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Life Table of Cotton Bollworm, *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae) in Batac, Ilocos Norte, Philippines

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The mortality factors and reproductive potential of *Helicoverpa armigera* (Hubner) were determined in life table studies conducted at different growth stages of cotton under field and screen house conditions. High mortality rates of *H. armigera* were observed under field conditions and were increased from early squaring to bolling stage. The high mortality rates of eggs were caused by *Trichogramma* parasitization, and of larvae by disappearance (predation/ migration), disease, failure to pupate and *Eriborus* parasitization. Mortality rates of those reared in the screen house were minimal which were caused by infertility of eggs, inability to feed by newly-hatched larvae and larval disease. Because of high mortality of *H. armigera* in the field, intrinsic rate of increase (r_m) ranged from 0.011 to 0.065 female/female/day which were much lower than those that were reared in the screen house (0.129 female/female/day). Eggs and early instar larvae were the most vulnerable stages.

Keywords: mortality factors, Trichogramma, Eriborus sp., predation, intrinsic rate of increase

The cotton bollworm *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) is a major insect pest of different crops in the Philippines. In cotton, it attacks the growing tips, leaves and fruiting structures like squares, flowers and bolls. In the Philippines, yield losses of cotton due to *H. armigera* ranges from 37 to 97% (Catedral, 1982).

The development of an adequate control strategy with minimal pesticide use requires basic knowledge of the pest's population dynamics. A life table provides a format for recording and accounting for all population changes in the life cycle of a species in its environment. It quantifies the impact of natural enemies and other mortality factors at various stages of the insect's life cycle. It gives information which life stage should be targeted to reduce effectively the pest population in its most damaging stage (Room et al., 1990). It can also be used to estimate the population growth of the insect pest.

Life tables of *Helicoverpa* sp. were studied using different host plants like cotton (Dhandapani and Balasubramanian, 1979; Wu et al, 1978, 1980; Wu, 1983 and 1992; Bilapate et al., 1984; Nanthagopal and Uthamasamy, 1989; Bilapate, 1989; Dai et al., 1991; Solsoloy et al., 1994; Sansone et al. 1997; Rao and Prassad, 1998), sorghum (Bilapate et al. 1979; Patel and Mittal, 1986; van den Berg and Cock 1993), groundnut (Koshiya and Patel, 1987), tobacco (Koshiya and Patel, 1987; Sekhar et al. 1995a,), tomato (Dhandapani and Balasubramanian, 1984),

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pulses (Bilapate and Pawar, 1978; Bilapate et al., 1979, 1981; Bilapate, 1989), safflower (Bilapate et al. 1980a and 1980b), corn (Butler and Scott, 1976; Vargas and Nishida, 1977; Bilapate et al, 1980b; van den Berg and Cock 1993; Sekhar et al. 1995a), lucerne (Patel and Koshiya, 1998), pearl millet (Patel and Koshiya, 1997), okra and mungbean (Sekhar et al. 1995b), sunflower (van den Berg and Cock 1993) and semi-synthetic diets (Reddy and Bhattacharya, 1988; Wu and Li, 1993). In these studies, the daily intrinsic rate of increase of *H. armigera* ranged from 0.13 to 0.19 depending on the host plant and diet used (Table 1); mortality factors were infertility, rainfall, insecticide treatment, diseases, natural enemies and unknown factors (Table 2).

In the Philippines, only one study quantified the mortality factors of *H. armigera*. Solsoloy et al., (1994) studied the mortality for one generation. Since *H. armigera* usually infests cotton from squaring to bolling, several cohorts during the different plant growth stages were monitored in the field and were compared with those reared in the screen house. In this study, the mortality factors of *H. armigera* were quantified and its reproductive potential were calculated at different growth stages of cotton (early squaring, peak squaring, flowering and bolling) in the field and those reared in the screen house.

Materials and Methods

Table 1. Intrinsic rate of increase of Helicoverpa armigera on different host plants.

Host Plant Plant Parts	Intrinsic Rate of Increase	Reference
Cotton	0.1902	Wu et al., 1980
		Rao and Prasad, 1998
Cotton Bolls	0.1475	Dhandapani and Balasubramanian, 1979
Cotton Squares	0.1297	Bilapate et al., 1984
Tobacco Capsule	0.1416	Koshiya and Patel, 1987
Pea pods	0.1346	Bilapate and Pawar, 1978
Safflower leaves	0.1328	Bilapate et al., 1980a
Maize cobs	0.1257	Bilapate et al., 1980b
Safflower	0.1343	Bilapate et al., 1980b
Chick pea	0.1387	Bilapate et al., 1981
Sorghum	0.1800	Patel and Mittal, 1985
Tobacco	0.1416	Koshiya and Patel, 1987
Tomato	0.1190	Dhandapani and Uthamasamy, 1989
Pearl millet	0.1423	Patel and Koshiya, 1997
Lucerne	0.1272	Patel and Koshiya, 1998

Table 2. Mortality factors of *Helicoverpa armigera* and *H. zea* on different host plants.

Species/Host Plant	Mortality Factors	Reference
H. armigera		
sorghum, pigeon pea and chick pea	pupal mortality	Bilapate et al., 1979
groundnut	unknown causes, NPV and parasitism	Koshiya and Patel, 1987
cotton	wind, rainfall and predation	Wu, 1983
	predation, dispersal, parasitism disease, unknown causes	Nanthagopal and Uthamasamy, 1989
	parasitism, predation, insecticide treatment	Dai et al., 1991
	disease, natural enemies, insecticide treatment, abnormality	Solsoloy et al., 1994
	predation	Sansone et al., 1997
	wind and rain	Wu, 1982
sunflower, sorghum and corn	predation (ants and anthocorids), parasitism and pathogens	van den Berg and Cock, 1993
cotton and pigeon pea	parasitism and predation	Bilapate, 1989
corn and tobacco	migration and unknown causes	Sekhar et al., 1995a
okra and mungbean	weather factors and natural enemies	Sekhar et al., 1995b
H. zea		
sweet corn	predation, parasitism and viral infection	Vargas and Nishida, 1977

Life table experiments on *H. armigera* were conducted under field and screen house conditions.

Field Experiment

The study was conducted at the Central Experimental Station of the Cotton Research and Development Institute (now the Cotton Development Administration), Batac, Ilocos Norte, Philippines. The preceding crop was corn. In the adjacent fields, farmers practiced multiple cropping of corn, tobacco, vegetables and other cash crops.

A cohort (age-specific) life table was used and the age-specific mortality rate was calculated from repeated census of a group of individuals born at the same time. Cohorts were monitored in three replicates starting from early squaring to bolling stages using different cohorts and plots at different growth stages.

In each plot (8 m^2), 10 randomly selected plants were covered with polyethylene cylindrical cages. In each cage, one pair of laboratory-reared moths was introduced. After 24 hours, the cages were removed and 100 eggs per plot were tagged. Excess eggs and those laid by wild female moths were removed. The tagged eggs were monitored until hatching. After hatching, the number of egg shells was counted by using a hand lens. Those that failed to hatch were collected and brought to the laboratory for further observation. Lost eggs were recorded and predators present were identified. Eggs that remained white were considered infertile. Black eggs were observed for 13 days after collection for parasitoid emergence; parasitoids that did not emerge were considered dead.

Larvae from the first until the sixth instar were counted every two days. Diseased and inactive larvae were reared in the laboratory to monitor parasitoid emergence or disease occurrence. Since the pupal stage cannot be monitored in the soil, sixth instar larvae were collected and allowed to pupate in the laboratory. Therefore, pupal mortality due to predation, unfavorable weather conditions, and soil disturbance was not included. The pupae were sexed using a binocular microscope (20x). Five male and female pupal pairs from each of early and peak squaring stages, and two pairs from each of flowering and bolling stages were kept separately in small plastic jars for emergence and oviposition. Cotton swabs dipped in 10% honey solution were provided as food for the adults. A muslin cloth, placed on top of each plastic container for oviposition, was changed daily, and female fecundity was noted daily until all females died.

Screen House Experiment

The plants were planted at 1 m between rows and 0.5 m between hills. Two pairs of male and female moths were placed in each of three plastic jars for oviposition with a 10% honey solution in cotton swabs as food. Muslin cloth was placed on top of the plastic containers for oviposition. After 24 hours, the muslin cloth was removed and 100 eggs per jar were allowed to hatch. The newly hatched larvae were counted. Since the adult lays most of its eggs on the first leaf below the terminal of the main stem (Pascua, 1993), the larvae were released at this place. The larvae were counted daily until the sixth instar. They were then collected and allowed to pupate in the laboratory. The pupae were sexed and five pairs from each replicate were placed in a plastic jar with a 10% honey solution in cotton swabs as food. Each jar was covered with muslin cloth for oviposition. The muslin cloth was changed daily and fecundity was recorded until the female died. The remaining females were placed in separate cages with a 10% honey solution in cotton swabs as food. They were checked daily for mortality.

Data Analysis

The data on insect survival from the three replicates were combined and summarized in a life table. The number of unparasitized, parasitized and disappeared eggs and the number of disappeared, parasitized, diseased and healthy larvae were tabulated. The K values for each category of loss were calculated based on the method of Varley and Gradwell (1960). These values were summed up to determine the contribution of each factor (Varley et al., 1973).

Key factor analysis is a procedure to identify the mortality factors that are most responsible for a change in population density between generations. The total K value and K values of each mortality factor were plotted for each plant stage. Through visual assessment, any individual K that was most closely correlated with the total K was considered to be the key mortality factor (Varley and Gradwell, 1960).

An age-specific life table was constructed. Survivorship (l_x), expected number of daughters at age x (m_x), net reproduction rate ($Ro= l_x m_x$), mean generation time ($T= xl_x m_x / l_x m_x$) and intrinsic rate of increase ($r= \log_e Ro/T$) were calculated (Southwood and Henderson, 2000; Price, 1984).

The corrected intrinsic rate of increase (r_m) was calculated using the equation (Southwood and Henderson, 2000)

$$\sum e^{7-rmx} l_x m_x = 1.$$

Two arbitrary intrinsic rate of increase were designated based on the ranges caculated using three replicates. The extracted numbers from the equation and the arbitrary r were plotted in a graph where r_m in the y axis and $e^{7-r}m^{x}$ lxmx on the x axis. Other parameters were calculated using the following formulae: finite rate of increase in numbers (l)= antilog e^{rm}; corrected generation time (T)= $\log_e Ro/r_m$; weekly multiplication of population= $(e^{rm})^7$; hypothetical F_2 females= $(Ro)^2$.

The population trend index (I) was determined using the formula:

$$\frac{\text{actual number of eggs } (N_2)}{\text{eggs from preceding generation } (N_1)}$$

The index predicts whether the insect population for the next generation increases (I > 1) or decreases (I < 1) (Harcourt, 1969).

Results

Mortality

The mortality factors at different developmental stages of *H. armigera* varied greatly under field and screen house conditions. Mortality rates were much higher in the field than those reared in the screen house.

Under field conditions, egg mortality was due to infertility, parasitization by *Trichogramma* and disappearance (predation by *Cyrtopeltis tenuis)* and ranged from 27 to 41% at different growth stages (early squaring, peak squaring, flowering and bolling) of cotton (Table 3-6). Parasitization by *Trichogramma* caused the highest mortality: 24% at early squaring, 25% at peak squaring, 32% at flowering and 23% at bolling stage. Mortality due to infertility ranged from 2.3 to 5.3% and disappearance (egg predation) from 3.7 to 4.0%

The mortality of first instar larvae ranged from 23 to 29% and was primarily caused by disappearance (predation and migration) and inability to feed. The mortality of second instar larvae at different plant growth stages ranged from 8 to 22% due to disappearance (predation/migration). Infection of larvae caused by fungus occurred only at the early squaring stage of cotton.

The mortality of third instar larvae parasitized by *Eriborus* sp. increased from the early squaring (7%) to the bolling stage (47%), while larval mortality caused by disease and disappearance (predation/migration) remained below 15% at the squaring and at flowering stage, and was 27% at the bolling stage. During different plant growth stages, the mortality of fourth instar larvae ranged from 26 to 55% due to disease and disappearance (predation/migration). In the fifth and sixth instar larvae, the mortality ranged from 31 to 50% due to disease and failure to pupate.

Pupal death caused by *Carcelia sp.* parasitization was the highest at the flowering stage (54.5%) and lowest at the bolling stage (0%).

Table 3. Life table for *Helicoverpa armigera* at early squaring stage of cotton in Batac, Ilocos Norte, Philip-

Age interval (x)	No. alive at beginning (lx)	Factors responsible for dx (dxF)	No. died during x (dx)	dx as % of lx (100qx)	K
Egg	300	infertility	8	2.67	0.0118
		Trichogramma parasitization	72	24.00	0.1229
		Sub-total	80	26.67	0.1347
Larva 1	220	inability to feed	36	16.36	0.0776
		disappearance (predation/migration)	14	6.36	0.0345
		Sub-total	50	22.72	0.1121
Larva 2	170	diseases	13	7.65	0.0345
		disappearance (predation/migration)	15	8.85	0.0436
		Sub-total	28	16.47	0.0781
Larva 3	142	Eriborus sp., parasitization	11	7.75	0.0350
		diseases	1	0.70	0.0034
		disappearance (predation/migration)	17	11.97	0.0508
		Sub-total	28	20.42	0.0882
Larva 4	113	diseases	12	10.62	0.0488
		disappearance (predation/migration)	29	25.66	0.1470
		Sub-total	41	36.28	0.1968
Larva 5-6	72	diseases	15	20.83	0.1015
		failure to pupate	13	17.81	0.1124
		Sub-total	28	38.84	0.2138
Pupa	44	Tachinid	8	18.18	0.0871
		Sub-total	8	18.18	0.0871
Adult	36				
			K		0.8208

Table 4. Life table for *Helicoverpa armigera* at peak squaring of cotton in Batac, Ilocos Norte, Philippines

Age interval (x)	No. alive at beginning (lx)	Factors responsible for dx (dxF)	No. died during x (dx)	dx as % of lx (100qx)	K
Egg	300	Infertility	13	4.33	0.0191
		Trichogramma parasitization	76	25.33	0.1336
		disappearance (egg predation)	12	4.00	0.0295
		Sub-total	101	33.88	0.1782
Larva 1	159	Inability to feed	31	15.58	0.0735
		disappearance (predation/migration)	26	13.06	0.0730
		Sub-total	67	28.84	0.1486
Larva 2	142	disappearance (predation/migration)	23	16.20	0.0768
		Sub-total	28	18.20	0.0788
Larva 3	119	Eriborus sp., parasitization	32	26.89	0.035
		diseases	8	6.72	0.0034
		disappearance (predation/migration)	8	6.72	0.0508
		Sub-total	48	40.88	0.0882
Larva 4	71	diseases	4	5.63	0.0252
		disappearance (predation/migration)	26	36.62	0.2029
		Sub-total	30	42.26	0.2281
Larva 5-6	41	diseases	3	7.32	0.0330
		failure to pupate	11	26.83	0.1484
		Sub-total	14	34.16	0.1814
Pupa	27	Tachinid parasitization	4	14.81	0.0697
		Sub-total	4	14.81	0.0887
Adult	23	Abnormal wings	2	8.69	0.0395
		Sub-total	2	8.88	0.0886
	21		K		1.1444

Table 5. Life table for *Helicoverpa armigera* at flowering of cotton in Batac, Ilocos Norte, Philippines

Age interval (x)	No. alive at beginning (lx)	Factors responsible for dx (dxF)	No. died during x (dx)	dx as % of lx (100qx)	K
Egg	300	Infertility	16	5.33	0.0238
		Trichogramma parasitization	96	32.00	0.1791
		disappearance (egg predation)	11	3.67	0.0268
		Sub-total	123	41.00	0.2287
Larva 1	177	Inability to feed	29	16.38	0.0777
		disappearance (predation/migration)	22	12.43	0.0699
		Sub-total	61	28.81	0.1478
Larva 2	126	disappearance (predation/migration)	20	15.87	0.0751
		Sub-total	20	16.87	0.0761
Larva 3	106	Eriborus sp., parasitization	49	46.23	0.2694
		diseases	4	3.77	0.0316
		disappearance (predation/migration)	10	9.43	0.0908
		Sub-total	63	69.43	0.3818
Larva 4	43	diseases	3	6.98	0.0314
		disappearance (predation/migration)	8	18.61	0.0970
		Sub-total	11	26.69	0.1284
Larva 5-6	32	diseases	2	6.25	0.0280
		failure to pupate	8	25.00	0.1347
		Sub-total	10	31.26	0.1627
Pupa	22	Tachinid parasitization	12	54.54	0.3424
		Sub-total	12	64.64	0.3424
Adult	10	Abnormal wings	4	40.00	0.2218
		Sub-total	4	40.00	0.2218
	6		K		1.8886

Table 6. Life table for Helicoverpa armigera at bolling stage of cotton in Batac, Ilocos Norte, Philippines.

Age interval (x)	No. alive at beginning (lx)	Factors responsible for dx (dxF)	No. died during x (dx)	dx as % of lx (100qx)	K
Egg	300	Infertility	7	2.33	0.0102
		Trichogramma parasitization	68	22.67	0.2147
		disappearance (egg predation)	11	3.67	0.0218
		Sub-total	88	28.87	0.2487
Larva 1	214	inability to feed	23	10.75	0.0494
		disappearance (predation/migration)	35	16.36	0.0879
		Sub-total	68	27.11	0.1878
Larva 2	155	disappearance (predation/migration)	35	22.53	0.1103
		Sub-total	86	22.68	0.1108
Larva 3	121	Eriborus sp., parasitization	57	47.11	0.2766
		diseases	4	3.57	0.0230
		disappearance (predation/migration)	29	23.97	0.2358
		Sub-total	80	74.86	0.6814
Larva 4	31	diseases	3	9.68	0.0442
		disappearance (predation/migration)	14	45.16	0.3011
		Sub-total	17	74.86	0.8468
Larva 5-6	14	diseases	4	28.57	0.1461
		failure to pupate	3	21.43	0.1549
		Sub-total	7	60.00	0.801
Pupa	7				
Adult	7	Abnormal wings	3	42.86	0.2430
		Sub-total	8	42.88	0.2430
	4		K		1.876

Mortality rates of *H. armigera* larvae during the early stage of the crop (squaring) were lower than those observed during the later stages (flowering and bolling). High mortalities of eggs, first and third instar larvae were due to *Trichogramma* and *Eriborus* sp. parasitization, to disappearance (predation/ migration), and to a fungus disease.

Key mortality factors were egg parasitization by *Trichogramma,* disappearance (predation/migration) and larval parasitization by *Eriborus* sp*.* These caused an increased mortality rate from early squaring to bolling stages (Fig. 1). The larval stage was the most vulnerable exhibiting the highest loss (69.8%) followed by the egg (14.1%), pupal (8.9%) and adult (7.2%) stage (Table 7). Disappearance (predation/migration) (31.2%) contributed to the highest loss followed by failure to pupate (12.6%), diseases (11.5%), and *Eriborus* sp parasitization (11.4%). *Trichogramma* parasitization accounted for the highest loss (11.6%) during the egg stage.

The survivorship curves of *H. armigera* at different growth stages of cotton under field condition were Slobodkin's type III. This indicates that the mortality at various developmental stages was almost equal (Fig. 2) except those of third instar larvae at flowering and bolling stages where high mortality was observed which mainly contributed by *Eriborus* sp. parasitization.

Under screen house condition, the mortality of eggs were 3% while 24.9% in the first and 12.7% in the second instar larvae and lower than 4% in the older instars (Table 8). Mortalities were mainly attributed to inability to feed and disease. The survivorship curve was of Slobodkin's type IV (Fig.2).

In the field, the generation survival decreased from 12.0 to 2.3% and the population trend indices were 22.8 to 2.0% from the early squaring to the bolling stages. A much higher generation survival (0.70) and population trend index were obtained from those reared in the screen house (Table 9).

Reproductive Potential

The net reproductive rate (Ro) representing the total female births decreased from 17.1 to 1.6 during the early squaring to bolling stage in the field while 171.8 in the screen house. The mean time of completing a generation ranged 39.7 to 42.36 days. The intrinsic rate of increase (r_m) of *H. armigera* was much higher on those reared in the screen house (0.13 female/female/day) than those in the field (0.011 to 0.065 female/female/day) (Table 10).

The stable age distribution of *H. armigera* was calculated with the procedure of Dhandapani and Balasubramanian (1979). When reaching the stable age distribution, the population age composition of *H.*

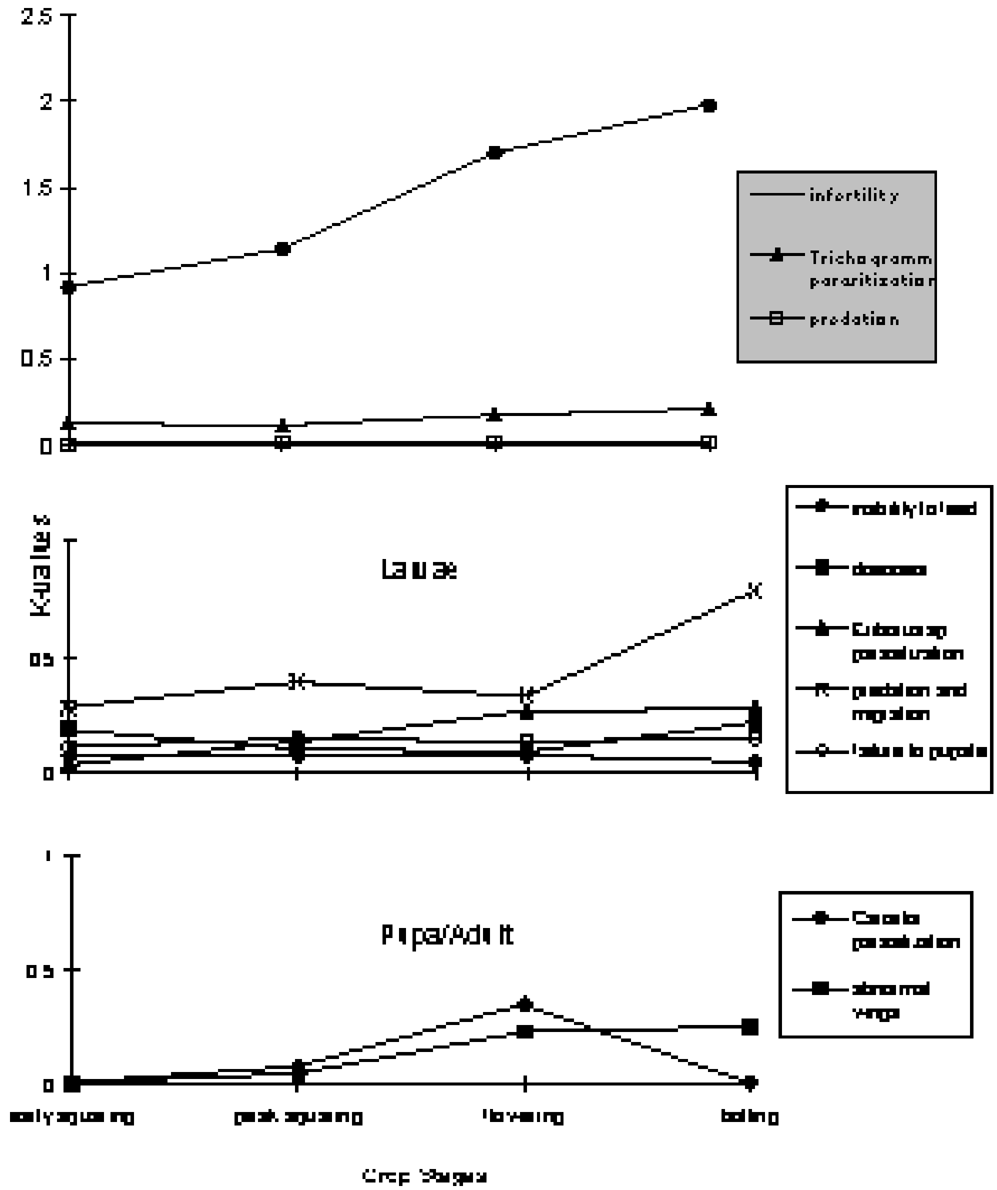

Figure 1. K-values of mortality factors Helicoverpa armigera during the different cotton growth stage.

armigera had slight variations in the screen house and in the field (Table 11).

Discussion

Mortality factors such as infertility of eggs, inability of the larvae to feed and disease were observed both in the field and screen house. The mortality of newly-hatched larvae can be attributed to the inability of the insect to feed on the various plant parts. The presence of trichomes on the leaves interferes with feeding and digestion. Trichomes have large amount of cellulose and lignin resulting in an unbalanced diet of the larva (Norris and Kogan, 1980). A disease decreased the population size both in the field and screen house. However, the mortality caused by disease in the field was much higher. Damo (1993) documented the presence of fungi such as *Numorea rileyi* attacking *H. armigera* in cotton growing areas.

In the field, other mortality factors such as parasitization, disappearance, failure to pupate and abnormal wings of adults were observed which contributed the higher mortalities than those in the screen house. *Trichogramma* caused the highest mortality of *H. armigera* eggs. *Trichogramma* is an

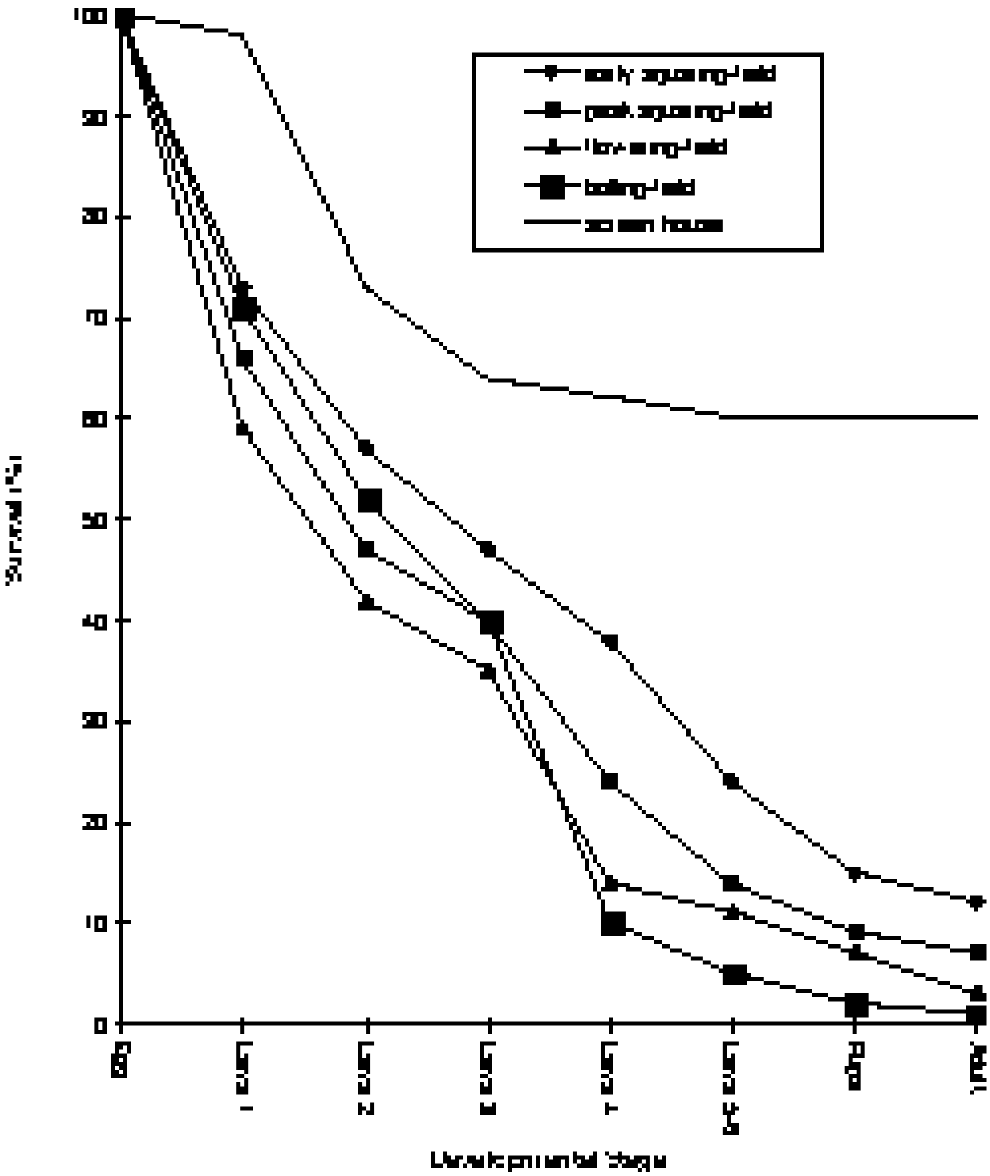

Figure 2. Survival of different developmental stages of Helicoverpa armigera at different growth stages of cotton under field and screenhouse conditions.

interesting biological control agent for lepidopterous pests like *H. armigera* because it attacks and kills eggs before the pest causes damage to the crop. In the northern Philippines, it parasitizes an average of 48% of *H. armigera* eggs in cotton growing areas (Pascua and Pascua, 1995). In the study, parasitization during early squaring was quite low but increased up to 32% during the flowering stage, probably because of population build-up. Alba (1978) reported that *Trichogramma* completes its life cycle within seven days.

Disappearance of eggs was generally attributed to predation caused by *C. tenuis* and occurred during the peak of squaring to bolling stage. This predator was observed at the terminal buds of the cotton plant. Torreno and Rugian (1983) considered *C. tenuis* as a voracious feeder of *H. armigera* eggs in tobacco. It was first documented in cotton by James (1988).

The highest mortality of *H. armigera* larvae population was caused by disappearance generally attributed to predation and migration. The migration of larvae could not be differentiated from predation. These larvae may have been preyed upon. The migrating larvae were exposed to predators like ants, spiders and predatory birds that were abundant in the field.

Helicoverpa armigera females deposit eggs at the upper-third of the cotton plant (Ugare et al., 1986;

Table 7. Summary of K values on egg, larval and pupal stages of the Helicoverpa armigera during the different growth stages of cotton in Batac, Ilocos Norte, Philippines.

Causes of Loss	Early Squaring		Peak Squaring		Flowering		Bolling		Mean
	K	%	K	%	K	%	K	%	%
Egg									
Infertility	0.0118	1.28	0.0191	1.87	0.0233	1.40	0.0102	0.52	1.22
Trichogramma parasitization	0.1229	13.25	0.1328	11.87	0.1791	10.54	0.2147	10.37	11.51
Disappearance (Predation)	0.000	0.00	0.0255	2.29	0.0263	1.58	0.0213	1.10	1.29
Sub-total	0.1347	14.53	0.1782	15.97	0.2287	13.52	0.2467	12.49	14.7
Larva									
Inability to feed	0.0178	3.4	0.0795	6.4	0.0777	4.8	0.0494	2.5	5.5
Disease	0.1331	20.4	0.1045	9.1	0.0910	5.4	0.2139	11.0	11.5
Eriborus parasitization	0.0250	3.3	0.1360	11.9	0.2634	15.3	0.2766	14.0	11.4
Disappearance (Predation/Migration)	0.2359	51.0	0.5946	54.5	0.3323	19.8	0.7381	38.3	51.2
Failure to pupate	0.1124	12.2	0.1434	13.0	0.1947	7.3	0.1549	7.8	10.2
Sub-total	0.4327	73.53	0.8570	74.90	0.9586	53.23	1.4833	73.27	69.87
Pupa									
Tachinid parasitization	0.0371	12.2	0.1434	13.0	0.3424	20.15	0.0000	0.00	8.39
Sub-total	0.0377	73.53	0.8570	74.90	0.3424	20.15	0.0000	0.00	8.53
Adult									
Abnormal wings	0.0000	0.00	0.0385	3.45	0.2218	13.05	0.2430	12.30	7.2
Sub-total	0.0000	0.00	0.0385	3.45	0.2218	13.05	0.2430	12.30	7.20
TOTAL	0.9268	100.00	1.1449	100.00	1.6995	100.00	1.9753	100.00	100.00

Table 8. Life table of Helicoverpa armigera on cotton under screenhouse condition in Batac, Ilocos Norte, Philippines.

x	lx	dxF	dx	100qx	K
Eggs	300	failed to hatch	7	2.33	0.02
First instar	293	inability to feed	73	24.91	0.29
Second instar	220	disease	28	12.73	0.14
Third instar	192	disease	7	3.64	0.04
Fourth instar	185		0	0.00	0.00
Fifth instar	185	disease	5	2.70	0.03
Sixth instar	180		0	0.00	0.00
Pupa	180		0	0.00	0.00
Adult	180				
Total Mortality				46.31	0.51

Table 9. Life table data of Helicoverpa armigera during the different growth stages of cotton under field and screen house condition in Batac, Ilocos Norte, Philippines.

Parameters	Field				Screen House
	Growth Stages				
	Early Squaring	Peak Squaring	Flowering	Bolling	
Initial Population	300	300	300	300	300
No. of adults survived	36	21	6	4	210
No. of females survived	17	10	4	2	126
No. of eggs produced	6831	4853	1342	679	64386
Population trend index (N_2/N_1)	22.8	16.2	4.5	2.3	214.6
Generation survival (N_2/N_1)	0.12	0.07	0.02	0.01	0.70

Table 10. Calculated life table parameters of *Helicoverpa armigera* on cotton under field and screen house conditions at 28 to 32°C in Batac, Ilocos Norte, Philippines

Parameters	Field				Screen House
	Early Squaring	Peak Squaring	Flowering	Bolling	
Generation time (days)	42.14	42.36	41.13	41.01	41.11
Net reproductive rate (Ro)	17.06	15.61	3.48	1.61	171.87
Rate of population increase (rc)					
(female/female/day)	0.067	0.065	0.030	0.012	0.125
Corrected rate of population increase (rm)					
(female/femal/day)	0.065	0.064	0.031	0.011	0.13
Corrected generation time (days)	43.64	42.94	40.23	43.29	39.71
Finite rate of increase in numbers (λ)					
(female/female/day)	1.067	1.066	1.031	1.011	1.14
Week multiplication of population	1.58	1.56	1.24	1.08	2.48
Hypothetical F_2 females	291.04	234.67	12.11	2.59	2939.30

Table 11. Stable age-distribution of *Helicoverpa armigera* on cotton under field and screen house condi-

Parameters	Field				Screen House
	Early Squaring	Peak Squaring	Flowering	Bolling	
Egg	42.75	48.45	44.04	41.46	52.30
Larva 1	18.47	18.88	17.69	20.86	18.94
Larva 2	15.81	14.66	17.080	20.28	12.38
Larva 3	7.62	7.03	6.01	8.58	5.53
Larva 4	6.38	4.66	4.73	3.36	4.57
Larva 5	2.62	1.80	2.64	1.38	2.10
Larva 6	1.91	1.32	2.12	1.07	1.42
Pupa	3.32	2.40	4.67	1.81	2.31
Adult	1.09	0.80	0.71	0.80	0.45

Solsoloy et al., 1994), mostly on the first leaf below the terminal part of the main stem (Pascua, 1993) or on young growing leaves and small buds at the branch tip (Mabbett et al. 1980). Newly hatched larvae move until a suitable feeding site is reached (Pearson, 1958). The first and second instar larvae are virtually restricted to feed on succulent plant parts like the terminal buds and small squares (Pascua and Pascua, 2002). As they grow older, they move downward seeking for better quality food like squares and bolls (Mabbett et al. 1980; Pearson, 1958), They also migrate from one fruiting structure to another, especially if they feed on squares. A single larva consumes 1.7 to 4.7 squares daily depending on its age (Orlido, 1981). Larval dispersal could contribute to increased survival as it prevents cannibalism (Nanthagopal and Uthamasamy, 1989). However, migrating larvae face the risk of being preyed upon or starvation (Mabbet et al., 1980). The possibility of larvae to migrate to other plants on nearby plots was nil because the plots were distanced 2 m apart. It is unlikely that the decline of the population was affected by dispersion through wind because the recorded wind speed during the conduct of the study was quite low ranging from 0.2 to 2.0 m/s (PAG-ASA, 1997).

The *C. tenuis,* spider, and ants, observed in the field experimental area, were reported as predators by Cahatian and Baltazar (1993), Torreno and Rugian (1983), and Cacayorin et al. (1993). Predatory birds were also observed in the area and may also have preyed on *H. armigera* larvae.

Eriborus sp, a larval parasitoid, was the highest mortality factor of the third instar larva in the field. This can be expected because the first and second instar larvae feed on the emerging leaves and young buds on the periphery of the canopy where they are exposed to the parasitoid. The parasitiod deposits its eggs on the first and second instar larvae (Cacayorin et al. 1993). The rate of parasitization increased from squaring to bolling. This may be attributed to the population build-up of the parasitoid.

Carcelia sp., a larval-pupal parasitoid, also decreased *H. armigera* populations in the field. It deposits its eggs in the larval stage and emerges at the pupal stage (Cacayorin et al. 1993). Suharto (1989) mentioned that this parasitoid is one of the common larval-pupal parasitoids infesting *H. armigera* in the Philippines.

The above mentioned parasitoids in the field were also observed in studies conducted in the Philippines on tobacco by Marcos and Rejesus (1992), and on cotton by Cahatian and Baltazar (1993), Cacayorin et al. (1993), Solsoloy et al. (1994), and Divina and Irabagon (1976).

The presence of these natural enemies in the area could have been influenced by the cropping pattern and crop diversity. The preceding crop was corn, and some adjacent fields were planted with corn, tomato, tobacco and beans. These host plants of *H. armigera* could have been sources of natural enemies. Natural enemies during the early squaring stage caused low mortalities probably due to their low population level. This developmental stage of the crop coincided with few standing crops in adjacent fields unlike during the flowering and bolling stages.

Larvae failing to pupate and adults with abnormal wings were common in *H. armigera* reared on cotton. This was probably due intake of a bacterium. Damo (1990) found that larvae fed with *Bacillus thuringiensis* developed morphologically abnormal pupae and adults. She discovered 48 *Bacillus* isolates from soil samples and from *H. armigera* larvae collected in cotton growing areas in the Philippines.

Larval mortality could have been caused by two or more factors acting together such as disease, predation and parasitization. An insect infected by a disease becomes more susceptible to predation or parasitization. Natural enemies and disappearance (migration and/or predation) were the main mortality factors of *H. armigera* as observed by Solsoloy et al. (1994) and Nanthagopal and Uthamasamy (1989). The result indicated that *Trichogramma, Eriborus* sp*.,* and predators were the main mortality factors. They attack the most vulnerable stages, the egg by *Trichogramma* and predators, and first and second instar larvae by *Eriborus* sp. and predators. These stages composed the highest percentage in overlapping generations of *H. armigera* in the field. The presence of these mortality factors had contributed a very low intrinsic rate of increase and population trend index on *H. armigera.*

Implications for pest management

The presence of natural enemies in the ecosystem plays an important role in the decrease of *H. armigera* population. This ultimately can contribute to a very low intrinsic rate of increase of the pest and in effect, a slow population build-up. As a result, the cost of insect control can be lessened.

To fully harness the potential of these natural enemies, several considerations should be taken into account. The parasitization of eggs by *Trichogramma* is significant for pest management of *H. armigera* because it prevents crop damage at later stages. However, the parasitization levels of *Trichogramma* in the field are low especially during the early stage of the crop (Table 3-6; Pascua and Pascua, 1995). The control of *H. armigera* eggs by *Trichogramma* would increase if high populations occur early in the season. In previous studies, inundative release of laboratory-reared *Trichogramma chilonis* from 50 to 100 days after planting in combination with late chemical control were found effective by Famoso (1988; 1989), Perpetua (1987), Teruel & Jarbadan (1990), and Solsoloy et al., (1995). Using *T. chilonis,* insecticide applications can be delayed at the early stage of the crop to allow survival and build-up of natural enemy populations. As a result, the cost of insecticides can be reduced by 26 percent (Teruel and Jarbadan, 1990).

Early instar larvae of *H. armigera* are vulnerable and should be the next target for control. They are vulnerable because they are present on exposed plant parts like growing tips or small squares within the periphery of the plant canopy (Pascua and Pascua, 2002). One should refrain from applying synthetic insecticides to control these early instars as this would disrupt the control by natural enemies and cause resurgence. Instead, naturally-occurring *Eriborus* sp. and predators should be utilized and their impact could possibly be increased by habitat management. Habitat management can be implemented through provision of refugia and alternative food, as well as alteration of crop characteristics (Stinner and Bradley, 1985). This may encourage earlier colonization and population build-up of natural enemies. Intercropping with flowering herbaceous plants increases attraction, survival, fecundity, retention and suppression of the parasitoids and predators (Leius, 1961; Patt et al. 1997). A flowering intercrop could provide food and shelter to parasitoids and predators and the provision of alternative food could either maintain or attract natural enemies prior to invasion by *H. armigera.* In Tanzania, the parasitization of major parasitoids of *H. armigera* in one crop is strongly associated with the presence of other host crops (van den Berg, 1993). Alteration of crop characteristics such as cultural practices and selection of varieties could also enhance natural enemy action (Cortesero et al. 2000).

The fungus attacking *H. armigera* should be isolated and identified; its potential as biopesticide should be investigated. An indigenous practice of farmers is to erect bamboo poles taller than the cotton plants in the field as they attract predatory birds (personal observation). This sustainable strategy could reduce *H. armigera* population.

The biology of natural enemies of *H. armigera* and their value as biological agents, effect of host plants and cultural management should be the focus of research for the development of an effective and sustainable management scheme for *H. armigera.*

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