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# Field life tables and key mortality factors of Helicoverpa armigera infesting tomato *(Solanum lycopersicum)*

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ABSTRACT

Field life table studies of Helicoverpa armigera (Hübner) infesting tomato *(Solanum lycopersicum L.)* were undertaken during 2018 and 2019 at research farm of Punjab Agricultural University, Ludhiana, Punjab. Key mortality factors observed in early and late larval instar groups were *Campoletis chlorideae* (Uchida), *Beauveria bassiana* (Bals.), *Ha*NPV, *Bacillus thuringiensis* (Berliner), along with other unknown factors. The egg stage was the most vulnerable exhibiting the highest loss (32.0–91.0%) during main and spring season tomato crop followed by early larval stage (40.27–44.86%), late larval stage (35.84–40.95%), and pupal (24.45–29.23%) stage. Trend index was positive (4.54) on main season crop which showed that total mortality factors during this season were not effective in causing the pest decline and it was negative (0.22) on spring season crop which depicted that total mortality factors were more effective and the chances of increase in population during next season would be less. Generation survival was highest on main season crop (0.29) as compared to spring season (0.23) and indicated that maximum generation survival was in main season whereas, in spring season the generation survival was lower and contributed maximum towards mortality.

*Type your text* **Keywords**: Field life table, *Helicoverpa armigera*, Mortality factors, Survivorship, Tomato

Tomato *(Solanum lycopersicum L.)* is one of the most important and widely grown vegetable crops in the world with a high nutritive value. Many abiotic and biotic factors are responsible for low productivity and production of tomato crop in India. *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) is one of the major biotic factors limiting the quality of tomato production (Sarwar *et al.* 2014). Many chemical insecticides have been used for controlling *H. armigera,* but the pest could not be brought under control as these chemicals negatively affect natural enemies (Bisane *et al.* 2009) and are thus responsible for ecological disturbances. The life table studies have been considered not only as one of the most important approaches for understanding population dynamics (Harcourt 1969) but also the most significant tools in pest management, revealing the most vulnerable stage of the insects in the life cycle. Such ecological life tables provide a base to quantify rates of death from various factors over the course of a generation (Naranjo and Ellsworth 1999) in its natural environment (Harcourt 1969). Thus, in order to develop a better understanding of the variation in demography of the pest, it is necessary to develop life tables for *H. armigera* under different conditions. Despite an enormous volume of research work on influence of various abiotic and biotic factors on buildup of *H. armigera* population that has been used for constructing its life tables, the published studies that focused on the ecology of this pest continuously over two crop seasons are not available in India. Hence, the present investigation was carried out to study the population fluctuations through life tables for identifying key mortality factors of *H. armigera* on tomato crop and formulate suitable integrated management strategy under field conditions.

## MATERIALS AND METHODS

The present investigation on life table studies of *H. armigera* in tomato was carried out at Entomological Research Farm, Punjab Agricultural University, Ludhiana, Punjab during 2018 and 2019. The mean maximum and minimum temperature from February to August during 2018 and 2019 ranged between 22.83–39.18°C; 19.58–40.92°C and 9.14–27.16°C; 8.32–27.2°C, respectively. Mean rainfall during both the years was 648.4 and 744.3 mm with relative humidity in range of 36.23–75.81%. The crop was raised as per recommended practices. Different life stages of *H. armigera* were collected from an unsprayed tomato crop and reared for recording the mortality of different stages of the pest due to different parasitoids and other reasons. The life table was prepared for the entire season instead of generation as it has overlapping generations. In order to record the absolute population of the pest, sample quadrates of 2 m × 2 m were used. The pest was sampled from 20

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quadrates at weekly interval from main (February–March) and spring season (April–May) crop during 2018 and 2019, respectively. The eggs were collected at weekly interval and brought in the laboratory to record mortality due to infertility and parasitism. For the ease of sampling, the larval instars were grouped into two categories. The stage I–III was considered as early larval instar and IV–V as late larval instar. In each observation, the number of larvae as counted from 20 randomly selected quadrates and the population was computed on hectare basis.

The different stages of larvae were collected at weekly interval and reared individually in specimen tubes (37 mm × 5 mm) containing fresh leaves or tomato fruits until pupation for recording mortality. The pre-pupal larvae were collected as soon as they appeared in field and kept in glass jars having about 2 cm layer of sand at their base for adult emergence and observations on the number of deformed pupae, unsuccessful emergence and unknown causes were recorded. The individual pair of male and female pest that emerged from pupae were released in a glass jar (15 cm × 10 cm) covered with a filter paper from inside and black chart from outside for mating and egg laying. The freshly laid eggs were collected daily and used for fecundity studies. The data on development and survival of *H. armigera* and its natural enemies were collected for the construction of life table. The observations were recorded for pivotal age (egg, larva, pupa, adult); number of individuals in the beginning; number of individuals died; factors responsible for death; per cent apparent mortality; survival rate.

The criteria and procedures as proposed by Harcourt (1963), Atwal and Bains (1974) for constructing the life table for different developmental stages were followed. Survival ($l_x$) and mortality ($d_x$) of eggs was calculated on the basis of collected eggs from main and spring season crop. Younger larvae included first, second and third larval instars. The $l_x$ value for this group of larvae was calculated by direct sampling of the quadrates and computed on hectare basis. Older larvae included fourth and fifth larvae instars. The $l_x$ value for older larvae was calculated by deducting the larval mortality due to factors like parasitoids, fungus, virus, bacteria and unknown reasons from the younger larval population. The $l_x$ value for pupa was calculated by subtracting the mortality caused by parasitoid, virus, fungus, bacteria and unknown factors from the older group of larvae. The $l_x$ for moths was calculated on the basis of number of adults emerged from the pupa. Mortality reported during pupal stage was subtracted from the $l_x$ of pupae. The value of Trend Index 'I' was computed by taking the population of same developmental stage in two successive generations i.e. $N_2/N_1$. Generation survival (SG) is the ratio of population of individuals in the first developmental stage to the population of individuals in the last of generation. It was calculated by taking the ratio of females × 2 ($N_3$) to younger larvae ($N_1$) i.e. $N_3/N_1$.

*Identification of key mortality factors*: The most important step in explaining the population fluctuations is to determine the stage in the life of the pest which has major contribution to the index of population trend (I) or generation survival (SG). A separate budget was prepared to find out the key factors that mainly influenced the population trend in both the main and spring season tomato crop. The method of key factors analysis has been developed by Richards (1961) and by this method, the killing power (k) of such mortality factors in each age group was estimated as the difference between the logarithms of population density before and after its action.

As a series of mortality factors operate in succession during generation of a population, the total killing power of 'K' is equal to the sum of the killing power of k's. If,

$K_0$= log $l_x$ of egg stage - log $l_x$ of younger larval stage

$K_1$ = log $l_x$ of younger larval stage - log $l_x$ of older larval stage

$K_2$ = log $l_x$ of older larval stage - log $l_x$ of pupal stage

$K_n$= log $l_x$ of pupal stage - log $l_x$ of adult stage

Thus, 'K' is equal to $k_0 + k_1 + k_2 + k_n$

*Survivorship curve*: Differences in *H. armigera* population trend on tomato crop were best shown through survivorship curves as described by Southwood (1978). A survivorship curve is a graphical representation which shows what fraction of a starting group is still alive at each successive age in which the number (y axis) at a given age ($l_x$) is plotted against age (x). Generally four types of curves are obtained which explain the action of mortality factors in different ways.

## RESULTS AND DISCUSSION

The highest mortality (Table 1) was observed in early instar larval stage (40.27%) followed by late instar larval stage (35.84%), egg stage (32.00%) and pupal stage (24.45%). The egg mortality in *H. armigera* was mainly due to infertility as no egg parasitization was recorded. The mortality of first instar larvae ranged from 2.33 to 13.78% and was primarily caused by larval parasitoid, *Campoletis chlorideae* Uchida (13.78%) followed by HaNPV (12.18%) and unknown causes (8.84%). *Beauveria bassiana* (Bals.) and *Bacillus thuringiensis* (Berliner) accounted for low mortality of 3.15% and 2.33%, respectively. In the early instar larvae, which initially comprised of 12070 larvae, only 7209 survived. In case of late instar larvae, the mortality ranged from 3.52 to 11.83% during the main season crop. Infection by *Ha*NPV alone accounted for 11.83% mortality, whereas, *C. chlorideae, B. bassiana* and unknown factors contributed 10.54, 3.52 and 9.95% mortality, respectively. Only 4625 number of late instar larvae survived at the end of their age interval.

In the pupal stage, unsuccessful emergence of adults (10.13%) followed by pupal deformity (8.09%) and unknown reasons (6.23%) were the main mortality factors that contributed about 24.45% pupal mortality operating under field conditions. The generation survival of 0.29 indicated that only 29% of the initial population could survive and successfully complete their generation. The positive trend index on main season tomato crop was 4.54 which showed

Table 1 Life table of *H. armigera* for main season tomato crop (February-March) during 2018 and 2019

| Age interval | No. of individuals in the beginning | Factor responsible for death | No. of individuals died | Mortality per cent | Survival rate |
|---|---|---|---|---|---|
| x | $l_x$ | $d_{x\,F}$ | $d_x$ | 100qx | $S_x$ |
| Eggs | 17750 | Sterility/Mortality | 5680 | 32.00 | 0.68 |
| | | *Campoletis chlorideae* | 1663 | 13.78 | |
| | | *Ha*NPV | 1470 | 12.18 | |
| Early Instar larvae (I-III instar) | 12070 | Fungus (*Beauveria bassiana*) | 380 | 3.15 | 0.60 |
| ($N_1$) | | Bacteria (*Bacillus thuringiensis*) | 281 | 2.33 | |
| | | Unknown factors | 1067 | 8.84 | |
| | | Total | 4861 | 40.27 | |
| | | *Campoletis chlorideae* | 760 | 10.54 | |
| | | *Ha*NPV | 853 | 11.83 | |
| Late instar larvae (IV-V) | 7209 | Fungus (*Beauveria bassiana*) | 254 | 3.52 | 0.64 |
| | | Unknown factors | 717 | 9.95 | |
| | | Total | 2584 | 35.84 | |
| | | Pupal deformity | 374 | 8.09 | |
| Pupa | 4625 | Unsuccessful emergence | 469 | 10.13 | 0.76 |
| | | Unknown factors | 288 | 6.23 | |
| | | Total | 1131 | 24.45 | |
| Moths | 3494 | Sex 50% | | | |
| Females × 2 ($N_3$) | 3494 | | | | |
| Reproducing female | 1747 | | | | |

x, Pivotal age (egg, larva, pupa, adult); $l_x$ , Number of individuals in the beginning; $d_x$, Number of individuals died; $d_{xf}$ ,Factors responsible for death; 100qx, Per cent apparent mortality ($qx = d_x/l_x$); $S_x$, Survival rate.

Expected eggs = 576510, Number of dead/Sterile eggs = 490034, Viable eggs = 86476, Expected number of younger larvae = 86476, Actual number of younger larvae in the spring season ($N_2$) = 54768, Trend index ($I = N_2/N_1$) = 4.54, Generation survival ($SG= N_3/N_1$) = 0.29. Pooled data over two years.

that total mortality during this season was not effective in causing the pest decline and the chances of increase in the population during next season were more (Table 1). Results of key factor (Supplementary Table 1) revealed that maximum mortality occurred in the early instar larval stage (k=0.2238) as the highest value of 'k' was obtained for this group followed by late instar larval stage (k=0.1928), egg stage (k=0.1674) and pupal stage (k=0.1218).

In spring season crop, the highest mortality was observed in the egg stage (91%) which was due to high temperature (>35ºC) and low RH (43.46%) causing desiccation of eggs (Table 2). Mortality of early instar larvae (I–III) due to *C. chlorideae, Ha*NPV, *B. bassiana*, *B. thuringiensis* and unknown reasons was 12.22, 11.01, 2.82, 3.05, 2.38 and 16.20%, respectively. In late larval instars (IV–V), similar kind of mortality factors were observed except bacterial infections. Mortality of pupae was mainly due to unsuccessful emergence (9.99), pupal deformity (11.95) and unknown factors (7.29%). The generation survival of 0.23 on spring season crop indicated that only 23% of the initial population could survive and successfully complete their generation. The age-specific key mortality was highest in egg stage as 'k' value was 1.0223 followed by early instar stage (k=0.2586), late instar stage (k=0.2287) and pupal stage (k=0.1501) on spring season tomato (Supplementary Table 2).

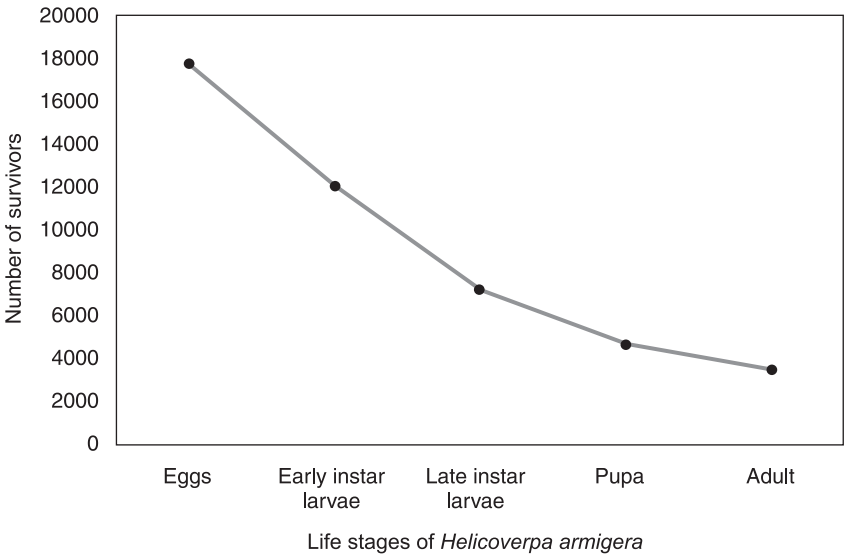


Fig 1 Survivorship curve of *H. armigera* on main season tomato crop during 2018 and 2019 (Pooled)

Table 2 Life tables of *H. armigera* for spring season tomato crop (April-May) during 2018 and 2019

| Age interval | No. of individuals in the beginning | Factor responsible for death | No. of individuals died | Mortality per cent | Survival rate |
|---|---|---|---|---|---|
| x | $l_x$ | $d_{x\ F}$ | $d_x$ | 100qx | $S_x$ |
| Eggs | 576510 | Sterility/Mortality | 521742 | 91.00 | 0.09 |
| | | *Campoletis chlorideae* | 6693 | 12.22 | |
| | | *Ha*NPV | 6030 | 11.01 | |
| Early Instar larvae (I-III instar) | 54768 | Fungus (*Beauveria bassiana*) | 1670 | 3.05 | 0.55 |
| ($N_1$) | | Bacteria (*Bacillus thuringiensis*) | 1303 | 2.38 | |
| | | Unknown factors | 8872 | 16.20 | |
| | | Total | 24569 | 44.86 | |
| | | *Campoletis chlorideae* | 3292 | 10.90 | |
| | | *Ha*NPV | 3606 | 11.94 | |
| Late instar larvae (IV-V) | 30199 | Fungus (*Beauveria bassiana*) | 1030 | 3.41 | 0.59 |
| | | Unknown factors | 4439 | 14.70 | |
| | | Total | 12366 | 40.95 | |
| | | Pupal deformity | 2131 | 11.95 | |
| Pupa | 17833 | Unsuccessful emergence | 1782 | 9.99 | 0.71 |
| | | Unknown factors | 1300 | 7.29 | |
| | | Total | 5213 | 29.23 | |
| Moths | 12620 | Sex 50 % | | | |
| Females × 2 ($N_3$) | 12620 | | | | |
| Reproducing female | 6310 | | | | |

x, Pivotal age (egg, larva, pupa, adult); $l_x$ , Number of individuals in the beginning; $d_x$, Number of individuals died; $d_{xf}$ ,Factors responsible for death; 100qx, Per cent apparent mortality ($qx = d_x/l_x$); $S_x$, Survival rate.

Expected eggs = 1577500, Number of dead/Sterile eggs = 1498625, Viable eggs = 78875, Expected number of younger larvae = 78875, Actual number of younger larvae in the spring season ($N_2$) = 12070, Trend index ($I = N_2/N_1$) = 0.22, Generation survival ($SG= N_3/N_1$) = 0.23. Pooled data over two years.

The curves obtained in the present study were almost similar to type III curves (have very low survivorship early in life and few individuals live to old age) indicating that the highest mortality rate occurred in the early stages of insect life cycle. It is indicated that larval mortality was more rapid in early instar larval stage on main season crop (Fig 1) whereas, on spring season crop, the highest mortality was observed in the egg stage (Fig 2). Further, the drop in survivorship was highest in the early instar larval stage (I–III instars) on main season crop and in the egg stage on spring season crop during both years.

The egg stage was the most vulnerable exhibiting the highest loss (32.0–91%) during main and spring season crop followed by early larval stage (40.27–44.86%), late larval stage (35.84–40.95%), and pupal stage (24.45–29.23%) . During the main season crop, no egg parasitoids were recorded as egg mortality (32.00%) in *H. armigera* was mainly due to infertility. Bisane *et al*. (2009) reported 14.55% egg unviability of *H. armigera* on chickpea.

Similarly, Pal and Katiyar (2010) revealed highest (50–65%) egg parasitisation of *H. armigera* by *T. chilonis* on sunflower. In this study, during spring season crop, the highest mortality of 91% was observed in *H. armigera* eggs during April-May. Our results are further supported by Qayyum and Zalucki (1987) who reported that

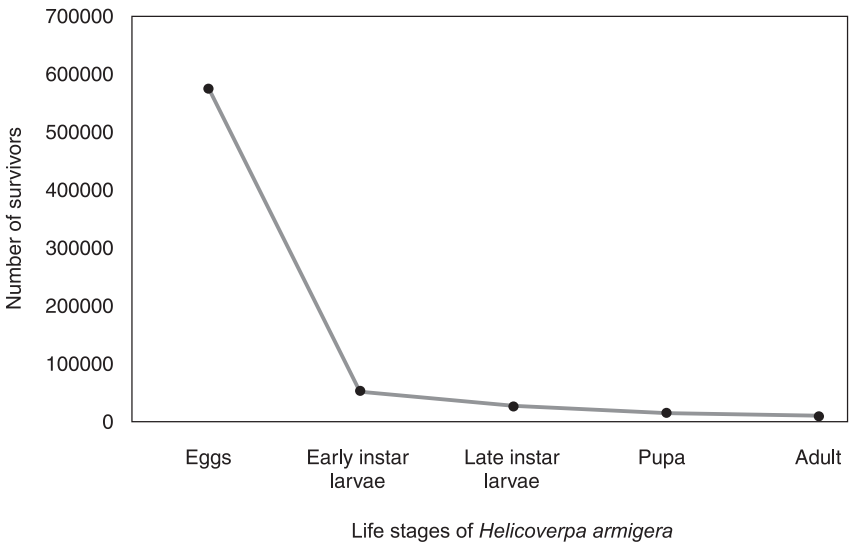


Fig 2 Survivorship curve of *H. armigera* on spring season tomato crop during 2018 and 2019 (Pooled)

low humidity (<75%) may have detrimental effects on hatching.

Mortality factors such as parasitisation, NPV, bacterial infection and unknown reasons were the key mortality factors in the first and late instar larval groups. Mabbett *et al*. (1980) reported that first and second instars of *H. armigera* were more exposed than grown up stages. In the present study, larval parasitoid, *C. chlorideae* contributed maximum mortality in early and late instar larval group and the findings of Kamble *et al*. (2007) who observed larval mortality of 24.6% on tomato due to *C. chlorideae* in Maharashtra further corrobrate the results. Similarly, Bisane and Katole (2008) evidenced that *Ha*NPV infection of *H. armigera* on pigeonpea also suppressed early and late instar larvae to an extent of 7.69 and 3.57%, respectively. Reddy *et al.* (2004) found that *Nomuraea rileyi* accounted for 14.5% larval mortality followed by unknown factor (3.00%). Bisane *et al.* (2009) also reported that pupal mortality due to failure of pupae to complete development was 12.09%. Jadhao *et al*. (2016) reported highest larval mortality of *H. armigera* due to unknown reasons (13.15%) and NPV (7.60%). The egg sterility was observed to be 13.14 % and its pupal mortality was due to unknown reasons (9.91%) which are comparable with the present findings. Results are also found to be in close proximity with those of Kaneria *et al.* (2018) who reported that the mortality in early instar larvae was mainly due to bacterial infection, unknown factors, *Ha*NPV whereas, mortality in late instar larvae was due to fungus and *Ha*NPV on chickpea.

In present studies, the findings of positive trend index on main season crop, negative trend index on spring season crop and a generation survival of 0.29 on main season crop as compared to 0.23 during spring season were in accordance with results reported by Shelke (2019). It was observed that the survivorship curves obtained in the present study were almost similar to type III curves which are in accordance with Mironidis and Savopoulou-Soultani (2008) who observed that at higher temperature regimes, the shape of the age specific survivorship curve changes progressively to type III.

Overall, the results provide a basis of understanding the role of various factors in population fluctuation in the field and developing management strategies for *H. armigera* in tomato. The potential of natural enemies in the ecosystem should be exploited as they play an important role in decreasing the intrinsic rate of increase of the pest and as a result, the cost of insect control can be reduced. The fungus attacking *H. armigera* in the natural conditions of the crop should be isolated and identified by collecting the diseased insect cadavers. The local isolates are always better alternative than the market formulations and their potential as biopesticide should be further investigated. The identification of key mortality factors for *H. armigera* by studying field life tables is a continuous process and it should be the focus of further research for the development of an effective and sustainable management programme for *H. armigera* in tomato crop.

REFERENCES

Atwal A S and Bains S S. 1974. *Applied Animal Ecology*, pp. 245. Kalyani Publishers, Delhi.

Bisane K D and Katole S R. 2008. Life-table studies of *Helicoverpa armigera* (Hübner) on pigeonpea. *Indian Journal of Entomology* **70**(4): 350–55.

Bisane K D, Khande D M, Bhamare V K and Katole S R. 2009. Life table studies of *Helicoverpa armigera* (Hübner) on chickpea. *International Journal of Plant Protection* **2**(1): 54–58.

Harcourt D G. 1963. Major mortality factors in the population dynamics of the diamondback moth, *Plutella maculipennis* (C.) (Lepidoptera: Plutellidae). *Memoirs of the Entomological Society of Canada* **32**(1): 55–56.

Harcourt D G. 1969. The development and use of life-tables in the study of natural insect population. *Annual Review of Entomology* **14**(3): 175–96.

Jadhao S M, Shinde P R, Sawant, C G and Shetgar S S. 2016. Field life-tables and key mortality factors of lepidoperous pests of sunflower. *Journal of Entomological Research* **40**(4): 387–91.

Kamble S K, Shetgar S S and Nalwandikar P K. 2007. Field life- tables and key mortality factors of *Helicoverpa armigera* (Hübner) on tomato. *Indian Journal of Entomology* **69**: 38–41.

Kaneria P B, Kabaria B B, Variya M V and Bharadiya A M. 2018. Field life table studies of *Helicoverpa armigera* (Hübner) infesting chickpea in Saurashtra conditions, Gujarat, India. *Journal of Entomology and Zoological Studies* **6**(5): 2403–06.

Mabbett T, Dareepat P and Nachapong M. 1980. Behaviour studies on *Heliothis armigera* and their application to scouting techniques for cotton in Thailand. *Tropical Pest Management* **26**(3): 268–73.

Mironidis G K and Savopoulou-Soultani M. 2008. Development, survivorship, and reproduction of Helicoverpa armigera (Lepidoptera: Noctuidae) under constant and alternating temperatures. *Environmental Entomology* **37**: 16–28.

Naranjo S E and Ellsworth P C. 1999. The contribution of conservation biological control to integrated control of *Bemisia tabaci* in cotton. *Biological Control* **51**(3): 458–70.

Pal R K and Katiyar R A. 2010. Reaction of natural enemies on insect-pests of sunflower. *International Journal of Plant Protection* **3**(1): 111–13.

Qayyum A and Zalucki M P. 1987. Effects of high temperature on survival of eggs of *Heliothis armigera* (Hübner) and *H. punctigera* Wallengren (Lepidoptera: Noctuidae). *Journal of the Australian Entomological Society* **26**: 295–96.

Reddy K S, Rao G R, Rao P A and Rajasekhar P. 2004. Life table studies of the capitulum borer, *Helicoverpa armigera* (Hübner) infesting sunflower. *Journal of Entomological Research* **28**(1): 13–18.

Richards O W. 1961. The theoretical and practical study of natural insect populations. *Annual Review of Entomology* **6**: 147–62.

Sarwar M. 2014. Some insect pests (Arthropoda: Insecta) of summer vegetables, their identification, occurrence, damage and adoption of management practices. *International Journal of Sustainable Agricultural Research* **1**(4): 108–17.

Shelke S H. 2019. 'Field life-tables and population dynamics of insect-pests of tomato intercropped with coriander'. MSc Thesis, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India.

Southwood T R E. 1978. *Ecological Methods with Particular Reference to the Study of Insect Populations.* The English Language Book Society and Chapman and Hall, New York, US.