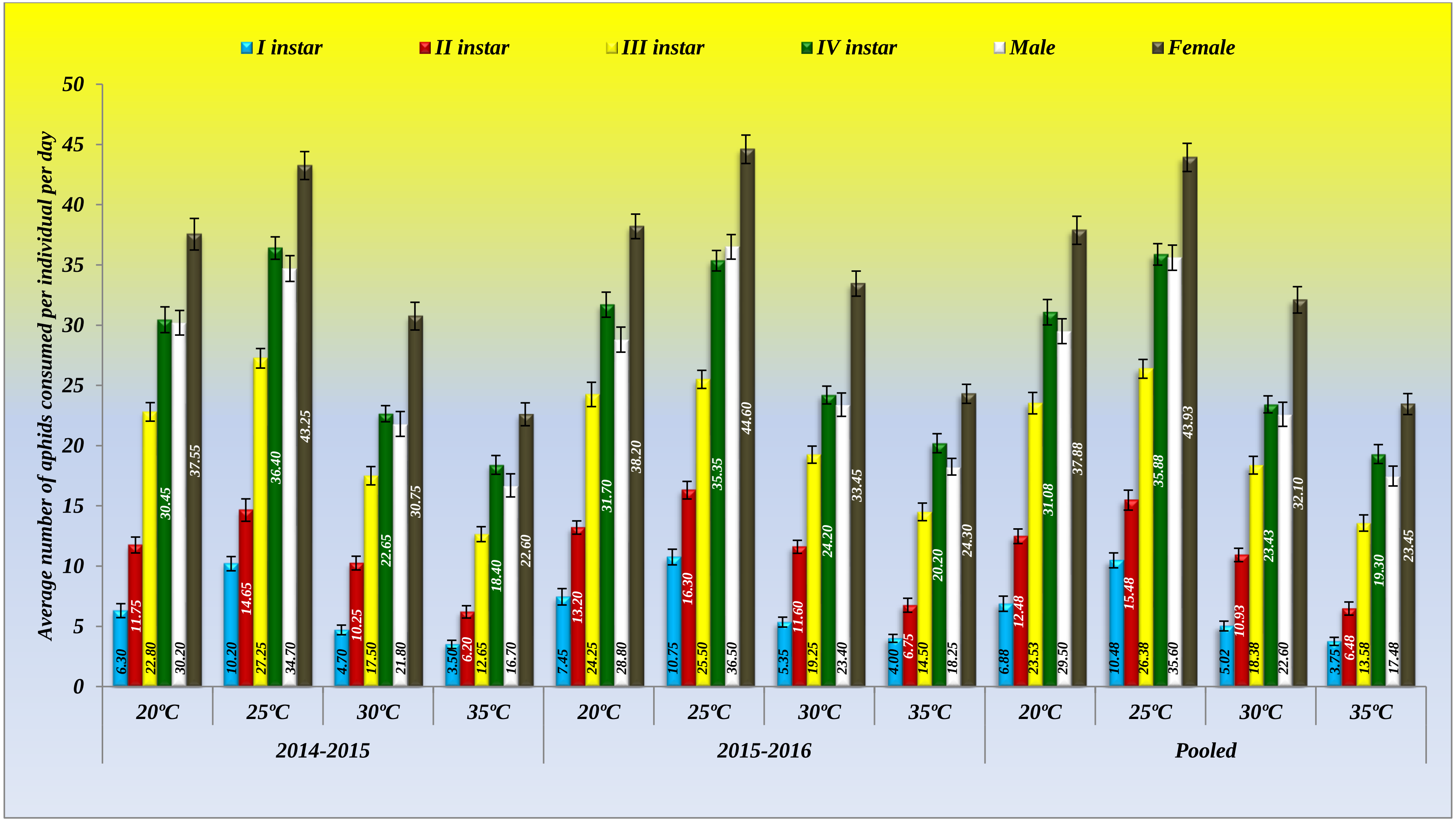

Fig 12a: Feeding potential different stages of *C. transversalis* per individual per day reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

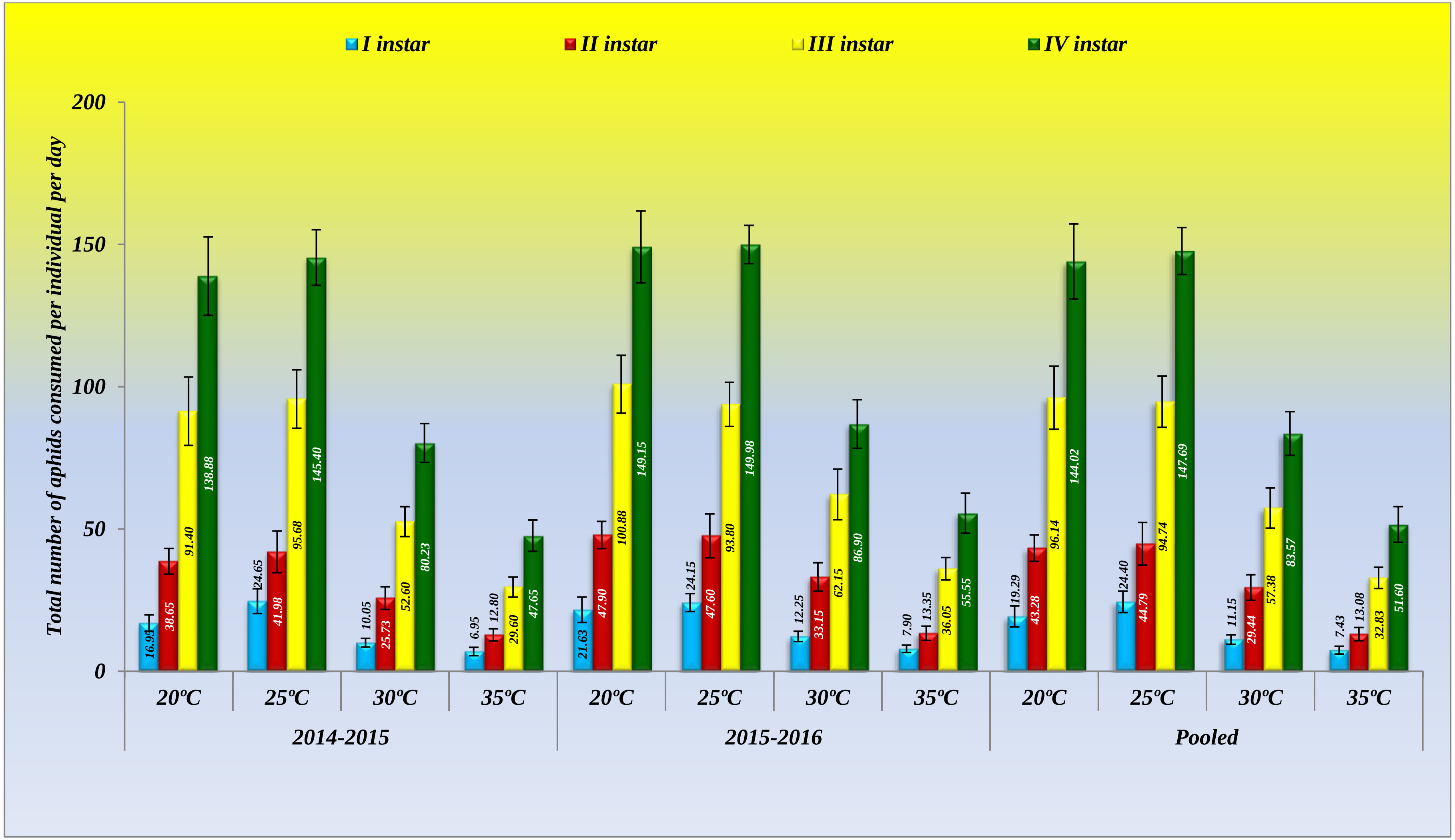

Fig 12b: Total number of aphids consumed by *C. transversalis* grubs per individual reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

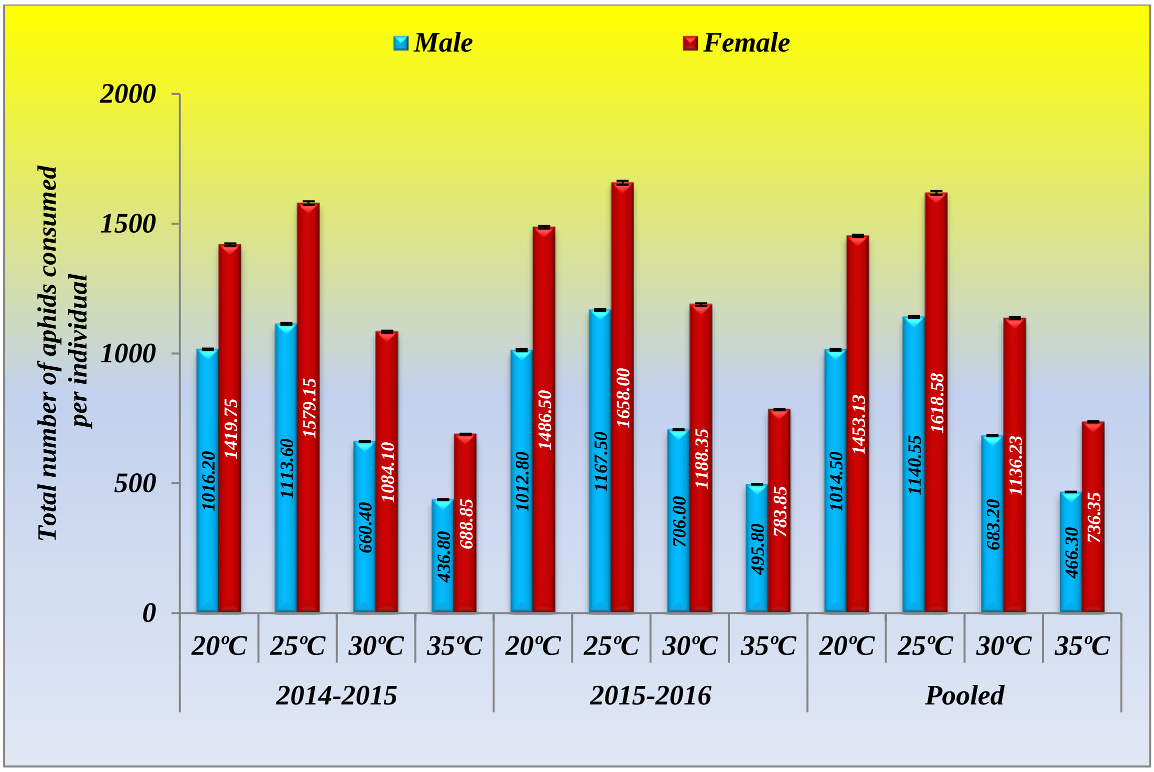

Fig 12c: Total number of aphids consumed by *C. transversalis* adults per individual reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

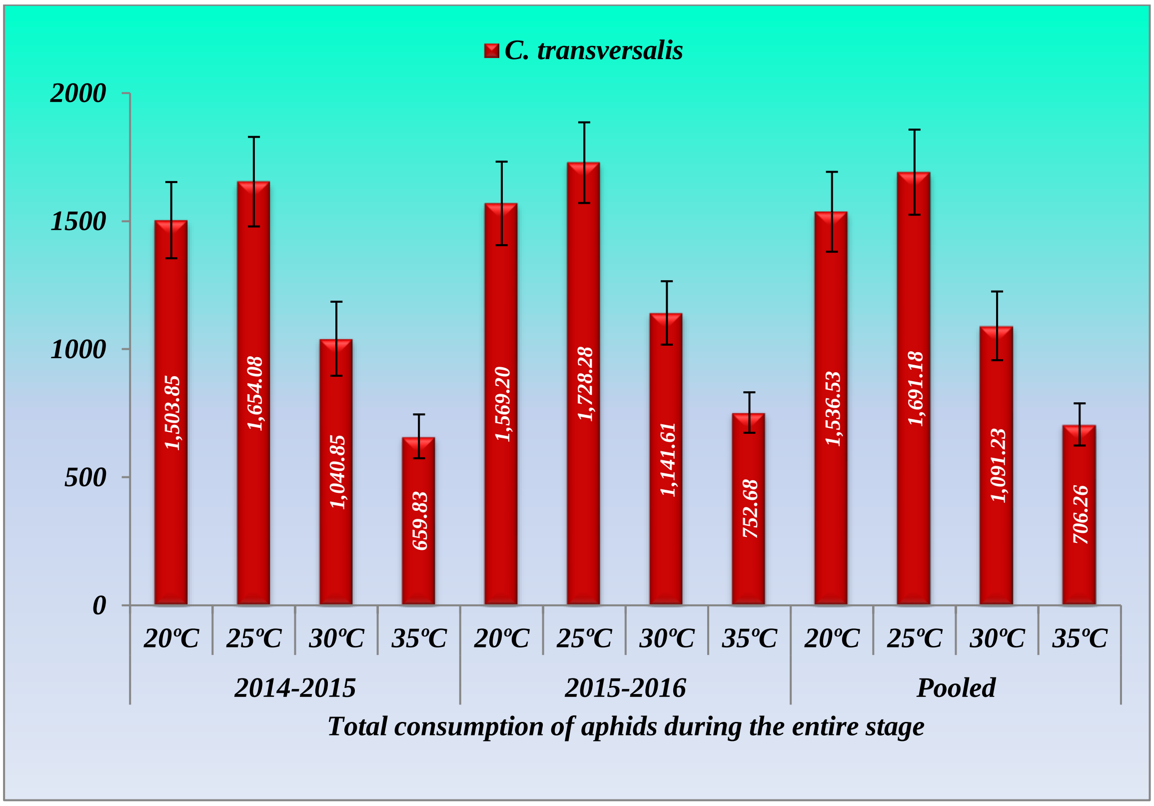

Fig 12d: Total number of aphids consumed by *C. transversalis* during the entire stage reared on mustard aphid, *L. erysimi* under the influence of different temperatures during 2014-2015 and 2015-2016

4.5.3. Total consumption of aphids by *Coccinella transversalis* during the entire stage reared on mustard aphid, *Lipaphis erysimi* under the influence of different temperatures

The data pertained in table 25 and fig. 12d showed that the total consumption of aphids by *C. transversalis* during the entire stage reared on *L. erysimi* ranged from 659.83 ± 59.35 to 1654.08 ± 107.24 and 752.68 ± 56.79 to 1728.28 ± 94.49 aphids during 2014-2015 and 2015-2016, respectively at four temperature regimes. The results revealed that the highest consumption of aphid during the entire stage were recorded about 1654.08 ± 107.24 and 1728.28 ± 94.49 aphids at 25°C during 2014-2015 and 2015-2016, respectively with mean as 1691.18 ± 100.86. These were followed by 1503.85 ± 120.80 and 1569.20 ± 105.05, 1040.85 ± 81.99 and 1141.61 ± 88.99 and 659.83 ± 59.35 and 752.68 ± 56.79 aphids at 20°C, 30°C and 35°C, respectively with means as 1536.53 ± 112.93, 1091.24 ± 85.49 and 706.25 ± 58.07, respectively.

The present results are in partial agreement with the findings of Jadhav and Shukla (2015) who reported that the feeding potential of *C. transversalis* to complete one generation was about 2795.68 ± 508.780 aphids. However, there was a variation on the feeding efficiency of *C. transversalis* during the entire stage reported from location to location; this could be due to the rearing conditions at different temperature or on different prey species.

4.6. Toxicity of different pesticides to major coccinellid beetles, *Coccinella septempunctata* and *C. transversalis* reared on mustard aphid, *Lipaphis erysimi*

In general, beneficial coccinellid beetles can encounter the pesticides used against target insect pest either by direct contact during their application, or by contact with their residues on plant, or even ingestion of poisoned prey. The details of findings on the toxicity of different pesticides to *Coccinella septempunctata* and *C. transversalis* reared on *L. erysimi* are emphasized under the following heads:

4.6.1. Toxicity of different pesticides to *Coccinella septempunctata* reared on mustard aphid, *Lipaphis erysimi*

4.6.1.1. Toxicity of different pesticides to *Coccinella septempunctata* grubs by residual film method

The toxic effect of different pesticides on *C. septempunctata* grubs by residual film method exhibited significant difference with respect to the time after treatment (Table 26, 27 and 28 and Fig. 13a and 13b). Significant difference (F=109.60, *df* =5,

Table 26: Toxicity evaluation of different pesticides to *C. septempunctata* grubs by residual film method during 2014-2015

Treatments	***Per cent grubs mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	33.33 ± 6.67^{b}	40.00 ± 0.00^{c}	46.67 ± 6.67^{c}	46.67 ± 6.67^{c}	53.33 ± 6.67^{c}	53.33 ± 6.67^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	40.00 ± 0.00^{b}	46.67 ± 6.67^{b}	60.00 ± 0.00^{b}	73.33 ± 6.67^{ab}	73.33 ± 6.67^{b}	80.00 ± 0.00^{b}	86.67 ± 6.67^{ab}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	66.67 ± 6.67^{a}	66.67 ± 6.67^{a}	73.33 ± 6.67^{a}	86.67 ± 6.67^{a}	93.33 ± 6.67^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	13.33 ± 6.67^{d}	20.00 ± 0.00^{d}	26.67 ± 6.67^{d}	26.67 ± 6.67^{d}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	40.00 ± 0.00^{b}	40.00 ± 0.00^{b}	53.33 ± 6.67^{b}	66.67 ± 6.67^{b}	66.67 ± 6.67^{b}	73.33 ± 6.67^{b}	80.00 ± 0.00^{b}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}
F value	109.60	31.73	65.60	32.36	41.25	61.33	66.93
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	8.84	15.32	12.51	19.77	17.69	15.32	15.32

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance. Means within columns were separated by Tukey's Honestly Significant Difference.

Table 27: Toxicity evaluation of different pesticides to *C. septempunctata* grubs by residual film method during 2015-2016

Treatments	***Per cent grubs mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	33.33 ± 6.67^{c}	33.33 ± 6.67^{c}	46.67 ± 6.67^{c}	46.67 ± 6.67^{c}	53.33 ± 6.67^{d}	53.33 ± 6.67^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	46.67 ± 6.67^{b}	53.33 ± 6.67^{ab}	60.00 ± 0.00^{ab}	73.33 ± 6.67^{ab}	73.33 ± 6.67^{b}	80.00 ± 0.00^{b}	80.00 ± 0.00^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	66.67 ± 6.67^{a}	66.67 ± 6.67^{a}	73.33 ± 6.67^{a}	80.00 ± 0.00^{a}	93.33 ± 6.67^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	13.33 ± 6.67^{d}	20.00 ± 0.00^{d}	20.00 ± 0.00^{e}	26.67 ± 6.67^{d}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	40.00 ± 0.00^{b}	40.00 ± 0.00^{bc}	53.33 ± 6.67^{b}	60.00 ± 0.00^{bc}	60.00 ± 0.00^{bc}	66.67 ± 6.67^{c}	73.33 ± 6.67^{b}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{f}	0.00 ± 0.00^{e}
F value	58.10	33.93	43.80	47.53	53.33	94.80	61.33
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	12.51	15.32	15.32	15.32	15.32	12.51	15.32

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.
Means within columns were separated by Tukey's Honestly Significant Difference.

Table 28: Toxicity evaluation of different pesticides to *C. septempunctata* grubs by residual film method during 2014-2015 and 2015-2016 (Pooled)

Treatments	***Per cent grubs mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	33.33 ± 6.77^{c}	36.67 ± 3.33^{c}	46.67 ± 6.67^{c}	46.67 ± 6.67^{c}	53.33 ± 6.67^{c}	53.33 ± 6.67^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	43.33 ± 3.33^{b}	50.00 ± 6.67^{b}	60.00 ± 0.00^{b}	73.33 ± 6.67^{ab}	73.33 ± 6.67^{b}	80.00 ± 0.00^{b}	83.33 ± 3.33^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	66.67 ± 6.67^{a}	66.67 ± 6.67^{a}	73.33 ± 6.67^{a}	83.33 ± 3.33^{a}	93.33 ± 6.67^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	13.33 ± 6.67^{d}	20.00 ± 0.00^{d}	23.33 ± 3.33^{d}	26.67 ± 6.67^{d}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	40.00 ± 0.00^{b}	40.00 ± 0.00^{bc}	53.33 ± 6.67^{b}	63.33 ± 3.33^{bc}	63.33 ± 3.33^{b}	70.00 ± 6.67^{b}	76.67 ± 3.33^{b}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}
F value	75.27	32.83	52.52	38.05	46.43	74.72	64.13
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	10.31	14.58	13.31	16.83	15.74	13.31	14.58

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.

Means within columns were separated by Tukey's Honestly Significant Difference.

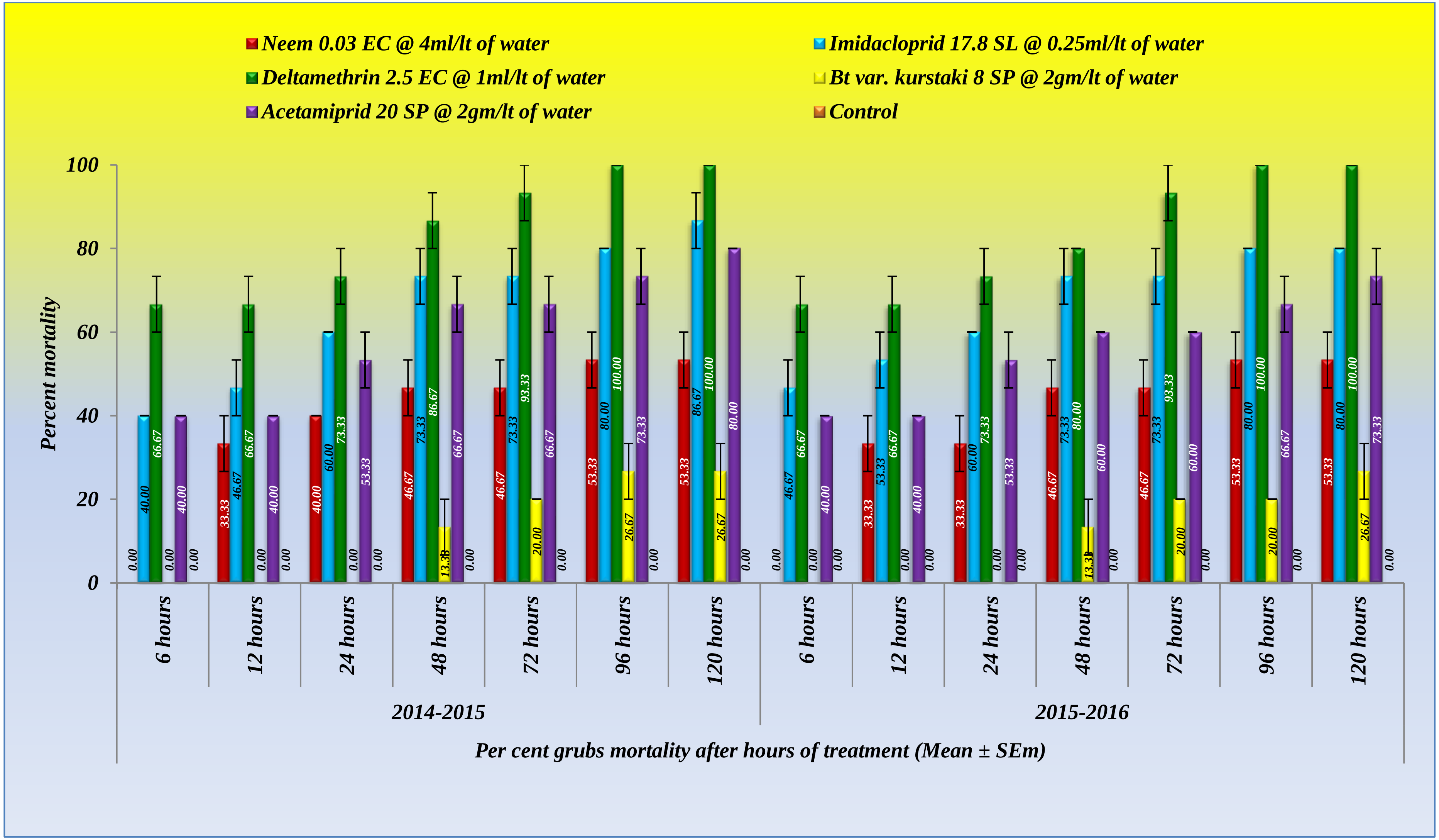

Fig 13a: Toxicity evaluation of different pesticides to *C. septempunctata* grubs by residual film method during 2014-2015 and 2015-2016

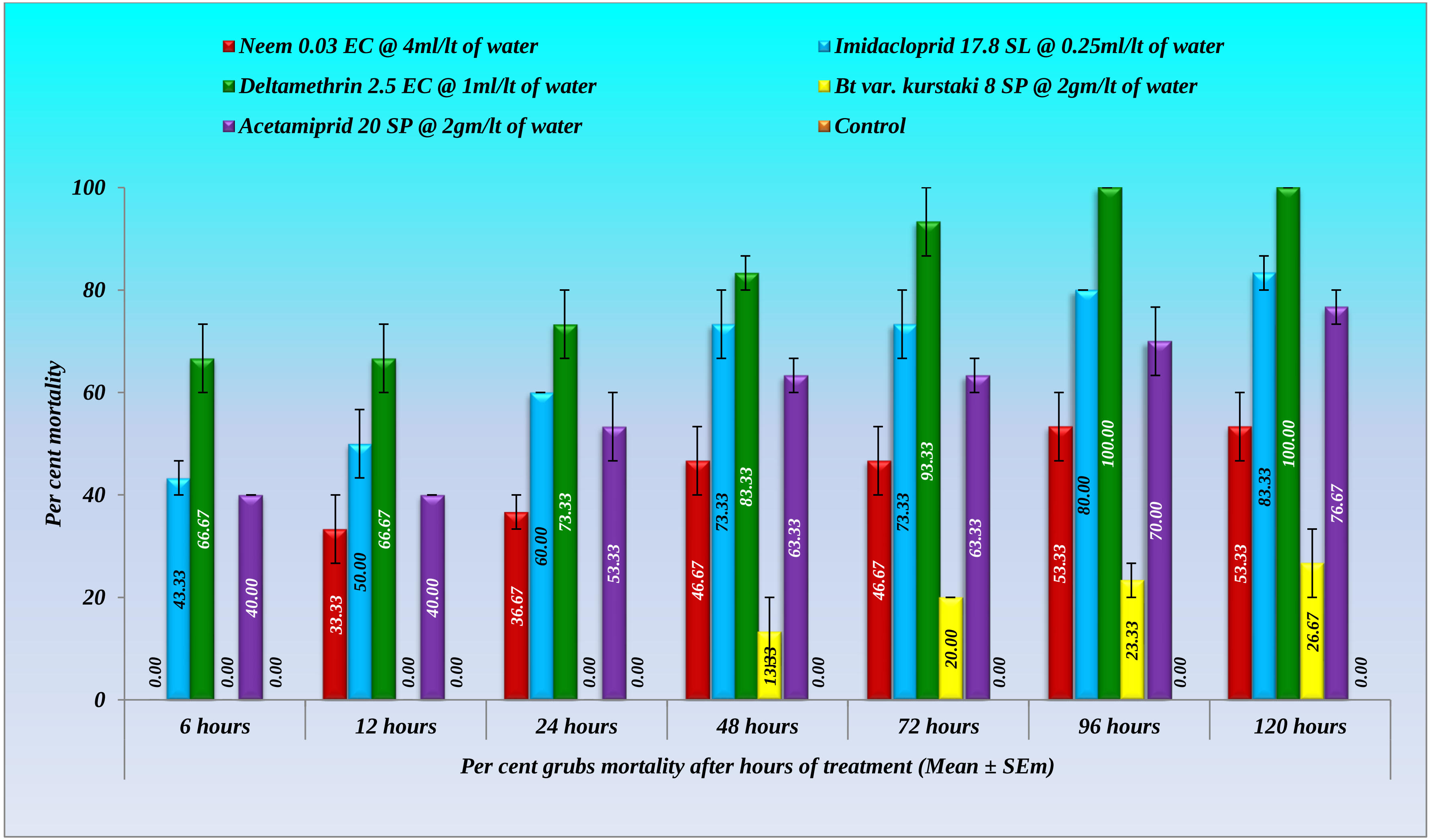

Fig 13b: Toxicity evaluation of different pesticides to *C. septempunctata* grubs by residual film method during 2014-2015 and 2015-2016 (Pooled)

$p<0.01$; $F=58.10$, $df=5$, $p<0.01$ and $F=75.27$, $df=5$, $p<0.01$) were observed in mortality of *C. septempunctata* grubs exposed to different pesticides even just after 6 hours of treatment and maximum mortality was recorded in Deltamethrin 2.5 EC i.e., 66.67 ± 6.67% and 66.67 ± 6.67% during 2014-2015 and 2015-2016, respectively with mean as 66.67 ± 6.67% followed by Imidacloprid 17.8 SL (40.00 ± 0.00% and 46.67 ± 6.67%) and Acetamiprid 20 SP (40.00 ± 0.00% and 40.00 ± 0.00%) with means as 43.33 ± 3.33% and 40.00 ± 0.00% mortality, respectively.

Toxicity of Neem 0.03 EC was found only after 12 hours of treatment i.e., 33.33 ± 6.67% and reached about 53.33 ± 6.67% mortality after 120 hours of treatment in both the years. Toxicity of *Bt* var. *kurstaki* 8 SP was observed only after 48 hours of treatment i.e., 13.33 ± 6.67% and reached about 26.67 ± 6.67% mortality after 120 hours of treatment in both the years. In the control, no *C. septempunctata* grubs mortality occurred from 6 to 120 hours after treatment. With the increase of time after exposure to different pesticides, the mortality rate of *C. septempunctata* grubs kept on increasing and complete mortality was recorded after 96 hours of treatment in Deltamethrin 2.5 EC i.e., 100.00 ± 0.00% and 100.00 ± 0.00% during 2014-2015 and 2015-2016, respectively followed by Imidacloprid 17.8 SL (86.67 ± 6.67% and 80.00 ± 0.00%), Acetamiprid 20 SP (73.33 ± 6.67% and 66.67 ± 6.67%) and Neem 0.03 EC (53.33 ± 6.67% and 53.33 ± 6.67%) with means as 80.00 ± 6.67%, 73.33 ± 6.67% and 53.33 ± 6.67% mortality, respectively.

Overall Deltamethrin 2.5 EC was observed to be highly toxic with 100% mortality of *C. septempunctata* grubs within 96 hours of treatment followed by Imidacloprid 17.8 SL and Acetamiprid 20 SP while *Bt* var. *kurstaki* 8 SP treatment was found to be safer to *C. septempunctata* grubs, having least mortality rate as compared to other pesticides.

The present results are quite similar with the findings of Yu *et al.* (2014) who reported that Imidacloprid 17.8 SL caused about 50.00% mortality to *C. septempunctata* grubs after 72 hours of treatment by residual film method. Negative effect of neem to coccinellid has also been reported by several researchers who reported that neem oil caused about 40.00% and 22.00% adult mortality on *Adonia variegate* and *Menochilus sexmaculatus*, respectively (Swaminathan *et al*., 2010; Khan *et al*., 2015).

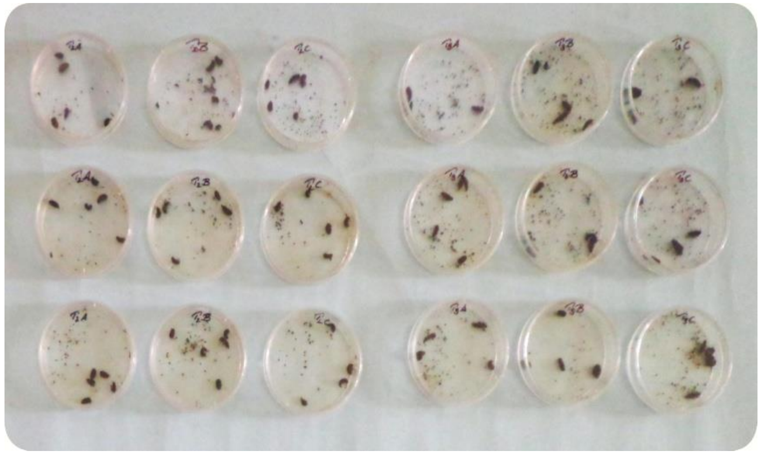

Plate 13a: Bioassay study against *C. septempunctata* grubs by residual film method

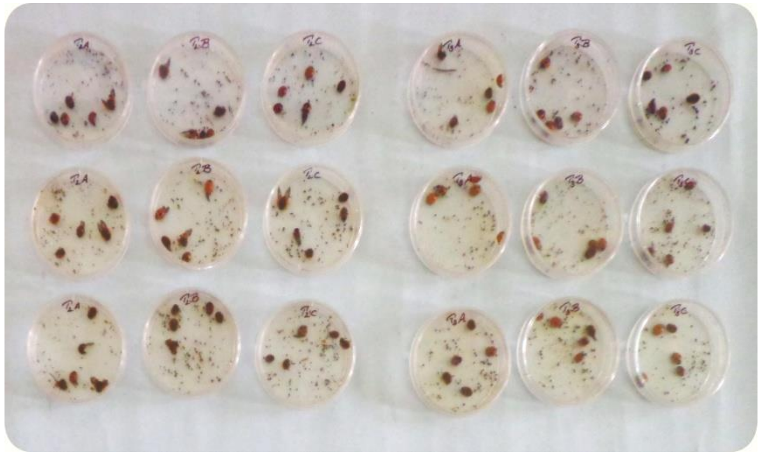

Plate 13b: Bioassay study against *C. septempunctata* adults by residual film method

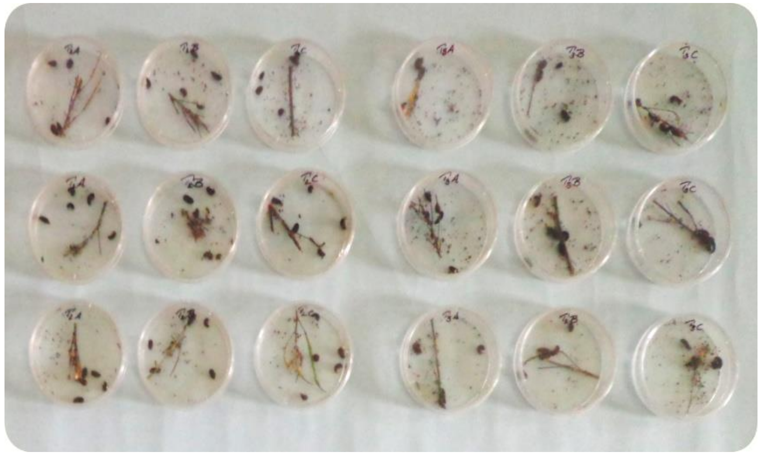

Plate 13c: Bioassay study against *C. septempunctata* grubs by diet contamination method

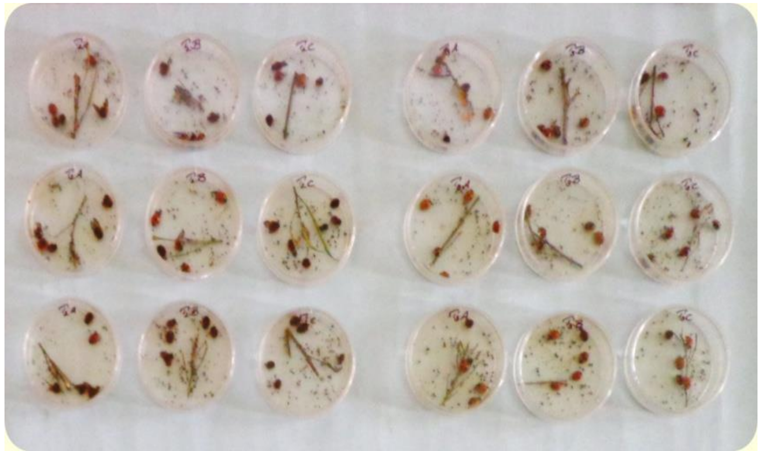

Plate 13d: Bioassay study against *C. septempunctata* adults by diet contamination method

Plate 13: Bioassay study of different pesticides against *C. septempunctata* grubs and adults

4.6.1.2. Toxicity of different pesticides to *Coccinella septempunctata* grubs by diet contamination method

The toxic effect of different pesticides on *C. septempunctata* grubs by diet contamination method exhibited significant difference with respect to the time after treatment (Table 29, 30 and 31 and Fig. 14a and 14b). Significant difference ($F=21.20$, $df=5$, $p<0.01$; $F=21.20$, $df=5$, $p<0.01$ and $F=21.20$, $df=5$, $p<0.01$) were observed in mortality of *C. septempunctata* grubs exposed to different pesticides even just after 6 hours of treatment and maximum mortality was recorded in Deltamethrin 2.5 EC i.e., 40.00 ± 0.00% followed by Imidacloprid 17.8 SL and Acetamiprid 20 SP with 26.67 ± 6.67% and 26.67 ± 6.67% mortality, respectively in both the years.

Toxicity of Neem 0.03 EC was found only after 12 hours of treatment i.e., 13.33 ± 6.67% and 20.00 ± 0.00% during 2014-2015 and 2015-2016, respectively and reached about 40.00 ± 0.00% mortality after 120 hours of treatment in both the years. Toxicity of *Bt* var. *kurstaki* 8 SP was observed only after 24 hours of treatment i.e., 13.33 ± 6.67% and 13.33 ± 6.67% and reached about 33.33 ± 6.67% and 40.00 ± 0.00% mortality after 120 hours of treatment during 2014-2015 and 2015-2016, respectively. In the control, no *C. septempunctata* grubs mortality occurred from 6 to 120 hours after treatment. With the increase of time after exposure to different pesticides, the mortality rate of *C. septempunctata* grubs kept on increasing and mortality was recorded after 120 hours of treatment in Deltamethrin 2.5 EC i.e., 73.33 ± 6.67% and 73.33 ± 6.67% during 2014-2015 and 2015-2016, respectively, followed by Imidacloprid 17.8 SL (60.00 ± 0.00% and 60.00 ± 0.00%), Acetamiprid 20 SP (60.00 ± 0.00% and 53.33 ± 6.67%), and Neem 0.03 EC (40.00 ± 0.00% and 40.00 ± 0.00%) with means as 60.00 ± 0.00%, 56.67 ± 3.33% and 40.00 ± 0.00% mortality, respectively.

Overall Deltamethrin 2.5 EC was observed to be highly toxic with 73.33% mortality of *C. septempunctata* adults within 120 hours of treatment followed by Imidacloprid 17.8 SL and Acetamiprid 20 SP while *Bt* var. *kurstaki* 8 SP treatment was found to be safer to *C. septempunctata* adults, having least mortality rate as compared to other pesticides.

The present results are quite similar with the findings of few researchers who reported that Imidacloprid 17.8 SL caused about 59.32% and 64.00% mortality to *C. septempunctata* grubs after 72 and 96 hours of treatment, respectively by diet contamination method (Amin *et al.*, 2014; Solangi *et al.*, 2007). Negative effect of neem

Table 29: Toxicity evaluation of different pesticides to *C. septempunctata* grubs by diet contamination method during 2014-2015

Treatments	***Per cent grubs mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	13.33 ± 6.67^{b}	26.67 ± 6.67^{bc}	33.33 ± 6.67^{bc}	33.33 ± 6.67^{bc}	40.00 ± 0.00^{bc}	40.00 ± 0.00^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	26.67 ± 6.67^{b}	26.67 ± 6.67^{ab}	40.00 ± 0.00^{ab}	46.67 ± 6.67^{ab}	46.67 ± 6.67^{ab}	53.33 ± 6.67^{ab}	60.00 ± 0.00^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	40.00 ± 0.00^{a}	40.00 ± 0.00^{a}	53.33 ± 6.67^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}	66.67 ± 6.67^{a}	73.33 ± 6.67^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}	13.33 ± 6.67^{c}	20.00 ± 0.00^{c}	26.67 ± 6.67^{c}	33.33 ± 6.67^{c}	33.33 ± 6.67^{c}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	26.67 ± 6.67^{b}	33.33 ± 6.67^{a}	33.33 ± 6.67^{b}	40.00 ± 0.00^{ab}	40.00 ± 0.00^{b}	53.33 ± 6.67^{ab}	60.00 ± 0.00^{b}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
F value	21.20	13.13	12.25	17.13	18.73	18.25	46.40
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	12.51	15.32	17.69	15.32	15.32	17.69	12.51

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance. Means within columns were separated by Tukey's Honestly Significant Difference.

Table 30: Toxicity evaluation of different pesticides to *C. septempunctata* grubs by diet contamination method during 2015-2016

Treatments	***Per cent grubs mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	20.00 ± 0.00^{c}	26.67 ± 6.67^{cd}	33.33 ± 6.67^{bc}	33.33 ± 6.67^{bc}	40.00 ± 0.00^{bc}	40.00 ± 0.00^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	26.67 ± 6.67^{b}	33.33 ± 6.67^{ab}	40.00 ± 0.00^{ab}	46.67 ± 6.67^{ab}	53.33 ± 6.67^{a}	53.33 ± 6.67^{ab}	60.00 ± 0.00^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	40.00 ± 0.00^{a}	40.00 ± 0.00^{a}	53.33 ± 6.67^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}	66.67 ± 6.67^{a}	73.33 ± 6.67^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	13.33 ± 6.67^{d}	26.67 ± 6.67^{c}	26.67 ± 6.67^{c}	33.33 ± 6.67^{c}	40.00 ± 0.00^{c}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	26.67 ± 6.67^{b}	26.67 ± 6.67^{bc}	33.33 ± 6.67^{bc}	46.67 ± 6.67^{ab}	46.67 ± 6.67^{ab}	53.33 ± 6.67^{ab}	53.33 ± 6.67^{b}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
F value	21.20	19.20	12.25	10.28	16.05	18.25	42.80
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
HSD$_{P=0.05}$	12.51	12.51	17.69	19.77	17.69	17.69	12.51

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance. Means within columns were separated by Tukey's Honestly Significant Difference.

Table 31: Toxicity evaluation of different pesticides to *C. septempunctata* grubs by diet contamination method during 2014-2015 and 2014-2015 (Pooled)

Treatments	***Per cent grubs mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	00.00 ± 0.00^{c}	16.67 ± 3.33^{b}	26.67 ± 6.67^{bc}	33.33 ± 6.67^{bc}	33.33 ± 6.67^{cd}	40.00 ± 0.00^{bc}	40.00 ± 0.00^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	26.67 ± 6.67^{b}	30.00 ± 6.67^{a}	40.00 ± 0.00^{ab}	46.67 ± 6.67^{ab}	50.00 ± 6.67^{ab}	53.33 ± 6.67^{ab}	60.00 ± 0.00^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	40.00 ± 0.00^{a}	40.00 ± 0.00^{a}	53.33 ± 6.67^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}	66.67 ± 6.67^{a}	73.33 ± 6.67^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	13.33 ± 6.67^{c}	23.33 ± 3.33^{c}	26.67 ± 6.67^{d}	33.33 ± 6.67^{c}	36.67 ± 3.33^{c}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	26.67 ± 6.67^{b}	30.00 ± 6.67^{a}	33.33 ± 6.67^{b}	43.33 ± 3.33^{ab}	43.33 ± 3.33^{bc}	53.33 ± 6.67^{ab}	56.67 ± 3.33^{b}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
F value	21.20	15.56	12.25	12.85	17.20	18.25	44.60
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	11.90	13.31	16.83	16.83	15.74	16.83	11.90

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.

Means within columns were separated by Tukey's Honestly Significant Difference.

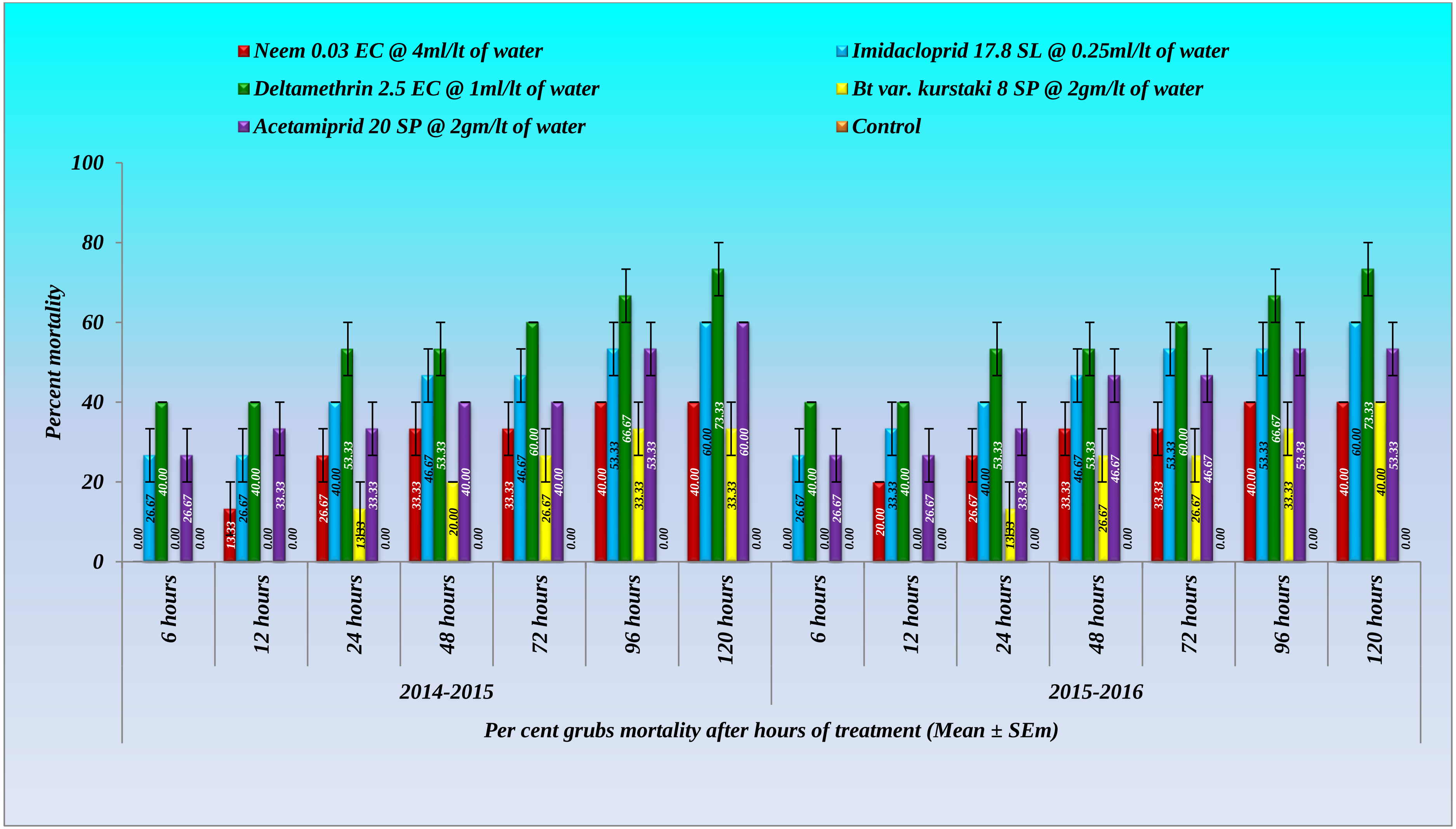

Fig 14a: Toxicity evaluation of different pesticides to *C. septempunctata* grubs by diet contamination method during 2014-2015 and 2015-2016

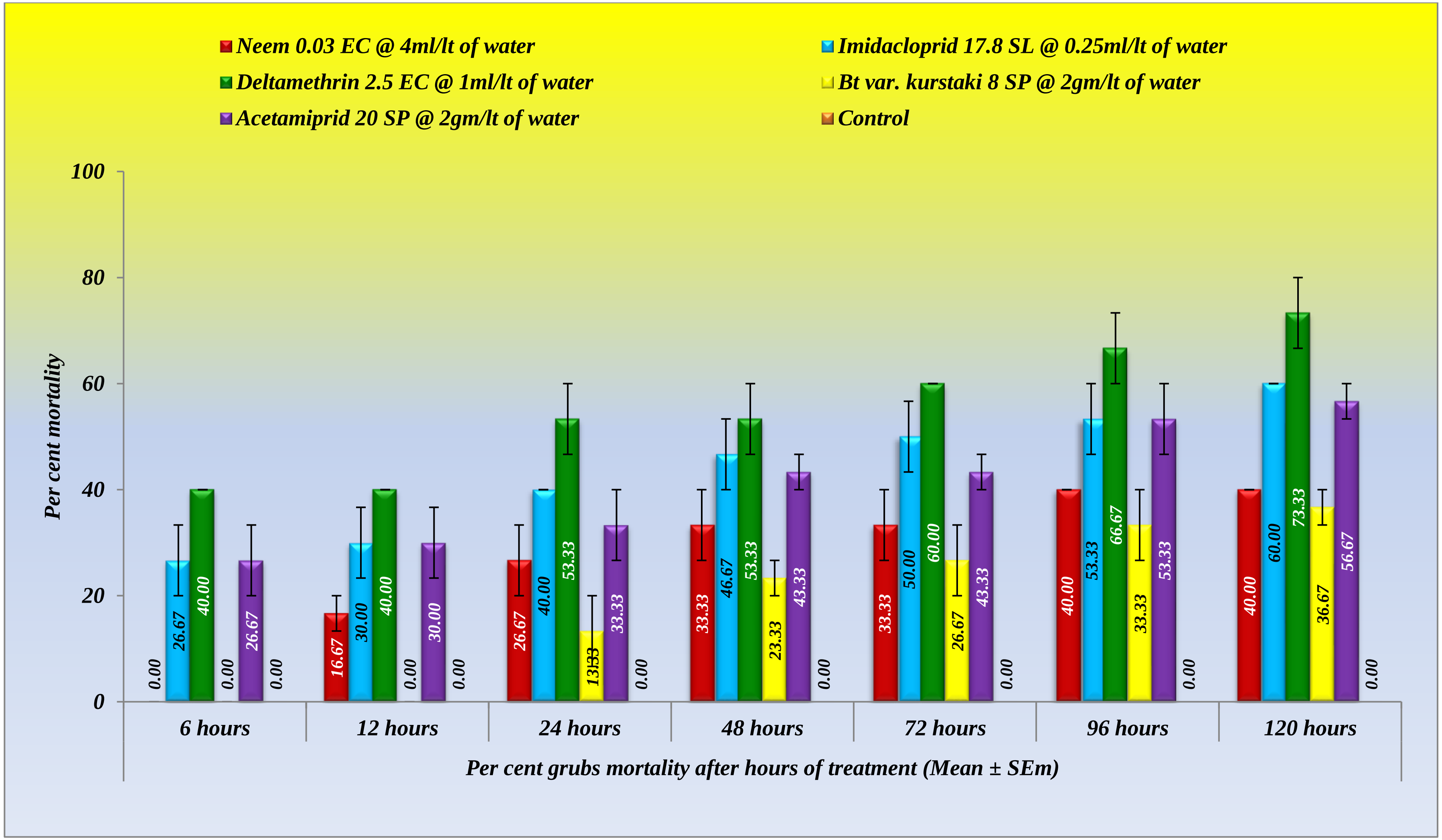

Fig 14b: Toxicity evaluation of different pesticides to *C. septempunctata* grubs by diet contamination method during 2014-2015 and 2015-2016 (Pooled)

to coccinellid has also been reported by several researchers who reported that neem oil caused about 40.00% and 22.00% adult mortality on *Adonia variegate* and *Menochilus sexmaculatus*, respectively (Swaminathan *et al*., 2010; Khan *et al*., 2015).

4.6.1.3. Toxicity of different pesticides to *Coccinella septempunctata* adults by residual film method

The toxic effect of different pesticides on *C. septempunctata* adults by residual film method exhibited significant difference with respect to the time after treatment (Table 32, 33 and 34 and Fig. 15a and 15b). Significant difference ($F=24.00$, $df=5$, $p<0.01$; $F=33.60$, $df=5$, $p<0.01$ and $F=27.84$, $df=5$, $p<0.01$) were observed in mortality of *C. septempunctata* adults exposed to different pesticides even just after 6 hours of treatment and maximum mortality was recorded in Deltamethrin 2.5 EC i.e., 53.33 ± 6.67% and 46.67 ± 6.67% during 2014-2015 and 2015-2016, respectively with mean as 50.00 ± 6.67% followed by Imidacloprid 17.8 SL (33.33 ± 6.67% and 40.00 ± 0.00%) and Acetamiprid 20 SP (33.33 ± 6.67% and 33.33 ± 6.67%) with means as 36.67 ± 3.33% and 33.33 ± 6.67% mortality, respectively.

Toxicity of Neem 0.03 EC was found only after 24 hours of treatment i.e., 26.67 ± 6.67% and 33.33 ± 6.67%, respectively with mean as 30.00 ± 6.67% and reached about 46.67 ± 6.67% mortality after 120 hours of treatment in both the years. Toxicity of *Bt* var. *kurstaki* 8 SP was observed only after 72 hours of treatment i.e., 6.67 ± 6.67% and reached about 13.33 ± 6.67% mortality after 120 hours of treatment in both the years. In the control, no *C. septempunctata* adults mortality occurred, from 6 to 120 hours after treatment. With the increase of time after exposed to different pesticides, the mortality rate of *C. septempunctata* adults kept on increasing and the maximum mortality was recorded after 96 hours of treatment in Deltamethrin 2.5 EC i.e., 86.67 ± 6.67% and 86.67 ± 6.67% during 2014-2015 and 2015-2016, respectively with mean as 86.67 ± 6.67%, followed by Imidacloprid 17.8 SL (60.00 ± 0.00% and 66.67 ± 6.67%) and Acetamiprid 20 SP (60.00 ± 0.00% and 60.00 ± 0.00%) with means as 63.33 ± 3.33% and 60.00 ± 0.00% mortality, respectively.

The present results are in conformity with the findings of Ahmad *et al.* (2011) who reported that the maximum mortality of *C. undecimpunctata* adults was recorded in Deltamethrin 2.5 EC and Acetamiprid 20 SP with 83.30% mortality each under residual film method. In other studies of Tank *et al.* (2007) reported that Acetamiprid 20 SP caused about 53.37% mortality to *Cheilomenes sexmaculatus* adults after 72 hours of

Table 32: Toxicity evaluation of different pesticides to *C. septempunctata* adults by residual film method during 2014-2015

Treatments	***Per cent adults mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	26.67 ± 6.67^{c}	33.33 ± 6.67^{c}	33.33 ± 6.67^{c}	40.00 ± 0.00^{c}	46.67 ± 6.67^{b}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	33.33 ± 6.67^{b}	40.00 ± 0.00^{b}	46.67 ± 6.67^{b}	53.33 ± 6.67^{b}	53.33 ± 6.67^{b}	60.00 ± 0.00^{b}	60.00 ± 0.00^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	53.33 ± 6.67^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}	73.33 ± 6.67^{a}	73.33 ± 6.67^{a}	80.00 ± 0.00^{a}	86.67 ± 6.67^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	6.67 ± 6.67^{d}	13.33 ± 6.67^{d}	13.33 ± 6.67^{c}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	33.33 ± 6.67^{b}	40.00 ± 0.00^{b}	40.00 ± 0.00^{b}	46.67 ± 6.67^{bc}	53.33 ± 6.67^{b}	53.33 ± 6.67^{b}	60.00 ± 0.00^{b}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{c}
F value	24.00	83.20	41.60	29.65	22.44	60.50	46.93
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	15.32	8.84	12.51	17.69	19.77	12.51	15.32

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance. Means within columns were separated by Tukey's Honestly Significant Difference.

Table 33: Toxicity evaluation of different pesticides to *C. septempunctata* adults by residual film method during 2015-2016

Treatments	*Per cent adults mortality after hours of treatment (Mean ± SEm)*						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	33.33 ± 6.67^{b}	33.33 ± 6.67^{b}	40.00 ± 0.00^{c}	40.00 ± 0.00^{c}	46.67 ± 6.67^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	40.00 ± 0.00^{ab}	46.67 ± 6.67^{a}	53.33 ± 6.67^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{b}	60.00 ± 0.00^{b}	66.67 ± 6.67^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	46.67 ± 6.67^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}	66.67 ± 6.67^{a}	80.00 ± 0.00^{a}	86.67 ± 6.67^{a}	86.67 ± 6.67^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	6.67 ± 6.67^{d}	13.33 ± 6.67^{d}	13.33 ± 6.67^{d}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	33.33 ± 6.67^{b}	46.67 ± 6.67^{a}	46.67 ± 6.67^{ab}	53.33 ± 6.67^{a}	53.33 ± 6.67^{bc}	60.00 ± 0.00^{b}	60.00 ± 0.00^{bc}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{d}
F value	33.60	32.53	31.53	26.40	44.33	70.50	36.85
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	12.51	15.32	15.32	17.69	15.32	12.51	17.69

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.
Means within columns were separated by Tukey's Honestly Significant Difference.

Table 34: Toxicity evaluation of different pesticides to *C. septempunctata* adults by residual film method during 2014-2015 and 2015-2016 (Pooled)

Treatments	***Per cent adults mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	30.00 ± 6.67^{c}	33.33 ± 6.67^{c}	33.33 ± 3.33^{c}	40.00 ± 0.00^{c}	46.67 ± 6.67^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	36.67 ± 3.33^{b}	43.33 ± 3.33^{a}	50.00 ± 6.67^{ab}	53.33 ± 6.67^{ab}	53.33 ± 6.67^{b}	60.00 ± 0.00^{b}	63.33 ± 3.33^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	50.00 ± 6.67^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}	70.00 ± 6.67^{a}	76.67 ± 3.33^{a}	83.33 ± 3.33^{a}	86.67 ± 6.67^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	6.67 ± 6.67^{d}	13.33 ± 6.67^{d}	13.33 ± 6.67^{d}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	33.33 ± 6.67^{b}	43.33 ± 3.33^{a}	43.33 ± 3.33^{b}	46.67 ± 6.67^{bc}	56.67 ± 3.33^{b}	56.67 ± 3.33^{b}	60.00 ± 0.00^{bc}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{d}
F value	27.84	45.20	35.56	28.03	30.65	65.50	41.17
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
HSD$_{P=0.05}$	13.31	11.90	13.31	16.83	16.83	11.90	15.74

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance. Means within columns were separated by Tukey's Honestly Significant Difference.

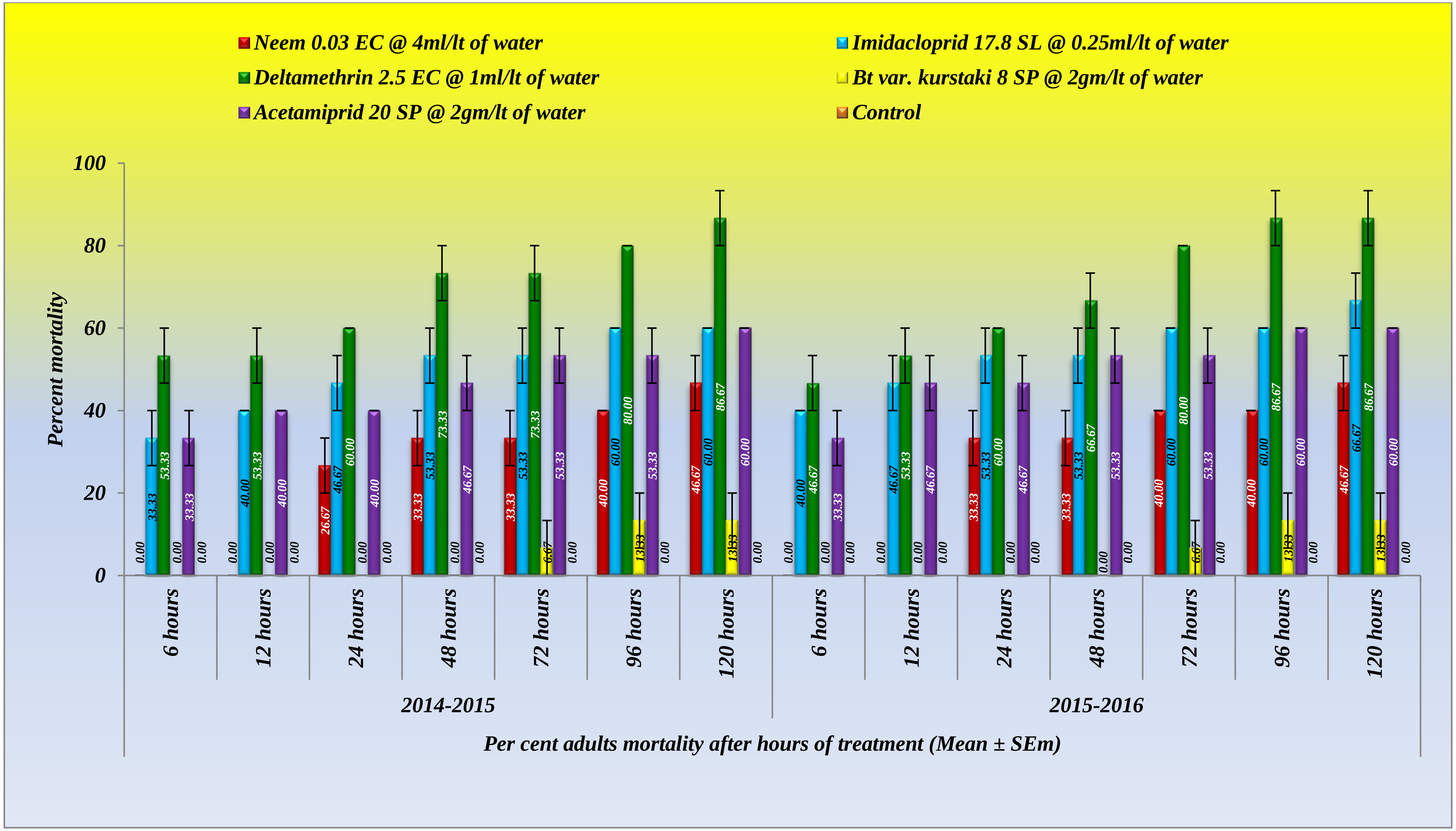

Fig 15a: Toxicity evaluation of different pesticides to *C. septempunctata* adults by residual film method during 2014-2015 and 2015-2016

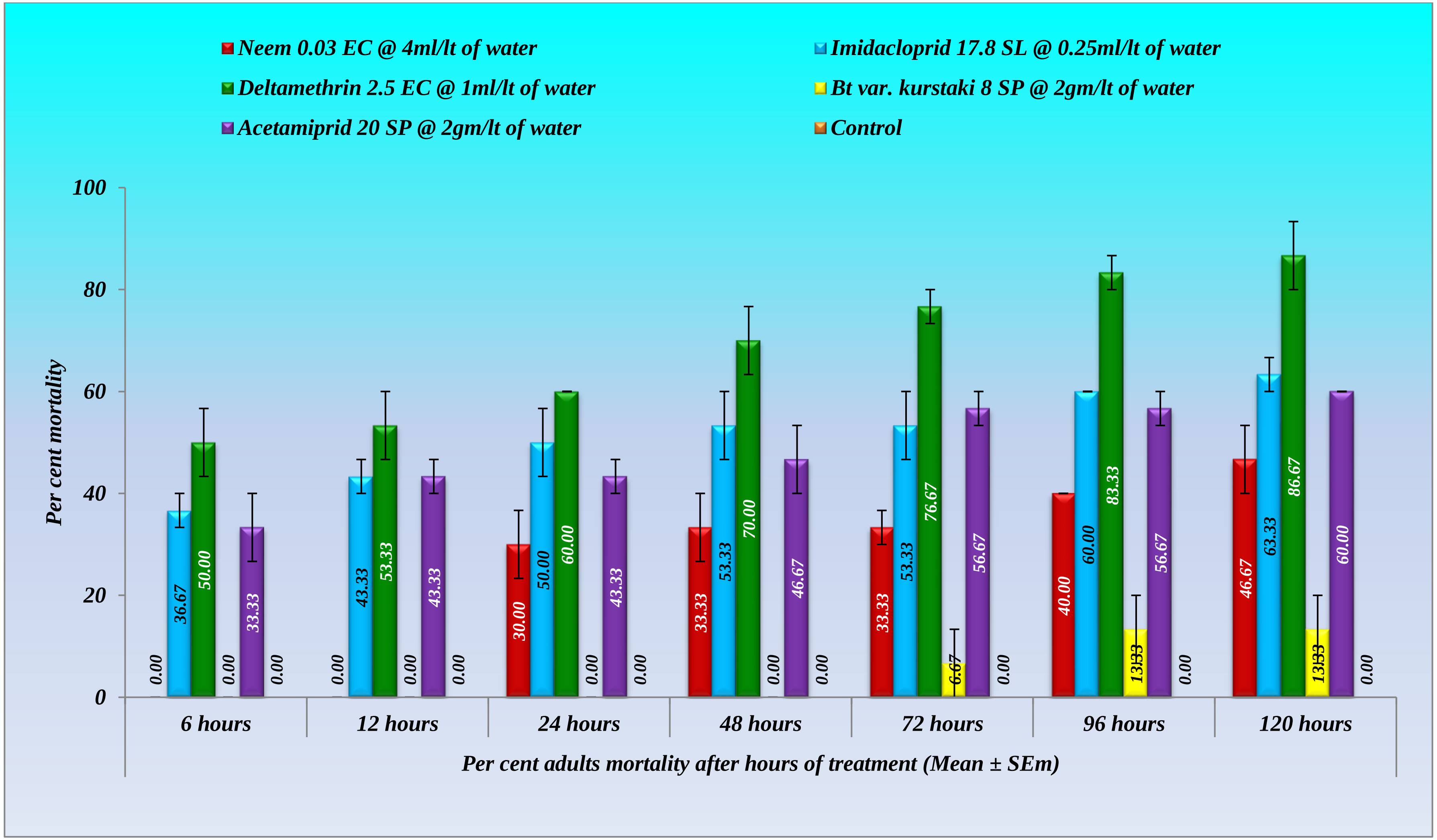

Fig 15b: Toxicity evaluation of different pesticides to *C. septempunctata* adults by residual film method during 2014-2015 and 2015-2016 (Pooled)

treatment in residual film method.

4.6.1.4. Toxicity of different pesticides to *Coccinella septempunctata* adults by diet contamination method

The toxic effect of different pesticides on *C. septempunctata* adults by diet contamination method exhibited significant difference with respect to the time after treatment (Table 35, 36 and 37 and Fig. 16a and 16b). Significant difference ($F=9.30$, *df* =5, $p<0.01$; $F=9.30$, *df* =5, $p<0.01$ and $F=9.30$, *df* =5, $p<0.01$) were observed in mortality of *C. septempunctata* adults exposed to different pesticides even just after 6 hours of treatment and maximum mortality was recorded in Deltamethrin 2.5 EC i.e., 26.67 ± 6.67% followed by Acetamiprid 20 SP and Imidacloprid 17.8 SL and with 20.00 ± 0.00% and 13.33 ± 6.67% mortality, respectively in both the years.

Toxicity of Neem 0.03 EC was found only after 24 hours of treatment i.e., 20.00 ± 0.00% and 20.00 ± 0.00% during 2014-2015 and 2015-2016, respectively and reached about 33.33 ± 6.67% mortality after 120 hours of treatment in both the years. Toxicity of *Bt* var. *kurstaki* 8 SP was observed only after 48 hours of treatment i.e., 13.33 ± 6.67% and 6.67 ± 6.67% and reached about 20.00 ± 0.00% and 26.67 ± 6.67% mortality after 120 hours of treatment during 2014-2015 and 2015-2016, respectively. In the control, no *C. septempunctata* adults mortality occurred from 6 to 120 hours after treatment. With the increase of time after exposure to different pesticides, the mortality rate of *C. septempunctata* adults kept on increasing and mortality was recorded after 120 hours of treatment in Deltamethrin 2.5 EC i.e., 60.00 ± 0.00% followed by Imidacloprid 17.8 SL, Acetamiprid 20 SP and Neem 0.03 EC with 46.67 ± 6.67%, 46.67 ± 6.67% and 33.33 ± 6.67% mortality in both the years.

The present results are in conformity with the findings of Ahmad *et al.* (2011) who reported that the maximum mortality of *C. undecimpunctata* adults was recorded in Deltamethrin 2.5 EC with 63.30% mortality followed by Acetamiprid 20 SP with 53.30% mortality under leaf dip method after 72 hours of treatment. Negative effect of neem to coccinellid has also been reported by several researchers who reported that neem oil caused about 40.00% and 22.00% adult mortality on *Adonia variegate* and *Menochilus sexmaculatus*, respectively (Swaminathan *et al*., 2010; Khan *et al*., 2015).

Table 35: Toxicity evaluation of different pesticides to *C. septempunctata* adults by diet contamination method during 2014-2015

Treatments	*Per cent adults mortality after hours of treatment (Mean ± SEm)*						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	20.00 ± 0.00^{b}	26.67 ± 6.67^{bc}	26.67 ± 6.67^{bc}	33.33 ± 6.67^{b}	33.33 ± 6.67^{bc}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	13.33 ± 6.67^{b}	20.00 ± 0.00^{b}	26.67 ± 6.67^{b}	33.33 ± 6.67^{ab}	33.33 ± 6.67^{bc}	40.00 ± 0.00^{b}	46.67 ± 6.67^{ab}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	26.67 ± 6.67^{a}	33.33 ± 6.67^{a}	40.00 ± 0.00^{a}	46.67 ± 6.67^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}	60.00 ± 0.00^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	13.33 ± 6.67^{c}	13.33 ± 6.67^{c}	20.00 ± 0.00^{c}	20.00 ± 0.00^{c}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	20.00 ± 0.00^{ab}	20.00 ± 0.00^{b}	26.67 ± 6.67^{b}	33.33 ± 6.67^{ab}	40.00 ± 0.00^{ab}	40.00 ± 0.00^{b}	46.67 ± 6.67^{ab}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
F value	9.30	27.40	17.30	7.40	14.93	56.80	21.13
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	12.51	8.84	12.51	19.77	15.32	8.84	15.32

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.

Means within columns were separated by Tukey's Honestly Significant Difference.

Table 36: Toxicity evaluation of different pesticides to *C. septempunctata* adults by diet contamination method during 2015-2016

	Per cent adults mortality after hours of treatment (Mean ± SEm)						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	20.00 ± 0.00^{b}	20.00 ± 0.00^{cd}	26.67 ± 6.67^{bc}	26.67 ± 6.67^{b}	33.33 ± 6.67^{bc}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	13.33 ± 6.67^{b}	20.00 ± 0.00^{b}	26.67 ± 6.67^{b}	26.67 ± 6.67^{bc}	33.33 ± 6.67^{b}	40.00 ± 0.00^{ab}	46.67 ± 6.67^{ab}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	26.67 ± 6.67^{a}	33.33 ± 6.67^{a}	40.00 ± 0.00^{a}	40.00 ± 0.00^{a}	53.33 ± 6.67^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	6.67 ± 6.67^{de}	13.33 ± 6.67^{cd}	26.67 ± 6.67^{b}	26.67 ± 6.67^{c}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	20.00 ± 0.00^{ab}	20.00 ± 0.00^{b}	26.67 ± 6.67^{b}	33.33 ± 6.67^{ab}	40.00 ± 0.00^{ab}	46.67 ± 6.67^{a}	46.67 ± 6.67^{ab}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{e}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}
F value	9.30	27.40	17.30	10.73	12.25	12.25	14.80
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	12.51	8.84	12.51	15.32	17.69	17.69	17.69

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance. Means within columns were separated by Tukey's Honestly Significant Difference.

Table 37: Toxicity evaluation of different pesticides to *C. septempunctata* adults by diet contamination method during 2014-2015 and 2014-2015 (Pooled)

Treatments	*Per cent adults mortality after hours of treatment (Mean ± SEm)*						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00[c]	0.00 ± 0.00[c]	20.00 ± 0.00[b]	23.33 ± 3.33[bc]	26.67 ± 6.67[b]	30.00 ± 6.67[bc]	33.33 ± 6.67[b]
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	13.33 ± 6.67[b]	20.00 ± 0.00[b]	26.67 ± 6.67[b]	30.00 ± 6.67[ab]	33.33 ± 6.67[b]	40.00 ± 0.00[b]	46.67 ± 6.67[a]
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	26.67 ± 6.67[a]	33.33 ± 6.67[a]	40.00 ± 0.00[a]	43.33 ± 3.33[a]	53.33 ± 6.67[a]	56.67 ± 3.33[a]	60.00 ± 0.00[a]
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00[c]	0.00 ± 0.00[c]	0.00 ± 0.00[c]	10.00 ± 6.67[c]	13.33 ± 6.67[c]	23.33 ± 3.33[c]	23.33 ± 3.33[b]
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	20.00 ± 0.00[ab]	20.00 ± 0.00[b]	26.67 ± 6.67[b]	33.33 ± 6.67[ab]	40.00 ± 0.00[ab]	43.33 ± 3.33[b]	46.67 ± 6.67[a]
Control (T_0)	0.00 ± 0.00[c]	0.00 ± 0.00[c]	0.00 ± 0.00[c]	0.00 ± 0.00[c]	0.00 ± 0.00[c]	0.00 ± 0.00[d]	0.00 ± 0.00[c]
F value	9.30	27.40	17.30	8.65	12.25	21.04	17.51
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	11.90	8.42	11.90	16.83	16.83	13.31	15.74

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.

Means within columns were separated by Tukey's Honestly Significant Difference.

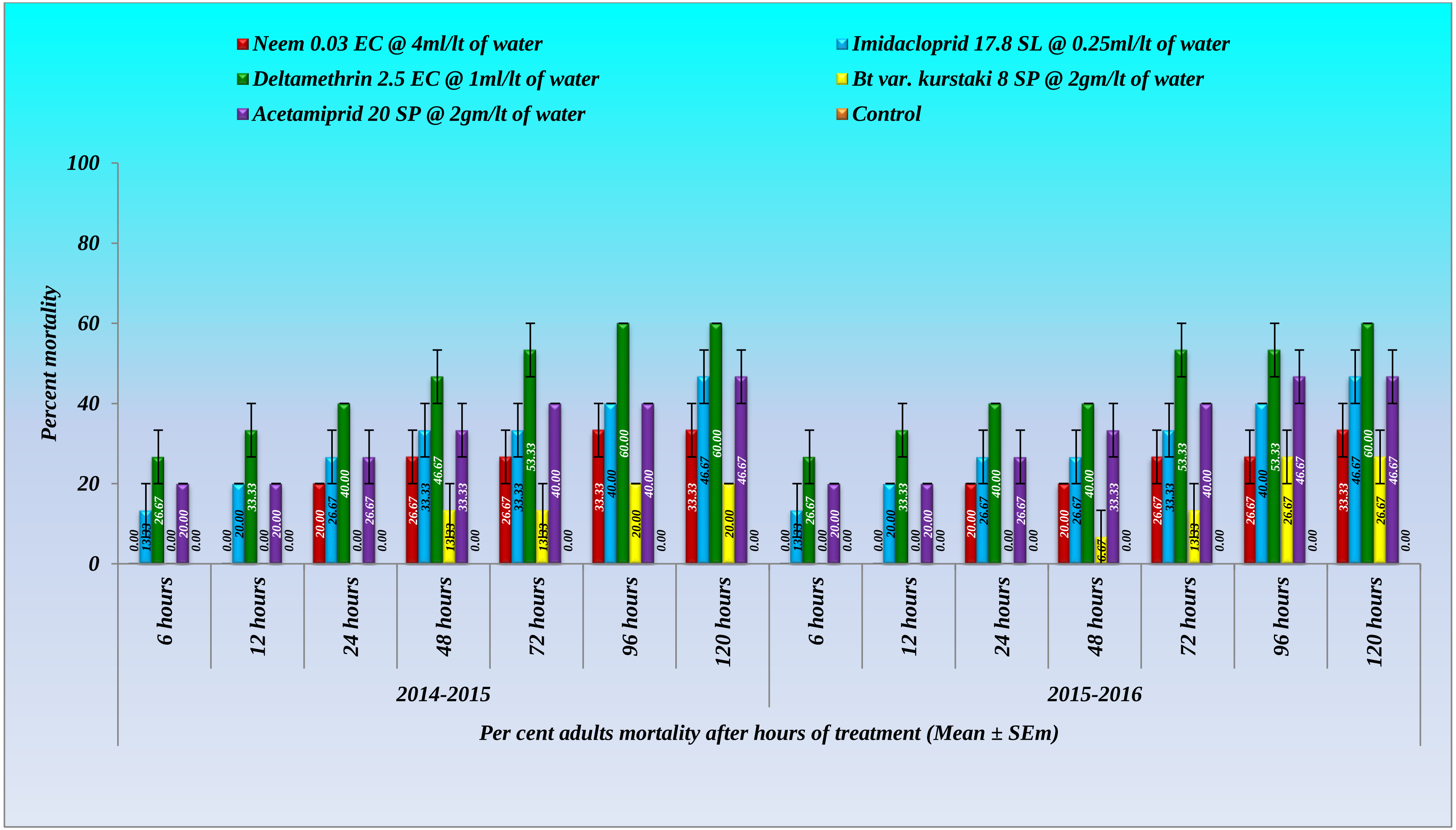

Fig 16a: Toxicity evaluation of different pesticides to *C. septempunctata* adults by diet contamination method during 2014-2015 and 2015-2016

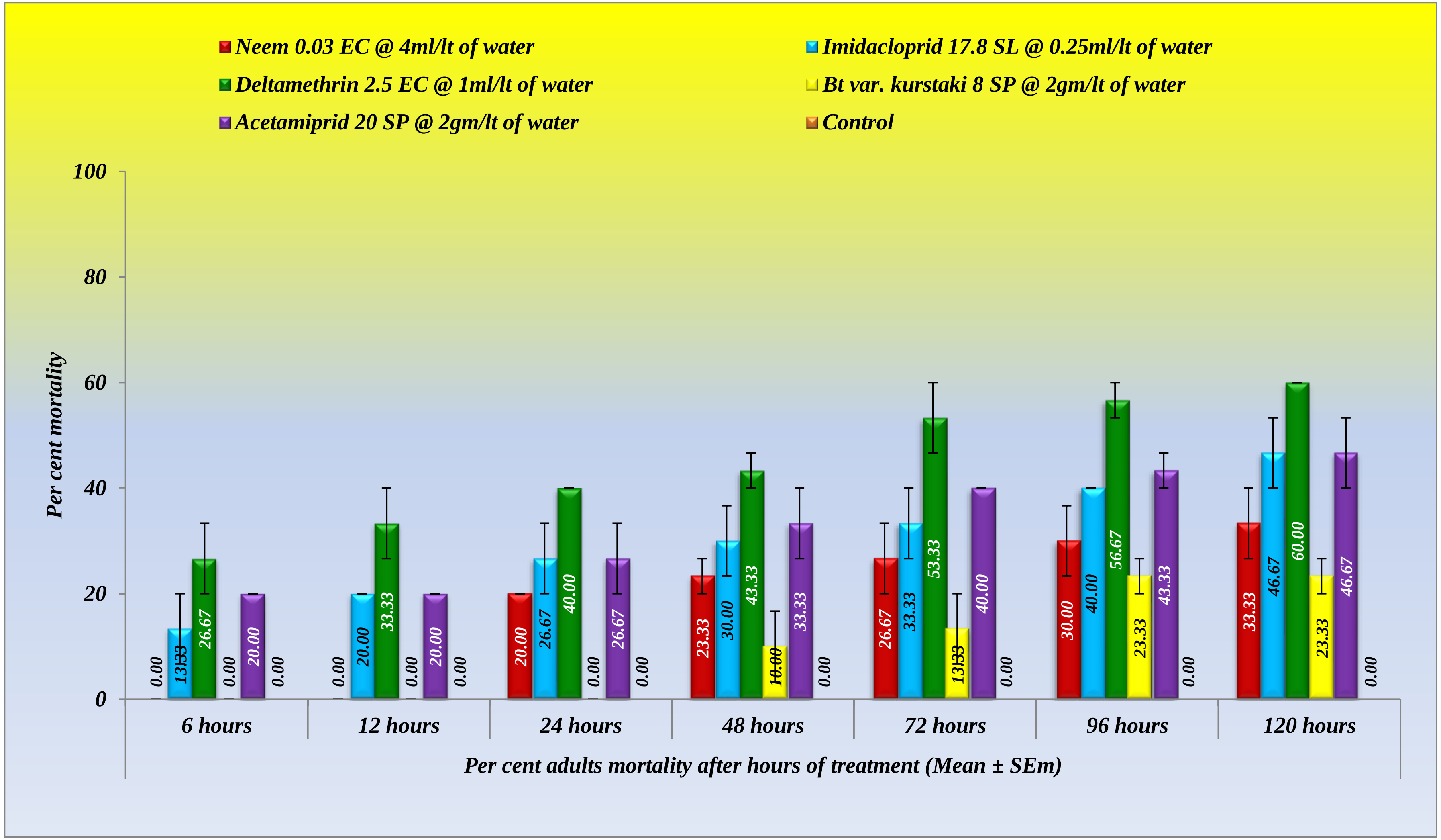

Fig 16b: Toxicity evaluation of different pesticides to *C. septempunctata* adults by diet contamination method during 2014-2015 and 2015-2016 (Pooled)

4.6.2. Toxicity of different pesticides to *Coccinella transversalis* reared on mustard aphid, *Lipaphis erysimi*

4.6.2.1. Toxicity of different pesticides to *Coccinella transversalis* grubs by residual film method

The toxic effect of different pesticides on *C. transversalis* grubs by residual film method induced significant difference with respect to the time after treatment (Table 38, 39 and 40 and Fig. 17a and 17b). Significant difference (F=40.80, *df* =5, p<0.01; F=58.10, *df* =5, p<0.01 and F=47.72, *df* =5, p<0.01) were observed in mortality of *C. transversalis* grubs exposed to different pesticides even just after 6 hours of treatment and maximum mortality was recorded in Deltamethrin 2.5 EC i.e., 66.67 ± 6.67% and 66.67 ± 6.67% during 2014-2015 and 2015-2016, respectively with mean as 66.67 ± 6.67% followed by Imidacloprid 17.8 SL (46.67 ± 6.67% and 46.67 ± 6.67%) and Acetamiprid 20 SP (46.67 ± 6.67% and 40.00 ± 0.00%) with means as 46.67 ± 6.67% and 43.33 ± 3.33% mortality, respectively.

Toxicity of Neem 0.03 EC was found only after 12 hours of treatment i.e., 33.33 ± 6.67% and reached about 53.33 ± 6.67% mortality after 120 hours of treatment in both the years. Toxicity of *Bt* var. *kurstaki* 8 SP was observed only after 48 hours of treatment i.e., 13.33 ± 6.67% and 20.00 ± 0.00% during 2014-2015 and 2015-2016, respectively with mean as 16.67 ± 3.33% and reached about 26.67 ± 6.67% mortality after 120 hours of treatment in both the years. In the control, no *C. transversalis* grubs mortality occurred from 6 to 120 hours after treatment. With the increase of time after exposure to different pesticides, the mortality rate of *C. transversalis* grubs kept on increasing and complete mortality was recorded after 96 hours of treatment in Deltamethrin 2.5 EC i.e., 100.00 ± 0.00% and 100.00 ± 0.00% during 2014-2015 and 2015-2016, respectively followed by Imidacloprid 17.8 SL (86.67 ± 6.67% and 86.67 ± 6.67%), Acetamiprid 20 SP (86.67 ± 6.67% and 80.00 ± 0.00%) and Neem 0.03 EC (53.33 ± 6.67% and 53.33 ± 6.67%) with means as 86.67 ± 6.67, 83.33 ± 3.33% and 53.33 ± 6.67% mortality, respectively.

Overall Deltamethrin 2.5 EC was observed to be highly toxic with 100% mortality of *C. transversalis* grubs within 96 hours of treatment followed by Imidacloprid 17.8 SL and Acetamiprid 20 SP while *Bt* var. *kurstaki* 8 SP treatment was found to be safer to *C. transversalis* grubs, having least mortality rate as compared to other pesticides.

Table 38: Toxicity evaluation of different pesticides to *C. transversalis* grubs by residual film method during 2014-2015

Treatments	***Per cent grubs mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00[c]	33.33 ± 6.67[b]	40.00 ± 0.00[c]	46.67 ± 6.67[c]	53.33 ± 6.67[c]	53.33 ± 6.67[c]	53.33 ± 6.67[c]
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	46.67 ± 6.67[b]	46.67 ± 6.67[b]	60.00 ± 0.00[b]	73.33 ± 6.67[ab]	73.33 ± 6.67[b]	86.67 ± 6.67[b]	86.67 ± 6.67[b]
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	66.67 ± 6.67[a]	66.67 ± 6.67[a]	73.33 ± 6.67[a]	86.67 ± 6.67[a]	93.33 ± 6.67[a]	100.00 ± 0.00[a]	100.00 ± 0.00[a]
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00[c]	0.00 ± 0.00[c]	0.00 ± 0.00[d]	13.33 ± 6.67[d]	20.00 ± 0.00[d]	20.00 ± 0.00[d]	26.67 ± 6.67[d]
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	46.67 ± 6.67[b]	46.67 ± 6.67[b]	53.33 ± 6.67[b]	66.67 ± 6.67[b]	66.67 ± 6.67[bc]	80.00 ± 0.00[b]	86.67 ± 6.67[b]
Control (T_0)	0.00 ± 0.00[c]	0.00 ± 0.00[c]	0.00 ± 0.00[d]	0.00 ± 0.00[d]	0.00 ± 0.00[e]	0.00 ± 0.00[e]	0.00 ± 0.00[e]
F value	40.80	24.85	65.60	32.36	41.20	106.50	52.45
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	15.32	17.69	12.51	19.77	17.69	12.51	17.69

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.

Means within columns were separated by Tukey's Honestly Significant Difference.

Table 39: Toxicity evaluation of different pesticides to *C. transversalis* grubs by residual film method during 2015-2016

Treatments	***Per cent grubs mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	33.33 ± 6.67^{c}	40.00 ± 0.00^{c}	46.67 ± 6.67^{c}	46.67 ± 6.67^{c}	53.33 ± 6.67^{c}	53.33 ± 6.67^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	46.67 ± 6.67^{b}	53.33 ± 6.67^{ab}	66.67 ± 6.67^{ab}	73.33 ± 6.67^{ab}	73.33 ± 6.67^{b}	80.00 ± 0.00^{b}	86.67 ± 6.67^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	66.67 ± 6.67^{a}	66.67 ± 6.67^{a}	73.33 ± 6.67^{a}	86.67 ± 6.67^{a}	93.33 ± 6.67^{a}	100.00 ± 0.00^{a}	100.00 ± 0.00^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	20.00 ± 0.00^{d}	20.00 ± 0.00^{d}	26.67 ± 6.67^{d}	26.67 ± 6.67^{d}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	40.00 ± 0.00^{b}	46.67 ± 6.67^{bc}	53.33 ± 6.67^{bc}	60.00 ± 0.00^{b}	60.00 ± 0.00^{bc}	73.33 ± 6.67^{b}	80.00 ± 0.00^{b}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}
F value	58.10	26.40	46.73	48.33	53.33	61.33	66.93
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	12.51	17.69	15.32	15.32	15.32	15.32	15.32

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance. Means within columns were separated by Tukey's Honestly Significant Difference.

Table 40: Toxicity evaluation of different pesticides to *C. transversalis* grubs by residual film method during 2014-2015 and 2015-2016 (Pooled)

Treatments	***Per cent grubs mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^c	33.33 ± 6.67^b	40.00 ± 0.00^c	46.67 ± 6.67^c	50.00 ± 6.67^c	53.33 ± 6.67^c	53.33 ± 6.67^c
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	46.67 ± 6.67^b	50.00 ± 6.67^{ab}	63.33 ± 3.33^{ab}	73.33 ± 6.67^{ab}	73.33 ± 6.67^b	83.33 ± 3.33^b	86.67 ± 6.67^b
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	66.67 ± 6.67^a	66.67 ± 6.67^a	73.33 ± 6.67^a	86.67 ± 6.67^a	93.33 ± 6.67^a	100.00 ± 0.00^a	100.00 ± 0.00^a
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^c	0.00 ± 0.00^c	0.00 ± 0.00^d	16.67 ± 3.33^d	20.00 ± 0.00^d	23.33 ± 3.33^d	26.67 ± 6.67^d
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	43.33 ± 3.33^b	46.67 ± 6.67^b	53.33 ± 6.67^b	63.33 ± 3.33^b	63.33 ± 3.33^{bc}	76.67 ± 3.33^b	83.33 ± 3.33^b
Control (T_0)	0.00 ± 0.00^c	0.00 ± 0.00^c	0.00 ± 0.00^d	0.00 ± 0.00^d	0.00 ± 0.00^e	0.00 ± 0.00^e	0.00 ± 0.00^e
F value	47.72	25.63	54.28	38.35	46.40	79.40	58.66
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	13.31	16.83	13.31	16.83	15.74	13.31	15.74

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.
Means within columns were separated by Tukey's Honestly Significant Difference.

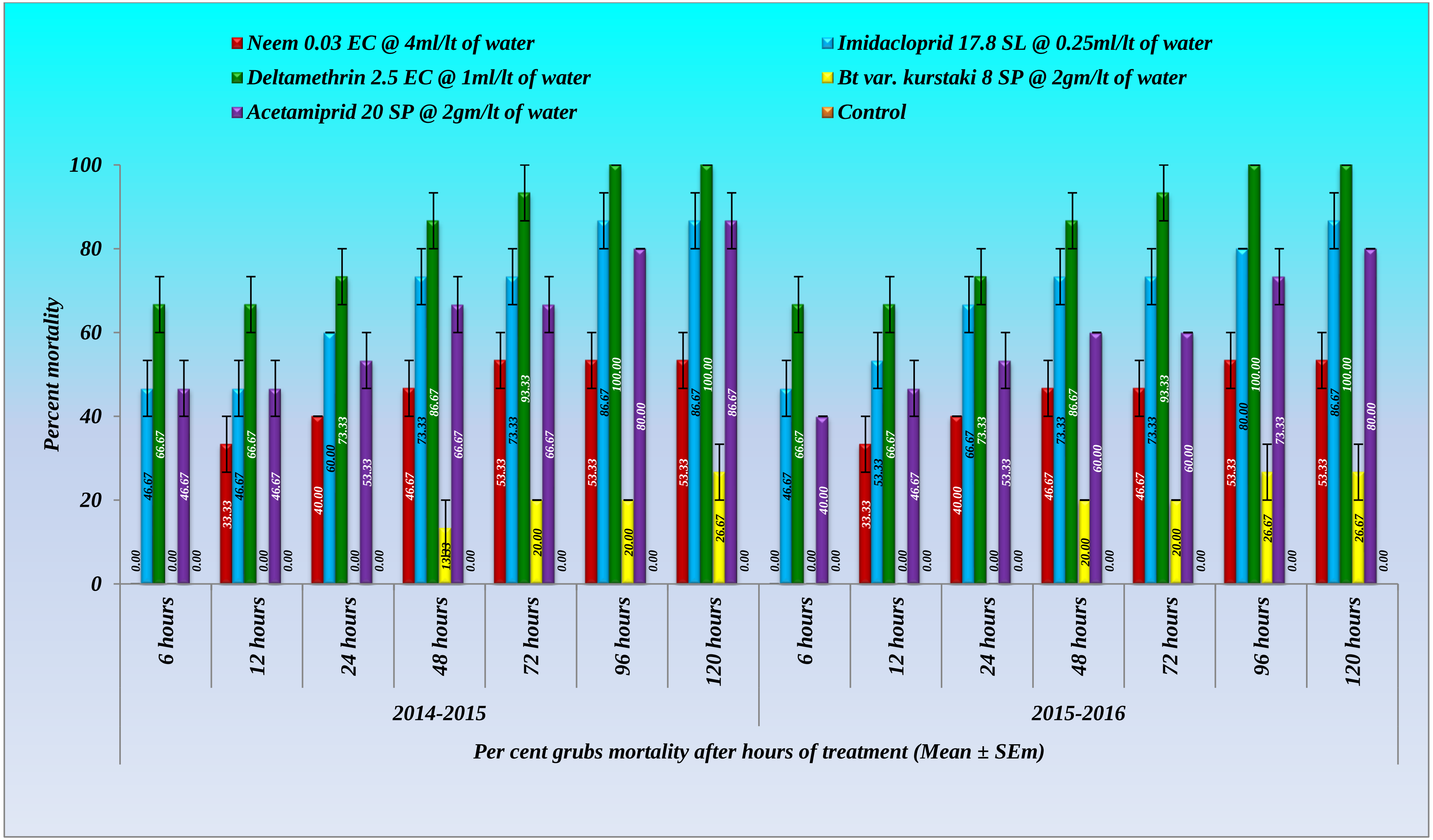

Fig 17a: Toxicity evaluation of different pesticides to *C. transversalis* grubs by residual film method during 2014-2015 and 2015-2016

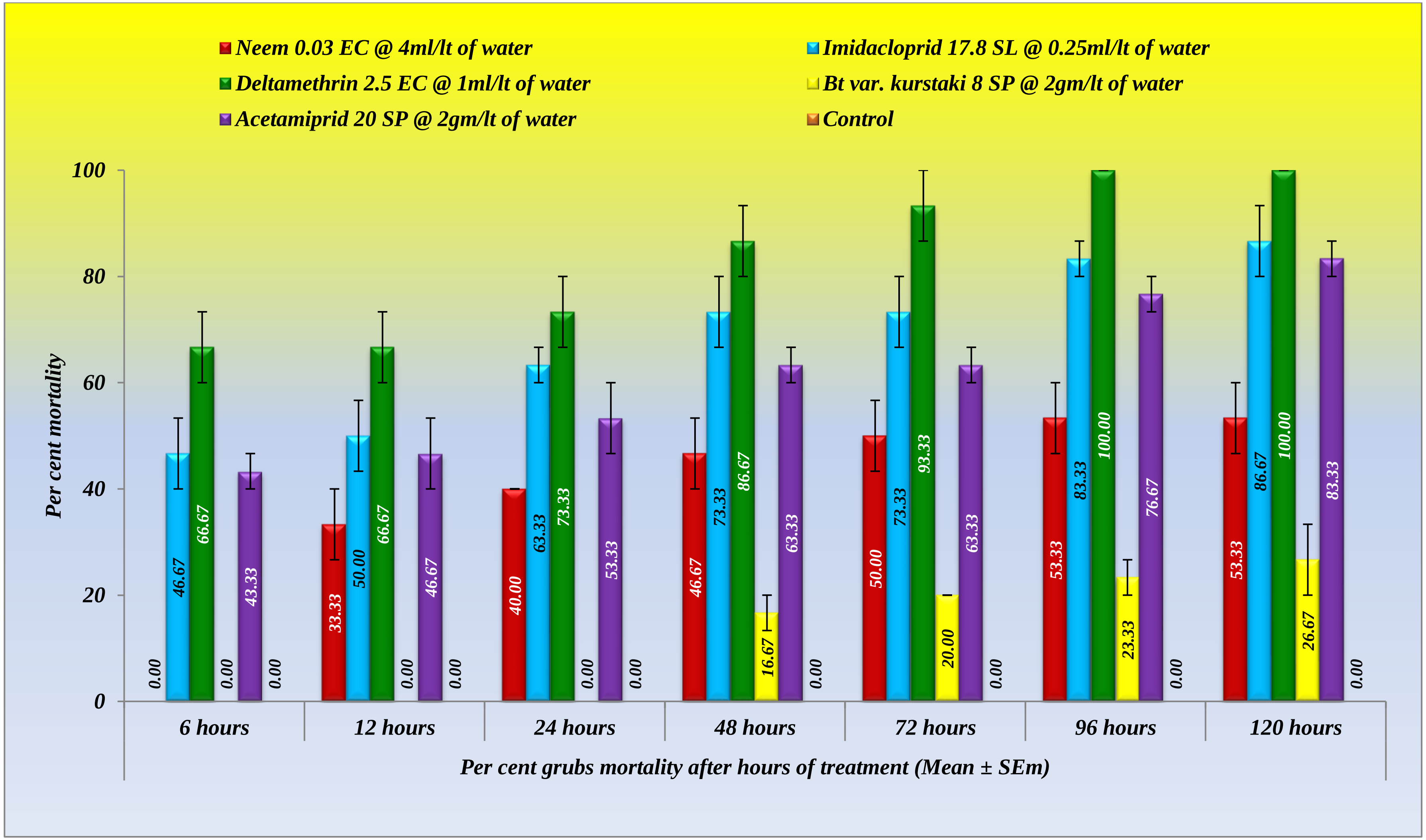

Fig 17b: Toxicity evaluation of different pesticides to *C. transversalis* grubs by residual film method during 2014-2015 and 2015-2016 (Pooled)

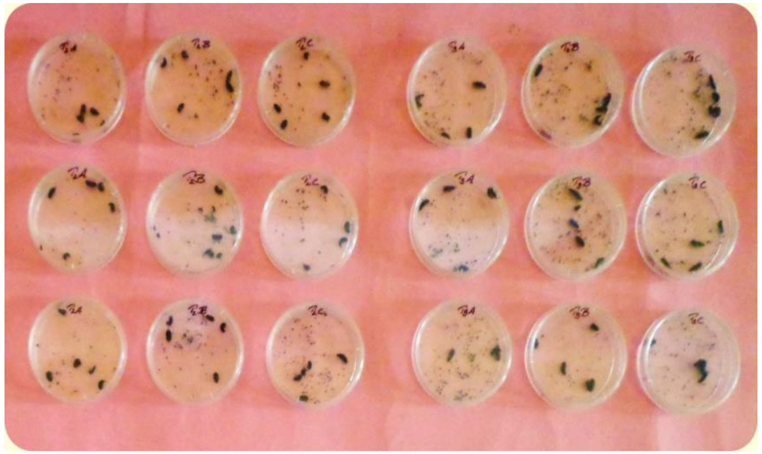

Plate 14a: Bioassay study against *C. transversalis* grubs by residual film method

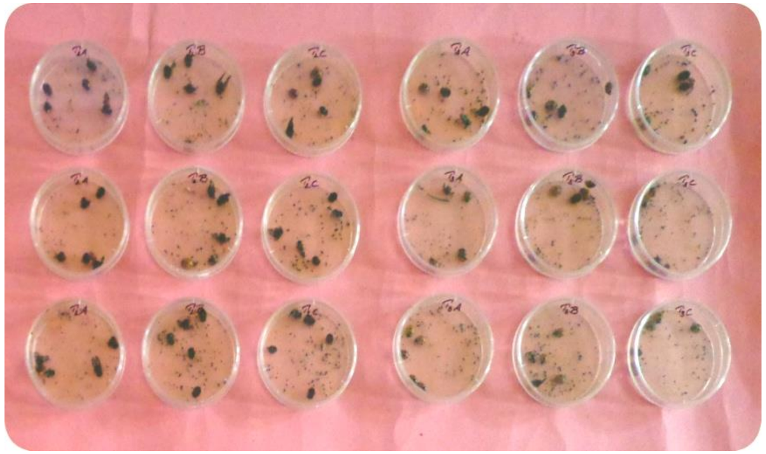

Plate 14b: Bioassay study against *C. transversalis* adults by residual film method

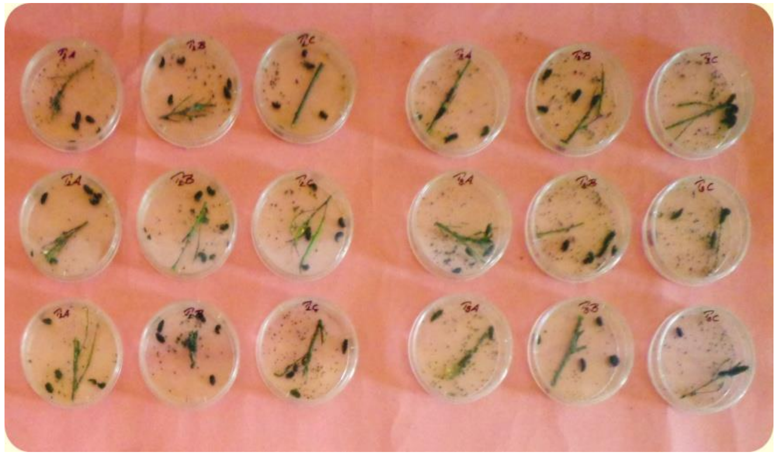

Plate 14c: Bioassay study against *C. transversalis* grubs by diet contamination method

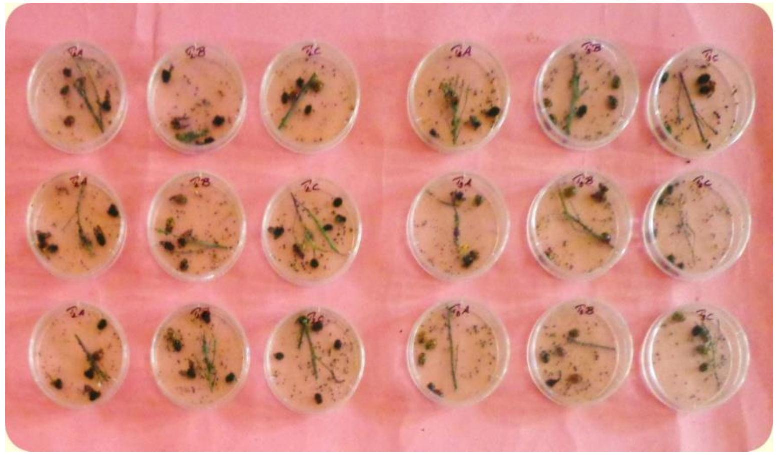

Plate 14d: Bioassay study against *C. transversalis* adults by diet contamination method

Plate 14: Bioassay study of different pesticides against *C. transversalis* grubs and adult

The present results are quite similar with the findings of Yu *et al.* (2014) who reported that Imidacloprid 17.8 SL caused about 50.00% mortality to *C. septempunctata* grubs after 72 hours of treatment by residual film method. Negative effect of neem to coccinellid has also been reported by several researchers who reported that neem oil caused about 40.00% and 22.00% adult mortality on *Adonia variegate* and *Menochilus sexmaculatus*, respectively (Swaminathan *et al*., 2010; Khan *et al*., 2015).

4.6.2.2. Toxicity of different pesticides to *Coccinella transversalis* grubs by diet contamination method

The toxic effect of different pesticides on *C. transversalis* grubs by diet contamination method induced significant difference with respect to the time after treatment (Table 41, 42 and 43 and Fig. 18a and 18b). Significant difference (F=11.53, *df* =5, p<0.01; F=21.20, *df* =5, p<0.01 and F=15.40, *df* =1, p<0.01) were observed in mortality of *C. transversalis* grubs exposed to different pesticides even just after 6 hours of treatment and maximum mortality was recorded in Deltamethrin 2.5 EC i.e., 33.33 ± 6.67% and 40.00 ± 0.00% during 2014-2015 and 2015-2016, respectively with mean as 36.67 ± 3.33% followed by Imidacloprid 17.8 SL and Acetamiprid 20 SP with 26.67 ± 6.67% and 26.67 ± 6.67% in both the years.

Toxicity of Neem 0.03 EC was found only after 12 hours of treatment i.e., 20.00 ± 0.00% and reached about 40.00 ± 0.00% mortality after 120 hours of treatment in both the years. Toxicity of *Bt* var. *kurstaki* 8 SP was observed only after 24 hours of treatment i.e., 13.33 ± 6.67% and reached about 40.00 ± 0.00% mortality after 120 hours of treatment in both the years. In the control, no *C. transversalis* grubs mortality occurred, from 6 to 120 hours after treatment. With the increase of time after exposure to different pesticides, the mortality rate of *C. transversalis* grubs kept on increasing and maximum mortality was recorded after 120 hours of treatment in Deltamethrin 2.5 EC i.e., 73.33 ± 6.67% and 73.33 ± 6.67% during 2014-2015 and 2015-2016, respectively followed by Acetamiprid 20 SP (60.00 ± 0.00% and 66.67 ± 6.67%), Imidacloprid 17.8 SL (60.00 ± 0.00% and 60.00 ± 0.00%) and Neem 0.03 EC (40.00 ± 0.00% and 40.00 ± 0.00%) with means as 63.33 ± 3.33, 60.00 ± 0.00% and 40.00 ± 0.00% mortality, respectively.

Overall Deltamethrin 2.5 EC was observed to be highly toxic with nearly 100% mortality of *C. transversalis* grubs within 120 hours of treatment followed by Imidacloprid 17.8 SL and Acetamiprid 20 SP while *Bt* var. *kurstaki* 8 SP treatment was

Table 41: Toxicity evaluation of different pesticides to *C. transversalis* grubs by diet contamination method during 2014-2015

Treatments	***Per cent grubs mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{b}	20.00 ± 0.00^{b}	26.67 ± 6.67^{bc}	33.33 ± 6.67^{bc}	40.00 ± 0.00^{bc}	40.00 ± 0.00^{b}	40.00 ± 0.00^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	26.67 ± 6.67^{a}	26.67 ± 6.67^{b}	40.00 ± 0.00^{ab}	46.67 ± 6.67^{ab}	53.33 ± 6.67^{ab}	60.00 ± 0.00^{a}	60.00 ± 0.00^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	33.33 ± 6.67^{a}	40.00 ± 0.00^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}	66.67 ± 6.67^{a}	66.67 ± 6.67^{a}	73.33 ± 6.67^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{b}	0.00 ± 0.00^{c}	13.33 ± 6.67^{c}	26.67 ± 6.67^{c}	33.33 ± 6.67^{c}	33.33 ± 6.67^{b}	40.00 ± 0.00^{c}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	26.67 ± 6.67^{a}	26.67 ± 6.67^{b}	33.33 ± 6.67^{b}	46.67 ± 6.67^{ab}	53.33 ± 6.67^{ab}	60.00 ± 0.00^{a}	66.67 ± 6.67^{ab}
Control (T_0)	0.00 ± 0.00^{b}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}
F value	11.53	17.30	12.25	14.80	18.25	41.70	48.00
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	15.32	12.51	17.69	17.69	17.69	12.51	12.51

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.
Means within columns were separated by Tukey's Honestly Significant Difference.

Table 42: Toxicity evaluation of different pesticides to *C. transversalis* grubs by diet contamination method during 2015-2016

Treatments	***Per cent grubs mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	20.00 ± 0.00^{c}	26.67 ± 6.67^{cd}	33.33 ± 6.67^{bc}	40.00 ± 0.00^{bc}	40.00 ± 0.00^{bc}	40.00 ± 0.00^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	26.67 ± 6.67^{b}	33.33 ± 6.67^{ab}	46.67 ± 6.67^{ab}	46.67 ± 6.67^{ab}	53.33 ± 6.67^{ab}	53.33 ± 6.67^{ab}	60.00 ± 0.00^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	40.00 ± 0.00^{a}	40.00 ± 0.00^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}	60.00 ± 0.00^{a}	66.67 ± 6.67^{a}	73.33 ± 6.67^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	13.33 ± 6.67^{de}	26.67 ± 6.67^{c}	26.67 ± 6.67^{c}	33.33 ± 6.67^{c}	40.00 ± 0.00^{c}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	26.67 ± 6.67^{b}	26.67 ± 6.67^{bc}	33.33 ± 6.67^{bc}	40.00 ± 0.00^{bc}	46.67 ± 6.67^{ab}	53.33 ± 6.67^{ab}	60.00 ± 0.00^{b}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
F value	21.20	19.20	10.88	18.73	21.33	18.25	89.80
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	12.51	12.51	19.77	15.32	15.32	17.69	8.84

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.
Means within columns were separated by Tukey's Honestly Significant Difference.

Table 43: Toxicity evaluation of different pesticides to *C. transversalis* grubs by diet contamination method during 2014-2015 and 2014-2015 (Pooled)

Treatments	***Per cent grubs mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{b}	20.00 ± 0.00^{b}	26.67 ± 6.67^{bc}	33.33 ± 6.67^{bc}	40.00 ± 0.00^{bc}	40.00 ± 0.00^{b}	40.00 ± 0.00^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	26.67 ± 6.67^{a}	30.00 ± 6.67^{ab}	43.33 ± 3.33^{ab}	46.67 ± 6.67^{ab}	53.33 ± 6.67^{ab}	56.67 ± 3.33^{a}	60.00 ± 0.00^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	36.67 ± 3.33^{a}	40.00 ± 0.00^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}	63.33 ± 3.33^{a}	66.67 ± 6.67^{a}	73.33 ± 6.67^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{b}	0.00 ± 0.00^{c}	13.33 ± 6.67^{cd}	26.67 ± 6.67^{c}	30.00 ± 6.67^{c}	33.33 ± 6.67^{b}	40.00 ± 0.00^{c}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	26.67 ± 6.67^{a}	26.67 ± 6.67^{b}	33.33 ± 6.67^{b}	43.33 ± 3.33^{b}	50.00 ± 6.67^{ab}	56.67 ± 3.33^{a}	63.33 ± 3.33^{ab}
Control (T_0)	0.00 ± 0.00^{b}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}
F value	15.40	18.25	11.49	16.49	19.57	26.07	61.93
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
***HSD**$_{P=0.05}$*	13.31	11.90	17.85	15.74	15.74	14.58	10.31

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.

Means within columns were separated by Tukey's Honestly Significant Difference.

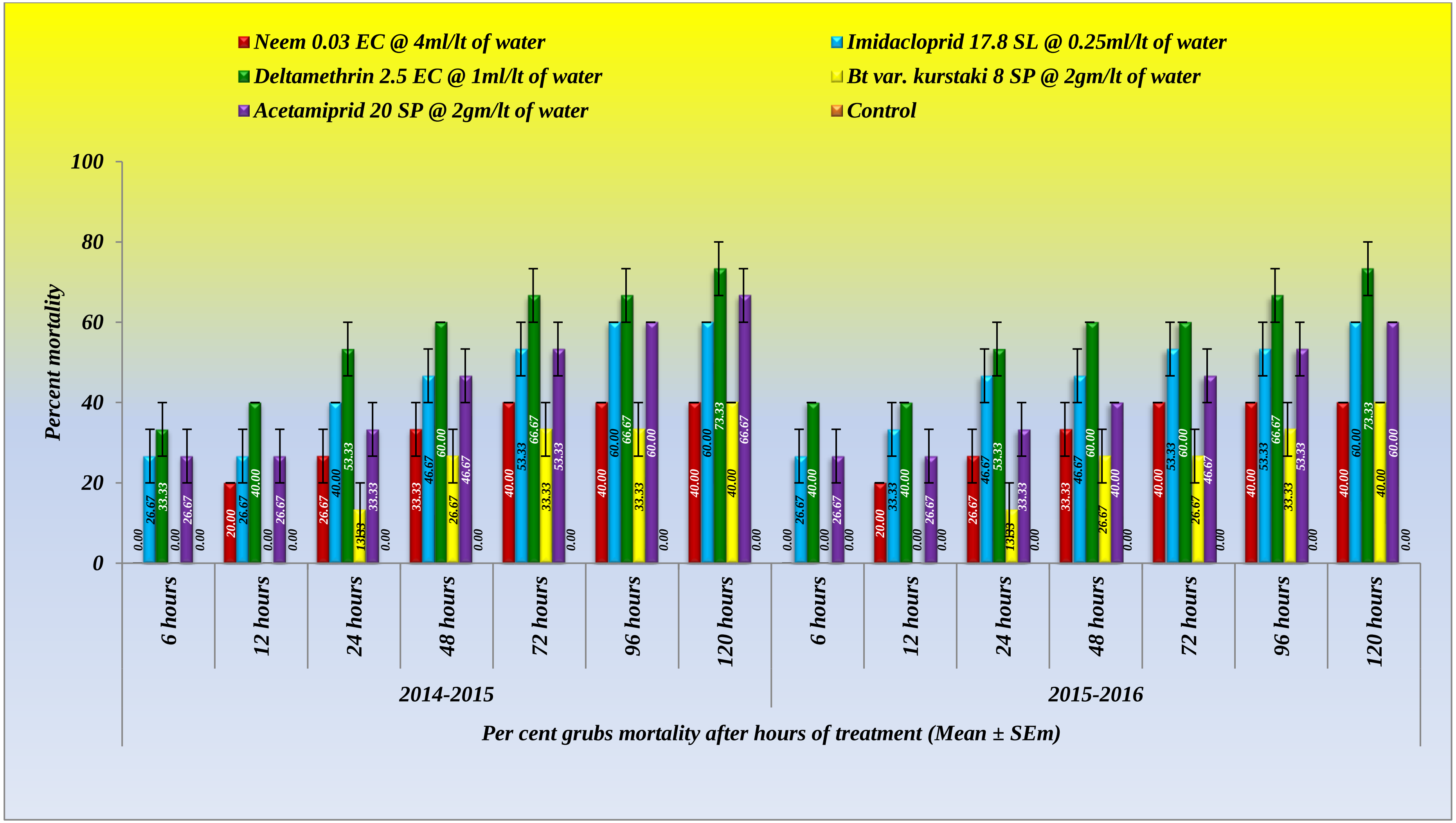

Fig 18a: Toxicity evaluation of different pesticides to *C. transversalis* grubs by diet contamination method during 2014-2015 and 2015-2016

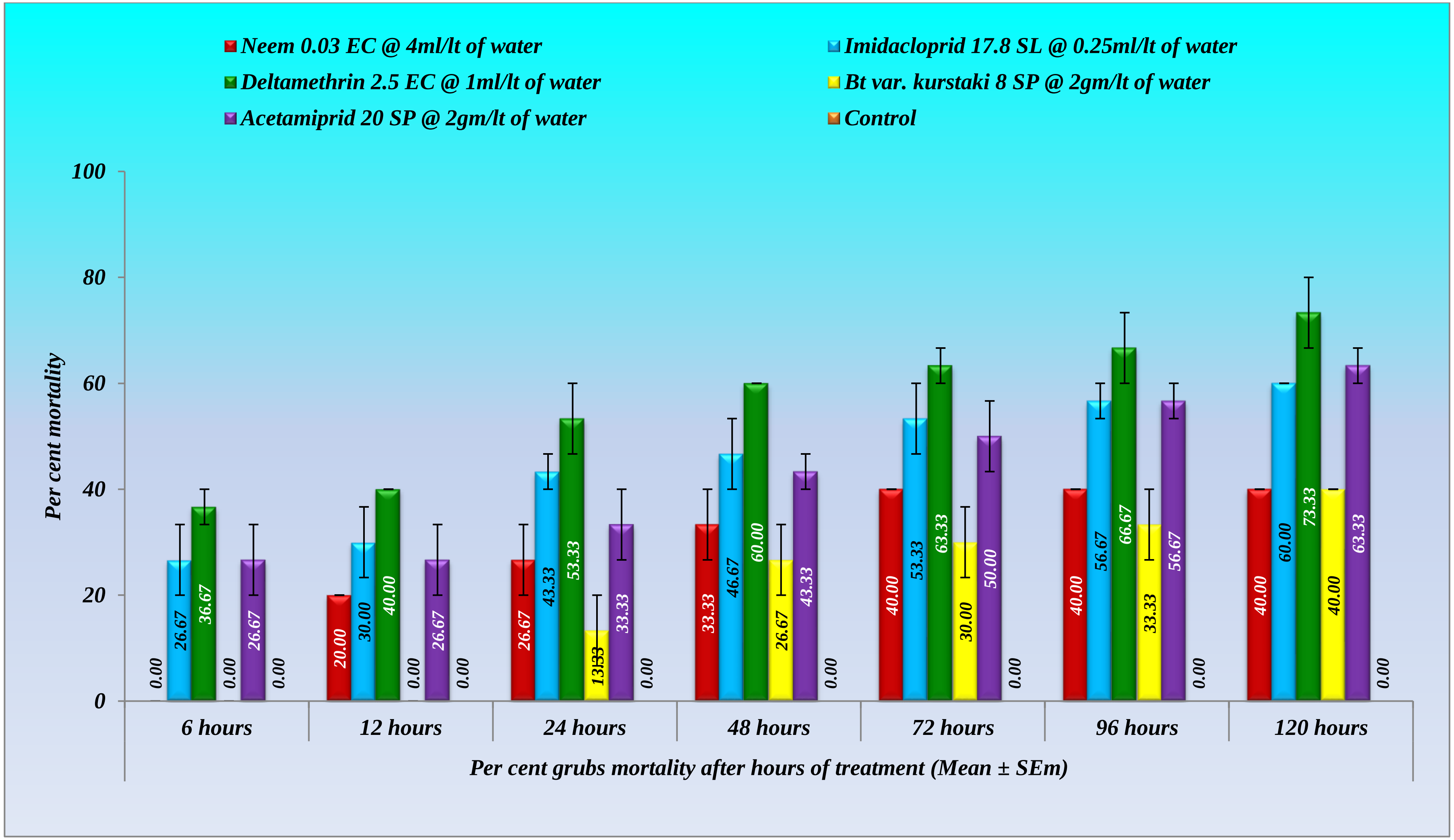

Fig 18b: Toxicity evaluation of different pesticides to *C. transversalis* grubs by diet contamination method during 2014-2015 and 2015-2016 (Pooled)

found to be safer to *C. transversalis* adults, having least mortality rate as compared to other pesticides.

The present results are quite similar with the findings of few researchers who reported that Imidacloprid 17.8 SL caused about 59.32% and 64.00% mortality to *C. septempunctata* grubs after 72 and 96 hours of treatment, respectively by diet contamination method (Amin *et al.*, 2014; Solangi *et al.*, 2007). Negative effect of neem to coccinellid has also been reported by several researchers who reported that neem oil caused about 40.00% and 22.00% adult mortality on *Adonia variegate* and *Menochilus sexmaculatus*, respectively (Swaminathan *et al*., 2010; Khan *et al*., 2015).

4.6.2.3. Toxicity of different pesticides to *Coccinella transversalis* adults by residual film method

The toxic effect of different pesticides on *C. transversalis* adults by residual film method induced significant difference with respect to the time after treatment (Table 44, 45 and 46 and Fig. 19a and 19b). Significant difference (F=38.90, *df* =5, p<0.01; F=73.00, *df* =5, p<0.01 and F=50.27, *df* =5, p<0.01) were observed in mortality of *C. transversalis* adults exposed to different pesticides even just after 6 hours of treatment and maximum mortality was recorded in Deltamethrin 2.5 EC i.e., 53.33 ± 6.67% and 46.67 ± 6.67% during 2014-2015 and 2015-2016, respectively with mean as 50.00 ± 6.67% followed by Imidacloprid 17.8 SL (40.00 ± 0.00% and 40.00 ± 0.00%) and Acetamiprid 20 SP (33.33 ± 6.67% and 40.00 ± 0.00%) with means as 40.00 ± 0.00% and 36.67 ± 3.33% mortality, respectively.

Toxicity of Neem 0.03 EC was found only after 24 hours of treatment i.e., 33.33 ± 6.67% and reached about 46.67 ± 6.67% mortality after 120 hours of treatment in both the years. Toxicity of *Bt* var. *kurstaki* 8 SP was observed only after 72 hours of treatment i.e., 13.33 ± 6.67% and 6.67 ± 6.67% during 2014-2015 and 2015-2016, respectively with mean as 10.00 ± 6.67% and reached about 20.00 ± 0.00% mortality after 120 hours of treatment in both the years. In the control, no *C. transversalis* adults mortality occurred from 6 to 120 hours after treatment. With the increase of time after exposure to different pesticides, the mortality rate of *C. transversalis* adults kept on increasing and maximum mortality was recorded after 120 hours of treatment in Deltamethrin 2.5 EC i.e., 93.33 ± 6.67% and 93.33 ± 6.67% during 2014-2015 and 2015-2016, respectively followed by Imidacloprid 17.8 SL (73.33 ± 6.67% and 66.67 ± 6.67%), Acetamiprid 20 SP (66.67 ± 6.67% and 60.00 ± 0.00%) and Neem 0.03 EC (46.67 ± 6.67% and 46.67 ±

Table 44: Toxicity evaluation of different pesticides to *C. transversalis* adults by residual film method during 2014-2015

Treatments	***Per cent adults mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	33.33 ± 6.67^{b}	33.33 ± 6.67^{c}	40.00 ± 0.00^{c}	40.00 ± 0.00^{c}	46.67 ± 6.67^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	40.00 ± 0.00^{b}	46.67 ± 6.67^{ab}	46.67 ± 6.67^{b}	53.33 ± 6.67^{b}	60.00 ± 0.00^{b}	66.67 ± 6.67^{b}	73.33 ± 6.67^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	53.33 ± 6.67^{a}	53.33 ± 6.67^{a}	66.67 ± 6.67^{a}	73.33 ± 6.67^{a}	80.00 ± 0.00^{a}	86.67 ± 6.67^{a}	93.33 ± 6.67^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	13.33 ± 6.67^{d}	13.33 ± 6.67^{d}	20.00 ± 0.00^{d}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	33.33 ± 6.67^{b}	40.00 ± 0.00^{b}	40.00 ± 0.00^{b}	46.67 ± 6.67^{b}	53.33 ± 6.67^{b}	60.00 ± 0.00^{b}	66.67 ± 6.67^{b}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}
F value	38.90	45.30	31.73	29.65	60.50	49.33	41.25
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
HSD$_{P=0.05}$	12.51	12.51	15.32	17.69	12.51	15.32	17.69

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.

Means within columns were separated by Tukey's Honestly Significant Difference.

Table 45: Toxicity evaluation of different pesticides to *C. transversalis* adults by residual film method during 2015-2016

Treatments	*Per cent adults mortality after hours of treatment (Mean ± SEm)*						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	33.33 ± 6.67^{b}	33.33 ± 6.67^{c}	40.00 ± 0.00^{b}	40.00 ± 0.00^{c}	46.67 ± 6.67^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	40.00 ± 0.00^{a}	46.67 ± 6.67^{a}	53.33 ± 6.67^{a}	53.33 ± 6.67^{b}	53.33 ± 6.67^{b}	60.00 ± 0.00^{b}	66.67 ± 6.67^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	46.67 ± 6.67^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}	73.33 ± 6.67^{a}	86.67 ± 6.67^{a}	86.67 ± 6.67^{a}	93.33 ± 6.67^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	6.67 ± 6.67^{c}	13.33 ± 6.67^{d}	20.00 ± 0.00^{d}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	40.00 ± 0.00^{a}	46.67 ± 6.67^{a}	46.67 ± 6.67^{ab}	53.33 ± 6.67^{b}	53.33 ± 6.67^{b}	60.00 ± 0.00^{b}	60.00 ± 0.00^{b}
Control (T_0)	0.00 ± 0.00^{b}	0.00 ± 0.00^{b}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}
F value	73.00	32.53	31.53	31.00	35.40	70.50	50.73
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	8.84	15.32	15.32	17.69	17.69	12.51	15.32

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance. Means within columns were separated by Tukey's Honestly Significant Difference.

Table 46: Toxicity evaluation of different pesticides to *C. transversalis* adults by residual film method during 2014-2015 and 2015-2016 (Pooled)

Treatments	***Per cent adults mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	33.33 ± 6.67^{c}	33.33 ± 6.67^{c}	40.00 ± 0.00^{c}	40.00 ± 0.00^{c}	46.67 ± 6.67^{c}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	40.00 ± 0.00^{ab}	46.67 ± 6.67^{a}	50.00 ± 6.67^{ab}	53.33 ± 6.67^{b}	56.67 ± 3.33^{b}	63.33 ± 3.33^{b}	70.00 ± 6.67^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	50.00 ± 6.67^{a}	53.33 ± 6.67^{a}	63.33 ± 3.33^{a}	73.33 ± 6.67^{a}	83.33 ± 3.33^{a}	86.67 ± 6.67^{a}	93.33 ± 6.67^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	10.00 ± 6.67^{d}	13.33 ± 6.67^{d}	20.00 ± 0.00^{d}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	36.67 ± 3.33^{b}	43.33 ± 3.33^{a}	43.33 ± 3.33^{bc}	50.00 ± 6.67^{b}	53.33 ± 6.67^{bc}	60.00 ± 0.00^{b}	63.33 ± 3.33^{b}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{e}	0.00 ± 0.00^{e}
F value	50.27	37.64	31.63	30.33	43.77	57.80	45.31
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	10.31	13.31	14.58	16.83	14.58	13.31	15.74

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.

Means within columns were separated by Tukey's Honestly Significant Difference.

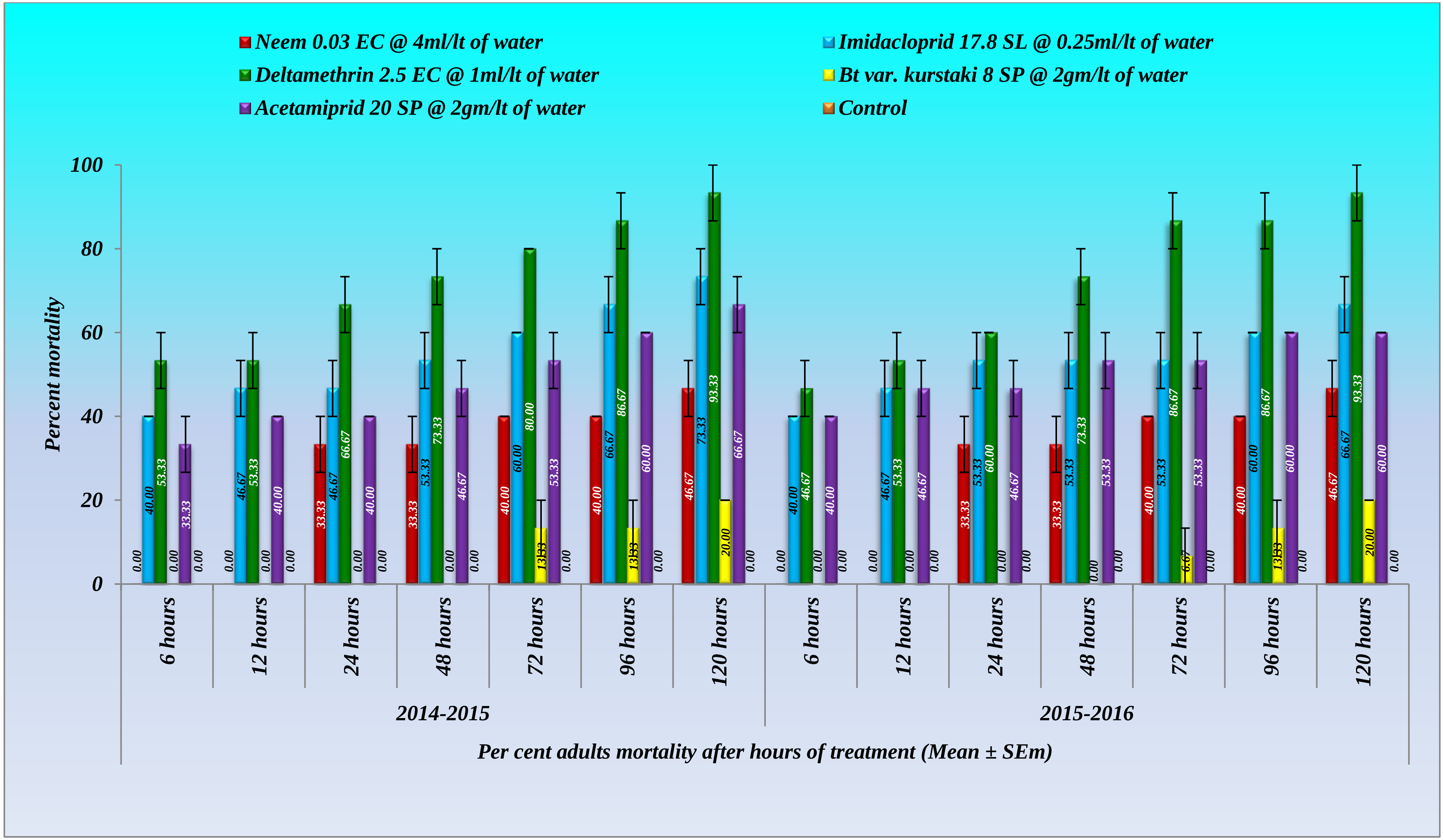

Fig 19a: Toxicity evaluation of different pesticides to *C. transversalis* adults by residual film method during 2014-2015 and 2015-2016

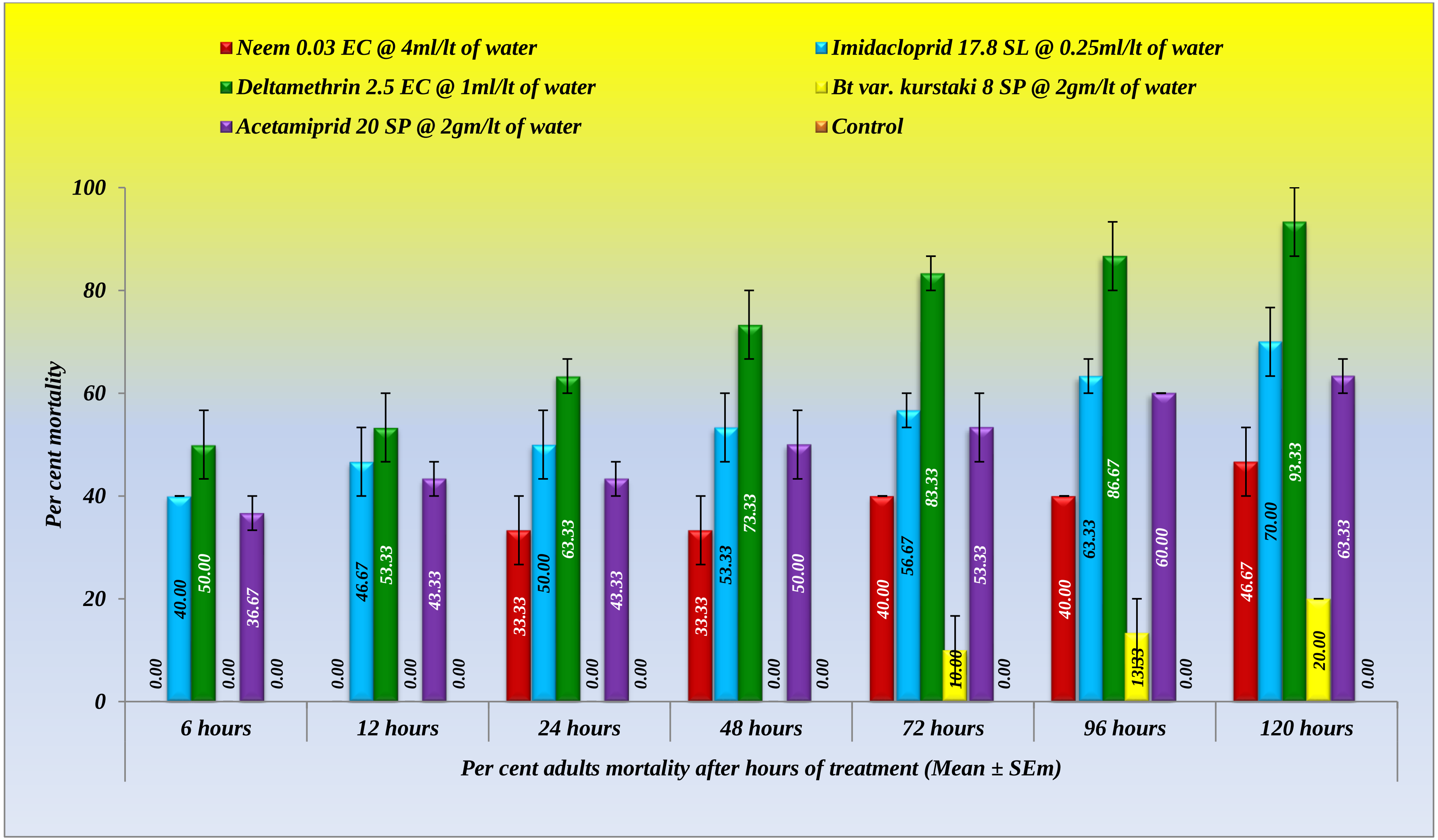

Fig 19b: Toxicity evaluation of different pesticides to *C. transversalis* adults by residual film method during 2014-2015 and 2015-2016 (Pooled)

6.67%) with means as 70.00 ± 6.67, 63.33 ± 3.33% and 46.67 ± 6.67% mortality, respectively.

Overall Deltamethrin 2.5 EC was observed to be highly toxic with 100% mortality of *C. transversalis* adults within 120 hours of treatment followed by Imidacloprid 17.8 SL and Acetamiprid 20 SP while *Bt* var. *kurstaki* 8 SP treatment was found to be safer to *C. transversalis* adults, having least mortality rate as compared to other pesticides.

The present results are in conformity with the findings of Ahmad *et al.* (2011) who reported that the maximum mortality of *C. undecimpunctata* adults was recorded in Deltamethrin 2.5 EC and Acetamiprid 20 SP with 83.30% mortality each by residual film method. In other studies of Tank *et al.* (2007) reported that Acetamiprid 20 SP caused about 53.37% mortality to *Cheilomenes sexmaculatus* adults after 72 hours of treatment in residual film method. Efficacy of Imidacloprid 17.8 SL on *C. transversalis* adults was reported by Horne (2009) and found that 100% mortality by residual film method.

4.6.2.4. Toxicity of different pesticides to *Coccinella transversalis* adults by diet contamination method

The toxic effect of different pesticides on *C. transversalis* adults by diet contamination method induced significant difference with respect to the time after treatment (Table 47, 48 and 49 and Fig. 20a and 20b). Significant difference (F=12.80, *df* =5, $p<0.01$; F=9.30, *df* =5, $p<0.01$ and F=11.05, *df* =1, $p<0.01$) were observed in mortality of *C. transversalis* adults exposed to different pesticides even just after 6 hours of treatment and maximum mortality was recorded in Deltamethrin 2.5 EC i.e., 33.33 ± 6.67% and 26.67 ± 6.67% during 2014-2015 and 2015-2016, respectively with mean as 30.00 ± 6.67% followed by Acetamiprid 20 SP and Imidacloprid 17.8 SL with 20.00 ± 0.00% and 13.33 ± 6.67% in both the years.

Toxicity of Neem 0.03 EC was found only after 24 hours of treatment i.e., 20.00 ± 0.00% and reached about 33.33 ± 6.67% mortality after 120 hours of treatment in both the years. Toxicity of *Bt* var. *kurstaki* 8 SP was observed only after 48 hours of treatment i.e., 13.33 ± 6.67% and 6.67 ± 6.67% during 2014-2015 and 2015-2016, respectively and reached about 13.33 ± 6.67% mortality after 120 hours of treatment in both the years. In the control, no *C. transversalis* adults mortality occurred from 6 to 120 hours after treatment. With the increase of time after exposure to different pesticides, the mortality

Table 47: Toxicity evaluation of different pesticides to *C. transversalis* adults by diet contamination method during 2014-2015

Treatments	***Per cent adults mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	20.00 ± 0.00^{b}	26.67 ± 6.67^{bc}	33.33 ± 6.67^{b}	33.33 ± 6.67^{bc}	33.33 ± 6.67^{bc}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	13.33 ± 6.67^{b}	20.00 ± 0.00^{b}	26.67 ± 6.67^{b}	33.33 ± 6.67^{ab}	33.33 ± 6.67^{b}	40.00 ± 0.00^{b}	46.67 ± 6.67^{b}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	33.33 ± 6.67^{a}	33.33 ± 6.67^{a}	40.00 ± 0.00^{a}	46.67 ± 6.67^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}	66.67 ± 6.67^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	13.33 ± 6.67^{cd}	26.67 ± 6.67^{b}	26.67 ± 6.67^{c}	26.67 ± 6.67^{c}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	20.00 ± 0.00^{b}	20.00 ± 0.00^{b}	26.67 ± 6.67^{b}	33.33 ± 6.67^{ab}	40.00 ± 0.00^{ab}	40.00 ± 0.00^{b}	46.67 ± 6.67^{b}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
F value	12.80	27.40	17.30	7.40	10.60	26.40	13.80
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	12.51	8.84	12.51	19.77	17.69	12.51	19.77

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.

Means within columns were separated by Tukey's Honestly Significant Difference.

Table 48: Toxicity evaluation of different pesticides to *C. transversalis* adults by diet contamination method during 2015-2016

Treatments	***Per cent adults mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	20.00 ± 0.00^{c}	20.00 ± 0.00^{b}	26.67 ± 6.67^{bc}	33.33 ± 6.67^{bc}	33.33 ± 6.67^{bc}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	13.33 ± 6.67^{b}	20.00 ± 0.00^{b}	33.33 ± 6.67^{ab}	33.33 ± 6.67^{ab}	33.33 ± 6.67^{bc}	40.00 ± 0.00^{ab}	46.67 ± 6.67^{ab}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	26.67 ± 6.67^{a}	33.33 ± 6.67^{a}	40.00 ± 0.00^{a}	40.00 ± 0.00^{a}	53.33 ± 6.67^{a}	53.33 ± 6.67^{a}	60.00 ± 0.00^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	6.67 ± 6.67^{bc}	20.00 ± 0.00^{c}	26.67 ± 6.67^{c}	26.67 ± 6.67^{c}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	20.00 ± 0.00^{ab}	20.00 ± 0.00^{b}	26.67 ± 6.67^{bc}	33.33 ± 6.67^{ab}	40.00 ± 0.00^{ab}	46.67 ± 6.67^{ab}	46.67 ± 6.67^{ab}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
F value	9.30	27.40	19.20	11.73	14.93	12.00	14.80
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
$HSD_{P=0.05}$	12.51	8.84	12.51	15.32	15.32	17.69	17.69

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance. Means within columns were separated by Tukey's Honestly Significant Difference.

Table 49: Toxicity evaluation of different pesticides to *C. transversalis* adults by diet contamination method during 2014-2015 and 2014-2015 (Pooled)

Treatments	***Per cent adults mortality after hours of treatment (Mean ± SEm)***						
	6 hours	***12 hours***	***24 hours***	***48 hours***	***72 hours***	***96 hours***	***120 hours***
Neem 0.03 EC @ 4ml/lt of water (T_1)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	20.00 ± 0.00^{b}	23.33 ± 3.33^{bc}	30.00 ± 6.67^{bc}	33.33 ± 6.67^{bc}	33.33 ± 6.67^{bc}
Imidacloprid 17.8 SL @ 0.25ml/lt of water (T_2)	13.33 ± 6.67^{b}	20.00 ± 0.00^{b}	30.00 ± 6.67^{ab}	33.33 ± 6.67^{ab}	33.33 ± 6.67^{bc}	40.00 ± 0.00^{bc}	46.67 ± 6.67^{ab}
Deltamethrin 2.5 EC @ 1ml/lt of water (T_3)	30.00 ± 6.67^{a}	33.33 ± 6.67^{a}	40.00 ± 0.00^{a}	43.33 ± 3.33^{a}	53.33 ± 6.67^{a}	56.67 ± 3.33^{a}	63.33 ± 3.33^{a}
Bt var. *kurstaki* 8 SP @ 2gm/lt of water (T_4)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	10.00 ± 6.67^{c}	23.33 ± 3.33^{c}	26.67 ± 6.67^{c}	26.67 ± 6.67^{c}
Acetamiprid 20 SP @ 2gm/lt of water (T_5)	20.00 ± 0.00^{ab}	20.00 ± 0.00^{b}	26.67 ± 6.67^{b}	33.33 ± 6.67^{ab}	40.00 ± 0.00^{ab}	43.33 ± 3.33^{ab}	46.67 ± 6.67^{ab}
Control (T_0)	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}	0.00 ± 0.00^{d}
F value	11.05	27.40	18.25	9.03	12.46	16.80	14.24
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
***HSD**$_{P=0.05}$*	11.90	8.42	11.90	16.83	15.74	14.58	17.85

(Tukey's HSD, P = 0.05)

Note: Different small letters within the columns after mean values indicate significant differences among treatments at 5% level of significance.
Means within columns were separated by Tukey's Honestly Significant Difference.

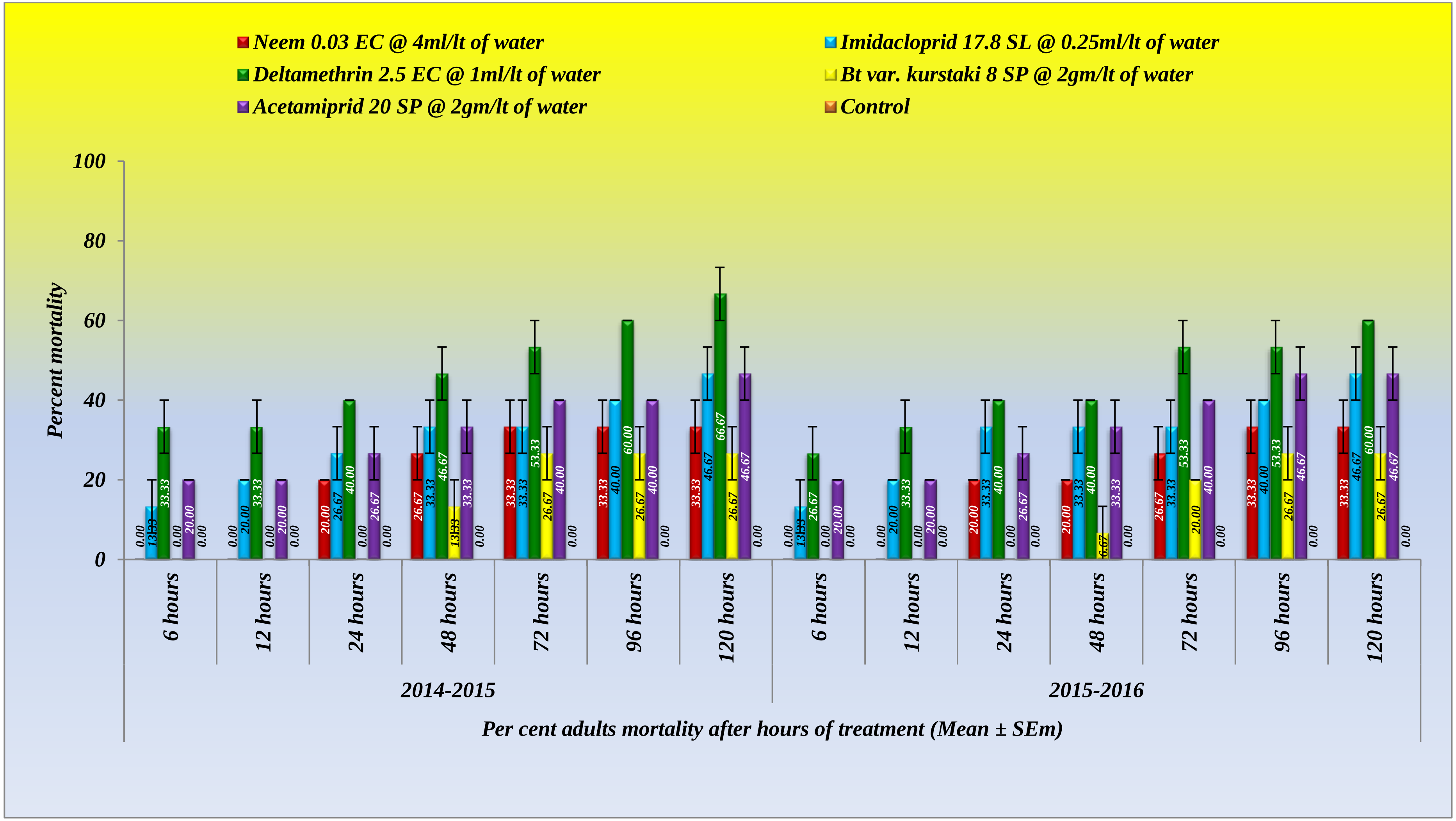

Fig 20a: Toxicity evaluation of different pesticides to *C. transversalis* adults by diet contamination method during 2014-2015 and 2015-2016

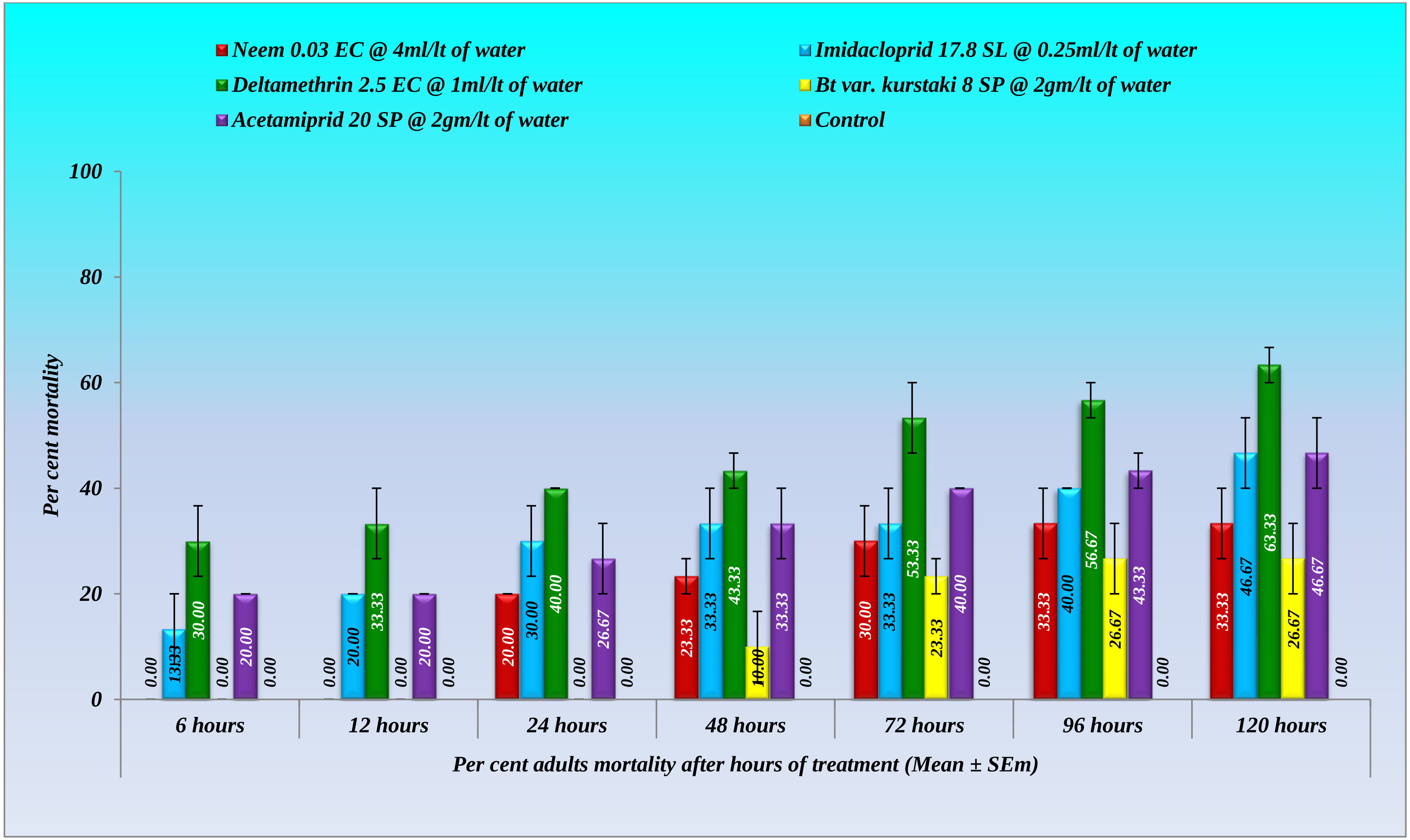

Fig 20b: Toxicity evaluation of different pesticides to *C. transversalis* adults by diet contamination method during 2014-2015 and 2015-2016 (Pooled)

rate of *C. transversalis* adults kept on increasing and maximum mortality was recorded after 120 hours of treatment in Deltamethrin 2.5 EC i.e., 66.67 ± 6.67% and 60.00 ± 6.67% during 2014-2015 and 2015-2016, respectively followed by Imidacloprid 17.8 SL, Acetamiprid 20 SP and Neem 0.03 EC with 46.67 ± 6.67%, 46.67 ± 6.67% and 33.33 ± 6.67% mortality, respectively in both the years.

The present results are in conformity with the findings of Ahmad *et al.* (2011) who reported that the maximum mortality of *C. undecimpunctata* adults was recorded in Deltamethrin 2.5 EC with 63.30% mortality followed by Acetamiprid 20 SP with 53.30% mortality by leaf dip method after 72 hours of treatment. Negative effect of neem to coccinellid has also been reported by several researchers who reported that neem oil caused about 40.00% and 22.00% adult mortality on *Adonia variegate* and *Menochilus sexmaculatus,* respectively (Swaminathan *et al*., 2010; Khan *et al*., 2015). Efficacy of Imidacloprid 17.8 SL on *C. transversalis* adults was reported by Horne (2009) and found that 100% mortality by diet contamination method.

CHAPTER - V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Studies on “Effect of different temperatures and pesticides on the biological attributes of major coccinellid beetles predating on mustard aphid, *Lipaphis erysimi* (Kaltenbach)” were carried out in the experimental cum research farm, Department of Entomology at School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema campus, Nagaland and Division of Crop Protection (Entomology), ICAR Research Complex for NEH Region, Umiam, Meghalaya during the year 2014-2015 and 2015-2016. In both the areas of studies, three ecological plots (6 x 4) m^2 of mustard were maintained to study the species composition of different coccinellid beetles in mustard between Meghalaya and Nagaland. All the laboratory experiments regarding the biological attributes and the toxicity evaluation of *C. septempunctata* and *C. transversalis* were carried out in the Biological Control laboratory and Integrated Pest Management (IPM) laboratory at ICAR Research Complex for NEH Region, Division of Crop Protection (Entomology), Umiam, Meghalaya. The findings of these experiments are summarized below:

- About seven (7) species of coccinellid beetles viz., *Coccinella septempunctata*, *Coccinella transversalis*, *Micraspis discolor*, *Harmonia dimidiata*, *Menochilus sexmaculata*, *Oenopia sexareata* and *Oenopia kirbyi* were observed in Entomology experimental field at ICAR Research Complex for NEH Region, Umiam, Meghalaya whereas only three (3) species were found viz., *Coccinella septempunctata*, *Coccinella transversalis* and *Micraspis discolor* in Experimental cum research farm at SASRD, Nagaland University throughout the study period.
- The maximum mean fecundity, size of egg cluster, percentage of grub emergence and percentage of adult emergence was found at 25ºC whereas the minimum was found at 35ºC on *C. septempunctata* and *C. transversalis*.
- With the increase in temperature the developmental period and consumption rate of *C. septempunctata* and *C. transversalis* decreased significantly.
- Among the four different temperature levels i.e., 20ºC, 25ºC, 30ºC and 35ºC, the longest developmental period of *C. septempunctata* and *C. transversalis* i.e., mean ovipositional period, incubation period, total larval period, pre-pupal, pupal period, total developmental period and adult longevity was found at 20ºC whereas the shortest was found at 35ºC.

- In all the four temperature levels, the average longevity of adult female took more days to complete its development in comparison to the adult male. On *C. septempunctata* and *C. transversalis*, the longest mean longevity of adult female and male was observed at 20ºC whereas the shortest mean longevity of adult female and male was recorded at 35ºC.
- The longest and shortest life cycle of *C. septempunctata* and *C. transversalis* was observed at 20ºC and 35ºC respectively.
- The largest egg size of *C. septempunctata* and *C. transversalis* was found at 20°C whereas the smallest was recorded at 35°C.
- The mean length and width of first, second, third and fourth instar grubs of *C. septempunctata* and *C. transversalis* showed longest at 20°C which was at par with 25°C, whereas the shortest was recorded at 35°C.
- The longest and shortest pupa length and width of *C. septempunctata* and *C. transversalis* was observed at 20°C and 35°C respectively.
- The average body size of *C. septempunctata* and *C. transversalis* adult was found largest at 20°C and as the temperature increase the body size reduced. In contrast between male and female, the results showed that female body size was recorded bigger than male in all the four different temperature regimes on both the species.
- The mean length and width of *C. septempunctata* and *C. transversalis* head capsule size of first, second, third and fourth instar grubs was recorded longest at 20°C which was at par with 25°C, whereas the shortest was recorded at 35°C.
- With the increase in temperature the average head size of *C. transversalis* and *C. transversalis* adult feeding on *L. erysimi* reduced significantly. On both the species the largest head size was recorded 25°C whereas the smallest was recorded at 35°C. In contrast between male and female, the results revealed that female head size was recorded bigger than male in all the four different temperature regimes on both the species.
- The maximum mean feeding potential of first, second, third and fourth instar grubs of *C. septempunctata* and *C. transversalis* was observed at 25°C whereas the minimum was recorded at 35°C. As the temperature increase beyond 25°C, the feeding potential of first, second, third and fourth instars decreased significantly on both the species. Among the instars, fourth instar grubs were the most voracious, followed by third, second and first instars in case of both the species.

- Similarly, the maximum mean aphid consumption per beetle per day and total consumption per beetle during the entire stage by *C. septempunctata* and *C. transversalis* beetles was recorded at 25°C whereas the minimum was recorded at 35°C. In comparison with the adult, female beetles consumed more aphids as compared to male as this could be due to higher nutrition requirement for reproduction.
- The toxic effect of different pesticides on *C. septempunctata* and *C. transversalis* exhibited significant difference with respect to the time after treatment. Among the pesticides, maximum mortality was recorded in Deltamethrin 2.5 EC followed by Imidacloprid 17.8 SL, Acetamiprid 20 SP and Neem 0.03 EC whereas the minimum mortality was recorded in *Bt* var. *kurstaki* 8 SP. Overall Deltamethrin 2.5 EC was observed to be highly toxic with maximum mortality of *C. septempunctata* and *C. transversalis* both in residual film and diet contamination method followed by Imidacloprid 17.8 SL and Acetamiprid 20 SP while *Bt* var. *kurstaki* 8 SP treatment was found to be safer to *C. septempunctata* and *C. transversalis*, having least mortality rate as compared to other pesticides.

Conclusion:

The presence of seven species of coccinellid beetles in mustard ecosystem alone in two different study sites in two years study suggests that Northeast Hill Region of India have diverse and rich fauna of coccinellid beetles. Further survey is needed in future of those areas that were not covered in this study to fully explore coccinellids fauna of the region. The present investigation can be concluded that, mustard ecosystem harbour several species of coccinellids, where we have lots of potential for their conservation and further utilization in biological control programmes.

Temperature requirements and prey consumption of *C. septempunctata* and *C. transversalis* show their high potential as biological control agents of *L. erysimi*. This knowledge could be essential for their most appropriate use but also in efforts to develop efficient mass rearing systems. However, apart from temperature and dietary requirements, additional work is needed, i.e. study on population increase and on searching efficiency, for a more accurate evaluation of the impact of these predators on mustard aphid populations. Among different temperatures (20°C, 25°C, 30°C and 35°C), 25°C has been proved as a most suitable for superior development, maximum survival and minimum mortality of *C. septempunctata* and *C. transversalis* on *L. erysimi*. Therefore, *C. septempunctata* and *C. transversalis* can be mass multiplied at given temperature for their successful evaluation in biological control program against *L. erysimi* and soft bodied insects.

On the basis of present study conducted it can be concluded that, all five commonly used pesticides against *L. erysimi* are harmful to its predators and therefore the use of these pesticides should not be encouraged especially during peak activity of natural enemies. However, *Bt* var. *kurstaki* 8 SP is comparatively safe pesticide for *C. septempunctata* and *C. transversalis*, therefore it could be used during severe infestation of mustard aphid.

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