Field Life-Tables and Key Mortality Factors of *Plutella xylostella* Infesting Sole and Onion Intercropped Cabbage

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**A B S T R A C T**

The present investigation was made to study the field life-tables and key mortality factors of *Plutella xylostella* infesting sole and onion intercropped cabbage. *P. xylostella* passed through 3 and 2 generations on sole and onion intercropped cabbage, respectively during rainy season 2011. On sole cabbage the highest mortality of early and late instar larvae of *P. xylostella* in first, second and third generations during rainy season 2011 was observed to be 33.90, 37.62 and 32.73 per cent due to *Cotesia vestalis* followed by unknown causes (10.10, 13.52 and 0.00 per cent). While in onion intercropped cabbage, the highest mortality of early and late instar larvae of *P. xylostella* was observed to be 37.69 and 35.25 per cent due to *Cotesia vestalis* followed by unknown causes (14.62 and 8.10 per cent in first and second generations, respectively). Pupal mortality was observed to the extent of 6.08 and 13.61 per cent in first and second generations, respectively due to *Tetrastichus* sp. One generation of *P. xylostella* was reduced on onion intercropped cabbage as compared to sole crop of cabbage. During rainy seasons of 2011, the trend indices of *P. xylostella* were 0.52, 0.29 and 0.00 in first, second and third generations, respectively on sole cabbage and 0.42 and 0.00 in first and second generations, respectively on onion intercropped cabbage.

**Keywords**

*Plutella xylostella*, field life-tables, Key mortality factors, Cabbage, Onion

**Introduction**

The graph of world’s population has been increasing continuously and as a result, food requirement has also increased. Agriculture takes a vow of providing food to all. Vegetables play a vital role in ensuring the health and nutritional security of human beings in addition to improve the economy of the people of the country. Cabbage (*Brassica oleracea var capitata* L.) is a cold loving plant and is supposed to have originated in Mediterranean region. This crop is grown in China, India, Poland, Rumania, U.S.A., Canada etc. In India, it is grown mainly in West Bengal, Bihar, Assam, Karnataka, Maharashtra, Gujarat and Tamil Nadu. It is grown over an area of about 3.79 lakh hectares and production is about 85.81 lakh metric tonnes with productivity of 22.0 metric tonnes per hectare in India. In Maharashtra the annual production of cabbage was 1.55 lakh metric tonnes from an area of 7.15 thousand hectares in 2014-15 with a productivity of 26.0 metric tonnes per hectare (Anonymous, 2017).
Cabbage has been reported to be attacked by number of insects-pests. More than 27 species of insect-pests were recorded on cabbage in India (Bhatia and Verma, 1993). The insect-pests viz., diamondback moth (*Plutella xylostella* Linnaeus), cabbage butterfly (*Pieris brassicae* Linnaeus), tobacco caterpillar (*Spodoptera litura* Fabricius), cabbage semilooper (*Trichoplusia ni* Hubner), aphids (*Brevicoryne brassicae* Linnaeus), painted bug (*Bagradauges brassicae* Kirkaldy), cabbage leaf webber (*Crocidolomia binotalis* Zeller), cabbage borer (*Hellula undalis* Fabricius), cabbage flea beetle (*Phyllotreta cruciferae* Goeze) and Bihar hairy caterpillar (*Spilosoma obliqua* Walk) are observed commonly on cabbage in different seasons and cause considerable losses.

The diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is an oligophageous pest of plants in the family Brassicaceae (Furlong *et al.*, 2013). Diamondback moth is cosmopolitan in distribution (Hill, 1975 and Zhang, 1994) and causes serious economic losses worldwide (Jankowska & Wiech, 2006). Worldwide, this pest generates losses of over 80% (U.S. $4 to U.S. $5 billion) in annual crop production (Verkerk & Wright, 1996; Sarfraz *et al.*, 2005; Zalucki *et al.*, 2012). In India, it was first recorded on cruciferous vegetables in 1914 (Fletcher, 1914) and now it is distributed throughout the country. Pandey and Raju (2003) found diamondback moth as most devastating pest of cole crops in the states of Punjab, Haryana, Himachal Pradesh, Uttar Pradesh, Bihar, Maharashtra, Tamil Nadu and Karnataka. It has a pest status of national importance. Annual cost of managing this pest was estimated to be 1 billion U.S. dollars (Talekar and Shelton, 1993). Krishnakumar *et al.*, (1983) estimated about 52 per cent losses in marketable yield due to the diamondback moth. The losses could be more than 80 per cent under severe infestation of diamondback moth on cabbage (Cheliah and Srinivasan, 1986). Sarfraz & Keddie (2005) reported the physiological capacity of *P. xylostella* detoxify glucosinolates, the natural defense system of Brassicaceae.

Life-tables and key mortality factors are one of the tools most useful in the study of insect population dynamics. Field life-tables and key mortality factors may be analysed to determine what stage in the life cycle of an insect contributes the most when series of life-tables are available (Atwal and Bains, 1974). The construction of field life-tables provides a useful approach to pest management strategies. Life-tables are particularly well suited to the population and analysis of population trends (Harcourt, 1970). A key factor is any biological or environmental condition associated with mortality that is useful in predicting future trend in a population (Morris, 1959). The uses of field life-tables have been made recently for studying the natural population of insect pests when the environmental parameters are related to several causes of mortality of pests. The field life-tables form a budget of the successive process that operates in a given population (Harcourt, 1966 and 1969).

Recently, emphasis is being given on ecological basis of pest control based on suitable integrated pest management strategies. As cabbage crop is heavily infested by *Plutella xylostella*, it is necessary to study the effect of intercropping of onion with cabbage on population fluctuations and field life-tables of lepidopterous pests in comparison to sole crop of cabbage.

**Materials and Methods**

The investigations on field life-tables and key mortality factors of *Plutella xylostella* infesting sole and onion intercropped cabbage
were carried out at the Department of Agricultural Entomology, College of Agriculture, Latur during rainy season 2011.

**Experimental details**

The non-replicated field experiment comprising eighty quadrats of $1.80 \times 1.80 \ m^2$ size each was during rainy season, 2011 to investigate and prepare field life-tables of *Plutella xylostella* infesting sole and onion intercropped cabbage. The cabbage variety, Golden acre was transplanted at the spacing of $60 \times 60 \ cm^2$ in eighty quadrats and out of these forty quadrats were intercropped with onion variety, N-53 with spacing of $10 \times 20 \ cm^2$. The field experiment was conducted under pesticide free condition.

**Field generation studies**

After transplanting four weeks old seedlings, frequent field visits were made in order to record the first incidence (egg stage) of *Plutella xylostella* of cabbage. After having made frequent field visits at regular intervals, the known number of eggs as a start of first generation of the pest were collected along with the plant material. After hatching of these eggs, the larvae were reared on cabbage in clean plastic boxes of $5\times5\times5 \ cm$ size till the cessation of pest population in the field. This culture was considered as a check culture for deciding the number of regular generations of pests under field conditions.

The sampling of early and late instar larvae was done on the basis of development of pests in the laboratory reared culture. At each observation, three quadrats from each sole and onion intercropped cabbage were carefully examined twice in a week for the number of larvae of *P. xylostella*. The field collected larvae and pupae were brought to the laboratory and reared on cabbage. This was referred to as a field culture. The food was changed as and when required. The culture was reared till adult emergence.

The observations were made on the larval and pupal parasitism as well as mortality because of unknown reasons and entomopathogens in early and late larval instars and pupal stage as well. An interval of four to six days was provided before sampling of eggs of next generation after the mean adult emergence of previous generation. This period was considered for completion of oviposition by moths of the previous generation.

**Preparation of life tables**

The column headings proposed by Morris and Miller (1954) and Harcourt (1969) were used in the life-tables of the present study. Harcourt (1963) had proposed the criteria for filling the data in the life-table for each age interval (stage). The same criteria were used in this study. Trend analysis and generation survival percentage were calculated based on the obtained data.

**Results and Discussion**

The studies on field life-tables of *Plutella xylostella* infesting sole and onion intercropped cabbage was undertaken at the Department of Agricultural Entomology, College of Agriculture, Latur during rainy seasons 2011. The results obtained during the course of experimentation are presented under the following headings:

**First Generation**

The results on field life-tables and key mortality factors of *P. xylostella* on sole cabbage and onion intercropped cabbage in first generation during rainy season 2011 are presented in Table 1, 2, 3 and 4. It is evident from Table 1 and 3 that the incidence of *P. xylostella* was first recorded in 33rd
meteorological week. On sole cabbage, due to sterility 5 per cent eggs did not hatch into the larvae. The mortality of early instar larvae to the extent of 6.87 per cent was observed due to *Cotesia vestalis* Haliday (Braconidae). However, the mortality of late instar larvae to the extent of 27.03 and 10.10 per cent was observed due to *Cotesia vestalis* and unknown reasons, respectively. The pupal mortality (7.49 per cent) was observed due to unknown reasons. The negative trend index (0.52) revealed that the mortality factors operated during first generation were effective in suppressing the population of *P. xylostella* in second generation. The generation survival was 0.56. Table 2 showed that the maximum contribution towards generation mortality came from late instar larvae (k= 0.1831) followed by pupae (k=0.0338). The total ‘K’ for all life-stages was 0.5712. On onion intercropped cabbage, 5 per cent eggs did not hatch into the larvae due to sterility. The mortality of early (10.18 and 3.78 per cent) and late (27.51 and 10.84 per cent) instar larvae were killed due to *Cotesia vestalis* and unknown reasons, respectively. The pupal mortality to the extent of 7.61 and 8.48 per cent was due to *Tetrastichus* sp. and unknown reasons, respectively. The generation survival was 0.47. Zero trend index indicated that the pest population of *P. xylostella* ceased after second generation. Table 8 showed that the maximum contribution towards generation mortality came from late instar larvae (K= 0.1887) followed by pupal stage (K=0.0636). The total ‘K’ for all life-stages was 0.6125.

Second generation

The results on key mortality factors of *P. xylostella* infesting sole and onion intercropped cabbage for second generation during rainy season 2011 are summarized in Table 5, 6, 7 and 8. The data (Table 5 and 7) revealed that 5 per cent eggs did not hatch into larvae due to sterility in each of the cropping pattern. On sole cabbage early instar larvae to the extent of 8.77 per cent were killed by *C. vestalis*. Whereas, the mortality of late instar larvae to the extent of 28.85 and 13.52 per cent was observed due to *C. vestalis* and unknown reasons. The pupal mortality to the extent of 7.61 and 8.48 per cent was due to *Tetrastichus* sp. and unknown reasons, respectively. The generation survival was 0.47. The negative trend index (0.29) revealed that the mortality factors operated during second generation were effective in suppressing the population of *P. xylostella* in third generation. Table 6 showed that the maximum contribution towards generation mortality came from late instar larva (K= 0.2109) followed by pupal stage (K=0.0738). The total ‘K’ for all life-stages was 0.6479. The results on key mortality factors of *P. xylostella* infesting onion intercropped cabbage for second generation (Table 7) revealed that early instar larvae to the extent of 8.10 per cent were killed by unknown reasons. Whereas, the late instar larvae to the extent of 35.25 per cent were parasitized by *Cotesia vestalis*. The pupal mortality to the extent of 13.61 per cent was due to *Tetrastichus* sp. The generation survival was 0.51. Zero trend index indicated that the pest population of *P. xylostella* ceased after second generation. Table 8 showed that the maximum contribution towards generation mortality came from late instar larvae (K= 0.1887) followed by pupal stage (K=0.0636). The total ‘K’ for all life-stages was 0.6125.

Third generation

The results on key mortality factors of *P. xylostella* infesting sole cabbage for third generation during rainy season 2011 are summarized in Table 9 and 10. The data (Table 9 and 10) revealed that 5 per cent eggs did not hatch into larvae due to sterility. On sole cabbage early instar larvae to the extent
of 15.03 per cent were killed by *Cotesia vestalis*. The corresponding mortality of late instar larvae was 17.70 per cent. The pupal mortality to the tune of 21.50 per cent was due to *Tetrastichus* sp. The generation survival was 0.54. The pest population ceased after third generation (trend index = Zero). It is evident from Table 10 that maximum mortality of *P. xylostella* was observed in pupal stage (k= 0.1051) followed by late instar larvae (k = 0.0846). The total K’s was 0.5838.

The larval parasitoid viz., *Cotesia vestalis* and pupal parasitoid viz., *Tetrastichus* sp. were found to be major mortality factors of *P. xylostella*. The larval parasitization of *P. xylostella* on sole and onion intercropped cabbage varied from 32.73 to 37.62 and 35.25 to 37.69 per cent due to *C. vestalis* during rainy season 2011. While, its pupal mortality due to *Tetrastichus* sp. ranged from 7.61 to 21.50 and 6.08 to 13.61 per cent. The late larval instar of *P. xylostella* was observed to be parasitized more than its early larval instars. Yadav *et al.*, (1975 and 1979) reported that *P. xylostella* was found to be parasitized to the extent of 66 and 77.7 per cent by *Cotesia plutellae* during August 1973 and September 1974, respectively.

### Table.1 Key mortality factors of *P. xylostella* on sole cabbage for first generation

| Age interval               | Number alive / ha at the beginning of x | Factors responsible for d_x | Number dying during x | d_x as % of l_x | Survival rate at age x |
|----------------------------|-----------------------------------------|-----------------------------|-----------------------|-----------------|------------------------|
| Expected eggs              | 15775                                   | Sterility                  | 789                   | 5.00            |                        |
| Viable eggs                | 14986                                   | -                           |                       |                 |                        |
| **Larval population**      |                                          |                             |                       |                 |                        |
| Early instar larvae (N_1) | 14986                                   | *Cotesia vestalis*         | 1029                  | 6.87            | 0.93                   |
| Late instar larvae         | 13957                                   | *Cotesia vestalis*         | 3773                  | 27.03           | 0.65                   |
|                           | 10184                                   | Unknown reasons            | 1029                  | 10.10           |                        |
| Pupae                     | 9155                                    | Unknown reasons            | 686                   | 7.49            | 0.92                   |
| Moths                     | 8469                                    | Sex 50 % females           |                       |                 |                        |
| Females x 2 (N_3)         | 8469                                    | (Reproducing females= 4234)|                       |                 |                        |
| Trend index (N_2/N_1)     |                                          |                             | 0.52                  |                 | -                      |
| Generation survival (N_3 / N_1) |                                   |                             | 0.56                  |                 | -                      |
Table 2: Budget of P. xylostella on sole cabbage for first generation

| Age interval                                      | Number / ha | Log No./ha | ‘k’ values |
|--------------------------------------------------|-------------|------------|------------|
| Expected Eggs                                    | 15775       | 4.1979     | -          |
| Viable Eggs                                      | 14986       | 4.1756     | 0.0223     |
| Early instar larvae                              | 14986       | 4.1756     | 0.0000     |
| After mortality due to parasitoid - Late instar larvae | 13957       | 4.1447     | 0.0309     |
| After mortality due to parasitoid and unknown reasons - Pupae | 9155        | 3.9616     | 0.1831     |
| After mortality due to unknown reasons - Moths   | 8469        | 3.9278     | 0.0338     |
| Reproducing females                              | 4234        | 3.6267     | 0.3011     |

K = 0.5712

Table 3: Key mortality factors of P. xylostella on onion intercropped cabbage for first generation

| Age interval                                      | Number alive /ha at the beginning of x | Factors responsible for d<sub>x</sub> | No. dying during x | d<sub>x</sub> as % of l<sub>x</sub> | Survival rate at age x |
|--------------------------------------------------|----------------------------------------|--------------------------------------|-------------------|----------------------------------|-----------------------|
| X                                                | l<sub>x</sub>                          | d<sub>x</sub>F                        | d<sub>x</sub>      | 100 q<sub>x</sub>                | S<sub>x</sub>          |
| Expected eggs                                    | 10631                                  | Sterility                            | 531               | 5.00                             |                       |
| Viable eggs                                      | 10100                                  | -                                    |                   |                                  |                       |

Larval population

| Age interval                                      | Number alive /ha | Factors responsible for d<sub>x</sub> | No. dying during x | d<sub>x</sub> as % of l<sub>x</sub> | Survival rate at age x |
|--------------------------------------------------|------------------|--------------------------------------|-------------------|----------------------------------|-----------------------|
| Early instar larvae (N₁)                         | 10100            | Cotesia vestalis                      | 1029              | 10.18                            | 0.86                  |
|                                                  | 9071             | Unknown reasons                      | 343               | 3.78                             |                       |
| Late instar larvae                               | 8728             | Cotesia vestalis                      | 2401              | 27.51                            | 0.65                  |
|                                                  | 6327             | Unknown reasons                      | 686               | 10.84                            |                       |
| Pupae                                            | 5641             | Tetrastichusssp.                     | 343               | 6.08                             | 0.94                  |
| Moths                                            | 5298             | Sex 50 % females                     |                   |                                  |                       |
| Females x 2 (N₃)                                 | 5298             | (Reproducing females = 2649)         |                   |                                  |                       |
| Trend index (N₂/N₁)                              |                  |                                      |                   | 0.42                             | -                     |
| Generation survival (N₃ / N₁)                     |                  |                                      |                   | 0.52                             | -                     |
Table 4: Budget of *P. xylostella* on onion intercropped cabbage for first generation

| Age interval                                      | Number / ha | Log No./ha | ‘k’ values |
|--------------------------------------------------|-------------|------------|------------|
| Expected Eggs                                    | 10631       | 4.0265     | -          |
| Viable Eggs                                      | 10100       | 4.0043     | 0.0222     |
| Early instar larvae                              | 10100       | 4.0043     | 0.0000     |
| After mortality due to parasitoid and unknown reasons - Late instar larvae | 8728       | 3.9409     | 0.0634     |
| After mortality due to parasitoid and unknown reasons - Pupae | 5641       | 3.7513     | 0.1896     |
| After mortality due to parasitoid and Moths      | 5298        | 3.721      | 0.0272     |
| Reproducing females                              | 2649        | 3.4230     | 0.3011     |
|                                                  |             |            | K = 0.6035 |

Table 5: Key mortality factors of *P. xylostella* on sole cabbage for second generation

| Age interval          | Number alive / ha at the beginning of x | Factors responsible for \(d_x\) | Number dying during \(x\) \(d_x\) as % of \(l_x\) | Survival rate at age \(x\) |
|-----------------------|----------------------------------------|---------------------------------|-------------------------------------------------|-----------------------------|
| X                     | \(l_x\)                                 | \(d_x F\)                       | \(d_x\)                                         | \(100 q_x S_x\)             |
| Expected eggs         | 8230                                    | Sterility                       | 411                                             | 5.00                        |
| Viable eggs           | 7819                                    |                                 |                                                 |                             |
| **Larval population** |                                        |                                 |                                                 |                             |
| Early instar larvae (N\(_1\)) | 7819                           | *Cotesia vestalis*              | 686                                             | 8.77                        | 0.91                        |
| Late instar larvae    | 7133                                    | *Cotesia vestalis*              | 2058                                            | 28.85                       | 0.61                        |
|                       |                                        | Unknown reasons                 | 686                                             | 13.52                       |                             |
| Pupae                 | 4389                                    | *Tetrastichus spp.*             | 343                                             | 7.61                        | 0.84                        |
|                       |                                        | Unknown reasons                 | 343                                             | 8.48                        |                             |
| Moths                 | 3703                                    | Sex 50 % females                |                                                 |                             |                             |
| Females x 2 (N\(_3\)) | 3703                                 | (Reproducing females = 1851)    |                                                 |                             |                             |
| Trend index (N\(_2\)/N\(_1\)) |                                      |                                  | 0.29                                            | -                           | -                           |
| Generation survival (N\(_3\) / N\(_1\)) |                                  |                                  | 0.47                                            | -                           | -                           |
### Table 6: Budget of *P. xylostella* on sole cabbage for second generation

| Age interval                        | Number / ha | Log No./ha | ‘k’ values |
|-------------------------------------|-------------|------------|------------|
| Expected Eggs                       | 8230        | 3.9153     | -          |
| Viable Eggs                         | 7819        | 3.8931     | 0.0222     |
| Early instar larvae                 | 7819        | 3.8931     | 0.0000     |
| After mortality due to parasitoid   |             |            |            |
| Late instar larvae                  | 7133        | 3.8532     | 0.0399     |
| After mortality due to parasitoid   |             |            |            |
| and unknown reasons                 | 4389        | 3.6423     | 0.2109     |
| Pupae                               |             |            |            |
| After mortality due to parasitoid   |             |            |            |
| and unknown reasons                 | 3703        | 3.5685     | 0.0738     |
| Moths                               |             |            |            |
| Reproducing females                 | 1851        | 3.2674     | 0.3011     |

K = 0.6479

### Table 7: Key mortality factors of *P. xylostella* on onion intercropped cabbage for second generation

| Age interval                        | Number alive /ha at the beginning of x | Factors responsible for d<sub>x</sub> | Number dying during x | d<sub>x</sub> as % of l<sub>x</sub> | Survival rate at age x |
|-------------------------------------|----------------------------------------|--------------------------------------|------------------------|-------------------------------------|------------------------|
| Expected eggs                       | 4458                                   | Sterility                            | 223                    | 5.00                                |                        |
| Viable eggs                         | 4235                                   |                                       |                        |                                    |                        |

**Larval population**

| Age interval                        | Number | Factors responsible for d<sub>x</sub> | Number dying during x | d<sub>x</sub> as % of l<sub>x</sub> | Survival rate at age x |
|-------------------------------------|--------|---------------------------------------|------------------------|-------------------------------------|------------------------|
| Early instar larvae (N<sub>1</sub>)| 4235   | Unknown reasons                       | 343                    | 8.10                                | 0.92                   |
| Late instar larvae                  | 3892   | *Cotesia vestalis*                    | 1372                   | 35.25                               | 0.65                   |
| Pupae                               | 2520   | *Tetrastichus* sp.                    | 343                    | 13.61                               |                        |
| Moths                               | 2177   | Sex 50 %females                       | -                      |                                     |                        |
| Females x 2 (N<sub>3</sub>)         | 2177   | (Reproducing females= 1088)           | -                      |                                     |                        |
| Trend index (N<sub>3</sub>/N<sub>1</sub>) | 0.00   | -                                     | -                      | -                                   | -                      |
| Generation survival (N<sub>3</sub>/ N<sub>1</sub>) | 0.51   | -                                     | -                      | -                                   | -                      |
### Table 8: Budget of *P. xylostella* on onion intercropped cabbage for second generation

| Age interval                                      | Number / ha | Log No./ha | ‘k’ values |
|--------------------------------------------------|-------------|------------|------------|
| Expected Eggs                                    | 4458        | 3.6491     | -          |
| Viable Eggs                                      | 4235        | 3.6268     | 0.0223     |
| Early instar larvae                              | 4235        | 3.6268     | 0.0000     |
| After mortality due to unknown reasons           | 3892        | 3.5901     | 0.0367     |
| Late instar larvae                               | 2520        | 3.4014     | 0.1887     |
| After mortality due to parasitoid Pupae          | 2177        | 3.3378     | 0.0636     |
| After mortality due to parasitoid Moths          | 1088        | 3.0366     | 0.3012     |
| Reproducing females                              |             | K = 0.6125 |            |

### Table 9: Key mortality factors of *P. xylostella* on sole cabbage for third generation

| Age interval                                      | Number alive / ha at the beginning of x | Factors responsible for $d_x$ | Number dying during x | $d_x$ as % of $l_x$ | Survival rate at age x |
|--------------------------------------------------|----------------------------------------|-------------------------------|------------------------|---------------------|------------------------|
| X                                                | $l_x$                                   | $d_x F$                       | $d_x$                  | 100 $q_x$           | $S_x$                  |
| Expected eggs                                     | 2401                                   | Sterility                     | 120                    | 5.00                |
| Viable eggs                                       | 2281                                   | -                              |                        |

**Larval population**

| Age interval                                      | Number alive / ha | Factors responsible for $d_x$ | Number dying during x | $d_x$ as % of $l_x$ | Survival rate at age x |
|--------------------------------------------------|-------------------|-------------------------------|------------------------|---------------------|------------------------|
| Early instar larvae ($N_1$)                       | 2281              | *Cotesia vestalis*            | 343                    | 15.03               | 0.85                   |
| Late instar larvae                                | 1938              | *Cotesia vestalis*            | 343                    | 17.70               | 0.82                   |
| Pupae                                            | 1595              | *Tetrastichus* spp.           | 343                    | 21.50               | 0.78                   |
| Moths                                            | 1252              | Sex 50 % females              |                        |                     |                        |
| Females x 2 ($N_3$)                               | 1252              | (Reproducing females = 626)   |                        |                     |                        |
| Trend index ($N_2/N_1$)                           | 0.00              | -                             | -                      | -                   |                        |
| Generation survival ($N_3 / N_1$)                 | 0.54              | -                             | -                      | -                   |                        |
Table 10 Budget of *P. xylostella* on sole cabbage for third generation

| Age interval                                      | Number / ha | Log No./ha | ‘k’ values |
|--------------------------------------------------|-------------|------------|------------|
| Expected Eggs                                    | 2401        | 3.3803     | -          |
| Viable Eggs                                      | 2281        | 3.3581     | 0.0222     |
| Early instar larvae                              | 2281        | 3.3581     | 0.0000     |
| After mortality due to parasitoid - Late instar larvae | 1938        | 3.2873     | 0.0708     |
| After mortality due to parasitoid - Pupae        | 1595        | 3.2027     | 0.0846     |
| After mortality due to parasitoid - Moths        | 1252        | 3.0976     | 0.1051     |
| Reproducing females                              | 626         | 2.7965     | 0.3011     |

K = 0.5838

The larvae and pupae of diamondback moth were reported to be parasitized by *T. sokolowskii* and *A. plutellae* in Hebbal area of Bangalore (Jayarathanam, 1977). Cheliah and Srinivasan (1986) reported that *A. plutellae* parasitizing upto 72 per cent and *Tetrastichussokolowskii* were found to be dominant larval and pupal parasitoids of *P. xylostella* on cabbage. Bertolaccini *et al.*, (2011) demonstrated that *Diadegmaunesulare* and *Oomyzussokolowskii* were found to be the most successful parasitoids against *P. xylostella*. *Cotesia vestalis* was found attracted to blend of sabinene, n-heptanal, α-pinene, and (Z)-3 hexenyl acetate at ratios 1.8:1.3:2.0:3.0 (Uefune *et al.*, 2012). In South Africa, it is the most efficient species often accounting for more than 80 % of total parasitism levels of *P. xylostella* (Nofemela, 2013; Bopape *et al.*, 2014). As far as *Cotesia vestalis* and *Tetrastichus* sp. are concerned the results of the present investigations on parasitoid of *P. xylostella* are in conformity with the results reported by earlier workers.

Srinivasan and Krishna (1991) reported that intercropping of non-host crops such as onion, tomatoes and pepper in cabbage could lead to the disruption of lifecycle of *P. xylostella*. Said and Itulya (2003) found that onion has repellent effect on diamondback moth. Asare-Bediako *et al.*, (2010) recorded less infestation of diamondback moth on cabbage intercropped with onion and tomato. Cai *et al.*, (2011) proved that increase in size and pupal mortality was significantly higher in *P. xylostella*, when Chinese cabbage (*Brassica chinensis*) was intercropped with garlic (*Allium sativum*) and lettuce (*Lactuca sativa*).

Elwell and Mass (1995) reported that tomato and onion released compounds have repellent effect on adult diamondback moth. Renwick (1999) reported that garlic and other plants in the Allium family release strong volatiles which can reduce the attraction of phytophagous insects. Presence of saponin, a feeding deterrent, is a major reason for the low survival of *P. xylostella* on *Barbarea vulgaris* (Shinoda *et al.*, 2002; Agerbirk *et al.*, 2003).

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