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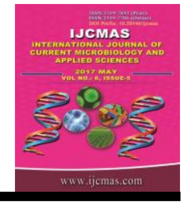

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Field Life-Tables and Key Mortality Factors of *Plutella xylostella* Infesting Sole and Onion Intercropped Cabbage

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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.

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 (*Pierisbrassicae* Linnaeus), tobacco caterpillar (*Spodopteralitura* Fabricius), cabbage semilooper (*Trichoplusiani* Hubner), aphids (*Brevicoryne brassicae* Linnaeus), painted bug (*Bagradacruciferarum* Kirkaldy), cabbage leaf webber (*Crocidolomiabinotalis* Zeller), cabbage borer (*Hellulaundalis* Fabricius), cabbage flea beetle (*Phyllotretacruciferae* Goeze) and Bihar hairy caterpillar (*Spilosomaobliqua* Walk) are observed commonly on cabbage in different seasons and cause considerable losses.

The diamond back moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae), is an oligophagous 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*to 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 × 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 × 60 cm^2 in eighty quadrats and out of these forty quadrats were intercropped with onion variety, N-53 with spacing of 10 x 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 5×5×5 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 33^{rd}

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 (6.08 per cent) was observed due to *Tetrastichus* sp (Table 3).The negative trend index (0.42) revealed that the mortality factors operated during first generation were effective in suppressing the population of *P. xylostella* in second generation. Table 4 showed that the maximum contribution towards generation mortality came from late instar larvae (K= 0.1896) followed by early instar larvae (K=0.0634). The total 'K' for all life-stages was 0.6035.

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 larvae (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
X	l_x	d_xF	d_x	100 q_x	S_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 parasitoidand 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_x	No. dying during x	d_x as % of l_x	Survival rate at age x
X	l_x	d_xF	d_x	100 q_x	S_x
Expected eggs	10631	Sterility	531	5.00	
Viable eggs	10100	-			
Larval population					
Early instar larvae (N_1)	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	*Tetrastichus*sp.	343	6.08	0.94
Moths	5298	Sex 50 % females			
Females x 2 (N_3)	5298	(Reproducing females = 2649)			
Trend index (N_2/N_1)			0.42	-	-
Generation survival (N_3 / N_1)			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 parasitoidand unknown reasons - Late instar larvae	8728	3.9409	0.0634
After mortality due to parasitoidand unknown reasons - Pupae	5641	3.7513	0.1896
After mortality due to parasitoid - 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_xF	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
	5075	Unknown reasons	686	13.52	
Pupae	4389	*Tetrastichus*sp.	343	7.61	0.84
	4046	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 parasitoidand unknown reasons Pupae	4389	3.6423	0.2109
After mortality due to parasitoidand unknown reasons Moths	3703	3.5685	0.0738
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_x	Number dying during x	d_x as % of l_x	Survival rate at age x
X	l_x	d_xF	d_x	100 q_x	S_x
Expected eggs	4458	Sterility	223	5.00	
Viable eggs	4235	-			
Larval population					
Early instar larvae (N_1)	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_3)	2177	(Reproducing females= 1088)			
Trend index (N_2/N_1)			0.00	-	-
Generation survival (N_3 / N_1)			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 Late instar larvae	3892	3.5901	0.0367
After mortality due to parasitoid Pupae	2520	3.4014	0.1887
After mortality due to parasitoid Moths	2177	3.3378	0.0636
Reproducing females	1088	3.0366	0.3012
		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_xF	d_x	100 q_x	S_x
Expected eggs	2401	Sterility	120	5.00	
Viable eggs	2281	-			
Larval population					
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*sp.	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 *Diadegmainsulare* 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.

The population and number of generations of *P. xylostella* were observed to be less on onion intercropped cabbage than on sole crop of cabbage. This could be because of repellent effect of onion on *P. xylostella*. However, there was no any repellent effect of onion on its parasitoid, *C. vestalis.*

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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