CHAPTER VI

DISCUSSION
DISCUSSION

The cabbage aphid, *Brevicoryne brassicae* (L.) infests *Brassica oleracea* L. (local variety) for about seven to nine months during winter and spring season. However, it maintains its density on other cruciferous plants, such as, mustard, cauliflower, cabbage, radish, knol khol, etc., during the off-season of *B. oleracea* L. Therefore, migration of a part of the population may also occur from the above plant hosts. Hughes (1963) was of the opinion that the annual population cycle of *B. brassicae* can be divided into two phases, a) autumn and winter on brassica crops, and b) spring and summer on brassica seed crops or cruciferous weeds in Australia. The aphid population fluctuation is governed directly or indirectly by various factors, such as, temperature, relative humidity and rainfall (abiotic); predators, parasites and food plant condition (biotic) in nature (Dixon, 1985). One factor or combination of two or more becomes responsible for the maintenance of aphid population.

The highest peak population of the pest varied from one place to another. At Mao and Kangpokpi (higher altitude), the pest attained maximum during January and February. Similar peak period of activity for other cruciferous aphids was reported by Atwal and Sethi (1963), Sachan and Srivastava (1972), Roy (1975), Chandra and Kushwaha (1986), Ahuja (1990) and Sinha et al. (1990)
from different parts of the country. Rao (1969) observed the occurrence of B. brassicae all through the year on potted plants of Brassica spp. in the laboratory with peak in January and February in Bangalore. It was also reported that August to December was the period of low incidence of this pest. Roy and Pande (1991) also reported the peak period of Lipaphis erysimi infesting cabbage in January with high range of aphid population between December to March which corroborates the present finding.

Tandon et al. (1977) observed the peak period of B. brassicae during March-May on cauliflower seed crop ecosystem in Himachal Pradesh with minimum temperature ranging from 5.0-22.5°C and maximum temperature between 16.0-37.0°C respectively. The above finding confirms the present peak population in May at Imphal (Study site I) with minimum and maximum temperature ranging 5.32-22.2°C and 21.0-32.4°C. The delay in the period of incidence of the aphid in Imphal might be due to late cultivation practices and the prevailing climatic conditions. Moreover, the food plants are available in the form of sprouts for a longer period. Hughes (1963) had also reported the peak population of B. brassicae during April in Australia. However, the maximum abundance of B. brassicae was also reported during the period between July and September in Vancouver (Raworth et al., 1984) and Kenya (Bahana and Karuhize, 1986) which might be due to the availability of the plant host in the respective places.
Therefore, the seasonal population fluctuations of *B. brassicaceae* ranged from late autumn to late spring through whole winter and less abundant during summer months in Maniour.

During the present study, it was found that the percentage on the composition of the aphid population varied at different places. Of all the forms, nymphal population predominated, comprising 72.5-94.6% of the population followed by apterous (2.08-27.5%) and alates (0.45-7.69%). Similar results were also reported for the aphid, *L. erysimi* on mustard and radish (Ghosh and Mitra, 1983) and *Cervaphis quercus* on Oak (Shantibala, 1993). Maximum abundance of apterous during peak period was responsible for the production of nymphs whereas alates were for immigration, dispersal and emigration. Hughes (1963) opined that aerial migration in cabbage aphid was essential for survival because its food plants were not perennial. Roy (1975) also observed that the alates were responsible for the initial population build up of the aphid, *L. erysimi*.

The distributional pattern of this aphid on its food plant revealed that the pest initially appeared on the unfolded leaves of middle and lower stratum of the plant. Finally, with the increase of the plant age and maturity of the crop, the pest population shifted to the tender leaves of the sprouts. This habit may be due to their affinity towards the saturated sap which
sufficiently available in the tender tissues. Roy (1975) reported the pattern of distribution of *L. erysimi* was more on upper and lower leaves than on the middle leaves of mustard which might be due to better nourishment because of succulent and growing leaves. The pattern may be different for different species on a particular plant. Dixon (1985) also reported that when the plants are actively growing or the leaves are approaching senescence, the phloem sap contains relatively high concentrations of amino-nitrogen in the form of many amino acids that promote reproductive rate of aphids. As the concentration of amino-nitrogen in the phloem sap falls due to cessation of growth of the plant, the birth rate drops and reproduction checked.

Broadbent (1950) reported that the variations in the microclimate might be a factor determining the distribution of the species on the plant. Regarding the aphid abundance, change in the quality of the food plants appeared to be important (Dalber, 1971). With the maturity of the crop, moisture content of the plant becomes less, resulting in the migration of alates to another suitable crop (Atwal and Sethi, 1963; Roy, 1975). Relatively low temperature (10.63–19.72°C) and comparatively more vigorous growth of the food plant at *Mao* provides the aphid nutritionally favourable that might lead to increase in their reproductive rate to the extent of 1,257.67 aphids/sample during the peak abundance period. This is in agreement with the findings of Dixon (1985).
Regarding the relationship between the aphid population and abiotic factors, it was found to be negatively correlated in all seasons at different study sites excepting few cases. Average temperature showed significant correlation with the aphid population at Mao and Kangpokpi where the aphid abundance was comparatively high. Maximum abundance of aphid at the above sites might be due to prevailing low range of temperature (10.63-19.72°C and 10.85-22.48°C). However, significant correlation was obtained between humidity and aphid population at Mao in 1989-90. Rainfall was also negatively correlated with the aphid density. It was observed that a maximum of 566 mm rainfall in June would have resulted in drastic reduction of the aphids at Mao. As regards the meteorological factors, rain appeared to be the most consistent factor in checking the population of aphid (Dunn and Wright, 1955; Roy, 1975). Atwal et al. (1971) reported that rainfall along with high wind velocity were the limiting factors for the build up of aphid population.

Chandra and Kushwaha (1986) reported that the population of *L.erysimi* and *M.persicae* were negatively correlated with temperature and positively correlated with humidity in general on cabbage, mustard and cauliflower in Udaipur. This supports the present findings to some extent. Broadbent and Hollings (1951) reported that both *M.persicae* and *B.brassicae* in crop withstood temperature more than their thermal death point (30-40°C).
Further, it was also opined that extreme hot and cold weather conditions proved detrimental to the aphid (Broadbent and Heathcote, 1961; Takada, 1976).

In the present study, it was observed that the pest can survive and build up its population at a wide range of temperature (5.32–32.9°C) as also reported (5–37°C) by Tandon et al. (1977) in Himachal Pradesh. Hughes (1963) reported that 5°C as the threshold of development temperature for the cabbage aphid. Atwal et al. (1971) claimed that the aphid population was greatly influenced at temperatures beyond 38°C together with the enhanced activity of its natural enemies. Roy and Pande (1991) observed that L. erysimi population showed a negative trend at 26°C. Both temperature and rainfall showed significantly negative correlation which is in conformity with the present finding. Singh et al. (1986) also observed that there were no significant correlations between aphid population and abiotic factors (temperature, rainfall and wind velocity), indicating that M. persicae can survive and build up at a wide range of temperature (5–30°C) as also reported by Barlow (1962).

Thus, it is evident in the present study that moderately low temperature, minimum rainfall and tender plant parts are conducive for the population build up of B. brassicae.
In the present investigation, the trend in growth rate and the reproductive potential of cabbage aphid, _B. brassicae_ were almost similar to that of the field abundance of the pest in all the study sites. It indicates that GR and RP could also be used as an indicator to know the seasonal variations of the population of the pest. The maximum growth rate was obtained at Study site III followed by site II and site I respectively (Table 3). While the reproductive potential was found to be more at Study site II followed by site III and site I.

In addition to the role of abiotic factors, biotic factors also appeared to influence the populations of _B. brassicae_. Present study revealed the occurrence of Coccinellids and Syrohids in the aphid colony besides sporadic incidence of the parasites. On the contrary, several workers reported the effectiveness of the parasite, _Diaseretiella rapae_ on cabbage aphid with 72% parasitism in Netherlands (Hafez, 1961); 80% in Bulgaria (Kaitazov, 1963); 90% in Egypt (Herakley and El-azz, 1970); 93% in case of _L. erysimi_ at Udaipur (Chandra and Kushwaha, 1987) and 76% activity in Kenya (Bahana and Karuhize, 1986). However, very low incidence of this parasite was observed in the present study. Some workers also reported negligible population with very low parasitism and ineffectiveness of the parasite in a few instances as like van Emden, 1966; Tandon _et al._, 1977 and Chua, 1979.
Present results on the occurrence of Coccinellids and Syrphids as natural enemies of this pest are in general agreement with the findings of Atwal and Sethi (1963), Tandon et al. (1977), Kotwal (1982), Kotwal et al. (1984), Verma and Makhmoor (1987), Chandra and Kunswha (1987), Sharma and Verma (1993). Roy and Pande (1991) recorded six natural enemies from the colony of L.erysimi infecting cabbage. However, their role was found to be ineffective in reducing the aphid population due to the rapid multiplication of the aphid species.

As observed in this study, synchronised peak activity of the aphid and syrphid larvae during January-April was also reported by Azab et al. (1965), Mahmoud et al. (1981) and Verma and Makhmoor (1987). Sharma and Verma (1993) reported the peak period of activity of the coccinellid predators of B. brassicae during April but it was observed during May in the present study. In all the study sites, Syrphids were dominant in proportion ranging from 47.25-65.75% over the Coccinellids (34.25-41.93%) which was similar to the observations of Kotwal (1982) and Kotwal et al. (1984). Among the predators, M. (M.) confrexer (17.92-25.03%) was the most abundant followed by G. septemnotata (15.15-33.03%) representing both syrphids and coccinellids in the present investigation. Similarly, M. (M.) confrexer (30.49-43.03%) and G. septemnotata (47.3%) were reported as abundant predator of B. brassicae (Tandon et al., 1977; Verma and Makhmoor,
1987; Sharma and Verma, 1993). The predators showed positive correlation with aphid population in all the seasons at all study sites. They also played role in influencing the aphid population to some extent. The impact of natural enemies was reported to be greater than the abiotic factors for the aphid, L. erysimi and M. persicae infesting cruciferous crops (Atwal et al., 1971; Daiber, 1971; Sachan and Srivastava, 1972). On the contrary, the abiotic factors appear to be more contributory in the present case in regulating the field abundance of B. brassicae.

Generally, alates are responsible for immigration, dispersal and emigration. Studies on the trap catches pertaining to the aerial activity of aphids would be of useful to predict the appearance of aphids in the field. Dispersal is essential for the survival of the cabbage aphid since its host plants are not perennial (Hughes, 1963). Present investigation revealed the highest peak of alate activity during January and February. Hughes (1963) also reported the similar peak during January to April at Canberra (Australia) for the cabbage aphid. It was also reported that the pattern of migratory flights in time fits well with the observed occurrence of infestations of the species in the area. Bahana and Karuhize (1986) observed the high alate activity of B. brassicae during September with the help of sticky trap catches which is coincided with the field data. Ghosh (1975) reported the greatest abundance of about 18 species of aphids during
February-March collected in YPT. It was also reported that the alate catches in the trap was negatively correlated with temperature \((r=-0.393)\) and relative humidity \((r=-0.452)\) which supports the present finding. From the present investigation, it appeared that the minimum temperature \((5.0-11.57^\circ\text{C})\), maximum temperature \((19.16-23.85^\circ\text{C})\) and moderate humidity \((around 70\%)\) favourably influence the higher alate activity which is in agreement with the findings of Ghosh (1975) on other aphids.

Rajendran and Ram (1990) reported similar peak activity of alate aphids in potato crop during January-February with the help of Yellow sticky trap (YST) and Yellow pan trap (YPT). They were of the opinion that YPT is more efficient than YST in terms of abundance in monitoring potato aphids.

During the present study eight species of cruciferous plants were recorded as host of the cabbage aphid, \textit{B. brassicae} from Manipur. All the plants are cultivated and there is no record of uncultivated wild plants or weeds as host of this pest from Manipur. Several workers reported that \textit{B. brassicae} feeds on a wide range of cruciferous and other cultivated and wild plants. Majority of the crucifers were reported as food plants of this pest other than cabbage from different parts of the world (Herrick and Hungate, 1911; George, 1957; Batra, 1960; Hughes, 1963; Bahana and Karunize, 1986; Ghosh et al., 1980). In the present
observation the cabbage (local variety) can be distinguished from cabbage (improved variety) and other brassicas due to its cropping cycle, fleshiness and mode of severe infestation by the pest throughout the cropping season. None of the workers reported the similar peculiarity of the crop.

The pest was observed to infest on different parts of the crops. In cabbage (local variety), it was found to infest often in large numbers, attacking mainly on the undersurface of the leaves, heads and sprouts. Herrick and Hungate (1911) reported similar mode of infestation and the widespread injuries caused a serious and heavy loss to cabbage growers in USA. In flowering plants like mustard, radish, turnip, cauliflower the main shoots are attacked turning pale and succumbed quickly, even the seeds were unfit for sowing and subsequently caused death of the young plants (Batra, 1960; Wanjama, 1978; Bahana and Karuhize, 1986). This is in agreement with the present observation.

Biology of *Brevicoryne brassicae* including development, fecundity and longevity in the laboratory varied significantly in different seasons. In general, the trend was as the temperature increased there was a decrease in the developmental periods, fecundity and longevity. The present results are in general agreement with the findings of Sidhu and Singh (1964), Rout and Senapati (1968), Roy (1986) and Roy and Pande (1991) in the

The duration of various life stages recorded in the present observation is at variance with the earlier reports. This difference might be attributed to varying temperature and relative humidity in different parts of the country. The time interval between the two molts is dependent upon the above factors as well as the quality of the host. This corroborates the findings of Gautam and Verma (1983) and Roy and Pande (1991). The first instar nymph showed gradually increasing developmental trend unto fourth instar with maximum duration in fourth instar. The total nymphal development was prolonged at low temperature during winter (December-January) (13.52 days) and shortened in Autumn (7.91 days) where the temperature was comparatively high. Similar observations were reported by Atwal and Dhinra (1971), Radke et al. (1973), Gautam and Verma (1983), Amin and El-Defray (1981), Devi (1990), and Roy and Pande (1991). On the contrary, the durations of development of this pest was comparatively less in all life stages and the young nymphs showed decreasing trend of development to reach adult on mustard (Singh et al., 1992).
Among the reproductive phases, pre-reproductive period was the shortest (20.92-25.5 hr) and the reproductive period was the longest, which occupied, on an average, 15.66-22.83 days in all three seasons, which confirms the reports of Sidhu and Singh (1964), Amin and El-Defray (1981), Devi (1990), Roy and Pande (1991) and Shantibala (1993). Radke et al. (1973) opined that with the increasing temperature the fecundity also decreased in Aphis craccivora which supports the present finding to some extent. The maximum fecundity (64.5 nymphs/female) was obtained during winter where the temperature was comparatively low than the other seasons in the present study. Sidhu and Singh (1964), Rout and Senapati (1968) and Mitra (1974) observed an inverse correlation between fecundity and temperature which is in agreement with the present result. High temperature, recorded to reduce the fecundity in the present study was reported earlier by Baran (1970), DeLoach (1974) and Roy and Pande (1991).

Banks and Macaulay (1970) found significant increase in the mean fecundity of those reaching maturity early than those reaching late in A. fabae. It seems that an increase or decrease in fecundity largely depends on the length of the reproductive period than the development rate which is influenced by temperature. Similarly, the present result revealed the positive correlation between reproductive period and fecundity in all the seasons. The significant correlation was obtained in winter (r=0.82).
Gautam and Verma (1983) observed that the reproductive phases are considerably longer in winter than the summer in *E. lanigerum* but higher fecundity was observed in summer which is quite contradictory to the present study. Further, they opined that it may be due to efficient sap flow during summer as the host plant is dormant in winter.

Kenton (1955) also found that a decrease in temperature resulted in an increase in length of the life of *Acyrthosiphon pismum* which supports the present results to some extent that maximum adult longevity was obtained during winter (29.56 days). The duration of total life cycle was also longer in winter (43.08 days) followed by autumn (33.84 days) and spring (29.34 days) respectively.

From the above results, it may be mentioned that the durations of development stages, fecundity and longevity of cabbage aphid were temperature dependent. However, Raworth (1984) suggested that laboratory measures of developmental time, fecundity and longevity of *B. brassicae* were different from field measures due to differences in plant quality.

In Moulour, the cabbage aphid, *Brevicoryne brassicae* (L.) was found to infest on range of its hosts, such as, cabbage (local variety), cabbage (improved variety), cauliflower, knol khol,
mustard, radish, etc. The pest can survive on its hosts in any stage but favourably on some particular stages of the host plant in the field. The biology of this aphid on the above six hosts revealed that the life cycle was completed in all the hosts with varied durations of life stages and fecundity. Rajagopal and Kareem (1983) studied the comparative development of the green peach aphid, *Myzus persicae* on five different host plants and reported the complete development of the aphid on all the hosts. Similarly, Kandoria and Jamwal (1988) also studied the comparative biology of *Aphis gossypii* on okra, brinjal and chilli. Srikanth and Lakkundi (1988) also tested the life history of *Aphis craccivora* on seven hosts but the aphid did not survive beyond the first instar on pea and soyabean.

Nymphal development of this pest showed non-significant difference in the duration of each instar on six hosts. Total nymphal development was completed in about 12.91-15.15 days. Similar results were also observed by Rajagopal and Kareem (1983) for *M. persicae* in Coimbatore (Tamil Nadu) and Kandoria and Jamwal (1988) for *Aphis gossypii* in Punjab. Singh et al. (1992) reported comparatively shorter durations of developmental stages of *B. brassicae* on mustard in Manipur, but fecundity was more or less similar with the present result.

Rajagopal and Kareem (1983) opined that the aphid *M. persicae* grows faster, lived longer and the reproductive rate
was higher on the suitable hosts. Srikanth and Lakkundi (1988) also supported that the aphid *Aphis craccivora* appeared to have shown short pre-reproductive and long reproductive periods on suitable hosts and vice-versa on unsuitable hosts. Adult longevity and fecundity was also high on suitable hosts.

The above results on *M. persicae* and *A. craccivora* confirmed the finding of more or less short pre-reproductive period, longer reproductive period, high fecundity, long adult lifespan as well as longer life cycle of the pest on cabbage-II and knol khol. From the present developmental studies of *B. brassicae*, cabbage-II (local variety) and knol khol may be considered as the preferred hosts of this pest.

Variations on the fecundity of *M. persicae* between host plants were also reported by Heathcote (1952) on several cole crops. It was also suggested that variations in the duration of nymphal development and longevity of adult in the laboratory might be due to the environmental conditions and the nutritional status of the host plants (Rajagopal and Karaem, 1983, Raworth, 1984).

The recurring alternation of illumination and darkness in nature, is commonly known as photoperiod. Almost all the major groups of eukaryotic organisms utilize the daylength as sources
of environmental information (Beck, 1980). In response to such clue, animals adjust their morphogenetic development, behaviour and other related processes, so as to make them fit for survival. It is also evident in many groups of insects that photoperiodism enables them to undergo diapause or trigger their development or produce polymorphic individuals (Lees, 1966).

Apparently, from the past results, it would appear that photoperiod is one of the important factor having profound effect on the biology of aphids. Present results indicated that the total nymphal development of B. brassicae was fastest at LD 8:16 and the development prolongs significantly as the photoperiod increases upto LD 16:8. Kanton (1955) and Radke et al. (1973) are of the opinion that as the light regime was decreased, there was an increase in nymphal duration of Acanthosiphon pisum and Aphis craccivora which is contradictory with the present finding. They pointed out that temperature also played main role besides the photoperiod.

The reproductive period of B. brassicae was increased at short light regime, LD 8:16. The reverse trend was observed by Radke et al. (1973) who reported that within each light regime for the reproductive period vary inversely as the temperature increased. The influence of light regime on the reproductive period was evident. As the daylength was increased above 6 hr, the
reproductive period was lengthened. The rate of fecundity of the aphid showed a great variation due to the effect of photoperiods. The reproductive efficiency of short day exposed individuals was three times more than that of long day aphids. Since the reproductive period was also 8 days more for individuals reared at LD 8:16, the fecundity was also proportionately high in the treatment. Radke et al. (1973) found that the fecundity increased with the increase in light regime at different temperatures but the reverse is true in the present observation. Increased fecundity with an increase in photoperiod was also observed in *Macrosiphum pismum* (Kralovic, 1970).

More longevity of *B. brassicae* was found at short light regime, LD 8:16. A difference of about 6 days total longevity was indicated between the two extreme phototreatments, LD 8:16 and LD 16:8 at the same temperature. Kenton (1955) found that a decrease in temperature resulted in an increase in length of the life of *A. pisum*. Radke et al. (1973) concluded that light regime had no effect on the longevity of *A. craccivora*.

From the analysis of all the above parameters in relation with photoperiod, it was observed that short daylength is favourable for the survival of *B. brassicae* particularly on the cabbage. Generally, insects exhibiting positive response to short daylength are categorised as short day forms. This is by virtue
of continuous growth and development of the insects in relation to concerned photoperiod. The positive response of *B. brassicaceae* to short day photoperiod indicates its ecological adaptations for survival. It is known that the embryonic diapause of *B. brassicaceae* is being regulated by photoperiod (Bonnemaison, 1951) and it appears that induction of diapause is favoured at times of long daylength. This report further strengthens the present observation that *B. brassicaceae* is a short form.

The morphometric data of *B. brassicaceae* in different seasons revealed that there is a progressive increase in size of all the morphological parameters in general from one stage to the next (Table 13,14,15 and Fig. 24). Sometimes, overlapping or slight decrease in size of some parameters occurred but no remarkable decrease was noticed in any other part of the body. Slight change in colour also took place during the nymphal developmental period. It may be mentioned that winter is the favourable season for development of this pest as all the morphological characters showed maximum in size in this season followed by autumn and spring seasons respectively (Fig. 24). Among the characters body length and body width were 2.89-3.96 and 2.52-3.40 times increase in size from first instar to adult. However, the characters such as, antennae, antennal segment-III, p.t. length and cauda showed as maximum as 4.24-5.34, 5.92-6.74, 4.05-6.06 and 5.65-6.32 times increase in size in different seasons (Table 13,14,15). The other
characters like u.r.s., b.d. III, F.T.C. and h.t. 2 showed minimum degree of difference in size from first instar nymph to adult.

Morphologically, the first two instars of this pest are almost alike except in size. The two instars can be distinguished by the presence or absence of hairs on the antennal segment III and F.T.C. Antennae were 5-segmented in both the stage which become 6-segmented in the third instar and subsequent stages. Similar antennal segmentation in the respective stages was reported by Sood and Kakar (1989) in the case of Macrosiphoniella sanborni. The length of antennal segment III gradually increased from first instar (0.09 mm) and reached 0.64 mm in adult which is 6.74 times longer than the first instar during winter season. The hairs on segment III varied from 4-13 numbers in second instar to adult. The longest hair varied from 0.01-0.02 mm in length. The length of processus terminalis also gradually increased from first instar to adult with maximum in winter about 6.06 times longer than the first instar. The ultimate rostral segment bears 4 secondary hairs in all the stages. F.T.C. is 2,2,2 in first instar and 3,3,3 in second instar and the subsequent stages.

The length of the siphunculi showed comparatively more in winter (0.045-0.14 mm) than the other seasons but the ratio from first instar to adult is high (5.38 times) in spring season.
The size and shape of the cauda showed a maximum degree of difference from first instar to adult in all the three seasons. It varied from 0.029–0.166 in winter followed by autumn (0.023–0.130 mm) and spring (0.019–0.120 mm) respectively. Initially, it was not discernible and becomes more triangular in shape in the adult. The appearance of the pigmented patches and spots in the abdomen started from the third instar and becomes more in the subsequent stages.

Roy and Behura (1983) observed the numerical difference in the morphological characters of alate and apterous viruliformae of *Aphis gossypii* during three seasons but there was no significant variation in all the seasons, although winter season was believed to be the best season for aphid development. This is in agreement with the present finding. *Aphis gossypii* exhibits a great range of morphological variations even on the same host (Behura, 1973).

The gradual increase in size and shape of some morphological characters in the developing stages of *B. brassicae* are of practical importance in the identification of different stages of a species. The above results are supported by the findings of Devi (1990) on *Toxoptera citricidus*.

In general, the aphids reproduce by parthenogenetic viviparae and sexual forms have been recorded in very few cases.
Regarding the occurrence of sexuals the conventional idea is that only short daylength and low temperature help in the production of sexuals in aphid (Ghosh and Raychaudhuri, 1983). The present finding of apterous oviparous females of *B. brassicae* in the laboratory from three cruciferous hosts during December-January where the prevailing temperature was low and daylength was also short confirms the record of aphid sexuals in general. In India, the occurrence of apterous ovipara of this species was reported by David (1958) from South India but neither description nor morphometric data of the specimen were provided. Further, the collection of slate males of this species from Uttar Pradesh and Himachal Pradesh was made by Banerjee et al. (1969) and Ghosh et al. (1969). The detailed description of the specimens in the present study could be very helpful to the future workers.

In Manipur, the natural enemy complex of *B. brassicae* includes three species of Coccinellid predators, six species of Syrphid predators and one species of Aphidid parasitoid. Of these, predators have been found to be the key mortality factors but the parasitoid was too less. Among the predators, Syrphids were found to be more abundant than the Coccinellids. Several workers also reported similar findings of Coccinellids, Syrphids and Aphidids as natural enemy complex of this aphid (Tao and Chiu, 1971; Tandon et al., 1977; Kotwal et al., 1984; Verma and Makhmoor, 1987; Thakur et al., 1989). In addition to the above,
some workers also reported Cecidomyiid and Chrysopid as natural enemies of B. brassicae (George, 1957; Herakly and El-ezz, 1970; Raworth et al., 1984; Sharma and Verma, 1991) but these were not recorded in the present study.

In general, the duration of development of the predators progressively increased from first instar to fourth instar. Similarly, the larval voracity was also increased as the larva matured attaining maximum consumption in fourth instar. Developmental biology of C. septempunctata reveals that the larval period, pupal period and total development from egg to adult took 15.28, 4.40 and 25.87 days respectively. Singh and Malhotra (1979) reported shorter larval development of this predator at varying temperature of 20-24°C but pupal period is similar to that of the present finding. A single larva consumed 222.21 aphids during its larval development. The present result supports the findings of Singh and Malhotra (1979) and Sharma and Verma (1993) but rate of consumption is slightly higher. Tao and Chiu (1971) also reported similar developmental period with the present study but higher feeding efficiency of this predator. On the contrary to the present result, Agarwala and Saha (1986) observed the shorter larval development, longer pupal period and comparatively higher feeding rate of C. septempunctata on Aphis gossypii.
A look into the life history studies of *Menochilus sexmaculatus*, it was observed that the predator requires 21.23 days to complete its development from egg to adult. It took about 13.26 days during the larval developmental period with a mean pupal period of about 3.16 days. A single larva consumed as much as 224.23 aphids during its developmental period. Rao (1969) observed the larval and pupal period ranged from 9-14 and 4-12 days respectively during November-December at Jullunder. Tao and Chiu (1971) observed the variable range of developmental period and consumption of this predator when reared on different aphid species at the temperature varied from 28-30°C. The predator took 16-21 days for its development and consumption ranged from 213-254 aphids when fed on *Lipaphis erysimi* which is in general agreement with the present result. Agarwala and Saha (1986) also observed that the development from egg to adult was 9.8 days and consumed 217.4 aphids which are comparatively less from the present result when reared on *Aphis gossypii*.

Studies on the developmental biology including consumption of the Syrphid predator, *Metasyrphus (M.) confrrater* revealed that the predator took 20.4 days during the larval period. Total developmental period from egg to adult was 36.21 days including comparatively longer pupal period of about 14.5 days. The mean larval consumption of this predator was 260.28 aphids. Several
workers reported shorter larval development and higher rate of consumption of this predator when fed on different preys which is contradictory with the present findings (Roy and Basu, 1977; Agarwala and Saha, 1986; Makhmoor and Verma, 1987).

Present works on the developmental biology and larval voracity of *Ischiodon scutellaris*, it was observed that the predator completes its larval development in about 16.24 days. The pupal period was 8.4 days and complete development from egg to adult was 25.85 days. A total of 228.17 aphids was consumed by a single larva during its development. Tao and Chiu (1971) reported shorter larval period of this predator but the pupal period was similar with the present finding. Similarly, Roy and Basu (1977) and Agarwala and Saha (1986) were observed the shorter durations of larval development and higher feeding efficiency of this predator on other aphids but the durations of pupal development was same.

Results on the life history of *Episyrophus baleatus* revealed that the predator completed its larval development in 10.27 days. Total development from egg to adult was 18.86 days including a pupal period of 7.76 days. Larval consumption was about 184.83 aphids. The present result supports the findings of Makhmoor and Verma (1987) in some respect but the rate of consumption was slightly higher and pupal period was also
longer. Roy and Basu (1977) also reported similar larval duration but higher feeding efficiency. Tao and Chiu (1971) observed variable rate of consumption and duration development of this predator when reared on different aphid species. This is in general agreement with the present result.

Variations in the duration of development and comparatively low consumption rate of the predators in the present studies may be attributed to the nutritive status of the prey species and its size as well as different environmental factors.

Present morphological descriptions and sizes of different stages of Coccinellids, viz., C.septembactata and M.sexmaculatus are more or less similar to that of Baqai and Trehan (1945) and Singh and Malhotra (1979). More or less similar dimensions and morphological descriptions of the stages of Syrphid were reported by Lal and Gupta (1953), Tao and Chiu (1971), Roy and Basu (1977) and Makhmoor and Verma (1987).

Observations on the searching behaviour, feeding behaviour and other related aspects of the predators revealed that both the larvae and adults of Coccinellids were aphidophagous in habit but in Syrphids, only the larvae are aphidophagous and the adults are non-aphidophagous in habit. Both the predatory larvae are morphologically quite different and characterised
by different mode of locomotion. The searching behaviour and feeding behaviour of both the predators were slightly different in some respects but almost similar in general. The young larvae of the Coccinellids sucked the body fluid of the prey and rejected the sclerotized body parts. Later instars and adults consumed the whole body of the prey. However, the syrphid larvae after sucking out the body fluid of the prey, the sclerotized skin was discarded in all the cases. Syrphid larvae can survive longer periods of starvation than the Coccinellids, if water is provided.

Similar behavioural aspects on the searching and feeding of aphid by the Coccinellids were reported by Dixon (1959), Kapur (1942), Haagen (1962), Singh and Malhotra (1979), Poddar and Ghosh (1984). In case of syrphids, the results on the behaviours of the larvae in relation to searching and feeding of the prey were supported by Bhatia (1939), Roy and Basu (1977) and Agarwala (1987).

Although, the appreciable population of the Coccinellids are represented in the aphid colony, the larval voracity of the Coccinellids are less than the Syrphids. In support to the present result, Okamoto (1961) found that B. brassicae is less suitable for C. septempunctata. Yakhontov (1966) opined that both the larvae and adults of Coccinellids avoid aphids with a thick waxy cover but accept them in absence of other more suitable food. Iperti (1966) of the opinion that the voracity
of Coccinellid requires an abundance of food. Irrespective of the quantity, the quality of food is also very important for the development of predators. Starvation induced the phenomenon of cannibalism in Coccinellids, the larvae and adults of which will eat their own eggs, larvae, prepupae, pupae and newly emerged adults (Agarwala and Dixon, 1991). In Coccinellids, it is important for survival when aphids are scarce. Present observation on cannibalism in Coccinellids are in agreement with the results of Kapur (1942), Agarwala (1991). In the present study, cannibalism was also occurred in the field which is in fair agreement with the findings of Mills (1988). Cannibalism was not observed among the Syrphid larvae in the present study. On the contrary, Bhatia (1939) and Roy and Basu (1977) reported this phenomenon among the Syrphid larvae.

Present results on the larval voracity of the predatory larvae indicated that Syrphids are more efficient predator than the Coccinellids in terms of consumption. Similar results are reported by Sundby (1966), Saxena et al. (1970), Kotwal et al. (1984), Agarwala and Saha (1986). Among the syrphids M. (M.) confertar was found to be the most efficient predator of B. brassicaceae. The result is in fair agreement with the findings of Roy and Basu (1977).

Based on the mortality percentage of the cabbage aphid, it is evident that among the eight treatments, insecticides were more effective reaching cent percent mortality after 72 hr of
treatment. It is followed by the neem products giving 97.33% mortality by Nimbecidline which is superior than the control. Patel et al. (1993) reported similar results of higher mortality of bean aphid by Dimethoate (0.03%) and followed by neem product, Neemark (0.03%) while comparing with plant extracts and formulations. After 24 hr of treatment, Monocrotaphos (0.05%) was the most effective giving 99% mortality. Present result is supported by the findings of Naqvi et al. (1990) for the aphid Lipaphis erysimi on mustard. Quinalphos (0.05%), Malathion (0.05%) and Endosulfan (0.05%) were also effective against the cabbage aphid giving 84.66-97.00% mortality after 24 hr of treatment. This result is in general agreement with a number of earlier workers on different aphids infesting cruciferous crops (Batra, 1960; Rao and Borwal, 1983; Duhra and Hameed, 1990). Initially the neem products showed low rate of mortality and almost at par with the control. But the percent mortality increased reaching 67.33% after 72 hr of treatment by Nimbecidline (0.03%) showing promising effect against the aphid. Similarly, among the neem products, Neemark (0.03%) showed only 13.33% mortality of bean aphid after 24 hr of treatment but it increased in subsequent hours of interval reaching cent percent mortality after 72 hr of treatment which is at par with the insecticide Dimethoate (0.03%) (Patel et al., 1993).