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Studies on field life-tables and key mortality factors of cotton bollworm *Helicoverpa armigera* (Hubner) on deshi cotton

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Abstract
The non-replicated field experiment on field-life tables of bollworm infesting deshi cotton was conducted at the Experimental Farm of College of Agriculture, Latur (MS) India, during *kharif* 2016. On deshi cotton, early instar larvae of *Helicoverpa armigera* were died to the extent of 11.66, 4.76 and 8.19 per cent due to *Campoletis chlorideae* during first, second and third generation, respectively. While unknown reasons caused the mortality of early instar larvae of *H. armigera* to the tune of 7.54, 8.44 and 8.95 per cent in first, second and third generation, respectively. The entomopathogenic fungi caused the mortality of early instar larvae of *H. armigera* to the tune of 4, 3.33 and 1.78 per cent in first, second and third generation, respectively. *Ha*NPV caused the mortality of early instar larvae of *H. armigera* to the tune of 3.07 per cent in second generation, respectively. Late instar larvae of *H. armigera* were died to the extent of 6.3, 3.44 and 5.7 per cent due to unknown reason during first, second and third generation, respectively. While *C. chlorideae* caused the mortality of late instar larvae of *H. armigera* to the tune of 4.5, 1.78 and 3.63 per cent in first, second and third generation, respectively. Entomopathogenic fungi caused the mortality of late instar larvae of *H. armigera* to the tune of 1.81 and 1.78 per cent in second and third generation. While unknown reason caused the pupal mortality of *H. armigera* to the extent of 4.7 and 1.85 per cent in first and second generation, respectively. The maximum contribution towards generation mortality of *H. armigera* came from early instar larvae in all three generations (k = 0.1061, 0.0878 and 0.0857). The total K for first, second and third generation was 0.1761, 0.127 and 0.1359, respectively.

Keywords: Deshi cotton, bollworm, *Helicoverpa armigera*, *Campoletis chlorideae*

Introduction
India is the largest cotton growing country in the world. The top five producers in the world are China, India, USA, Pakistan and Uzbekistan. India occupies first rank in area and having second position in production. In India cotton is grown over an area of 105 lakh hectares with production of 351 lakh bales and productivity of 568 kg lint ha^{-1} (Annon. 2017). In Maharashtra, cotton is cultivated over an area of 38.06 lakh hectares with production of 89 lakh bales and having productivity of 398 lint kg ha^{-1} (Annon. 2017). Very less productivity of cotton in Maharashtra is mainly due to growing of cotton under rainfed condition (97-98 per cent of area).

The bollworms usually damage the fruiting bodies like buds, flowers and immature bolls. It is necessary to control the cotton bollworm complex effectively. The present strategy of controlling bollworms includes use of insecticides alone which are sprayed every year in enormous quantities on cotton crop to control bollworms. Nearly 40 per cent of the total pesticide consumption in India is on cotton crop alone, yet satisfactory control of bollworms is not attained. Besides these, the insecticides pollute soil, air and water resources in nature (Chaudhari, 2005**)** [4].

The major aim of studying life-table is one of the tools most useful in the study of insect population dynamics. When the environmental parameters are related to several cases of mortality, the field life-tables form a budget of successive process that operates in a given population. Field life-table studies indicate which age interval and independent variable should be studied in detail for the effective control of the pest. It is also important to grasp the real situation of seasonal prevalence of an insect-pest for its successful control.

Materials and Methods

The material used and methods adopted to study the field life-tables and key mortality factors of bollworms infesting deshi cotton are described below.

The non-replicated field experiment comprising 120 quadrats of 1.80 x 1.80 sq. m. size. The deshi cotton variety, Parbhani Turab was sown at the spacing of 45 x 15 cm.

Field life-tables of bollworms infesting deshi cotton

Field generation studies

After germination frequent field visits were made in order to record the first incidence (egg stage) of bollworms on deshi cotton. After having made frequent field visits at regular intervals, the known number of eggs as a start of first generation of respective pests were collected along with the plant material. On hatching of these eggs, the tiny larvae were reared in plastic boxes (6.5 x 2.5 cm) individually on fresh cotton flowers, buds or bolls in laboratory. Food was changed as and when required. These larvae were reared till adult emergence. A gap of four to six days was observed for the start of next generation. The laboratory culture was used as check culture for deciding the number of regular generations of pests in the field condition. The sampling of early and late instar larvae was done on the basis of development of pest in laboratory-reared culture. At each observation five quadrats were carefully examined twice in a week for number of larvae of target pests. The field collected larvae and pupae were brought to the laboratory and reared on cotton. This was refered as 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 instars, late 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 the moth of previous generation.

Analysis of causes of fluctuation of population and 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). Separate budget was prepared to find out the key factors that influenced the population trend of cotton bollworms. The method of key factors analysis developed by Varley and Gradwell (1963 and 1965) was used to detect density relationship of mortality factors. By this method, the killing power (K) of such mortality factors or group of mortality factors in each age group was estimated as the difference between the logarithams of population density before and after its action. As a series of mortality factors operated in succession during generation or a population, the total killing power of 'K' was equal of the sum of the killing power of 'K's.

Results and Discussion

First Generation

The results on field life-tables and key mortality factors of *H. armigera* on deshi cotton in first generation during *kharif* season 2016.

It is evident from Table 1 that the incidence of *H. armigera* in first generation was first recorded in 37th standard meteorological week. The mortality of early instar larvae infesting deshi cotton was observed to the extent of 11.66, 7.54 and 4 per cent due to parasitoid *C. chlorideae*, unknown reason and entomopathogenic fungi, respectively.

The mortality of late instar larvae to the extent of 6.3 and 4.5 per cent was also observed due to unknown reasonand *C. chlorideae*, respectively. The pupal mortality was observed to be 4.7 per cent due to unknown reason. The positive trend index (1.18) revealed that the mortality factors operated during first generation were not effective in suppressing the population of *H. armigera* in second generation. The generation survival was 0.66.

Table 1: Key mortality factors for first generation of *H. armigera* on deshi cotton

Age interval	Number alive /ha at the beginning of x	Factors responsible for d_x	Number dying during x	d_x as % of 1_x	Survival rate at age x
X	1_x	d_xF	d_x	100 q_x	s_x
Larval population					
Early instar larvae (N_1)	37037	*C. chlorideae*	4320	11.66	0.78
	32717	Unknown reason	2469	7.54	-
	30248	Entomopathogenic fungi	1235	4	-
Late instar larvae	29013	Unknown reason	1852	6.3	0.89
	27161	*C. chlorideae*	1235	4.5	-
Pupae	25926	Unknown reason	1235	4.7	0.95
Moths	24691	-	-	-	-
Females x 2 (N_3)	24691	(Reproducing female = 12345)			
Trend index (N_2/N_1)	43827/37037			1.18	
Generation survival (N_3/N_1)	24691/37037			0.66	

Table 2: Budget of H. armigera for first generation

Age interval	Number / ha.	Log No./ ha.	'k' values
Early instar larvae After mortality due to *C. chlorideae*, unknown reason and Entomopathogenic fungi	37037	4.5686	-
Late instar larvae After mortality due to unknown reason and *C. chlorideae*	29013	4.4625	0.1061
Pupae After mortality due to unknown reason	25926	4.4137	0.0488
Moth	24691	4.3925	0.0212
			K= 0.1761

Table 2 indicated that the maximum contribution towards generation mortality came from early instar stage (k= 0.1061) followed by late instar larvae (k= 0.0488) andpupae (k= 0.0212). The total 'K' for all life-stages was 0.1761.

Second generation

The results on key mortality factors of *H. armigera* sinfesting dashi cotton in second generation during *kharif* season 2016 are summarized in Table 3 and 4.

The incidence of *H. armigera* in second generation was noticed in 41st standard meteorological week. The data (Table 3) revealed that early instar larvae to the extent of 8.44, 3.07, 4.76 and 3.33 per cent were killed by unknown reason, *Ha*NPV, *C. chlorideae* and entomopathogenic fungi, respectively. In late instar larvae the mortality was observed to the extent of 3.44, 1.78 and 1.81per cent due to unknown reason, *C. chlorideae* and entomopathogenic fungi, respectively. The pupal mortality was observed to be 1.85 per cent due to unknown reason. The negative value of trend index (0.94) indicated that the mortality factors operated during second generation were effective in decline in pest population in next generation. The generation survival was 0.74.

Table 3: Key mortality factors for second generation of *H. armigera* on deshi cotton

Age interval	Number alive /ha at the beginning of x	Factors responsible for d_x	Number dying during x	d_x as % of 1_x	Survival rate at age x
X	1_x	d_xF	d_x	100 q_x	s_x
Larval population					
Early instar larvae (N_1)	43827	Unknown reason	3703	8.44	0.81
	40124	*Ha*NPV	1235	3.07	-
	38889	*C. chlorideae*	1852	4.76	-
	37037	Entomopathogenic fungi	1235	3.33	-
Late instar larvae	35802	Unknown reason	1235	3.44	0.93
	34567	*C. chlorideae*	617	1.78	-
Pupae	33950	Entomopathogenic fungi	617	1.81	-
	33333	Unknown reason	617	1.85	0.98
Moths	32716	-	-	-	-
Females x 2 (N_3)	32716	(Reproducing female = 16358)			
Trend index (N_2/N_1)	41358/43827			0.94	
Generation survival (N_3/N_1)	32716/43827			0.74	

It is evident from Table 4 that maximum mortality of *H. armigera* was observed in the early instar larvae (k= 0.0878) followed by late instar larvae (k= 0.0311) and pupal stage (k = 0.0081). The total 'K' for all the life-stages was 0.127.

Table 4. Budget of *H. armigera* for second generation

Age interval	Number / ha.	Log No. / ha.	'k' values
Early instar larvae After mortality due to unknown reason, *Ha*NPV, *C. chlorideae* and Entomopathogenic fungi	43827	4.6417	-
Late instar larvaeAfter mortality due to unknown reason, *C. chlorideae* and Entomopathogenic fungi	35802	4.5539	0.0878
Pupae After mortality due to unknown reason	33333	4.5228	0.0311
Moth	32716	4.5147	0.0081
			K=0.127

Third generation

The results on key mortality factors of *H. armigera* infesting deshi cotton for third generation during *kharif* season 2016 are summarized in Table 5 and 6.

The incidence of *H. armigera* in third generation was noticed in 47th standard meteorological week. The data (Table 5) revealed that early instar larvae to the extent of 8.95, 8.19 and 1.78 per cent were killed by unknown reason, *C. chlorideae* and entomopathogenic fungi, respectively. The mortality of late instar larvae to the extent of 3.63, 1.78 and 5.7 per cent was observed due to *C. chlorideae*, entomopathogenic fungi and unknown reason, respectively. The zero trend index revealed that the population of *H. armigera* infesting deshi cotton was ceased after third generation. The generation survival was 0.73.

Table 5: Key mortality factors for third generation of *H.armigera* on deshi cotton

Age interval	Number alive /ha at the beginning of x	Factors responsible for d_x	Number dying during x	d_x as % of 1_x	Survival rate at age x
X	1_x	d_xF	d_x	100 q_x	s_x
Larval population					
Early instar larvae (N_1)	41358	Unknown reason	3703	8.95	0.82
	37655	*C. chlorideae*	3086	8.19	-
	34569	Entomopathogenic fungi	617	1.78	-
Late instar larvae	33952	*C. chlorideae*	1235	3.63	0.89
	32717	Entomopathogenic fungi	617	1.78	-
	32100	Unknown reason	1852	5.7	
Pupae	30248	-	-	-	-
Moths	30248	-	-	-	-
Females x 2 (N_3)	30248	(Reproducing female = 15124)			

Trend index (N_2/N_1)	0/41358			0	
Generation survival (N_3/N_1)	30248/41358			0.73	

It is evident from Table 6 that maximum mortality of *H. armigera* was observed in the early instar larvae (k= 0.0857) followed by late instar larvae (k= 0.0502). The total 'K' for all the life-stages was 0.1359.

Table 6: Budget of *H. armigera* for third generation on deshi cotton

Age interval	Number / ha.	Log No./ ha.	'k' values
Early instar larvae After mortality due to *C. chlorideae*, unknown reason and Entomopathogenic fungi,	41358	4.6165	-
Late instar larvae After mortality due to *C. chlorideae*, unknown reason and Entomopathogenic fungi	33952	4.5308	0.0857
Pupae	30248	4.48069	0.0502
Moth	30248	4.4806	0.0000
			K= 0.1359

Srinivas (1989) [12]. Kaushal *et al.* (1999) [9]. Nath and Rai (1999) [11]. Kaur *et al.* (2000) [8]. Devi *et al.* (2002) [5]. and Gupta and Desh Raj (2003) reported that *C. chlorideae* was the most common parasitoid responsible for killing the larvae of *H. armigera* in the range of 0.98 to 68.50 per cent. Magar (2006) [10]. noted the maximum mortality of late instar larvae and pupae of *H. armigera* to the extent of 50.07 and 66.66 per cent on soybean due to unknown factors. Nath and Rai (1999) [11]. reported *Ha*NPV as a mortality factor of *H. armigera*. Bisane *et al*. (2009)[3]. reported that *Ha*NPV disease infection of 0.60 and 0.41 per cent was observed in early and late instar larvae, respectively. The present investigation also showed the more or less similar findings.

Conclusion

In conclusion it is to state that cotton bollworm passed through 3 generations each on deshi cotton during *kharif* 2016. *C. chlorideae***,** entomopathogenic fungi and unknown reason, Dipteran parasitoid and unknown reason and *Apanteles* sp. and unknown reason contributed more to cause the mortality of early instar larvae of *H. armigera* infesting deshi cotton.

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