Results and Discussion
4.1 INSECT-PEST SUCCESSION

Succession in general refers to the act of repeated following up of one by another in order of time or space. Successive changes are orderly and develop in certain sequence. The period of pest occurrence in group or in isolated manner is usually dependent on the stage of crop growth, population of natural enemies and prevailing weather conditions/factors.

In the present studies, the insect pest succession on mustard (Brassica campestris cv. Varuna) was gauged for two successive winter (rabi) seasons, 2000-01, and 2001-02 under agroclimatic conditions of Aligarh (India). The crop was sown on following dates for both the years.

First Sowing: October 9
Second Sowing: November 5
Third Sowing: November 24

4.1.1 Year: 2000-01
4.1.1.1 First sowing

Sawfly (Athalia lugens proxima) and painted bug (Bagrada hilaris) first invaded the mustard crop three weeks after sowing (WAS) coinciding with third week of October. The larvae of sawfly were cylindrical, greenish grey when freshly hatched. They turned greyish black at maturity (Plate 1). There were eight pairs of abdominal prolegs without crochets. They also possessed five black stripes on the back. The adults were small orange yellow insects with black markings on the body, smoky with black veins. The initial population of sawfly was 0.04/plant and its peak was recorded in the second and third week of November. The larvae were seen attacking the seedlings, making holes in the leaves.

The painted bug adults were sub-ovate black and had a number of orange or brownish spots on the body. The first and second instar nymphs were bright orange while the third and fourth red. The antennae and legs were black/smoky. Painted bug nymphs and adults had the tendency of sucking cell sap of the plant that led to the whitening of the leaves. Its population statistics was similar to that of sawflies. Its peak activity vis-à-vis presence remained till the third week of November.

The mustard aphid (Lipaphis erysimi), made its appearance on the crop in the third week of November. They were wingless, 2.3 mm in length; globular soft and pale green, while the winged forms, appeared later, had transparent homogenous
wings and yellowish abdomen. The nymphs were small in size with prominent cornicles at the posterior portion of the abdomen. The aphids multiplied parthenogenetically and attained their highest population of 150.50 aphids/10 cm terminal shoot in the fifth week of January (Plate 2). There was a significant positive correlation with its predators (coccinellids and syrphids).

The activity of leaf miner (*Chromatomyia horticola*) commenced in the third week of December, multiplied at a slow rate, and attained its peak (1.58 mines/plant) in the fourth week of February. The population remained unaffected even in the presence of aphids, syrphids as well as coccinellids. This can be attributed largely to the peculiar feeding habit of making mines into leaf lamina.

There were two peaks of activity of *Pieris brassicae* larvae, first at seedling and thereafter at pod formation stage. The young caterpillars were pale yellow, subsequently turned greenish yellow at maturity. There were prominent black spots at the dorsal surface of the body. The entire body was covered with short hair. It made its appearance initially at seedling stage of crop (4 WAS). At this stage, the population was comparatively low (0.08 to 0.32/plant). The second attack was observed at pod formation stage, wherein the maximum population to the tune of 0.68 larvae/plant was recorded. This insect species appeared to be a minor pest with sporadic occurrence.

The first batch of coccinellid beetles was noticed in the fourth week of November. The beetles were bright red coloured with seven black spots on the elytra (Plate 3). After third week of December, the population increased gradually and ultimately reached its peak of 3.12/plant (second week of February). After the first week of March they migrated to other hosts. The syrphid population was encountered in the first week of December and the highest number of maggots (1.32/10cm terminal shoot/plant) (slug-like, transparent, Plate 4) was found between the aphid colonies in the second week of February.

### 4.1.1.2 Second sowing

*Athalia* larvae made their appearance at 2 WAS (third week of November), while *Bagrada* and *Pieris* larvae at 7 and 8 WAS, respectively. The *Athalia* population reached its threshold with a very low density of 0.08 larvae/plant in the first week of December (4 WAS). The low population of *Bagrada* (0.04 nymphs/plant) was noticed for two weeks only. Cabbage butterfly larvae were
recorded with an initial population of 0.16 larvae/plant. There were two peak activity periods, first in the third week of December (6 WAS) and second from second week of February (14 WAS) to second week of March (15 WAS). The population count was 0.04 and 0.32/plant (Table 3). The painted bug, sawfly, and cabbage butterfly disappeared most probably due to the fall in the temperature in the first week of December, third and fourth week of December, respectively.

The aphids appeared on the crop in the second week of December (5 WAS). They multiplied rapidly and reached to the highest level of 428.00 aphids/10 cm terminal shoot during second week of February (14 WAS). They could be found in the field for the next two consecutive weeks but in low density. The crop maturity resulted in migration of aphids to alternate hosts particularly late sown cabbage and other cruciferous plants, weeds etc.

Leaf miner (*Chromatomyia horticola*) appeared on the crop with an initial population count of 0.08/plant at four weeks after sowing. The gradual increase in the count from 0.80 to 6.64/plant was observed in the later stages of crop growth (17 WAS). The maturity of the crop resulted into the steep decline of the population.

The status of syrphids and coccinellids had a strong positive correlation with aphid population. They initiated their appearance in the second week of December. The intensity of both predators was 0.74/10 cm terminal shoot/plant and 4.32/plant, respectively. With the reduction in number of aphids the population of predators also declined. The pupae of coccinellids were however, found stuck to the dried twigs of the crop.

**4.1.1.3 Third Sowing**

The sawfly and bugs were seen in the first week of December (2 WAS) in a very low strength of 0.08 and 0.04/plant, respectively. Their population disappeared due to decrease in temperature, making conditions unfavourable for their existence. The leaf miner attack was recorded twice, first at 3 to 5 weeks after sowing and thereafter at the flowering and pod formation stages. The population started with a count of 0.04/plant and reached to a high of 5.78/plant at the maturity of the crop.

The appearance of *L. erysimi* was noticed right from vegetative to pod formation stage. It was evident from the table that this species appeared in relatively low numbers (0.04 aphids/10 cm terminal shoot/plant 4 WAS on vegetative buds. Subsequently, the population increased at flowering and pod formation stages. The
population increased to 420.95-aphids/10 cm terminal shoot/plant (15 WAS) and declined to 20.09/10 cm terminal shoot/plant with the advancement of crop age.

Population trend of syrphids and coccinellids was similar to that of aphids. Their peak activity period coincided with the highest aphid incidence. The corresponding count was 2.54-syrphid/10 cm terminal shoot/plant and 3.24 coccinellids/plant during fourth week of February and second week of March, respectively. The population of both, however, declined with the crop maturity.

4.1.2 YEAR: 2001-02
4.1.2.1 First Sowing
The seedling stage was invaded by the sawfly larvae as well as painted bug at four weeks after sowing (Table 4). The initial population count of the former was 0.16/plant (4 WAS) that further elevated to 0.24/plant for two subsequent weeks. It declined thereafter to 0.08/plant (10 WAS). The latter made its appearance with an initial population of 0.04 (4 WAS) and touched a high of 0.16 during 6 to 7 WAS. It declined to 0.08/plant after 8 weeks of sowing.

The leaf miner incidence was recorded from third week of January with a count of 0.48 mines/plant. Its maximum frequency (0.92/plant) was encountered 17 WAS. Later with advancement of crop age, their population declined gradually. The immature stages of cabbage butterfly were noticed on the crop at 12 WAS with a population count of 2.8 larvae/plant. Their population increased further to 4.52/plant (14 WAS). It declined sharply thereafter, as the larvae disappeared from the field during fourth week of January.

The aphids with an initial count of 0.08/10 cm terminal shoot/plant were seen on the crop in the first week of December (8 WAS). Their population soon accelerated to achieve the highest peak of 17.08/10 cm terminal shoot/plant, in the first week of February. As the crop advanced, aphids started migrating to alternate sources of food and thus was no longer noticed on the different plant parts.

There was a positive correlation between syrphid maggots and aphid population. The highest number of 1.32/10 cm terminal shoot/plant maggots were recorded at 18 WAS synchronizing with high aphid incidence. Similarly, coccinellid started their presence with the alightment of aphids on the crop. Interestingly, when the crop entered 12 and 15-17 weeks of age, population count of coccinellids was negligible. This could be attributed to the fact that beetles might have hidden
underneath fallen leaves or the cracks and crevices and similarly grubs to underside of leaves. However, its highest population (1.72/plant) was encountered in the first week of March.

4.1.2.2 Second Sowing

The sawfly and painted bug invaded the crop simultaneously in the third week of November with an initial count of 0.04 and 0.08/plant, respectively (Table 4). They were not located on the crop in the third and fourth week of December, respectively. Cabbage butterfly larvae migrated to alternate hosts within weeks of their appearance (third week of February-to first week of March). Lowering temperature seemed to be a major cause of their decline.

*L. erysimi* alighted the crop at six weeks after sowing and was observed in negligible numbers till 14 WAS. The steady and rapid increase from 26.16 to 105.16-aphids/10 cm terminal shoot/plant was recorded between 15 and 19 weeks after sowing.

The leaf miner incidence was encountered from 10 WAS to crop maturity coinciding with flowering and pod formation stages. The peak period of activity was confined to the pod formation stage where the population reached its highest level of 5.48 mines/plant (14 WAS). The lower leaves were more heavily infested. Cabbage butterfly larvae exhibited feeding preference at the pod formation stage indicating favourable conditions for rapid increase from 2.8 (19 WAS) to 4.12/plant (20 WAS). The caterpillars caused severe defoliation of plants.

The syrphids made their appearance when the crop was 12 weeks old and remained present till the maturity. There was gradual population build-up from 0.08 to 0.36-maggots/ 10 cm terminal shoot/plant in the fourth week of February (20 WAS). The coccinellids on the other hand appeared in phases, first at 1-2 WAS, second 9-10 WAS and lastly 13-17 WAS. The latter phase showed maximum coccinellids (2.13/plant) 16 WAS.

4.1.2.3 Third Sowing

The sawfly larvae commenced their activity from 6 WAS (0.12/plant) to 10 WAS (0.04/plant). They showed positive correlation with temperature. Reduction in population count was directly proportional to temperature. The leaf miners started their appearance from fifth week of January (10 WAS) exhibiting initial population of
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0.20/plant. The peak activity was however, seen in the last week of February (13 WAS) as depicted from population of 3.72/plant. Heavy attack resulted into whitening of the leaves. The cabbage butterfly larvae appeared in the first and second week of December (2 and 3 WAS) with a very low population (0.04/plant). During this period the temperature plummeted and disfavoured their presence any longer on the crop. The aphids exhibited their activity at 6 weeks after sowing. The population reproduced rapidly and reached a high of 127.44-aphids/10 cm terminal shoot/plant (third week of Feb), being the highest count of the season.

Syrphids and coccinellids appeared simultaneously at 8 and 6 WAS with a count of 0.08 maggots/10 cm terminal shoot/plant and 0.04 grubs/plant, respectively. The incidence of both was low. Their peak activity coincided with high aphid count in the fourth week of February (13 WAS) the corresponding figures were 0.36 syrphids /10 cm terminal shoot/plant and 2.32/coccinellids/plant. At maturity of the crop, both predators migrated to other alternate crops in search of their prey.

Manipulating the planting dates results in the asynchronisation of the most susceptible stage of the crop and the maximum activity of the pest. This date varies from region to region. In case of north India sowing of mustard in late September or early October escapes aphid attack. However, the crops sown later receive high aphid infestation and result in subsequent yield losses. Singh et.al, (1983) reported that early sown crop (5 to 15 October) escapes aphid infestation as compared to late sown (25 to 5th November) in Punjab. Similar were the findings of Vir et.al, (1990), Bhadauria et.al., (1992), Bhadauria and Jakhmola (1995), Patel and Patel (1997) and Srivastava (1999). The present findings are in consonance with that of above workers. The early sown crop (October 9) received low aphid infestation as compared to timely (October 24) and late (November 5) sown crops. Other important pests like mustard sawfly appeared at the seedling stage, while leaf miner and painted bug was observed in the latter half of February and March. The leaf miner and painted bug were seen at high intensity on the late sown crop followed by timely and early. As far as cabbage butterfly larvae were concerned, they recorded maximum activity at the pod formation stage. Similar was the observation of Manzar et.al., (2000). The predators (syrphids and coccinellids) were witnessed from the start of January with less numbers and low activity. With increase in temperature and aphid population they were found actively searching for their prey. Similar were the observations made by Kulkarni and Patel (2001).
4.2 APHID INFESTATION INDEX (AII)

Observations were recorded at weekly intervals for both cropping seasons of 2000-01 and 2001-02 so as to obtain population trend of the *L. erysimi* (Kaltenbach) on different cultivars of *Brassica campestris*. A total of 33 varieties/germplasms were screened during three sowing periods, early (first), timely (second) and late (third). The results have been summarized here under:

4.2.1 YEAR: 2000-01

4.2.1.1 First Sowing

The first observation of 8/01/01 revealed aphid infestation index (AII) in the range of 0.5 to 1.5 followed by 1.3 to 2.0 on 15/01/01. However, it gradually increased from 2.3 to 3.8 on 22/01/01 due to increase in aphid intensity vis-à-vis the differential response of varieties. The prevalence of optimum conditions for rapid aphid multiplication was clearly evident from the observations recorded on 29/01/01, wherein, varieties/germplasms exhibited AII from 2.8 to 4.0. On the very next week (5/02/01) the population of aphids exploded and reached to a high range of 3.8 to 4.3 on different varieties/germplasms. During this period environmental conditions were found to be congenial for overall development of the aphids. Further, when temperature plummeted, aphid population also declined gradually from 3.8 to 2.5, 2.8 to 1.3 and 1.5 to 0.5 on 12/02/01, 19/02/01 and 26/02/01, respectively.

While considering mean aphid infestation index (MAII) on each of the varieties/germplasms, it was found that index had a pronounced variation, it fluctuated from 1.6 to 2.5. To simplify further, grading of mean index was done. MAII from 1.00 to 1.99 was encountered on RH-30, Bio-772, Sej-2, The higher MAII (>2) was however on RH-8113, CS-52, Bio-902, RH-8812. Pusa Bold, Vardan, PM-67, PR 8988, ZEM-1, Seeta, Krishna, Durgamani, GM-2. Sharma, RL-1359, RH-781, VSL-05, S-Asech, Rohini, PCR-07, Kranti, Jatai sarson, Urvashi, Varuna, TM-4, GM-1, PBR-91, RN-393 and RH-819.

4.2.1.2 Second Sowing

Aphids initiated their attack on 8/01/01. Different varieties/germplasms showed AII in the range of 0.3 to 1.8. When observations were taken on 15/01/01, all the varieties were graded in the range of 1.0 to 2.5 as compared to 1.5 to 2.5 on
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22/01/01. The scale further increased on account of favourable conditions for aphid multiplication, it elevated from 2.5 to 4.0 on 29/01/01. The scale further increased and reached a level of 4.3 on 5/02/01. The very next week (12/02/01) AII descended to 3.8 on some varieties but elevated to 4.5 on others. With advancement of crop age vis-à-vis increase in temperature, the scale declined gradually. It ranged between 3.5 to 2.5, 2.5 to 1.5 and 2.5 to 0.8 on 19/02/01, 22/02/01 and 5/03/01, respectively.

It was inferred from the data that all the varieties exhibited MAII at 2.0 or more. Varuna could withstand aphid injury to some extent as reflected from the lowest mean aphid attack of 2.1. This was followed by RH-30 (MAII: 2.2), Bio-772 (2.3), Seeta, PR 8988 and CS-52 (2.4). On the remaining cultivars MAII was more than 2.5.

4.2.1.3 Third Sowing

The data recorded on 5/02/01 revealed AII in the range of 1.0 to 2.0 in contrast to 1.3 to 3.3 on the following week. The scale and the number of aphids were directly proportional, hence an increase in the aphid population resulted into escalation of the values for the different varieties/germplasms. The grades fell between 2.5 to 4.0 on 19/02/01 against 2.5 to 3.5 on 26/02/01. On 5/03/01 the existence of unfavourable abiotic factors as well as crop maturity resulted in rapid decline of aphid numbers. This is evident from low aphid index from 2.3 to 1.0.


4.2.2 YEAR: 2001-02

4.2.2.1 First Sowing

The observations for AII on 01/01/02 exhibited its range from 0.7 to 1.3 against a high of 1.3 and low of 0.7 on 08/01/02. It was interesting to note that when AII was gauged on 16/01/02 and 22/01/02 the cultivars exhibited the range between
0.7 to 1.7 and 0.7 to 3.0; respectively. When observations were taken on 29/01/02, all the varieties were graded in the range of 0.7 to 3.3 as compared to 0.7 to 4.0 on 5/02/02. The data of AII recorded on 12/02/02 showed a range of 0.7 to 4.0 as compared to 0.7 to 3.7 on 19/02/02. Pronounced variation in the index (0.7 to 4.7) was evident on 26/02/02, while on 5/03/02 the scale decreased further and the different germplasms exhibited the range between 0.7 and 2.7.

When MAII was computed, it was inferred from the data that S-Asech, Bio-772, Sej-2, Urvashi, RH-30, Bio-902, PR 8988, Seeta, ZEM-1, Vardan, exhibited index less than 1.0. However, the other cultivars viz., Krishna GM-2, Rohini, GM-1, Pusa bold, TM-4, RH-8812, RH-8113, PCR-07, Sharma, PM-67, Durgamani, Jatai sarson, CS-52, RH-819, RN-393, RLM-619, RL-1359, Varuna and Kranti showed the index between 1.0 to 1.9. Whereas, PBR-91, VSL-05 and RH-781 reflected MAII between 2.0 and 2.9.

4.2.2.2 Second Sowing

The observation recorded on 29/01/02 revealed AII in the range of 0.7 and 2.7 against 0.7 to 3.4 on 5/02/02. Further investigations displayed that AII fell between 1.0 to 3.7 and 2.0 to 4.7 on 12/02/02 and 19/02/02, respectively. When the different varieties/germplasms were screened out on 26/02/02, 5/03/02 and 12/03/02 they were graded on the index scale between 0.7 to 4.3, 0.7 to 4.0 and 0.7 to 1.3, respectively.

The Mean AII for all the varieties ranged between 0.9 and 2.9. Only RH-30 was inferred to be tolerant to the aphid attack that encountered AII between 0.0 and 0.9. The varieties/germplasms graded in the higher scale of AII and from 1.0 to 1.9. Thus, Bio-772, PBR-91, RH-8113, TM-4, Bio-902, GM-2, CS-52, Vardan, and Durgamani were placed in moderately susceptible category, while others in susceptible exhibited MAII >2.0.

4.2.2.3 Third sowing

Investigations carried out on 5/02/02 exhibited AII in a range of 0.2 to 1.1, in contrast to 0.7 to 2.7 on 12/02/02. Marked variation in the index was computed on 19/02/02, it fluctuated from 1.1 to 4.0 as compared to 0.7 and 4.7 on 26/02/02. The last observations taken on 5/03/02 inferred the scale from 0.7 to 3.0.

The overall mean AII at three sowings of 2001-02 illustrated that Varuna, Rohini, Sej-2, RH-30, RH-8113, PBR-91, CS-52, Bio-772, RN 393, RLM-619, RH-
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819 PCR-07, VSL 05, Kranti, TM-4, Durgamani, GM-1, Jatai sarson, Pusa bold, Sharma, ZEM-1, S-Asech, RL-1359 and Urvashi recorded All between 1.0 and 1.9. However, susceptible ones were Vardan, Seeta, RH-781, RH-8812, Bio-902; PR 8988, PM-67 and GM-2. Krishna were found to be susceptible as showing All between 2.0 and 3.0.

Resistance is the expression of insect-pest interactions influenced by a number of environmental factors hence, knowledge of the plant, insect and their environment is essential for developing pest resistant varieties. Greater the diversity in the germplasms, higher are the chances of getting the good sources of resistance. Different methods have been evolved by various workers for screening of mustard varieties against its most serious pest, the mustard aphid. These include seedling survival, aphid injury, aphid population, aphid fecundity/development and yield evaluation. The factors, which contribute to developing a resistant variety in mustard include bio-physical (pattern of arrangement of buds on the inflorescence and its succulence, colour of leaves, non-waxiness, plant pilosity etc.) and the bio-chemical (antixenosis and antibiosis). The factors, which affect the expression of resistance, are responsible for a part of the discrepancy in results sometimes secured by various investigators under different environmental conditions. Besides, changes in the genes of either plant or animal might be a probable cause that affects the permanence of resistance.

Number of aphids per 10 cm terminal shoot/plant was assessed to determine the most favourable variety/germplasm for cultivation in the agroclimatic conditions of Aligarh region and its surrounding areas. On the basis of mean aphid infestation index (MAII), RH-30 followed by Sej-2, Bio-772 and RH-8113 were found to be suitable for cultivation in the region. Some of the promising germplasms identified have shown both similar as well as different results, hence got strong support by the works of Pathak, 1961; Teotia and Lal, 1970; Bakhetia and Sandhu, 1973; Bakhetia and Bindra, 1977; Brar and Sandhu, 1978; Anonymous, 1997, 1999; Manzar et.al., 1998; Malviya and Lal, 2000, and Vekaria and Patel, 2000. Deviation in the findings would have been due to seasonal variation in aphid pressure and other plant growth factors on test germplasms of Brassica under field conditions.
4.3 CORRELATION-REGRESSION ANALYSIS

In order to gauge the effect of the different abiotic (maximum and minimum temperature, maximum and minimum relative humidity, rainfall, evaporation and wind velocity) and biotic factors (coccinellids and syrphids) on the survival of *L. erysimi*, the correlation-regression analysis was applied to the data (Table 12) collected for two consecutive mustard cropping seasons of 2000-01 and 2001-02 so as to study

4.3.1 Linear Correlation-Regression Analysis

4.3.1.1 YEAR: 2000-01

4.3.1.1.2 First Sowing

The correlation analysis of the data revealed strong positive and significant relation of aphid with coccinellid (r=0.499), syrphids (0.675), wind velocity (0.765), rainfall (0.090) and evaporation (0.140). On the other hand, maximum and minimum temperature as well as maximum and minimum relative humidity showed negative correlations where 'r' was -0.220, -0.243, -0.552 and -0.181, respectively.

When maximum and minimum temperature, maximum and minimum relative humidity were analysed, it was revealed that they all acted upon in reducing aphid population by 4.84, 5.90, 30.47 and 3.27%, respectively. As far as wind velocity, evaporation and rainfall were concerned, they resulted in multiplication of aphids with corresponding increase by 58.52, 1.96 and 0.81%, respectively. However, coccinellids and syrphids exhibited direct increase in their respective population with an increase in aphid numbers by 24.90 and 45.56%, respectively.

The regression equations of aphid (X) on different parameters (Y) were as follows:

- Coccinellid (Y)
  \[ X = 16.8521 + 20.9424 \times Y \]

- Syrphid (Y)
  \[ X = 11.0867 + 42.5414 \times Y \]

- Maximum temperature (Y)
  \[ X = 78.9193 - 2.0384 \times Y \]

- Minimum temperature (Y)
  \[ X = 78.9193 - 2.0384 \times Y \]

- Maximum relative humidity (Y)
X = 455.0259 – 5.0102 (Y)
Minimum relative humidity (Y)
X = 67.89 – 0.89 (Y)
Evaporation (Y)
X = 6.91 + 7.34 (Y)
Wind Velocity (Y)
X = -24.93 + 36.99 (Y)
Rainfall (Y)
X = 27.24 + 0.44 (Y)

Thus by substituting the values of ‘Y’ the corresponding value of X (aphid) can be predicted from the above equations.

4.3.1.1.2 Second Sowing

The relationship between aphid and other independent variables except maximum and minimum relative humidity, \((r=-0.230\) and \(-0.177\)) was positively correlated. Maximum as well as minimum temperature, rainfall and evaporation showed slight positive correlation with aphids, their corresponding values were 0.136, 0.002, 0.077 and 0.177, respectively, while significant correlations was evident with coccinellids (0.555), wind velocity (0.474) and syrphids (0.305).

All the factors (biotic as well as abiotic) revealed marked variations in aphid population ranging from negligible to 30.805% \(\{(\text{minimum temperature}; r^2=0.00), 0.59\% \text{ (rainfall; 0.00594)}, 1.84\% \text{ (maximum temperature; 0.1844)}, 3.14\% \text{ (minimum temperature; 0.03141)}, 3.31\% \text{ (evaporation; 0.031329)}, 5.29\% \text{ (maximum humidity; 0.05293)}, 9.316\% \text{ (syrphid; 0.09316)}, 22.495\% \text{ (wind velocity, 0.22495)}, 30.805\% \text{ (coccinellid; 0.30805)}\}.

Although positive correlation was recorded with maximum and minimum temperature but it was the only minimum temperature that had negligible effect on aphid population.

The regression equations between aphid (X) and other parameters (Y) were as under:

Coccinella (Y)
\[ X = 41.3066 + 51.6523 \text{ (Y)} \]
Syrphid (Y)
\[ X = 65.5811 + 144.24808 \]
Maximum temperature (Y)  
\[ X = -23.7586 + 5.1108 \]

Minimum temperature (Y)  
\[ X = 90.5645 + 0.07200 (Y) \]

Maximum relative humidity (Y)  
\[ X = 466.188 - 4.5032 \]

Minimum relative humidity (Y)  
\[ X = 193.0137 - 2.4347 (Y) \]

Rainfall (Y)  
\[ X = 83.6889 + 1.0882 (Y) \]

Wind Velocity (Y)  
\[ X = -18.0789 + 67.5117 (Y) \]

Evaporation (Y)  
\[ X = 23.18 + 21.35 (Y) \]

The aphid population can thus be predicted by substituting corresponding values of ‘Y’ at any given point.

4.3.1.1.3 Third Sowing

A strong positive correlation ‘r’ was obtained between aphids and syrphids \( r = 0.910 \) against a weak of 0.414 with coccinellids. It could be attributed to the fact that syrphids had greater multiplication potential than coccinellids. As far as abiotic factors were concerned, there was a positive correlation between aphids and maximum temperature \( 0.373 \), minimum temperature \( 0.402 \), evaporation \( 0.454 \) and negative with maximum and minimum relative humidity, rainfall and wind velocity. The corresponding values were \(-0.270\), \(-0.330\), \(-0.113\) and \(-0.083\), respectively.

The biotic factors that actively contributed to population regulation of \textit{L. erysimi} were minimum and maximum relative humidity, rainfall and wind velocity causing a reduction in aphid population by 10.889, 7.305, 1.268 and 0.693\%, respectively. On the other hand coccinellids, syrphids, maximum and minimum temperature and evaporation showed linear increase in the aphid population by 17.15, 82.78, 13.93, 16.19 and 20.65\%, respectively.

The regression equation between \textit{L. erysimi} and other independent variables were as under:
Coccinellids (Y)
\[ X = 38.76119 + 47.3514 \ (Y) \]

Syrphid (Y)
\[ X = 24.8956 + 141.0139 \ (Y) \]

Maximum temperature (Y)
\[ X = -210.8216 + 12.516 \ (Y) \]

Minimum temperature (Y)
\[ X = -38.3948 + 15.6069 \ (Y) \]

Maximum relative humidity (Y)
\[ X = 452.5215 - 4.6667 \ (Y) \]

Minimum relative humidity (Y)
\[ X = 241.2771 - 4.1722 \ (Y) \]

Rainfall (Y)
\[ X = 78.6525 - 1.4362 \ (Y) \]

Evaporation (Y)
\[ X = -72.8121 + 41.9989 \ (Y) \]

Wind Velocity (Y)
\[ X = 86.6265 - 10.9817 \ (Y) \]

4.3.1.1 YEAR: 2001-02

4.3.1.1.1 First sowing

There was a negative correlation coefficient ‘r’ between aphids and coccinellids (-0.143), maximum (-0.459) and minimum temperature (-0.340). The reason for this unusual negative correlation could be attributed to the fact that the population of predator and prey was not synchronous, as also reported earlier by Mohapatra et.al. (1994) and Kalushkov (1990). On the other hand strong positive correlation of aphids was obtained with syrphids (0.863) followed by minimum relative humidity (r=0.397), wind velocity (r=0.377), maximum relative humidity (r=0.177), rainfall (r=0.154) and evaporation (r=0.009).

The regression equations computed were as under:

Coccinellid (Y)
\[ X = 4.1777 - 1.9559 \ (Y) \]
\[ R = 0.0241 \]

Syrphid (Y)
\[ X = 0.7504 + 15.4092 \ (Y) \]
\[ R= 0.7443 \]
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Maximum temperature (Y)
\[ X = 16.585 - 0.5403 \text{ (Y)} \]  \[ R=0.2107 \]

Minimum temperature (Y)
\[ X = 8.0312 - 0.5064 \text{ (Y)} \]  \[ R=0.1153 \]

Maximum relative humidity (Y)
\[ X = -8.2762 + 0.1441 \text{ (Y)} \]  \[ R=0.0313 \]

Minimum relative humidity (Y)
\[ X = -3.7366 + 0.1831 \text{ (Y)} \]  \[ R=0.1572 \]

Rainfall (Y)
\[ X = 3.0484 + 0.1112 \text{ (Y)} \]  \[ R=0.02359 \]

Evaporation (Y)
\[ X = 3.4717 + 0.0674 \text{ (Y)} \]  \[ R=0.00007 \]

Wind velocity (Y)
\[ X = -2.5056 + 1.7184 \text{ (Y)} \]  \[ R=0.1423 \]

All these factors explain variation in the aphid population ranging from 0.00-74.43%

4.3.1.2.2 Second sowing

The observations recorded in this particular experimental phase encountered negative correlation of aphid with maximum temperature and maximum relative humidity, their simultaneous values were \( r = -0.096, -0.144 \) respectively. All the other parameters showed positive correlation with aphid.

The regression equations computed were as below:

Coccinellid (Y)
\[ X = 19.7695 + 5.4460 \text{ (Y)} \]  \[ R=0.01246 \]

Syrphid (Y)
\[ X = 2.2600 + 181.8531 \text{ (Y)} \]  \[ R=0.4546 \]

Maximum temperature (Y)
\[ X = 42.4287 - 0.9254 \text{ (Y)} \]  \[ R=0.00925 \]

Minimum temperature (Y)
\[ X = 10.491 + 1.5010 \text{ (Y)} \]  \[ R=0.0144 \]

Maximum relative humidity (Y)
\[ X = 76.5947 - 0.6583 \text{ (Y)} \]  \[ R=0.0207 \]

Minimum relative humidity (Y)
\[ X = 0.6675 + 0.4900 \text{ (Y)} \]  \[ R=0.0309 \]
Results and Discussion

Rainfall (Y)
\[ X = 10.3856 + 3.3872 \times Y \] \[ R = 0.3465 \]

Evaporation (Y)
\[ X = 0.3387 + 7.7838 \times Y \] \[ R = 0.04855 \]

Wind velocity (Y)
\[ X = -20.5684 + 10.9362 \times Y \] \[ R = 0.1825 \]

Variation in aphid population ranged from 0.92 to 45.46% due to the effect of different parameters studied.

4.3.1.2.3 Third Sowing

Correlation analysis indicated positive relation of aphids with abiotic and biotic factors except maximum relative humidity. The different parameters viz., maximum and minimum temperature, minimum relative humidity, evaporation, rainfall, wind velocity, syrphids and coccinellids recorded positive correlation with aphids. Their corresponding values were 0.274, 0.503, 0.044, 0.317, 0.708, 0.455, 0.574, and 0.508, respectively.

The regression equation obtained were:

Coccinellid (Y)
\[ X = 10.5348 + 25.3374 \times Y \] \[ R = 0.2584 \]

Syrphid (Y)
\[ X = 7.0608 + 232.7575 \times Y \] \[ R = 0.3289 \]

Maximum temperature (Y)
\[ X = -51.5273 + 3.3719 \times Y \] \[ R = 0.0749 \]

Minimum temperature (Y)
\[ X = -29.9759 + 7.1767 \times Y \] \[ R = 0.2535 \]

Maximum relative humidity (Y)
\[ X = 153.6393 - 1.5649 \times Y \] \[ R = 0.0873 \]

Minimum relative humidity (Y)
\[ X = 15.2029 + 0.1561 \times Y \] \[ R = 0.00197 \]

Rainfall (Y)
\[ X = 4.7515 + 4.6580 \times Y \] \[ R = 0.5012 \]

Evaporation (Y)
\[ X = -12.4395 + 12.5639 \times Y \] \[ R = 0.1007 \]
Results and Discussion

X = -40.9236 + 15.3936 (Y)  \quad R=0.2072

It can be concluded after computation of coefficient of determination that all the abiotic as well as biotic parameters effect the aphid population from 0.197 to 50.12%. However, rainfall played a major role as in dislodging the aphids from the plants, thus reducing their numbers to a great extent.

4.3.2 Multiple Correlation-Regression Analysis

When the data was analysed to determine the cumulative effect of the different weather parameters as well as the predators on the population dynamics of the mustard aphid, it was revealed that during the third sowing of 2000-01, a strong positive correlation exhibited between the two, where ‘r’ (correlation coefficient) was to the tune of 0.9603, followed by 0.9397, 0.8338 in the first and second sowings, respectively. Similarly, the positive correlation coefficient ‘r’ existed (0.9246) between aphid and abiotic and biotic factors at second sowing of 2001-02. This was closely followed by 0.9245 and 0.9063 during third and first sowings, respectively. The regression equations computed to predict the aphid population for both the years at three sowings were as under:

4.3.2.1 Year: 2000-01

4.3.2.1.1 First Sowing


4.3.2.1.2 Second Sowing


4.3.2.1.3 Third Sowing


* Mn=Minimum, Mx=Maximum, T=Temperature, RH=Relative Humidity, Wv=Wind velocity, Ev=Evaporation, Rf=rainfall, Sy=Syrphid Cc=Coccinellid
4.3.2.2 Year: 2001-02

4.3.2.2.1 First Sowing
\[ Y = 1.093 + (0.163)(M \times T) + (-0.855)(MnT) + (-0.176)(M \times RH) + (0.128)(Mn\ RH) + (1.172)(Wv) + (3.652)(Ev) + (0.142)(Rf) + (9.844)(Sy) + (-6.488)(Cc). \]

4.3.2.2.2 Second Sowing
\[ Y = 87.799 + (-0.683)(M \times T) + (-0.110)(MnT) + (-1.646)(M \times RH) + (0.368)(Mn\ RH) + (1.454)(Wv) + (17.745)(Ev) + (2.728)(Rf) + (170.096)(Sy) + (-31.254)(Cc). \]

4.3.2.2.3 Third Sowing
\[ Y = 156.653 + (-0.422)(M \times T) + (0.364)(MnT) + (-1.359)(M \times RH) + (-1.004)(Mn\ RH) + (7.640)(Wv) + (-8.034)(Ev) + (5.527)(Rf) + (166.887)(Sy) + (-17.339)(Cc). \]

These regression equations can be incorporated in the algorithms of a forecasting model to predict the incidence of aphids in agro-advisory services.

From this analysis another important feature that emerged out, was the determination of the single most influential factor may be abiotic or biotic that adversely effected the aphid population. It was terminated that syrphid definitely had an influence on the aphid population as evidenced from the values obtained at the first and third sowing of 2000-01 and yet again in the first and second of 2001-02. Whereas, coccinellids exhibited significant impact on aphids at second sowing of 2000-01 while rainfall at third of 2001-02.

Singh and Malik (1998) and Kanth et al. (2000) concluded that aphids exhibited positive correlations with maximum and minimum temperature whereas, Kar and Chakraborty (2000) reported negative correlation between aphids and temperature. Bishnoi et al., (1992) opined that the temperature of 10-13.5°C and relative humidity of 72 to 85% in association with western disturbances in a region could be used to predict the rapid multiplication of mustard aphid in *B. napus* and *B. juncea*. They also advocated that when western disturbances got cleared and there was a sharp rise in temperature, the population build-up of aphid intensifies. Kashyap and Bishnoi, (1988) and Bishnoi et al., (1992) concluded that temperature had a direct bearing on aphid population, more the temperature, lesser was the population. Similar was the observation of Kanth et al., (2000), they concluded that temperature ranging from 17.5 to 22°C accompanied by relative humidity varying from 62 to 78% favoured aphid population but rainfall had adverse effects. Mathur and Singh (1986),
Sinha et al. (1989) and Singh and Malik (1998) reported that aphids were negatively correlated with maximum and minimum relative humidity.

As far as predators of the mustard aphid were concerned, syrphids showed profound influence over the coccinellids in terms of feeding efficiency as well as numerical strength. Further, fluctuation of their population was directly proportional to that of the prey numbers. This was evident from the high positive correlation with the aphid density. This scrutiny has been reinforced by the results of Kotwal et al. (1984), Shantibala et al. (1994), Devi et al. (1996), and Devjani et al. (1997). The combined effect of the two predators has also been well documented by Sharma and Adlakha (1981), Singh and Misra (1986), Mani and Krishnamoorthy (1989), Shenhmar and Brar (1995) and Devjani et al. (1997). All above workers have testified the effective role of both predators in the bringing down the population of aphids at a considerable low level. It further intensified when eco-friendly pesticides were used on calendar based schedule.

4.4 EFFICACY OF INSECTICIDAL SPRAYS AGAINST L. ERYSIMI

Relative efficacy of some of the most commonly used insecticides by the farmers of Aligarh and its adjoining areas was determined against L. erysimi, Kaltenbach. There were three insecticide spray schedules. The first, was done before the flowering stage when aphids initiated their attack in the field and the remaining two at 15 days interval after the first spray. Accordingly, spraying was done on the crop for two consecutive years. Observations on population count of aphids/10 cm terminal shoot/plant (replicated thrice) against different insecticides were recorded at 1, 7 and 14 days interval after each spray. Data so recorded, was pooled for performing analysis of variance. The results have been summarized here under.

4.4.1 YEAR: 2000-01

As far as the first spray was concerned (Table 13), the aphid intensity varied from 15.85-to 60.71-aphids/10 cm terminal shoot/plant in different treatments. It is evident from the data that all the treatments were significantly superior over control in reducing population of aphids. On further exploration, it was inferred that phosphamidon (0.03%) was the most effective treatment followed by oxydemeton-methyl (0.03%) and chlorpyriphos (0.05%) in reducing the aphid population, the corresponding values were 15.8, 18.2, and 19.9-aphids/10 cm terminal shoot/plant. A
glance over the data revealed that dimethoate (0.03%), endosulfan (0.05%) and malathion (0.05%) did not exhibit significant variation as shown from their values were 22.2, 23.9 and 24.4 aphids/10 cm terminal shoot/plant. Neemarin (1:100 dilution) exhibited poorest efficacy as (35.8 aphids/10 cm terminal shoot/plant) to bring down the aphid population at the reasonable level.

The data pertaining to the second spray of insecticides showed that all the treatments were significantly better over control. Phosphamidon (0.03%) proved to be the best treatment followed by oxydemeton-methyl (0.03%), chlorpyriphos (0.05%), endosulfan (0.05%), malathion (0.05%), dimethoate (0.03%), the corresponding values on population count were 39.0, 46.5, 49.1, 49.7, 51.2 and 52.2 aphids/10 cm terminal shoot/plant. Once again neemarin (1:100 dilution) remained as the least effective treatment showing 58.4 aphids/10 cm terminal shoot/plant.

A glance over data pertaining to the third spray revealed that of all the insecticides evaluated phosphamidon (0.03%) once again, showed superiority over other treatments. This treatment was closely followed by oxydemeton-methyl (0.03%), chlorpyriphos (0.05%) and dimethoate (0.05%). The respective population count through these treatments were 9.8, 12.7, 14.2, and 16.4 aphids/10 cm terminal shoot/plant, respectively. However, endosulfan (0.05%) and malathion (0.03%) remained at par with other (21.0 and 21.8 aphids/10 cm terminal shoot/plant). Neemarin (1:100 dilution) proved to be the least effective (31.2 aphids/10 cm terminal shoot/plant) but was far better against control (42.4 aphids/10 cm terminal shoot/plant).

The intratreatment efficacy based on the values obtained for the first spray, revealed that although phosphamidon (0.03%) proved to be the best, but was statistically at par with oxydemeton-methyl (0.03%), dimethoate (0.05%) and chlorpyriphos (0.05%). However, it differed significantly with endosulfan (0.05%), malathion (0.05%) and neemarin (1:100 dilution). Whereas, endosulfan (0.05%) and malathion (0.05%) were statistically at par with each other but differed significantly with phosphamidon (0.03%) as well as neemarin (1:100 dilution). When similar observations were made for the second spray, it became evident that despite the fact that phosphamidon (0.03%) was the best one, nevertheless, statistically at par with endosulfan (0.05%), chlorpyriphos (0.05%) and oxydemeton-methyl (0.03%). It however, differed significantly with malathion (0.05%), dimethoate (0.03%) and neemarin (1:100 dilution). The other treatments, neemarin (1:100 dilution),
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Dimethoate (0.03%), malathion (0.05%), endosulfan (0.05%), chlorpyriphos (0.05%) and oxydemeton-methyl (0.03%) were statistically at par with each other. As far as the third spray was concerned, a dissimilar trend was obtained as compared to the earlier two sprays wherein, phosphamidon (0.03%) was the most effective treatment, though at par with chlorpyriphos (0.03%) and oxydemeton-methyl (0.03%). It differed significantly with dimethoate (0.03%), malathion (0.05%), endosulfan (0.05%) and neemarin (1:100 dilution) while oxydemeton-methyl (0.03%) was statistically at par with chlorpyriphos (0.05%) and dimethoate (0.03%) but it differed significantly with dimethoate (0.03%), malathion (0.05%), endosulfan (0.05%) and neemarin (1:100 dilution). Nonetheless, dimethoate (0.03%), malathion (0.05%) and endosulfan (0.05%) were statistically at par with each other but differed significantly with neemarin (1:100 dilution).

When a comparison was made between the efficacy of the insecticide treatments of the first, second and third sprays, it was inferred that phosphamidon (0.03%) remained as the best treatment followed by oxydemeton-methyl (0.03%), chlorpyriphos (0.05%), dimethoate (0.03%), endosulfan (0.05%), malathion (0.05%) and finally neemarin (1:100 dilution).

4.4.2 YEAR: 2002

Data obtained for the first spray of 2001-02 revealed that phosphamidon (0.03%) happened to be the most effective insecticide against L. erysimi (10.0/10 cm terminal shoot/plant), followed by oxydemeton-methyl (10.4 aphids). The next order of preference was chlorpyriphos (0.05%), and dimethoate (0.03%) but were at par with each other (13.2 and 13.9-aphids/10 cm terminal shoot/plant). These treatments were very closely followed by endosulfan (0.05%), malathion (0.05%) and neemarin (1:100 dilution). The corresponding values were 14.8, 14.9, and 19.3 aphids/10 cm terminal shoot/plant.

As far as the effectiveness of the second spray was concerned, all the treatments proved to be superior over control. Here too, phosphamidon (0.03%) showed the best performance followed by oxydemeton-methyl (0.03%) and chlorpyriphos (0.05%), however, these two were at par with the former. Their corresponding values were 24.8, 26.2, and 26.8-aphids/10 cm terminal shoot/plant. The next effective treatments were dimethoate (0.03%), endosulfan (0.05%) and malathion (0.05%) showing a population count of 28.3, 29.0, and 29.8-aphids/10 cm terminal shoot/plant.
terminal shoot/plant. However, neemarin was the least effective treatment exhibiting a high population of 34.4 aphids/10 cm terminal shoot/plant.

The third spray of various insecticides revealed that all the treatments were significantly better over control. Phosphamidon (0.03%) was found to be the most effective treatment closely followed by oxydemeton-methyl (0.03%) and chlorpyriphos (0.05%). The results were more or less akin to first and second spray.

The intratreatment efficacy based on the data obtained from the test of variance exhibited that although phosphamidon (0.03%) was the most effective against *L. erysimi*, but it was statistically at par with oxydemeton-methyl (0.03%), chlorpyriphos (0.05%), dimethoate (0.03%), malathion (0.05%) and endosulfan (0.05%) while it differed significantly with neemarin (1:100 dilution). However, chlorpyriphos (0.05%) was statistically at par with dimethoate (0.03%), malathion (0.05%), endosulfan (0.05%) and neemarin (1:100 dilution) in the first and third spray. While, in the second spray a slight rearrangement in the trend was obtained. Here phosphamidon (0.03%) showed the best performance. It remained statistically at par with oxydemeton-methyl (0.03%), chlorpyriphos (0.05%), dimethoate (0.03%), malathion (0.05%) and endosulfan (0.05%) but differed significantly with neemarin (1:100 dilution). Oxydemeton-methyl (0.03%) was at par with chlorpyriphos (0.03%), dimethoate (0.03%), malathion (0.05%), endosulfan (0.05%) and neemarin (1:100 dilution).

A comparison of the two year data of the three sprays each, to determine the efficacy of the insecticide treatments against *L. erysimi* yielded the following results in descending order:- phosphamidon (0.03%) > oxydemeton-methyl (0.03%) > chlorpyriphos (0.05%) > dimethoate (0.03%) > endosulfan (0.05%) > malathion (0.05%) > neemarin (1:100 dilution).

These findings are in complete agreement with that of Bakhetia *et al.*, (1986) who reported that oxydemeton-methyl and chlorpyriphos were the best in reducing aphid population, while Lal and Singh (1987) opined that dimethoate (0.03%) followed by oxydemeton-methyl (0.025%) were the best treatments against aphids. Similarly, Khurana and Batra (1989) concluded that oxydemeton-methyl was the best treatment, while Kumar *et al.*, (1996) opined that chlorpyriphos (0.05%), oxydemeton-methyl (0.05%) and monocrotophos (0.04%) were effective in combating the mustard aphid menace whereas, malathion (0.05%) was the least effective. Prasad (1997) concluded that all the neem formulations were inferior to

4.5 BIO-EFFICACY OF INSECTICIDES ON RELATIVE ABUNDANCE OF BENEFICIAL INSECTS

Ever since their discovery, synthetic insecticides have been used indiscriminately to control harmful pests. These not only kill the target pest but also extinguish the population of non-target/beneficial (predators, parasites and pollinators) insects. Besides, their non-judicious use has resulted in hazards to environment, human and animal health. Chemicals should be applied only when they are needed. The recent concept of adopting other means of pest management, besides need based chemical control, emphasizes conservation of natural fauna of any crop ecosystem. The most commonly used pesticides, because of their easy availability do not assure conservation of non-target species. In the present experiment, while evaluating relative performance of various chemicals against aphids, an effort was also made to test their relative safety to most potential predators of aphids (C. septempunctata and I. scutellaris). The results obtained have been dealt here under on the basis of pooled data for two consecutive years.

4.5.1 COCCINELLA SEPTEMPUNCTATA

Observations were recorded on the population count of coccinellids (C. septempunctata) after each second spray of the different insecticides at weekly intervals till the crop maturity. All the treatments, except neemarin (2.9 coccinellids/plant), were found to be toxic. When we look at the comparative analysis of toxicity of remaining insecticides, it was inferred that endosulfan, malathion and chlorpyriphos were relatively better from the point of view of their deleterious effect. The population count on the plants through these treatments were 2.6, 2.1, and 1.8
coccinellids/plant. However, phosphamidon (0.03%), dimethoate and oxydemeton-methyl proved to be lethal.

4.5.2 *ISCHIODON SCUTELLARIS*

When chemicals were applied on the crop it was revealed that the highest syrphid population was recorded from neemarin @1:100 dilution, followed by endosulfan (0.05%), malathion (0.05%), and chlorpyriphos (0.05%). The corresponding values were 2.1, 1.5, 1.3, and 0.8 maggots/10 cm terminal shoot/plant, respectively. The lowest population was however, encountered on phosphamidon (0.03%) followed by oxydemeton-methyl (0.03%) treated crop exhibiting the population count of 0.1 and 0.4 maggots/10 cm terminal shoot/plant, respectively.

These observations find corroboration in the work of Sarup et al. (1966), Singh and Malhotra (1976), Sharma and Adlakha (1981), Misra and Satpathy (1984). They concluded that endosulfan was found to be the safest for *C. septempunctata*. However, Makhmoor and Malhotra (1993) argued that chlorpyriphos and endosulfan at the recommended concentrations could be used for aphid control along with the larvae of syrphids in IPM. Malik et al., (1998) opined that endosulfan and malathion were less detrimental to coccinellids, whereas Singh et al., (1999), and Sharma and Kashyap (2002) proposed that endosulfan was relatively safe to *Syrphis* sp. but highly toxic to *C. septempunctata*, which is not in agreement with our findings. Chakrabarti (2001) made it clear that phosphamidon was very unsafe to coccinellids and syrphids.

4.6 ECONOMICS OF DIFFERENT INSECTICIDAL SCHEDULES

Different treatments exerted differential response with reference to net profit as well as cost: benefit ratio (Table 15). The profit or net monetary return varied from Rs. 7279.7 to 18885.1. The highest return (18885.1) was obtained from the crop treated with phosphamidon (0.03%) followed by Rs. 16529.2, 14460.6, 14288.6, 13960.8, and 12050.8/ha. from oxydemeton-methyl (0.03%), dimethoate (0.03%), chlorpyriphos (0.05%), endosulfan (0.05%) and malathion (0.05%). The lowest net return of Rs. 7279.7/ha was however, obtained when the crop was treated with neemarin (1:100 dilution). Thus, it could be inferred that all the insecticides, except neemarin (1:100 dilution) when applied to the crop performed better. A similar trend was observed while calculating cost: benefit ratio. Maximum cost: benefit ratio of 1:71.94 was obtained from phosphamidon (0.03%) followed by 1:22.95 on both
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malathion (0.05%) and dimethoate (0.03%), 1:16.62, 1:16.40 and 1:9.72 from oxydemeton-methyl (0.03%), endosulfan (0.05%) and chlorpyriphos (0.05%), respectively while minimum of 1:6.08 from neemarin (1:100 dilution) treated crop.

Similar results were also reported by Verma (1980), Baral et al., (1986), Suri and Singh (1993). According to Kumar et al., (1996) chlorpyriphos followed by phenthoate and malathion gave the highest. Furthermore, Upadhyay and Agarwal (1993), Patel et al., (1995), Singh and Malik (1998), Singh et al., (1999) and Kumar (2000) concluded that spraying of phosphamidon and oxydemeton-methyl were very promising and gave the highest net profit and cost benefit ratio which is in strong conformity with present findings.

4.7 YIELD

It may not be out of place to mention here that the effect of various insecticides and consequent population build-up of *L. erysimi* had a direct bearing on the healthy pod setting and subsequent yield. The data clearly indicated that all the treatments differed significantly over control (Table 16). Efficacy of the insecticide treatments was also adjudged by the analysis of variance for seed yield.

In 2000-01, when phosphamidon (0.03%) was applied at three different intervals, at different stages of crop growth, it was gauged to be the best. The resultant yield was 1480.5 kg/ha. The second best treatment was of oxydemeton-methyl (0.03%), followed by dimethoate (0.03%), chlorpyriphos (0.05%), endosulfan (0.05%) and malathion (0.05%). Their corresponding yields were 1333.6, 1239.3, 1206.4, 1125.9, and 957.8 kg/ha. respectively. Crop treated with neemarin (1:100 dilution) produced the lowest yield of 651.1 kg/ha.

A study over the yield obtained during 2001-02 indicated that maximum seed yield (1545.6 kg/ha) was yet again obtained from phosphamidon (0.03%) treated crop followed oxydemeton-methyl (0.03%). The other effective treatments were dimethoate (0.03%), oxydemeton-methyl (0.03%), endosulfan (0.05%) and malathion (0.05%). Their corresponding yields were 1453.9, 1379.7, 1317.6, 1256.2, and 1094.7 kg/ha. respectively. Once again neemarin (1:100 dilution) did not show a promising role in restricting the multiplication of aphids as compared to others, though there was a significant improvement in increase of yield (797.1kg/ha) as compared to check (105.6kg/ha).
In an attempt to get a clear view of yield, the data of 2000-01 was subjected to analysis of variance and a comparison made between the treatments revealed that all the treatments differed significantly with control. The yield obtained through phosphamidon (0.03%), oxydemeton-methyl (0.03%), dimethoate (0.03%), chlorpyriphos (0.05%), and endosulfan (0.05%) were found to be at par, while neemarin (1:100 dilution) gave the least yield and differed significantly from the rest. For the next year 2001-02, analysis of variance exhibited that the yield from phosphamidon (0.03%) was at par with endosulfan (0.05%), chlorpyriphos (0.05%), dimethoate (0.03%) and oxydemeton-methyl (0.03%) but differed significantly with neemarin (1:100 dilution) and malathion (0.05%). Though malathion (0.05%) proved to be at par with endosulfan (0.05%), chlorpyriphos (0.05%), dimethoate (0.03%), oxydemeton-methyl (0.03%) and neemarin (1:100 dilution).

Pooled data (2000-02) for insecticide sprays to minimize the aphid attack and subsequent yield revealed that phosphamidon (0.03%) was found to be superior treatment with a resultant yield of 1573.067 kg/ha, followed by oxydemeton-methyl (0.03%), dimethoate (0.03%) and chlorpyriphos (0.05%). Their corresponding yields were 1393.783, 1309.555, and 1262.035 kg/ha, respectively. Spraying of endosulfan (0.05%) and malathion (0.05%) to control aphid gave resultant yield of 1191.066 and 1026.274 kg/ha, respectively. However, neemarin (1:100 dilution) did not ensure good yield (724.1 kg/ha) was not better. The test for analysis of variance revealed that phosphamidon remained at equivalence to dimethoate, chlorpyriphos and oxydemeton-methyl whereas; malathion, endosulfan, chlorpyriphos and dimethoate were at par.

Variation in seed yield obtained from the different treatments could be the result of a differential effect of the insecticides used in protecting the crop from aphid attack. Many workers have reported differences in seed yield by the application of various chemicals against aphid attack. Verma and Singh (1987) reported reduction in seed yield up to 93.3 per cent under severe infestations by the aphids, similar conditions prevailed in the present findings during 2000-01. Furthermore, Brar et.al. (1987) opined that yields obtained from different Brassica sp. resulted in yield variations from year to year and even in different fields at the same locations. Sekhon and Bakhetia (1994) proposed that there was an inverse relationship with aphid incidence as far as yield was concerned. Kakar and Dogra (1979) found that methyl-odemeton followed by dimethoate, methyl-parathion and endosulfan were the better
treatments in order to get effective control of mustard aphid, and also better seed yield. According to Zaman (1990) dimethoate and primicarb were better while Jadhav and Singh (1990) advocated rogor (0.03%) as the best treatments to obtain maximum yield. Recently, Kumar et al., (1996) and Kumar (2000) reported that chlorpyriphos, oxydemeton-methyl and monocrotophos were the most effective treatments in obtaining maximum yield in mustard against aphid attack. Such observations further strengthen our findings.

4.8 PREDATION POTENTIAL OF PREDATORS

4.8.1 C. SEPTEMPUNCTATA

At 18±1°C, the feeding potential of the various instars (I, II, III, and IV) varied from 7 to 33, 147 to 188, 172 to 199 in the first generation and 8 to 30, 57 to 121, 133 to 179, 162 to 191 aphids/larva in the second, respectively. Total consumption of aphids during the entire larval period ranged between 460 to 644 and 435 to 577 aphids/larva in the first and second generations, respectively. Similarly, at 24±1°C the corresponding values were 9 to 45, 60 to 130, 133 to 170, 164 to 185/larva and 1 to 55, 54 to 119, 122 to 157 and 154 to 188 aphids, during the first and second generations, respectively. Besides, the total consumption was 221 to 350 and 205 to 341 aphids/larva in the first and second generation, respectively. While at 28±1°C, the consumption of aphids by I, II, III, IV larval instars varied from 1 to 49, 72 to 141, 163 to 186 and 183 to 197 aphid nymphs/larva in the first generation and 12 to 52, 69 to 140, 149 to 188 and 181 to 190 aphids in the second, respectively. A single larva, during, during its life span, could consume 190 to 320 and 193 to 301 nymphs during first and second generation, respectively.

When studies were conducted at fluctuating temperatures it was revealed that at 18/24±1°C different instars of larvae (I, II, III and IV) of the first generation could consumed 13 to 52, 79 to 160, 150 to 179, 166 to 199 whereas of the second generation could feed on 16 to 54, 78 to 167, 144 to 170, 175 to 204 aphids/larva, respectively. A single larva was able consume aphid nymphs in the range of 397 to 450 and 361 to 437 during first and second generation, respectively. Furthermore, at 18/28±1°C the number of aphids consumed during the various developmental stages in the first generation, was 11 to 33, 44 to 98, 79 to 105 and 94 to 130 whereas, in second generation the quantum of feeding was 12 to 35, 40 to 93, 84 to 111, 87 to 129
aphids/larva. A single larva before entering into pupal stage predated upon 172 to 287 and 145 to 255 aphids in the first and second generation, respectively. Similarly, at 24/28°C the corresponding values of different larval instars were to the tune of 14 to 38, 36 to 74, 97 to 136, 109 to 143 in the first and 17 to 44, 32 to 62, 105 to 141, 101 to 137 aphids/instar in the second generation, respectively. The total feeding was to the tune of 131 to 220 (first generation) and 138 to 197 aphids/larva (second generation).

4.8.2 I. SCUTELLARIS

Three larval instars were recorded for I. scutellaris, all exhibited feeding potential of varying magnitude. At 18±1°C, different developmental instars (I, II, and III) consumed aphids in the range of 7 to 40, 74 to 158, 174 to 248, respectively during, first generation while the corresponding values in the second generation were 6 to 39, 71 to 151, 152 to 219 aphids/maggot. However, the total number of aphids consumed during entire life span was encountered as 350 to 475 (first generation) and 250 to 430 aphids/maggot (second generation). At 24±1°C, the number of aphids consumed by I, II, III larval instars was in the range of 10 to 61, 90 to 173, 197 to 295 (first generation) and 7 to 54, 73 to 140, 183 to 263 aphids (second generation), respectively. However, the total number of aphids’ consumed/maggot was found to be 337 to 776 and 290 to 457 in first and second generations, respectively. Nonetheless, it was only one maggot devoured 776 aphids while rest the others could consume on an average of 490 aphids. When observations were recorded at a temperature of 28±1°C, it was revealed that the different instars (I, II, and III) preyed upon 12 to 54, 81 to 160, 155 to 208 nymphs less were consumed by the population of second generation, the corresponding range for respective instars was 11 to 55, 77 to 130, 130 to 180. However, a single maggot was able to devour 245 to 435 and 218 to 423/larva, in the first and second generation, respectively.

When the experiment was conducted out at fluctuating temperature of 18/24±1°C, the feeding potential of the different instars (I, II, III) during the first generation was 16 to 60, 93 to 180, 160 to 225 and in the second generation as 12 to 62, 84 to 161, 150 to 217 (second generation), respectively. Nonetheless, the total number of aphids consumed by an individual was a 370 to 572 and 340 to 490 aphid, nymphs at first and second generation, respectively. At a fluctuating temperature of
18/28±1°C, the consumption of aphids during L. II. III instars was evaluated to be 11 to 47, 76 to 153, 149 to 171 in the first and 10 to 39, 77 to 133, 144 to 165 aphids at respective instars in the second generation. However, the total consumption by a single maggot during its life span ranged between 191 to 350 and 187 to 352 aphids for the first and second generation, respectively. When fluctuation in temperature was narrowed, but at higher side i.e. 24/28°C, the predation by the various instars was recorded as 17 to 49, 50 to 92, 87 to 120 and 5 to 37, 46 to 93, 67 to 104 during first and second generation, respectively. Furthermore, the total number of aphids devoured by a single maggot fluctuated between 150-197 and 141-192 in the first and second generation, respectively.

From the above findings it was inferred, that in all the cases feeding efficiency increased progressively with the advancement of age of the insect, as has also been observed by Mohammad and Mahmood (1986); Devi et al., (1996); Chandrababu et al., (1997); Kotwal et al., (1984); Shantibala et al., (1994). The combined effect of coccinellid and syrphids in the management of the aphid below the economic injury level has also been well documented by Sharma and Adlakha (1981); Singh and Misra (1986); Dhiman and Kumar (1986); Singh and Misra (1988); Mani and Krishnamoorthy (1989), Radhakrishnan and Muraleedharan (1993); Singh (1994); Shenhmar and Brar (1995); Singh and Misra (1988) advocated that at 20°C a single maggot can consume about 260 aphids (*R. maidis*) till pupation. Whereas, Lal and Haque (1965) observed the consumption of 321 aphids (*Rhopalosiphum pseudobrassicae* on mustard) at 22.2°C. Agarwal and Saha (1986) however, observed 618 aphids (*Aphis gossypii* Glover on cotton) at 12.7 to 30.7°C. Such differences might be due to prey specificity. The present findings are in complete agreement with the work of Lal and Haque (1965) and Roy and Basu (1977) who opined that at a high temperature, the voracity of predators larvae/day increases, but there would be reduction in the total consumption of prey due to shortening of the total feeding/larval period.

4.9 AGE SPECIFIC LIFE-TABLES

4.9.1 *C. SEPTEMPUNCTATA* AT CONSTANT TEMPERATURES

From the tables (18 to 23, Fig. 1-3) it was evident that this insect completed its generation in 68 days at 18±1°C (gen. II) followed by 65 and 50 days at 18±1°C (gen.
I), and 24±1°C (gen. I), respectively. In contrast the minimum period for the completion of the generation was of 40 days at 28±1°C (gen. II). The life expectancy pattern remained similar in all the cases wherein regular drop was recorded throughout the generation. However, a negligible rise was observed on the day 4, 5, 8 at 18±1°C (gen. I), day 2, 3, 8, 25, 47, 65 at 18±1°C (gen. II), day 3 at 24±1°C (gen. I, II), day 17 at 28±1°C (gen. I), day 2, 3, 13, 14 and 17 at 28±1°C (gen. II).

4.9.2 AT FLUCTUATING TEMPERATURES

Fluctuating temperatures (Table 24 to 29, Fig. 4-6) indicated that *C. septempunctata* required a maximum of 58 days at 18/28±1°C (gen. I) to complete its entire generation and a minimum of 46 days at 24/28±1°C (gen. II). However, it took 53 and 52 days at 18/24±1°C (gen. I), 18/28±1°C (gen. II), respectively. The life expectancy in general showed marginal decline till the culmination of generation. Negligible increase was however, encountered on day 8 at 18/24±1°C (gen. II), day 3 and 46 at 18/28±1°C (gen. I), day 2 and 3 at 18/28±1°C (gen. II), and 24/28±1°C (gen. I).

4.9.3 *I. SCUTELLARIS* AT CONSTANT TEMPERATURES

Perusal of data (Table 30 to 35, Fig. 7-9) indicated that the longest generation time (52 days) for *I. scutellaris* was recorded at 18±1°C (gen. I) followed by 45 and 42 days at 18±1°C (gen. II) and 24±1°C (gen. I), respectively, while the shortest (29 days) at 28±1°C (gen. II). Intermittent pauses in age specific survivorship (lx) were observed irrespective of the temperature, range during both generations. As far as, life expectancy (ex) was concerned it noted a steady decline throughout the generation at all the temperatures except at 18±1°C (gen. I). Nonetheless, negligible increase was encountered on day 2 and again at 18±1°C (gen. II) while day 2 and 3 revealed a marginal increase.

4.9.4 AT FLUCTUATING TEMPERATURES

A comparison of age specific life-tables (Tables 36 to 41, Fig. 10-12) at fluctuating temperatures was made. It was revealed that *I. scutellaris* required a maximum of 42 days at 18/24±1°C (gen. I) followed by 35 days at 18/28±1°C (gen. II) and 24/28±1°C (gen. I). In contrast, the minimum generation time was of 29 days
at 24/28±1°C (gen. II). After an initial drop in age specific survivorship (lx) from day 1 to 4, the stability in lx was observed for some days, intermittently, at varying temperatures and generations. The life expectancy (ex) exhibited a marginal drop till the culmination of the generation in all the investigations. However, it recorded negligible increase on day 11 at 18/28±1°C (gen. I), day 2 and 13 at 18/28±1°C (gen. II) and day 2 at 24/28±1°C (gen. II).

From the observations for both predators, it was inferred that C. septempunctata needed maximum of 68 days to complete its cycle at a constant temperature of 18°C (gen. II) followed by 65, 58 days at 18°C (gen. I) and at a fluctuating temperature of 18/28°C (gen. I). On the contrary, the minimum period was of 40 days at 28°C (gen. II). As far as life expectancy (ex) was concerned, it revealed slow and steady decline from the day one till the termination of the generation. It, however, noted a marginal increase on the day 4, 5, 8 at 18°C (gen. I), day 2, 3, 8, 25, 47, 65 at 18°C (gen. II), day 3 at 24°C (gen. I, II), day 17 at 28°C (gen. I), day 2, 3, 13, 14, and 17 at 28°C (gen. II) day 8 at 18/24°C (gen. II), day 3 and 46 at 18/28°C (gen. I), day 2 and 3 at 18/28°C (gen. II), and 24/28°C (gen. I).

On the other hand I. scutellaris required a maximum of 52 days at 18°C (gen. I) to complete its generation, followed by 45 days at 18°C (gen. II), 42 days at 24°C (gen. I) and 18/24°C (gen. I). Contrary to this, the minimum of 29 days at 28°C (gen. II) and 24/28°C (gen. II). Life expectancy (ex) had a more or less similar trend at all the temperatures and generations, it showed steady and gradual decline till the culmination of each generation. A marginal increase in ex was however, encountered on day 3 at 18°C (gen. I), day 2 and 3 at 18°C (gen. II), day 11 at 18/28°C (gen. I), day 2 and 3 at 18/28°C (gen. II) and day 2 at 24/28°C (gen. II).

The observations recorded and the resultant data for age specific life-table of C. septempunctata and I. scutellaris clearly indicated that survivorship (lx), death (dx) and life expectancy (ex) at the different temperatures vis-à-vis generations were not the same, though, the trend followed was evidently similar. Besides, the graphic representation of these three parameters also exhibited an analogous model.

The initial drop in survivorship was a result of the embryonic death in all the cases. The present study found similarity with the works of Choudhary and Bhattacharya (1986), Reddy and Bhattacharya (1988), Rizvi (1988), Naqvi (1998), Dar (1998), Pathak and Rizvi (2002) who have also held the same opinion in their
experiments on *Heliothis armigera*, *Spilosoma obliqua*, *Coreyra cephalonica*, *Spodoptera litura* and *P. demoleus*, respectively. After an initial decline, the decrease in survivorship was intermittent, and this pattern continued till the termination of the generation. Thereafter, steep derogation was noticed at adult stages irrespective of temperatures, insect species and generations. The survivorship curve thus obtained, gave stair-step appearance as already reported by Odum (1971) for holometabolous insects. Other workers have held the same opinion for such curves on a variety of insects (Singh, 1984; Choudhary and Bhattacharya, 1986; Dar, 1998; Naqvi, 1998; Khurshid, 2001). The survivorship curves also followed intermediate to standard type I and type II as proposed by Deevy (1947) and Slobodkin (1962). The present outcome is in strong agreement with that of Reddy and Bhattacharya (1988).

As far as life expectancy of *C. septempunctata* and *I. scutellaris* was concerned, it declined marginally till it reached 1.0, coinciding with culmination of the generation. At some instances negligible increase was however, noticed in the life expectancy. This tendency of increase and decrease in expectancy of life was attributed on account of death of the two insect species at different age interval. Similar was the opinion of Singh (1984), Pathak and Rizvi (2002) for varied insects. The duration of the different stages obtained in the present studies are in complete agreement with the findings of Butler (1982).

### 4.10 STAGE SPECIFIC LIFE-TABLES

#### 4.10.1 C. SEPTEMPUNCTATA AT CONSTANT TEMPERATURES

**Apparent Mortality**

A perusal of tables (42 to 47) pertaining to apparent mortality of *C. septempunctata* at three constant temperatures (18°C, 24°C, 28 ± 1°C) and 70 ± 5% relative humidity and two successive generations revealed pronounced variations in the trend of mortality at different developmental stages. At the egg stage, the highest apparent mortality (15%) was found at 28°C (gen. II) and lowest (8%) at 18°C (gen. II) and 24°C (gen. I). However at 18°C (gen. I), 24°C (gen. II) and 28°C (gen. I), the corresponding values were 9, 10 and 12%, respectively. As far as, first instar larval stage was concerned, apparent mortality was maximum (8.24%) at 28°C (gen. II) and minimum (5.43%) at 18°C (gen. II) whereas, values obtained at 18°C, 24°C, and 28°C were close to each other, it ranged from 5.49 to 6.52%. The second instar larval stage
of *C. septempunctata* at 18° C (gen. I) did not show any apparent mortality while the highest of 4.82% was computed at 28° C (gen. I). The intermediate values of 1.16, 2.30, 3.53 and 3.85% were obtained at 24° C (gen. I), 18° C (gen. II), 24° C (gen. II) and 28° C (gen. II), respectively. It was interesting to note that third instar larvae did not exhibit any mortality at 18° C (gen. I, II), 24° C (gen. I, II) and 28° C (gen. I), however, at 28° C (gen. II) the larvae did the deaths to the tune of 2.67%. As far as fourth instar larvae were concerned, they also exhibited pronounced variation in their mortality pattern. A high of 8.24% mortality was recorded at 24° C (gen. I) in contrast to cent per cent survival at 18° C (gen. II) and 24° C(gen. II). The mortality of 2.33, 2.53 and 5.48% was however recorded at 18° C (gen. I), 28° C (gen. I), 28° C (gen. II), respectively. Nevertheless, the mortality trend at the pre-pupal stage revealed less variation. The highest mortality of 11.76% was recorded at 18° C (gen. II) followed by 10.98, 10.14, 9.09, 8.97 and 8.33% at 24° C (gen. II), 28° C (gen. II), 28° C (gen. I), 24° C (gen. I) and 18° C (gen. I), respectively. In contrast, at the pupal stage, a reverse trend was noticed exhibiting variation of high magnitude. The maximum value (9.33%) was encountered at 18° C (gen. II) followed by 7.14, 6.49, 5.63, 4.11, 3.23% at 28° C (gen. I), 18° C (gen. I), 24° C (gen. I), 24° C (gen. II), 28° C (gen. II), respectively.

**Stage Specific Survival Fraction (Sx)**

Variation in survival fraction (Sx) was of low order at the egg stage at different temperatures vis-à-vis generations. However, the maximum Sx (0.92) was recorded at 18° C (gen. II), and 24° C (gen. I), and minimum (0.85) at 28° C (gen. II). When a comparison was made between the different larval stages, it was noted that the values were more or less at par with each other. The highest value (1.0) of Sx was obtained at second instar at 18° C (gen. I), third instar at 18° C (gen. I, II), 24° C (gen. I, II), 28° C (gen. I), and in the fourth instar at 18° C (gen. II), 24° C (gen. II), whereas, the lowest (0.92) at the first instar at 28° C (gen. II) and fourth instar stage at 24° C (gen. I). Similar was the pattern for Sx at pre-pupal stage where the value ranged between 0.88 and 0.92 at 18° C, gen. I and yet again at 18° C but gen. II. Further, at the pupal stage, the Sx was a high of 0.97 at 28° C (gen. II) followed by 0.96 at 24° C (gen. II), 0.94 at 18° C (gen. I), 0.93 at 28° C (gen. I) and lastly 0.91 at 18° C (gen. II).
Mortality Survivor Ratio (MSR)

The data on the survival ratio revealed that of all the developmental stages the highest (0.18) and the lowest ratio (0.14) was at the egg stage at 28°C (gen. II), 28°C (gen. I), however, second instar larval stage at 18°C (gen. I), third instar at 18°C (gen. I, II), 24°C (gen. I, II), 28°C (gen. I), fourth instar at 18°C (gen. I), 24°C (gen. II) did not reveal any mortality; hence the ratio remained as zero.

As far as the variations of MSR within the developmental stages was concerned, the values exhibited a decreasing trend from the egg to the late instar larval stage, then there was a sharp rise in ratio at the pre-pupal stage paving way for decline in value at the pupal stage irrespective of the temperatures and generations.

Indispensable Mortality (IM)

It was apparent from the data that the trend for IM was similar to that of MSR. When a comparison was made between the various developmental stages, the maximum IM to the tune of 10.59% was at the egg stage at 28°C (gen. II) followed by a second high of 9.07% at the pre-pupal stage at 18°C (gen. II). The minimum IM was zero at second instar at 18°C (gen. I), third instar at 18°C (gen. I, II), 24°C (gen. I, II), 28°C (gen. II), fourth instar at 18°C (gen. II), and 24°C (gen. II).

k-Values

The data evidently exhibited that k-values pattern was exactly similar to MSR and IM. There was an apparent variation in k-values computed for different developmental stages, the highest ‘k’ (0.0706) being at the egg stage at 28°C (gen. II) followed by 0.0544 at the pre-pupal stage at 18°C (gen. II). However, the second instar at 18°C (gen. I), third instar at 18°C (gen. I, II), 24°C (gen. I, II), 28°C (gen. II), fourth instar at 18°C (gen. II), 24°C (gen. II) did not reflect variation and ‘k’ remained as nil.

4.10.2 AT FLUCTUATING TEMPERATURES

Apparent Mortality

From the tables (48 to 53) it was inferred that apparent mortality showed a set trend, the values decreased from egg to third/fourth instar stage then increased at the pre-pupal stage and once again declined at the pupal stage. However, the highest apparent mortality of 13% was at the egg stage at a fluctuating temperature of
24/28°C (gen. II) followed by 11% at the same stage but at 18/28°C (gen. II) and 24/28°C (gen. I). Contrary to this, cent per cent survival was encountered at second instar at 18/24°C (gen. I), 18/28°C (gen. I, II), third instar at 18/24°C (gen. I, II), and 24/28°C (gen. II).

**Stage Specific Survival Fraction (Sx)**

A glance over data revealed that a reverse trend in Sx was obtained as compared to apparent mortality at various temperatures and generations. The comparison of Sx at various developmental stages recorded the highest value (1.0) at second instar at 18/24°C (gen. I), 18/28°C (gen. I, II), third instar at 18/24°C (gen. I, II), 24/28°C (gen. II) followed by 0.99 at second instar at 18/24°C (gen. II), third instar at 18/28°C (gen. I, II), 24/28°C (gen. I). In contrast, the lowest Sx (0.90) was at fourth instar at 24/28°C (gen. I) and at pupal stage at 18/28°C (gen. II), and 24/28°C (gen. II), respectively.

**Mortality Survivor Ratio (MSR)**

Variation in MSR was of high order among the different developmental stages at different temperatures vis-à-vis generations. The pattern was however, opposite to Sx but similar to apparent mortality. The highest MSR of 0.15 was found to be at the egg stage at 24/28°C (gen. II), in comparison to nil at second instar stage at 18/24°C (gen. I), 18/28°C (gen. I, II), third instar at 18/24°C (gen. I, II), and 24/28°C (gen. I). Nonetheless, the second lowest value was 0.01 at second instar at 18/24°C (gen. II), third instar at 18/28°C (gen. I, II), 24/28°C (gen. I), respectively.

**Indispensable Mortality (IM)**

A marked variation was recorded for IM values at different developmental stages. The highest IM to the tune of 8.19% was obtained at the pre-pupal stage at 18/24°C (gen. I) while, the second instar at 18/24°C (gen. I), 18/28°C (gen. I, II), third instar at 18/24°C (gen. I, II), and 24/28°C (gen. I) did not show any mortality.

**k-Values**

The k-values remained nil at the second instar at 18/24°C (gen. I), 18/28°C (gen. I, II), third instar at 18/24°C (gen. I, II), 24/28°C (gen. I) followed by 0.005 at the second instar at 18/24°C (gen. II) whereas, the maximum of 0.0605 was at egg
stage at 24/28°C (gen. II). When total generation mortality ‘K’ was computed, it was revealed that fluctuating temperature of 24/28°C (gen. I) did not favour the overall development of *C. septempunctata* wherein total ‘K’ remained at a high order (0.2147), in contrast to 0.1427 at 18/24°C (gen. II) indicating least suitability for the development.

**4.10.3 I. SCUTELLARIS AT CONSTANT TEMPERATURES**

**Apparent Mortality**

A perusal of tables (54 to 59) pertaining to apparent mortality at the various stages of development, generations, and temperatures revealed considerable variation in the values obtained. The maximum apparent mortality to the tune of 27.14% was at the pupal stage at 24°C (gen. I). On the contrary, its minimum value (zero) was at first instar at 24°C (gen. I), second instar at 18°C (gen. I, II), 24°C (gen. II), and pre-pupal stage at 24°C (gen. II).

**Stage Specific Survival Fraction (Sx)**

Data analysis for Sx at different developmental stages, revealed that its trend was opposite to apparent mortality. It was evident that maximum ratio (1.00) was at first instar at 24°C (gen. I), second instar at 18°C (gen. I, II), and pre-pupal stage at 24°C (gen. II). The minimum Sx (0.73) was obtained at 24°C (gen. I) at pupal stage.

**Mortality Survivor Ratio (MSR)**

MSR exhibited a maximum of 0.37 at the pupal stage at 24°C (gen. I), however, the minimum of zero was encountered at first instar at 24°C (gen. I), second instar at 18°C (gen. I, II), 24°C (gen. II), and pre-pupal stage at 24°C (gen. I, II).

**Indispensable Mortality (IM)**

Yet again marked variation was recorded for IM values between various developmental stages at different temperatures vis-à-vis generations. The highest IM of 19% was observed at pupal stage at 24°C (gen. I), and 28°C (gen. I) the first instar at 24°C (gen. I), second instar at 18°C (gen. I, II), and pre-pupal stage at 24°C (gen. II), respectively did not reveal any IM.
Results and Discussion

4.10.4 AT FLUCTUATING TEMPERATURES

Apparent Mortality

While comparing apparent mortality (Table 60 to 65) at the different temperatures vis-à-vis generations, it was revealed that the maximum apparent mortality to the tune of 13.51 followed by 13.25% was obtained at 24/28°C (gen. II), 18/28°C (gen. I), respectively. No mortality was however, recorded at first instar at 18/24°C (gen. I, II), 18/28°C (gen. I), second instar at 18/28°C (gen. II), 18/24°C (gen. II), 24/28°C (gen. I, II), and pre-pupal stage at 18/24°C (gen. I, II).

Stage Specific Survival Fraction (Sx)

As far as Sx was concerned, of all the stages compared, its lowest value (0.86) was obtained at pupal stage at 24/28°C (gen. II) whereas, the highest of 1.00 at 18/24°C (gen. I, II), 18/28°C (gen. I), 18/24°C (gen. II), 18/28°C (gen. II), 24/28°C (gen. I, II), 18/24°C (gen. I, II), at first instar, second instar, pre-pupal stage, respectively.

Mortality Survivor Ratio (MSR)

A reverse trend for MSR was obtained as compared to Sx, the maximum value (0.22) was at the pupal stage at 18/28°C (gen. I) and nil at first instar at 18/24°C (gen. I, II), 18/28°C (gen. I), second instar at 18/24°C (gen. II) 18/28°C (gen. II), 24/28°C (gen. I, II), and pre-pupal stage at 18/24°C (gen. I, II), respectively.

k-Values

k-values exhibited the pattern in accordance with IM, wherein maximum value to the tune of 0.1375 was obtained at the pupal stage at 24°C (gen. I) and the minimum of zero at first instar 24°C (gen. I), second instar at 18°C (gen. I, II), and pre-pupal stage at 24°C (gen. II). When a comparison was made between total generation mortality ‘K’ of *I. scutellaris*, it was propounded that different temperatures showed direct bearing on the overall development of this species. Total generation mortality was of high order (0.2924) followed by 0.2596 at 24°C in first generation and 28°C (gen. II), respectively. However, when this specie was reared at 18°C (gen. I) proved to be favourable (K= 0.1367) for the overall development.
Indispensable Mortality (IM)

A high of 12% IM was encountered at the pupal stage at 18/28°C (gen. I) as compared to zero at first instar at 18/24°C (gen. I, II), 18/28°C (gen. I), second instar at 18/24°C (gen. II), 18/28°C (gen. II), 24/28°C (gen. I, II), and pre-pupal stage at 18/24°C (gen. II), respectively.

k-Values

Comparative analysis of mortality at the different temperatures and generations exhibited highest ‘k’ of 0.0872 at pupal stage at 18/28°C (gen. I) contrary to zero at first instar at 18/24°C (gen. I, II), 18/28°C (gen. I), second instar at 18/24°C (gen. II), 18/28°C (gen. II), 24/28°C (gen. I, II), and pre-pupal stage at 18/24°C (gen. II). Furthermore, the total generation mortality ‘K’ was the maximum (0.2676) at 18/2°C (gen. I) followed by 0.2218 at 18/28°C (gen. II), respectively. Interestingly, the minimum of 0.0809 was recorded at 18/24°C (gen. I).

When a comparison of data for the different developmental stages and generations of *C. septempunctata* at three constant and fluctuating temperatures was made, it was inferred that apparent mortality remained at a maximum of 15% at egg stage at 28°C (gen. II) followed by 13% at 24/28°C (gen. II), 12% at 28°C (gen. I), 11% at the same stage at 18/28°C (gen. II), 24/28°C (gen. I). The second instar at 18°C (gen. I), 18/24°C (gen. I), 18/28°C (gen. I, II), third instar at 18°C (gen. I, II), 24°C (gen. I, II), 28°C (gen. I), 18/24°C (gen. I, II), 24/28°C (gen. II), fourth instar at 18°C (gen. II) and 24°C (gen. II) did not show any mortality.

The Sx was the lowest (0.85) at egg stage at 28°C (gen. II) followed by 0.87 at the same stage but at 24/28°C (gen. II) while, the highest (1.00) was at second instar at 18°C (gen. I) 18/24°C (gen. I), 18/28°C (gen. I, II), third instar at 18°C (gen. I, II), 24°C (gen. I, II), 28°C (gen. I), 18/24°C (gen. I, II), 24/28°C (gen. II), fourth instar at 18°C (gen. II) and 24°C (gen. II), respectively. Variation in Sx at all the developmental stages, of both the generations at all the six temperatures was of high order. Least variation was obtained at the third instar at all the temperatures and generations. This was followed by second, fourth and first instar larval stages. Further, the egg stage exhibited the highest variation as compared to others.

Data compared for MSR at the various stages recorded the maximum value to the tune of 0.13 at pre-pupal stage at 18°C (gen. II), 24/28°C (gen. II) in contrast to zero at second instar at 18°C (gen. I) 18/24°C (gen. I), 18/28°C (gen. I, II), third instar
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at 18°C (gen. I, II), 24°C (gen. I, II), 28°C (gen. I), 18/24°C (gen. I, II), 24/28°C (gen. II), and fourth instar at 18°C (gen. II) and 24°C (gen. II), respectively. Indispensable mortality (IM) exhibited similar trend as of mortality survivor ratio, where second instar larva of *C. septempunctata* at 18°C (gen. I), 18/24°C (gen. I), 18/28°C (gen. I, II), third instar at 18°C (gen. I, II), 24°C (gen. I, II), 28°C (gen. I), 18/24°C (gen. I, II), 24/28°C (gen. II), fourth instar at 18°C (gen. II) and 24°C (gen. II) did not show any mortality. The trend obtained for k-values was in accordance with indispensable mortality. The highest k-value (0.0605) was encountered at the egg stage at 24/28°C (gen. II) followed by 0.0555 at the same stage but at 28°C (gen. I). While it remained nil at the second instar at 18°C (gen. I) 18/24°C (gen. I), 18/28°C (gen. I, II), third instar at 18°C (gen. I, II), 24°C (gen. I, II), 28°C (gen. I), 18/24°C (gen. I, II), 24/28°C (gen. II), fourth instar at 18°C (gen. II) and 24°C (gen. II), respectively.

While comparing various life parameters on overall development of *I. scutellaris* on different temperatures, it was revealed that the maximum apparent mortality to the tune of 27.14% was at the pupal stage at 24°C (gen. I) followed by 18.18% at the same stage but at fluctuating temperature of 18/28°C (gen. I) and 17.14% yet again at the same stage but at a constant temperature of 28°C (gen. I). In contrast, a cent per cent survival was encountered at the first instar at 24°C (gen. I), 28°C (gen. I), 18/24°C (gen. I, II), 18/28°C (gen. I), second instar at 18°C (gen. I, II), 24°C (gen. II), and pre-pupal stage at 24°C (gen. II), 18/24°C (gen. I, II).

Variation in survival fraction (Sx) was of high magnitude. When a comparison was made, cent per cent survival was evident at the first instar at 24°C (gen. I), 28°C (gen. I), 18/24°C (gen. I, II), 18/28°C (gen. I), second instar at 18°C (gen. I, II), 24°C (gen. II), 18/28°C (gen. II), 24/28°C (gen. I, II), and at pre-pupal stage at 24°C (gen. II), and 18/24°C (gen. I, II). An opposite trend for mortality survivor ratio (MSR) was recorded as compared to Sx, where the highest ratio (0.37) was encountered at pupal stage at 24°C (gen. I). Nonetheless, the MSR remained nil at the first instar stage at 24°C (gen. II), 28°C (gen. I), 18/24°C (gen. I, II), 18/28°C (gen. I), second instar at 18°C (gen. I, II), 18/24°C (gen. II), 18/28°C (gen. II), 24/28°C (gen. I, II), and pre-pupal stage at 24°C (gen. II), and 18/24°C (gen. I, II). Indispensable mortality (IM) was in accordance with MSR. Comparative analysis exhibited that the highest IM of 19% was at pupal stage at 24°C (gen. I) however, the first instar at 18/24°C (gen. I, II), 28°C (gen. I), 24°C (gen. I), 18/28°C (gen. I), second instar at 18°C (gen. I, II).
18/24°C (gen. II), 18/28°C (gen. II), 24/28°C (gen. I, II), and pre-pupal stage at 24°C (gen. II), and 18/24°C (gen. I, II) did not exhibit any MSR.

Constant temperature of 24°C (gen. I) revealed the highest ‘k’ (0.1375) at the pupal stage followed by 0.0817 at the same stage but at 28°C (gen. I), 0.0740 at pre-pupal stage at 28°C (gen. I). In contrast, the minimum of zero was obtained at first instar at 24°C (gen. I), 28°C (gen. I), 18/24°C (gen. I, II), 18/28°C (gen. I), second instar at 18°C (gen. I, II), 18/24°C (gen. II), 18/28°C (gen. II), 24/28°C (gen. I, II), and pre-pupal stage at 24°C (gen. II), 18/24°C (gen. I, II). Total generation mortality ‘K’ was recorded to be of high order (0.2924) at 24°C followed by 0.2676, 0.2596, 0.2366 at 18/28°C (gen. I), 28°C (gen. II) and 28°C (gen. I), and a low of 0.0809 at 18/24°C (gen. II).

Similar attempts were made in the past to construct ecological life-tables in order to use them as the tools in the study dynamics of insects. Harcourt (1969) opined that these tables record a series of sequential measurements that reveal population changes throughout the life cycle of a species in its natural environment. When these measurements were related to the several causes of mortality, life-tables form a budget of successive processes that operate in a given population. Atwal and Bains (1974) inferred that the trend index value of less than unity pointed towards different mortality agents contributing to the generation mortality of *C. partellus*. The findings of Bilapte et al. (1979) on *H. armigera*, Roy and Bains (1983) on *Tryporyza nivella*, Sharma and Bhalla (1992) on *Metasyrphus* sp., Rizvi and Pathak (1998) on *S. obliqua*, Dar (1998) on *S. litura*, Khurshid (2001) on *C. septempunctata* have strengthened the present findings.

4.11 LIFE AND FERTILITY-TABLES

4.11.1 *C. SEPTEMPUNCTATA* AT CONSTANT TEMPERATURES

From tables (66 to 71) it was apparent that females oviposited during a definite period of pivotal age. The longest duration of natality of 21 day was encountered at 18°C, (gen. II) while the shortest of 9 days at 28°C (gen. I and II). There was a marked variation in egg laying capacity of *C. septempunctata* at different temperatures vis-à-vis generations. It was observed that the peak of egg laying (30.25%) took place at 28°C (gen. II), on 34.5 day. In contrast, to a dip of 5.83% on 57.5 day at 18°C (gen. I).
When a comparison of the various parameters was made (Table 90.), it was discerned that superior potential fecundity (211.65 eggs) was recorded at 18°C (gen. I) as compared to inferior of 75.70 eggs at 28°C (gen. II). High carrying capacity of 62.96 was observed at 18°C (gen. I) against a low of 16.73 at 28°C (gen. I). The maximum mean length generation to the tune of 55.70 days was at 18°C (gen. I) in contrast to minimum of 34.41 days at 28°C (gen. I). The accurate intrinsic rate of increase was of high order (0.096134) at 24°C (gen. I) against a low of 0.075091 at 18°C (gen. I). Finite rate of increase did show variation but not of high magnitude. It was the maximum (1.10) at 24°C (gen. I, II) and the minimum (1.08) at 18°C (gen. I, II) and 28°C (gen. I). The insect reared at 18°C (gen. II) took the longest period of 9.23 days for the population to double as compared to a low of 7.21 days at 24°C for generation I and II. Similarly, there was a marked effect of varying temperature on annual rate of increase of *C. septempunctata*. The highest ARI (2E+015) was at 24°C (gen. I, II), and the lowest (8E+011) at 18°C (gen. II).

4.11.2 AT FLUCTUATING TEMPERATURES

The data (Tables 72 to 77) clearly revealed that maximum range of oviposition period (15 days) was recorded at a fluctuating temperature of 18/24°C (gen. I) and 18/28°C (gen. I), and the minimum (12 days) at 18/28°C (gen. II). As far as, contribution towards egg laying was concerned, its highest value (22.77%) was on 38.5 day at 24/28°C (gen. I) and the lowest (8.79%) on 38.5 day at 18/24°C (gen. I). Maximum potential fecundity and net reproductive rate to the tune of 135.30 and 40.36 were at 18/24°C (gen. I) while minimum of 74.35 and 18.80 at 24/28°C (gen. II), respectively (Table 90). Evidently, mean time required by *C. septempunctata* to complete its generation ranged between 37.15 to 44.92 days at 24/28°C (gen. II) and 18/28°C (gen. I). Accurate intrinsic rate of increase exhibited extreme values of 0.079212 and 0.096720 at 24/28°C (gen. I) and 18/24°C (gen. II), respectively. Slight variation with respect to finite rate of increase was apparent at different temperatures. It was to the tune of 1.10 at 18/24°C (gen. I, II) and 1.08 at 18/28°C (gen. I), 24/28°C (gen. I, II). Higher doubling time of 8.75 days was at 24/28°C (gen. I) in contrast to a low of 7.17 days at 18/24°C (gen. II). Likewise, ARI was much higher (2E+015) at 18/24°C (gen. II) against a low of 4E+012 at 24/28°C (gen. I, II).
4.11.3 *I. SCUTELLARIS* AT CONSTANT TEMPERATURES

The tables (78 to 83) indicated that females laid eggs during a maximum of 11 days at 18°C (gen. I) and minimum of 7 at 28°C (gen. II). The maximum contribution of natality (28.57%) was on 26.5 day at 28°C (gen. I) and the minimum (12.38%) on 35.5 day at 18°C (gen. I). Variation in potential fecundity and net reproductive rate was quite considerable (Table 90), a high of 21.00 and 7.15 was recorded at 18°C (gen. I) and low of 13.20 and 1.95 at 28°C (gen. II), respectively. Highest mean length of generation (38.08 days) was at 18°C (gen. II) followed by a low of 25.38 days at 28°C (gen. II). Furthermore, maximum net reproductive rate, finite rate of increase, annual rate of increase to the tune of 0.05557, 1.06, and 7E+08 were exhibited at 18/24°C (gen. II) while the minimum at 28°C (gen. II). The corresponding values were 0.026291, 1.03, 1E+004, respectively. A reverse trend for doubling time was observed wherein the maximum of 26.36 days was encountered at 28°C (gen. II) while minimum 12.44 days at 18/24°C (gen. II).

4.11.4 AT FLUCTUATING TEMPERATURES

It was well indicated from the data (Tables 84 to 89) that the total oviposition period of *I. scutellaris* to tune of 7 days was recorded at 24/28°C (gen. I) and 6 days at 18/24°C (gen. I, II), 18/28°C (gen. I, II) and 24/28°C (gen. II), respectively. However, maximum (30.98%) contribution of egg laying was on 28.5 day at 24/28°C (gen. I) and the minimum (13.91%) on 29.5 day at 18/28°C (gen. I). Considerable variation in potential fecundity (Pf) was evidenced (Table 91), wherein the maximum (13.50 eggs/female) was at 18/24°C (gen. I) and the minimum (9.2) at 24/28°C (gen. I). Higher values for net reproductive rate, intrinsic rate of increase and finite rate of increase (2.94, 0.0375053, and 1.04), respectively were obtained at a fluctuating temperature of 18/28°C (gen. I) whereas a low of 1.58, 0.017876 at 24/28°C (gen. II) and 1.02 at 18/24°C (gen. I) and 24/28°C (gen. I, II), respectively. The highest mean length of generation (35.16 days) was at 18/24°C (gen. I) and the lowest (25.62 days) at 24/28°C (gen. II). Evidently, the maximum doubling time (38.78 days) and the minimum ARI (7E+002) were recorded at 24/28°C (gen. II), while the minimum (18.71 days) and the maximum ARI (7E+005) at 18/28°C (gen. I).

While comparing the data for both the species at different temperatures vis-à-vis generations it was revealed that revealed the total oviposition period of *C. septempunctata* ranged between 9 to 21 days at 18°C (gen. II) and 28°C (gen. I, II),
respectively. Highest natality of 30.25% was on 34.5 day at 28\(^{\circ}\)C (gen. II) and the lowest of 5.83% on 57.5 day at 18\(^{\circ}\)C (gen. I). The maximum value for potential fecundity (211.65 eggs/female) was at 18\(^{\circ}\)C during the first generation and the minimum (74.35 eggs/female) at a fluctuating temperature of 24/28\(^{\circ}\)C (gen. II). The net reproductive rate was recorded to be a high of 16.73 at 28\(^{\circ}\)C (gen. I) and a low of 62.96 at 18\(^{\circ}\)C (gen. II). The longest mean length of generation 55.70 days was obtained at 18\(^{\circ}\)C (gen. II) while the shortest (34.41 days) at 28\(^{\circ}\)C (gen. II). Similarly, maximum value of accurate intrinsic rate of increase (0.096720 females/female/day) was encountered at 18/24\(^{\circ}\)C (gen. II) and the minimum (0.075091) at 18\(^{\circ}\)C (gen. II).

As far as finite rate of increase was concerned, its superior value (1.10) was at 24\(^{\circ}\)C (gen. I, II) and 18/24\(^{\circ}\)C (gen. I, II) and the inferior (1.08) at 18\(^{\circ}\)C (gen. I, II), 28\(^{\circ}\)C (gen. I), 18/28\(^{\circ}\)C (gen. I) and 24/28\(^{\circ}\)C (gen. I, II), respectively. Doubling time exhibited pronounced variation, wherein the longest duration of 9.23 days was observed at 18\(^{\circ}\)C (gen. II) and shortest 7.17 days at a fluctuating temperature of 18/24\(^{\circ}\)C (gen. II). The maximum annual rate of increase to the tune of 2E+015 was at 24\(^{\circ}\)C (gen. I, II), 18/24\(^{\circ}\)C (gen. II) and the minimum (8E+011) at 18\(^{\circ}\)C-(gen. II).

*I. scutellaris* required a maximum of 11 days to complete its natality at 18\(^{\circ}\)C (gen. I), whereas the minimum of 6 days was encountered at 24\(^{\circ}\)C and 18/28\(^{\circ}\)C for both the generations and 24/28\(^{\circ}\)C for second generation. However, the highest contribution of egg laying (30.98%) was on 28.5 day at 24/28\(^{\circ}\)C (gen. I) and the lowest (12.38%) on 35.5 day at 18\(^{\circ}\)C (gen. I). Further, when potential fecundity and net reproductive rate were compared, they were found to be maximum 21.00 and 7.15 at 18\(^{\circ}\)C (gen. I) and the minimum 9.20 at 24/28\(^{\circ}\)C (gen. I) and 1.58 at 24/28\(^{\circ}\)C (gen. II), respectively. As far as, mean length of generation was concerned, it was a high of 38.08 days at 18\(^{\circ}\)C (gen. II) in comparison to a low of 25.38 days 28\(^{\circ}\)C (gen. II). The respective higher values for intrinsic, finite, and annual rate of increase were 0.05557, 1.06 and 7E+08 at 18/24\(^{\circ}\)C (gen. II) against a low of 0.017876, 1.02 at 24\(^{\circ}\)C (gen. I) and 7E+002 at 24/28\(^{\circ}\)C, gen. I, respectively. The population of second generation of *I. scutellaris*, when reared at fluctuating temperature of 24/28\(^{\circ}\)C exhibited highest doubling time (38.78 days) in contrast to a low (12.44 days) at a constant temperature of 18/24\(^{\circ}\)C (gen. II).

It could be inferred from above findings that varying temperatures did influence the development of *C. septempunctata* and *I. scutellaris* to a great extent. High temperature adversely affected both longevity and fecundity of both species. It
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is in conformity with the work of Lal and Haque (1965). They opined that higher temperature was detrimental to adults of *I. scutellaris*. Whereas, Makhmoor and Verma, (1987) advocated that low temperature to a certain limit favoured higher fecundity. During the course of investigation, it was also revealed that syrphid adults could survive for a short period. Such findings have been reported by a number of workers (Khan and Yunus, 1970; Patnaik and Bhagat, 1976 and Roy and Basu, 1977). While taking observations on potential fecundity of *I. scutellaris* it was found that this species could not deposit beyond 21 eggs/female. Lal and Haque (1965), Roy and Basu (1977), Singh and Malhotra (1979a), Radhakrishnan and Muraleedharan (1993), Singh and Singh (1994), Joshi *et al.*, (1998), and Rai *et al.*, (2002) also held the same opinion for low fecundity of this species. Singh (1994), Rizvi and Pathak (1998), and Pathak (1999) demonstrated that varying temperature greatly influenced the reproductive potential of insects. This further strengthened our findings.

4.12 LIFE-TABLE STUDIES UNDER NATURAL CONDITIONS

In order to gauge the vital statistics of *C. septempunctata* and *I. scutellaris* under natural conditions, studies were carried out for two consecutive years so as to get overall impact of abiotic and biotic factors on their population dynamics.

4.12.1 AGE SPECIFIC LIFE-TABLE

4.12.1.1 *C. SEPTEMPUNCTATA*

From the tables 92-93, it was evident that *C. septempunctata* completed its generation in 54 days in the year 2000-01 on *L. erysimi*. The age specific survivorship (Ix) declined at a faster-rate during 2-4 days of development. This decline coincided with mortality at egg stage and juvenile age of the larvae. However, intermittent stability in Ix was encountered on 5, 8-14, 16-17, 20-21, 24-27, 32, 35-40 days. A high drop in Ix was revealed on 41, 45 and 46 days. Highest mortality of 9 was on 45 day followed by 7 on 41 and 46th day. 5 on 34, 42, 43, and 49th day. However, mortality in the range of 1 to 4 was on 2-4, 6-7, 15, 18, 19, 22, 23, 28, 30, 31, 33, 47, 48, 50-54th day. The life expectancy (ex) declined throughout the generation except on day 3, wherein negligible increase was observed (Fig. 13).

When studies were conducted during 2001-02, it was revealed that *C. septempunctata* completed its generation in 55 days. It was further noticed that there was a reduction in survivorship on days 2-3, on 5-7, 11, 14-16, 18-24, 27, 29, 30, 33,
34, 42-45th day. On the contrary, the stability in lx was obtained at 4, 8-10, 12, 13, 17, 24-26, 28, 31, 32, 35-41st day.

A death count of varying magnitude ranging from 1-7 was observed between 42-55 days. The maximum mortality of 7 was on 46 and 49 followed by 6 on 52; 5 on 20, 34, 45 and 1 to 4 on 2, 3, 5-7, 11, 14-16, 18, 19, 21-23, 27, 29, 30, 33, 42-44, 47, 48, 50, 51, 54 and 55th day, respectively. As far as life expectancy was concerned, it reflected gradually declined till the end of generation with an exception of marginal increase on 6, 7, 20 and 34th day.

4.12.1.2 I. SCUTELLARIS

The population of 2001 required 40 days to complete its generation. There was a steep decline of age specific survivorship (Ix) during first 2-4 days. It kept on falling with few pauses on 9, 14, 17-20, 23-26th day. On all the other days, lx decreased marginally. Mortality (dx) to the tune of 7 was on 28, 32 and 37th day followed by 6 on 11 and 29th day. Nonetheless, 5 deaths each were recorded on 3, 10, 15 and 31st day whereas, it varied between 1 to 4 on 2, 4-8, 12, 13, 16, 21, 22, 27, 30, 34-36 and 38-40th day. The life expectancy (ex) showed gradual decline throughout the generation, except day 11 and 16 showing marginal increase (Fig. 14).

Similarly, in the second generation, sharp plunge in lx was noted on the first 2 to 4 days followed by long and short pauses on 16, 18-20, 22, 25-28, 31 and 32nd day. There was a prominent reduction in lx on 3, 8, 13, 21, 34-37th day. As far as dx was concerned, it was 8 on 37 day, 7 on 13 and 34th day. However, deaths to the count of 6 were exhibited on 3, 8, 21 and 36th day followed by 5 on 4, 14 and 35th day. On 2, 5-7, 9-12, 15, 17, 23, 24, 29-30, 33 and 38th day the death counts ranged between 1 and 4. Life expectancy got reduced gradually till the end of the generation however, showing insignificant increase on the day 4, 9 and between 13 to 15.

When the data was compared for 2002, the lx and ex exhibited the similar trend as of 2001. The population of second generation culminated within a period of 35 days. There was a regular decline in lx throughout the generation except on the day 9, 13, 17, 20, 22, 23, 30 to 32, where it remained stable. Maximum mortality of 9 was encountered on the day 8 followed 7 on 12 and 28, 6 on 7, 15, 26 and 33, 5 on 3, 5 and 18. Similarly, mortality of 1 to 4 was on the day 1, 2, 4, 6, 10, 11, 14, 16, 19, 21, 24, 25, 27, 29, 34, and 35th day. Furthermore, a steady reduction in the life expectancy
(ex) was observed till the culmination of generation with the exception of slight increase on 8, 28 and 29th day (Fig. 15).

The initial drop in lx as observed in all the generations at an early age interval was due to embryonic death or non-fertilisation. Further, intermittent decline in lx would have been a result of the existence of abiotic and biotic stresses particularly unfavourable temperature along with the attack of the parasitoids and some unknown intrinsic factors.

The derogation of lx resulted in the corresponding enhancement of the mortality curve. It was stair-step like as opined by Odum (1971) for holometabolous insects, Singh (1984), Choudhary and Bhattacharya (1986), Reddy and Bhattacharya (1988), Rizvi (1988). The survivorship curves were of standard type II and I as proposed by Deevy (1947) and Slobodkin (1962). The life expectancy decline in the beginning of the generation was primarily due to the death at the egg stage, the later was due to the larval mortality. With the advancement of insect age, the life expectancy dropped down gradually.

4.12.2 STAGE SPECIFIC LIFE-TABLE

4.12.2.1 C. SEPTEMPUNCTATA

Perusal of data pertaining to apparent mortality, MSR, IM and k-values at the different stages of development and years revealed that the maximum values of 14.63%, 0.17, 10.63 and 0.0257 were found at the pre-pupal stage during 2002. While, the corresponding minimum values were 0% at the second, third instars during 2001, and second instar 2002. The highest survival fraction was recorded at the second and third instar of 2001 and second instar of 2002. The total generation mortality was a high of 0.2076 during 2002 as compared to a low of 0.1367 in year 2001.

4.12.2.2 I. SCUTELLARIS

In the year 2001, the maximum apparent mortality, MSR, IM and k-values to the tune of 26%, 0.35, 13, 0.1308 were at the pupal stage (gen. I) while the minimum of 3.53%, 0.04, 1.24, 0.0156 were recorded at the first instar (gen. II). The Sx exhibited 0.74 and 0.96 at the pupal of the first generation and the first instar larval stage of second generation, respectively. The total generation mortality ‘K’ was of 0.4318 in the first and 0.4685 in the second generation respectively.
The comparison of both the generations in 2002 revealed that apparent mortality, MSR, IM and k-values exhibited maximum values of 23.81%, 0.31, 11.25, 0.1181 at the third instar and minimum of 9.64%, 0.11, 3.84, and 0.0440 at the first instar of the first generation. A reverse trend for Sx was obtained, where the highest value of 0.96 was encountered at the first instar and the lowest, 0.76 at the third larval instar of the first generation, respectively. The total generation mortality was of high order (0.4815) in the second as compared to a low of 0.4437 in the first generation.

High mortality recorded during the egg stage was attributed to the egg sterility and/or the inability of their eclosion. Abiotic and biotic intrinsic factors were considered to be the main cause of pre-pupal and pupal deaths of *C. septempunctata.* However, a parasitoid *Oomyzus scaposus* (Hymenoptera: Chalcidoidea: Eulophidae) also contributed its share to some extent for the mortality of pupae. On the other hand, *I. scutellaris* recorded higher mortality due to the hyper-parasitoids, a tachinid fly, (unidentified) at the larval stage and subsequently by *Diplazon orientalis* (Hymenoptera: Diplazonidae) at the pupal stage. The attack of hyper-parasitoids on the syrphids has also been reported by Schneider (1950), Patel and Patel (1969) and Desai and Patel (2004).

**4.12.2 LIFE AND FERTILITY-TABLE**

**4.12.2.1 C. SEPTEMPUNCTATA**

It is evident from the tables 104-05, that the females of *C. septempunctata* commenced egg laying on 34.5 day, which ended on 51.5th day during 2001, and 35.5 to 52.5th day in 2002. More number of eggs were laid on 42.5, 43.5 and 44.5th day contributing more than 50% towards total natality in 2001. Similar was the trend in 2002, the females produced more eggs between 43.5 to 45.5th day exhibiting a total share of 47% of the total egg laying. The potential fecundity and doubling time (155.85 eggs/female and 8.34 days, respectively) was more in 2001, as compared to 2002, wherein the corresponding values were recorded as 136.95 eggs/female and 7.64 in 2002 (Table 110). The superior values for net reproductive rate, mean length of generation, intrinsic rate of increase and annual rate of increase (51.10, 43.61, 0.090739, 2E+014, respectively) were encountered during 2002 in contrast to inferior (35.00, 43.12, 0.083087 and 1E+013) in 2001.
4.12.2.2 **I. SCUTELLARIS**

In the year 2001, *I. scutellaris* laid eggs during a definite period of time (33.5 to 39.5\textsuperscript{th} day and 31.5 to 37.5\textsuperscript{th} day) during first and second generation, respectively. The maximum contribution towards egg laying was encountered on 36.5 day (23.19\%) followed by 35.5\textsuperscript{th} day (22.29\%) in first and 35.5\textsuperscript{th} day (26.86\%) and 34.5 (20.49\%) in second generation, respectively (Table 106-107). As far as potential fecundity, mean length of generation and doubling time were concerned, they were of high magnitude of 16.60 eggs/female, 35.98, 37.60 in first and low of 14.15 eggs/female, 34.41 and 31.65 in second generation, respectively (Table 107). The second generation exhibited higher values for net reproductive rate (2.12), intrinsic rate of increase (0.021900 females/female/day) and annual rate of increase (3E+003) while corresponding figures in the first were 1.94, 0.018434, 8E+002.

During the year 2002 (Tables 108-109), the females of the first generation once again oviposited during a definite period of pivotal age (30.5 to 37.5\textsuperscript{th} day), the peak was on 33.5 (23.20\%) and 34.5\textsuperscript{th} day (24.75\%). Whereas the females of the second generation, commenced egg laying on 24.5 day and continued till 33.5 day. The maximum contribution was on 29.5\textsuperscript{th} day (25.17\%). Potential fecundity, net reproductive rate, intrinsic rate of increase and annual rate of increase exhibited higher values (15.95, 1.84, 33.43, 0.018180, 8E+002) in the first as compared to low (14.30, 1.63, 28.07, 0.017500, 6E+002) in the second generation, respectively. However, the doubling time was slightly higher (39.61 days) in the second, in contrast to low (38.13 days) in the first generation.

4.13 **INCIDENCE OF HYPERPARASITOIDS OF THE PREDATORS**

During the course of investigations (Table 111), it was found that *C. septempunctata* and *I. scutellaris* were attacked by hyperparasitoids. The two-year study demonstrated that *Oomyzus scaposus* emerged from the pupae of *C. septempunctata*. The extent of parasitisation was more (8\%) during 2002 as compared to a low (6\%) in 2001. The hyperparasitisation of *I. scutellaris* was of high order at maggot and pupal stages. The maggots were parasitised by a tachinid fly (unidentified) while pupae by *Diplazon orientalis*. Both parasitoids exhibited varying degree of parasitisation. The former exhibited 9.52 and 11.72\% whereas the latter 21.5 and 28.9\% emergence in the second generation during 2001 and 2002, respectively. It was observed that maximum hyperparasitisation on both species of
predators took place during the first and second week of March coinciding with the period of crop maturity.