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2.1 INSECT-PEST COMPLEX

The rapeseed-mustard crop is highly vulnerable to a large number of insect-pests (Fletcher, 1921) at different phases of plant growth. Rai (1976) listed 24 species of insect-pests attacking this crop. However, Bakhetia and Sekhon (1989) reported 38 insect species harbouring Brassica crop and nearly one fourth were of economic importance. Among them, the mustard aphid (Lipaphis erysimi Kalt.) was the key pest; it can inflict huge loss to the crop under severe infestation. The mustard sawfly (Athalia lugens proxima Klug), painted bug (Bagrada hilaris Burmeister), leaf miner (Chromatomyia horticola Gouereau), cabbage butterfly (Pieris brassicae Linnaeus.), bihar hairy caterpillar (Spilosoma obliqua Walker), pod fly (Melanagromyza sp.) (Sharma and Singh, 1990 and Mathur, 1993) and the cutworms are some of the other important pests of the crop. They attack the crop at different stages of growth. Hairy caterpillar, pea leaf miner, semilooper and larvae of cabbage butterfly damage the vegetative stage. The mustard aphid attack is serious throughout the crop season but most serious at the flowering phase. The pod borer (Helicoverpa armigera Hubner) (Judal and Upadhyay, 1989 and Bakhetia and Arora, 1993), cabbage top borer (Hellula undalis Fabricius) and diamond back moth (Plutella xylostella Linn.) are some of the other pests that cause damage to flowers/inflorescence (Bakhetia and Sachan, 1997).

2.1.1 LIPAPHIS ERYSIMI

2.1.1.1 Importance

The mustard aphid, L. erysimi is the main constraint for qualitative as well as quantitative production of mustard in India. Increase in population beyond 25-aphids/10 cm terminal shoot/plant reduces seed yield by 1.5 kg/ha (Singh et.al., 1983). The mustard aphid has been recorded from all parts of the country attacking every stage of the crop. It has attained the key pest status in rapeseed-mustard because of its prolific multiplication and severe damage.

2.1.1.2 Seasonal History

In north India, this insect species is present in the fields throughout the year showing intense activity in January-February. Its population on brown/yellow sarson (Brassica campestris) and raya or rai (B. juncea) reaches the peak during January-
February under different ecological conditions. March onwards, the population declines and is negligible on the crop in April. During summers, it can be searched on stray cruciferous plants and weeds in orchards.

Favourable conditions for rapid multiplication of mustard aphid are mean maximum and minimum temperatures of 16 to 30°C and 4 to 12°C, respectively, coupled with 60-80% relative humidity. Rainfall below 1.0 cm is useful as it increases the relative humidity but higher rainfall is detrimental as it washes and kills the aphid colonies (Bakhetia and Sachan, 1997).

2.1.1.3 Biology

The immigrant, winged forms (alate) usually alight on the crop in September/October and start reproduction. The mode of reproduction is viviparous parthenogenetic. From young ones, wingless female mothers develop after a period of 7 to 15 days. The winged forms, which constitute 5% of the population, are responsible for the dispersal. An adult female can give rise to 5 to 9 young ones in a day. A single female can produce as many as 135 off-springs and the oviposition period lasts for 15 to 30 days. One life cycle is completed in 23 to 60 days depending on the weather conditions. There are 35-60 overlapping broods in a year, out of which 16 are completed on cruciferous oilseeds (Bakhetia and Sachan, 1997).

2.1.1.4 Yield Losses

*L. erysimi* is one of the bottlenecks in achieving higher seed yield of rapeseed-mustard crop in India. Yield losses due to this nefarious pest varies with the variety, environmental factors and agro-technological practices. Different workers have reported varying degree of seed loss. Pradhan (1964) observed 87.7% seed loss while Bakhetia (1983) reported avoidable losses in an unprotected crop of *B. juncea* from 34.5 to 73.3%. Few years later, Bakhetia and Sekhon (1989) calculated the average loss of 54.2%, whereas Singh and Singh (1987) calculated 30 to 70% on all India basis.

Increase in exposure period subsequently decreases seed yield (Behera and Patro, 1999). Prasad and Phadke (1983) conducted an experiment on the effect of aphid infestation to assess the seed yield of different varieties and species of *Brassica* grown for oil and found losses from 8.9 to 71.5%. Loss in yield due to the aphid in
Indian mustard was 94.5% (Malik et al., 1998). Nonetheless, in the susceptible varieties the loss was to the tune of 38.2 to 46.56% against 2.86 to 17.53% in the resistant varieties (Singh et al., 1983). In terms of kg/ha, the loss was to the extent of 2.2 to 4.8 kg/ha in Brassica napus (Sekhon and Bakhetia, 1994). The different aphid species like L. erysimi; Brevicoryne brassicae and Myzus persicae caused 67.61, 62.51 and 50% seed yield loss, on B. campestris var. toria, B. campestris var. brown sarson and B. juncea, respectively (Sharma and Kashyap, 1998). The aphid infestation could cause yield loss from 9.59 to 57.46% under arid conditions of Rajasthan, India (Satyavir Singh and Henry, 1987). Whereas, in Punjab it was recorded to be 91.3% (Vir et al., 1990) and 69.6% in U.P (Singh and Sachan, 1994).

2.1.1.5 Economic Injury Level (EIL)

Aphid multiplication on mustard is dependent upon environmental factors and infestation is confined to winter with its peak during January-February. The aphid infestation can be managed with the use of persistent, contact and systemic insecticides, but this pest requires need-based application of insecticides at an appropriate stage so that their residues are not left in mustard grain and oil. Besides, the indiscriminate use of chemicals has resulted in wasteful expenditure, development of resistance in insects to insecticides, residue problem, resurgence and considerable effects on non-target species including parasites, predators and insect pollinators (Smith, 1970). Therefore, efforts were made to determine its multiplication in relation to environmental factors along with the assessment of economic threshold of the pest for suggesting the need based application of pesticides to achieve the maximum return and minimum insecticide input.

According to Prasad and Phadke (1983) the EIL (economic injury level) of mustard aphid at 70, 80, 90, 100 and 110 days after sowing were 3.3, 16.4, 15.7, 26.9 and 24.7 aphids/shoot, respectively when phorate granules were applied and with aldicarb granules the EIL at the above stages of plant growth were 3.7, 17.3, 15.9 and 11.2 aphids/shoot, respectively. Singh and Singh (1987) reported 9.19 aphids/shoot during first and second week of January. Bakhetia et al., (1989) determined ETL as 54 to 71 aphids/plant. Toria variety, M-27 recorded EIL of 30 to 40 aphids/10 cm terminal shoot during first and second week of January. According to Misra (1995) estimated EIL of L. erysimi on toria is 44.59-aphids/10cm terminal shoot. Recently,
Singh and Malik (1998) observed that the EIL was 20.4-aphids/10 cm terminal shoot/plant with an index of 0.98 and infestation level of 37.4% besides, the ETL was 15.42-aphids/10 cm terminal shoot with an average infestation level of 35% and aphid index of 0.82.

2.2 EFFECT OF DATE OF SOWING ON POPULATION BUILD-UP OF L. Erysimi

Different planting dates take advantage of absence of the pest on a crop. There is asynchronisation of the most susceptible stage of the crop with the most active period of the pest. Manipulation of planting dates becomes more meaningful when it is based on pest monitoring. The early planting of mustard from October 15 to 20, in central to north India, receives less aphid population and provides higher yield. Weather and time of sowing affect the incidence of mustard aphid on rapeseed-mustard crops (Ram and Gupta, 1987). Late September and early October sowings result in low aphid incidence and high yields (Bhadauria et al., 1992, Verma et al., 1993, Patel and Patel, 1997 and Singh Jyoti et al., 1998) but second fortnight of October sowings also give good yields (Ram and Gupta, 1987; Rehman et al., 1989; Jadhav and Singh, 1991; Surekha and Reddy, 1996, Prasad and Singh, 1999, Srivastava, Ajai, 1999 and Kanth et al., 2000).

Vir et al., (1990) observed that plants sown on different dates during October, November and December result in marked differences in aphid populations. November sown plants give 18 times greater yield than those sown in December was the finding of Islam et al., (1991), Kanchan Baral et al., (1998). Delay in sowing beyond October with different dates in November and December result in progressive increase in aphid population on succeeding late sown crops (Jakhmola, 1992, Sonkar and Desai, 1999 and Prasad and Lal, 2001).

2.3 HOST PLANT RESISTANCE

Screening is the experimental testing of different varieties/cultivars in the field to record their resistance/susceptibility against a particular insect causing immense losses to the crop in question. Once a variety is confirmed to be resistant to the pest, then growing such variety becomes the cheapest method for control of the pest as no extra amount is invested on pest management. Resistance of a variety varies from one
agroclimatic zone to another. Therefore, its efficiency is to be tested in different regions. Agricultural workers have tested different varieties to confirm their resistance to *L. erysimi*, some of these efforts have been summarised below.

* B. campestris* strains are generally less resistant to *L. erysimi* as compared to those of *B. juncea* (Rohilla *et al.*, 1990). The cultivars RW-255676-B and RK-8501 are susceptible, DIRA and Varuna medium susceptible and RW-5453-132 highly susceptible (Bhadauria *et al.*, 1995). High aphid infestation was recorded on *Sinapsis alba* and Porbiraya, moderate on RLM-198, RH-7361 and T-6342, whereas, the resistant varieties were RW-2-2, RW-15-6 and B-85 (Sachan and Sachan, 1996, Manzar *et al.*, 1998, Naveen Agarwal *et al.*, 1996). Rana and Khokar (1998) recorded the genotypes RW-32-2, GSL-1 and TMH-52 as tolerant, while RH-7846 moderately resistant and HC-2 as resistant to aphid infestation. Vekaria and Patel (2000) screened various cultivars; they have observed that genotypes PC-5, T-27 and T-6343 are resistant to *L. erysimi*.

### 2.4 CHEMICAL CONTROL

#### 2.4.1 Effect on target pests

A number of insecticides have been evaluated to suppress the aphid incidence (Bakhetia *et al.*, 1986; Singh *et al.*, 1987; Islam *et al.*, 1990 and Misra, 1993). Higher mortality is obtained by the application of oxydemeton-methyl, phosphamidon, quinalphos and endosulfan (Chundawat *et al.*, 1975). However, two sprays of chlorpyriphos, phosphamidon, oxydemeton-methyl and lindane give good results for the control of aphids (Prasad, 1978a). The timing of application is one point that significantly matters rather than the choice of insecticide applied (Bakhetia, 1984). Chlorpyriphos gives high net return profit and is also effective in controlling the aphid (Kumar *et al.*, 1996, and Baral and Sethi, 1997). Furthermore, endosulfan is a chemical if applied at 0.01 to 0.07%, the residues can be detected till 16 days from the date of application (Seema Kumari *et al.*, 1997). Effective control of mustard aphid can be obtained by two applications of malathion 50 EC (Rouf and Kabir, 1997) or methyl-o-demeton and deltamethrin followed by methyl-o-demeton (Malik *et al.*, 1998). Application of disulfoton granules @ 1kg/ha (30 DAS) followed by phorate also gives effective control of the aphid (Sinha *et al.*, 1999). Phosphamidon has been found to be a good insecticide as its toxicity to aphids persists up to 14 days (Pal
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et.al., 1983; Ahmad and Miah, 1989; Bhola et.al., 1990: Srivastava et.al., 1991; Dutta, 1992; Upadhyay and Agarwal, 1993; Singh and Sircar, 1995; Kumar et.al., 1996; Singh and Malik, 1998; Singh and Lal; 1999; Singh et.al., 1999; Sinha et.al., 1999 and Sinha et.al., 2001).

Prasad (1997) and Singh and Singh (2001) while comparing botanicals vis-à-vis synthetic insecticides found that neem formulations persisted for only 3 days and were inferior to organic insecticides. Two applications of methyl-o-demeton (0.025%) along with nicotine sulphate can keep the ETL at desired levels (Vekaria and Patel, 2000). Excellent control of mustard aphid can be obtained by a combination of neem cake+azadirachtin+2 sprays of phosphamidon (Chakraborti, 2001).

2.4.2 Effect on non-target/beneficial Insects

While applying chemical pesticides in rapeseed-mustard ecosystem to control the aphids, also kills natural enemies also get killed, thus leaving the crop vulnerable to attack of the rapidly multiplying aphid population. Singh et.al., (1987) found that methyl-o-demeton and endosulfan were relatively safe to pollinators and could be applied at flowering stage in rapeseed-mustard crops. However, phosphamidon (Chakraborti, 2001), chlorpyriphos and malathion are significantly detrimental for pollinators as well as predators at their normal dosages (Malik et.al., 1998). Neem products have been found to be safe for the braconid parasitoid (Diaeretiella rapae, Mc’Intosh) of mustard aphid (Kulkarni and Patel, 2000).

2.4.3 Coccinellids

Various workers have reported that majority of synthetic insecticides show deleterious effect on coccinellids and other beneficial, insects. Decamethrin, chlorpyriphos, and monocrotophos are toxic insecticides for coccinellid beetles while methyl -o- demeton; dimethoate, endosulfan, and malathion are relatively safe (Singh et.al., 1987; Tripathi et.al., 1988; Sharma et.al., 1991; Shukla et.al., 1994; Thomas and Phadke, 1995; Dhingra et.al., 1995; Singh and Sircar, 1995; Malik et.al., 1998; Singh et.al., 1999). Endosulfan is more toxic to the adult beetles than the larvae (Shukla et.al., 1990). In case of selective insecticides, development of predator population depends on the rate of mortality of the prey. Some insecticides also kill most of the coccinellids without having any effect on aphids (Zoebelein, 1988).
Malathion @ 2.85 gm a.i./l results in 100% mortality of *Coleomegilla maculata*, 72 hours after treatment and single dose of neem oil (10%) results in significantly greater mortality than control. Aqueous suspension of ground neem seeds reduces 50% predation by the beetle (Roger *et al.*, 1995). The fourth instar larvae of *C. septempunctata* are innately more sensitive to the growth disruption effects of acute exposures to azadirachtin than first instar (Banken and Stark, 1997). Imidacloprid is not compatible with the coccinellid predator *C. maculata* (Smith and Krischik, 1999). *C. septempunctata* responds positively to volatiles from aphid infested plants and previously aphid infested plants but not to volatiles from uninfested plants or from undisturbed aphids (Velemir Ninkovii *et al.*, 2001).

### 2.4.4 Syrphids

The relative toxicity of six insecticides was tested by Makhmoor and Malhotra (1993) against the larvae of *E. balteatus*. On the basis of intrinsic toxicity, phosphamidon was rated as highly toxic to syrphid larvae, followed by dimethoate, oxydemeton-methyl, and malathion. Endosulfan was the safest followed by chlorpyriphos. Safety indices confirmed the innocuity of chlorpyriphos to the larvae of *E. balteatus*, followed by endosulfan. Chlorpyriphos and endosulfan at the recommended concentrations could be used for aphid control along with larvae of syrphids in the integrated pest management. Recently, Sharma and Kashyap (2002) investigated the impact of pesticidal spray on the natural predators viz., *Syrphis* sp. *C. septempunctata*, *Oxyopes* sp. and parasitoid, *Diaeretiella* sp. in the tea ecosystem. They found that deltamethrin, cypermethrin and ethion sprays were highly toxic to both *Syrphis* sp. and *C. septempunctata* and their adult and larval population was not seen even on fourth and seventh days of spray, respectively. On the other hand neemark, achook and *Bacillus thuringiensis* Berliner, (Dipel 8L) were quite safe to natural enemies. Endosulfan was recorded to be relatively safe to *Syrphis* sp but toxic to *C. septempunctata*.

### 2.5 BIOLOGICAL CONTROL

Several predators-coccinellids, syrphids, chamaemyiid and parasitoids particularly *D. rapae* have been recorded from the rapeseed-mustard ecosystem.
Among the predaceous coccinellids of *L. erysimi* (Kalt.), *C. septempunctata* Linn. and *Menochilus sexmaculatus* Linn. are common and widely distributed. *C. septempunctata* greatly influences the population build-up of the mustard aphid (Shenhamar and Brar, 1995). Therefore, it is desirable that the population density of this predator is maintained at a level, which will keep the pest below the economic injury level. Temperature and relative humidity influence the effectiveness of beetles; high temperature and low relative humidity favour their development but suppress aphids, whereas the reverse condition favours aphids (Kalushkov, 1990). Both biotic and abiotic factors determine success of coccinellid larvae in capturing their prey. They are voracious feeders and forage both extensively and intensively to seek aphids (Ferran and Dixon, 1993). Their peak population and that of *L. erysimi* are often not synchronous (Mohapatra *et al.*, 1994). Nevertheless, it is the significant correlation of coccinellid with aphid prey quality, which results in feeding preferences, longevity and reproduction potential (Babu and Ananthakrishnan, 1993). Henceforth, in the absence of suitable prey the adult coccinellid beetles cannibalise eggs and it is the females that are more reluctant, this increases their larval growth and survival (Agarwal and Dixon, 1992). Species with small eggs take longer to complete development than those with proportionally large eggs (Stewart *et al.*, 1991).

When *F. virgata* is provided as prey, the coccinellid beetles prefer potato tubers for oviposition (52.20%) to tubers, glass surface or markin cloth (37.89, 7.95 and 0.5%, respectively). Besides, they start ovipositing after fourth week of adult emergence with peak in the tenth week, whereas, aphid fed beetles start ovipositing in the eleventh week of adult emergence (Gautam, 1990).

Coccinellid beetles reared on *A. craccivora* at 16-20°C and 60-80% relative humidity require 14.79 to 21 days to complete development from egg to adult. The pre-oviposition period lasts for 6-10.33 days and the fecundity is 14.65 egg/day (Agarwal *et al.*, 1988). At a constant temperature of 20°C, *C. septempunctata* fed on *D. noxia* completes development in 13.8 days (Michels and Flanders, 1992). Whereas, *C. septempunctata* reared on *A. pisum* at 23±2°C and LD 16:8 completes development in 13.1 days and on *R. maidis* in 16 days (Obrycki and Orr, 1990). Nevertheless, rearing of *C. septempunctata* on *B. brassicae* at an average maximum and minimum temperature of 32.13 and 29.63°C results in duration of I, II, III and IV larval instars
of 2±0.35, 1.6±0.31, 1.33±0.16 and 2.33±0.25 days, respectively. 466±1.97 eggs was the fecundity at the above conditions (Nirmala Devi et al., 1996).

The net reproductive rate and mean length of generation under lab and field conditions, of C. septempunctata fed on L. erysimi are 95.88, 54.18 and 28.88, 28.68 days, respectively (Singh et al., 1994). During February-March the minimum, maximum and average duration of C. septempunctata on L. erysimi varies from 10-11, 6-17 and 13-14 days, respectively. Mean longevity of beetles in February (16.73 days) is greater than in March (13.52 days) (Singh et al., 1994).

The fourth instar larvae of C. septempunctata consume more aphids than their un-starved adults but fewer than starved adults (Gupta and Yadava, 1989) but later on in 1994, Singh and co-workers made a contradiction and stated that beetles had a greater feeding potential than grubs. They observed that adult beetles could consume 78 to 80 nymphs/day as compared to 57 to 58 by the larvae. It consumes 43.1 aphids per day of D. noxia (Michels and Flanders, 1992) and an average of 141.33±1.78 aphids/day of B. brassicae at an average maximum temperature of 32.13°C and minimum 26.63°C (Nirmala Devi et al., 1996).

When a comparison was made between different species, Shenhmar and Brar (1995) reported that C. septempunctata consumed more (380.4) aphids than C. sexmaculatus (304.3) during the larval development. Kumar (1992) reported that the larvae of C. septempunctata and C. sexmaculatus consumed 564.9 and 383.0 nymphs of L. erysimi during their development whereas, Singh et al., (1994) reported that the former consumed 867.5 aphids during February and 2047.5 in March. However, Verma et al., (1993) observed that C. sexmaulatus consumed 598.5 Aphis gossypii during its development while it fed on 350 to 400 nymphs of A. craccivora (Patel and Vyas, 1986).

Hoverflies/Syrphids, which are known to mimic honeybees, are also important aphidophagous predators. Their maggots feed on the aphids by puncturing the cuticle of the prey, and sucking the body fluids/contents. The maggots are eyeless and also lack legs, they are slug like, a single maggot can consume up to 500 aphids during its larval stage. The consumption of aphids varies from species to species. In India, a number of syrphid species have been reported to be aphid predators (Sharma and Verma, 1993 and Ghorpade, 1981). However, nine different species have been reported from the mustard-rapeseed ecosystem (Singh, 1994).
With bio-control in the limelight, entomologists felt it germane to study and investigate the extent to which maggots of syrphid can act as an effective tool in maintaining the mustard aphid population below the economic injury level. Twenty-five species of syrphids have been recorded from Punjab (Singh et al., 1990). The density of the predators’ *E. balteatus* and *M. confrater* is dependent upon the density of *M. persicae*. The temperature, relative humidity and rainfall significantly affect the population of syrphids as well as aphids (Kumar et al., 1989 and Bijaya Devi et al., 1997). Insectary plants such as annual alyssum; cilantro, buckwheat, mustard, phacelia, fennel and yarrow serve as food for hoverflies (Luna, 1998). Among the early season flowering species coriander is the choice food of most syrphid species while Korean mint among the late season flower (Colley and Luna, 2000).

Pea and rose aphids are preferred prey of syrphids and nettle aphid is least preferred (Sadeghi and Gilbert, 2000). The fourth instar nymphs of *L. erysimii* are preferred by syrphids as compared to second or third instar nymphs (Agarwal et al., 1989). Two types of mate seeking behaviour of male syrphids are recorded, firstly, they search for females in the feeding places and secondly, lie in wait for females in oviposition plots (Mulin, 1996). Oviposition is elicited on plant tissues with aphids or residues of aphids or aphid honeydew but not on clean plant tissues (Belliure and Michaud, 2001).

Adults of syrphids are best preserved at 2-4°C as they survive this temperature for 10 days and pupae at 0-4°C, which increases pupation period (Guo-Junfeng et al., 1992). In *Eristalis tenax* eclosion occurs after 2 days, fertilised eggs change from white to grey after 24 hrs. Pupation occurs in concealed places and adults eclose after 2 weeks. Each female provides five egg batches and lives up to 125 days. High mortality of flies is observed after 2-3 months (Rosso et al., 1994). The survival of *Pseudodorus clavatus* on *A. spiraecola* is 24% from egg to adult and on *T. citricida* 36%. But larval development is significantly faster on the latter aphid. Males live for a mean of 16.8±3.8 days and ovipositing females for 29.8±1.9 days at 23°C. Pre-reproductive period is 6d and the majority of eggs are laid during morning hours with peak oviposition between 08:30 to 10:30 hours. Radhakrishnan and Muraleedharan (1993) reported that different species of syrphids (*Episyphus balteatus*, *Paragus tibialis*, *Allobaccha nubilipennis*, *Betasyrphus serarius*, *Dideopsis aegrota* and *Ischiodon scutellaris*) required 18 to 22 days for their development at 26±2°C and
80±5% relative humidity, *E. balteatus* develops faster (29.4±4.7 SD days) than *M. confrater* (34.7±3.2 SD days) (Bhatia and Shaffi, 1932, and Bijaya Devi *et al.*, 1997). However, Joshi *et al.*, (1999) advocated 16.7 to 20.9 and 16.9 to 20.3 days development period for *I. scutellaris* and *Paragus serratus* (Fabricius) on different hosts.

The seven/eight day old larvae of aphidophagous syrphids consume the maximum number of aphids (Radhakrishnan and Muraleedharan, 1993). When aphidophagous syrphids are used for control, normally 3 to 6 days after treatment, the aphid’s reduction ratio reaches 80-90% or more (SunXing-quan *et al.*, 1992). At 28±2°C the larvae of *Chrysopa* sp. consume an average of 35.32, 146.05 and 363.56 nymphs and adults of *L. erysimi*, respectively, whereas larvae of *E. balteatus* consume 38.34, 196.36 and 274.50 aphids in the three larval instars, respectively (Singh and Singh, 1994). Under field conditions, larvae of *E. balteatus* and *M. confrater* consume 344±13.9 SD and 397±21.3 SD aphids/larva, respectively over a period of 10.4±3.5 SD and 11.7±6 SD days, respectively (Bijaya Devi *et al.*, 1997). *I. scutellaris* and *P. serratus* prefer *A. craccivora* to *A. gossypii* and exhibit high rate of consumption as well as fecundity (Joshi *et al.*, 1999). Predation of *T. citricida* colonies by *P. clavatus* results in the delay in production of alate and produces fewer apterous migrants than colonies that escape predation (Belliure and Michaud 2001). *Eupeodes confrater* is large species and possesses great voracity potential (Agarwal *et al.*, 1989). Natural enemies of *L. erysimi* infesting *B. juncea* var. *rugosa* belong to syrphids, coccinellids, hemerobid and aphidiid. Syrphids dominate the other species in terms of density, species composition and prey consumption potential (Chitra Devi *et al.*, 2002).

### 2.6 LIFE-TABLES

Life-table is a table of statistics of probability of life or simply it provides essential information regarding the schedule of mortality for a known cohort of individuals. They are one of the most useful tools in the study of insect population dynamics. These tables record a series of, sequential measurements that reveal population change throughout the life cycle of a species in its natural environment. When these measurements are related to the several causes of mortality, the life-table forms a budget of successive processes that operate in a given population (Harcourt, 1969).
Pearl and Parker (1921) were the pioneers to study life-tables for insect populations of *Drosophila melanogaster* and *Tribolium confusum*, they were followed by life insurance agencies (Dublin and Lotka, 1925). The life expectancy of small animals (Leslie and Ranson, 1940), birds (Park, 1948) and laboratory culture of insects (Birch, 1948, 1953a,b, Howe, 1953) were also dealt with later. Leopold (1933) studied natural populations, classical publication of Pearl and Miner (1935) for lower organisms and “Life-tables for natural population of animals” by Deevy (1947) are some of the initial works by these scientists. Later, Ito (1959), Slobodkin (1962), Morris (1963), Witter et al. (1972) Southwood (1978) dealt with life-tables and the importance of key factors providing means of identifying the potential role of parasitoids and predators in regulating the pest population. Their efforts were followed by Atwal and Bains (1974) on a pest of wheat *Trogoderma granarium*, Atwal and Singh (1974) on *Chilo partellus* a pest of maize, Bilapate et al., (1979) on *Helicoverpa armigera* on different food plants, on *Tryporyza nivella* (Roy and Bains, 1983), *Metasyrphus corolla* (Sharma and Bhalla, 1992), *C. septempunctata* (Singh et al., 1994) *Spilosoma obliqua* (Rizvi and Pathak, 1998), and *Papilio demoleus* (Pathak and Rizvi, 2002).