Biology and Partial Ecological Life Table of the Cotton Bollworm in Ethiopia

Geremew Terefe[1] and Surachate Jamornmarn[2]
[1]EARO, Werer Research Cente, P.O.Box 2003, Addis Ababa, Ethiopia
[2]Department of Entomology, Kasetsart University
50 Pahoyothin Road, Bangkok 10900, Thailand

Abstract

The biology and partial ecological life tables of *Helicoverpa armigera* were studied during 2001 to 2002 at Werer, Ethiopia under controlled condition (30$\pm$ 3^{0}C). Egg development period lasted 2-3 days and the observed infertility was 47.20 %. Total larval period (1-6 instar) was 12-16 days. Pre-pupal period ranged between 1-2 days. Pupation lasted 7-12 days and 48 % of the pupae emerged within 9 days. Recorded average adult longevity was 7.4 days while average number of eggs per female was 256. Disease (unidentified) was the major mortality factor of larvae and pre-pupae, while desiccation was found to cause mortality over pupae. The calculated net reproductive rate (Ro), the intrinsic rate of increase (r) and cohort generation time (Tc) was 77.98, 0.78 and 26.5 days, respectively. The utility of these results in planning the management strategy for *H. armigera* in Ethiopia is discussed.

Introduction

The cotton bollworm, *Helicoverpa: armigera* (Hubner) (Lepidopter: Noctuidae) is the most important insect pest of cotton in Ethiopia. The pest has wide host range. It has been reported on maize, sorghum, groundnut, tobacco, kenaf, pepper, alfalfa, citrus, beans, legumes, and many other horticultural crops (Tsedeke 1982, Waktole 1996). According to the results of loss assessment studies, bollworms such as African, Pink, Sudan and Spiny cause 36 – 60% seed cotton yield loss (Tsedeke 1982).

Morris & Miller (1954), Harcourt (1969, 1971); Waters (1969), Varley & Gradwell (1971) and others have emphasized the value of life tables based on the field observations to determine the cause of mortality. Thus, the understanding gained from life tables can provide a rational basis for pest control by indicating which life stage should be attacked to have most effect in reducing numbers of the most damaging stages of a pest (Room et al. 1991). Above all, an understanding of the normal or expected trends of insect population and the causes for fluctuations in numbers is highly relevant to the type of control strategy that eventually should be developed and used for different pests (Knipling 1979). Therefore, this study was aimed to generate baseline data on the biology and build life table of cotton bollworm under controlled conditions.

Materials and Methods

Cotton bollworm population was established in cages under laboratory condition at the Werer Agricultural Research Center located at an altitude of 750 m, latitude 9^{0}16'North and longitude of 40^0 9' East. All populations were maintained at temperatures of 30 $\pm$ 3^{0}C and a photoperiod of 12:12 (L: D).

Population was established from larvae collected at Werer from cotton and tomato crops. Larvae were reared on modified semi-artificial diet prepared from soybean flour (125g), bread yeast (10g), sorbic acid (1.5g), methyl-4-hydroxybenzoate (3g), ascorbic acid (3g), casein salt (3g), agar powder (12.5g), 40% formalin (2ml), distilled water (750ml) and 10ml of vitamin stock solution prepared following the procedure of Taekle & Jenson (1985).

After eclosion, a pair of newly emerged adults was randomly placed in individual cages ($32x26x26cm^3$). Upon emergence and each day thereafter, adults were provided with diet modified from Griffith & Haskell (1988) and prepared from honey (40g), sugar (15g), and nipagine (methyl – 4 - hydroxybenzoate 0.1g dissolved in 0.2ml ethanol) using 4-4.5cm diameter cups plugged with cotton wool soaked in adult diet solution. Three to 4 young cotton plants or branches of old cotton were cut and kept in test tubes with water for oviposition and support for young adults. To support the test tubes with cotton plants a plastic pot of 11cm diameter was filled with soil. Then the test tubes were planted into the soil and placed in the center of adult cages.

Egg laying was checked three days after adult emergence. The newly laid eggs were counted on the leaves. Leaves with fresh white eggs were cut into small discs and then transferred to petridishes with artificial diet. The newly hatched larvae were counted and transferred into cups with fresh diet and development was recorded every 6 hours until pupation. Pupae were collected every morning and transferred to pupation cages or pots embedded with soil. Emerged adults were transferred into cages in pair and oviposition was followed. Adults were monitored daily until they die and eggs were counted for fecundity determination.

To study the biology and development stages, a cohort size of 200 eggs was counted and transferred onto petridishes with artificial diet. The biology study lasted for 10 months and development stages were followed on more than 1315 eggs replicated over time. Data on each development stage (instar), pre-pupation, pupation and adult period were recorded. A cohort (age-specific, horizontal) life table was constructed from data obtained by repeatedly counting a group of individuals born at the same time, as they get older. Population performances were evaluated from age specific death (d_x), survival (l_x) and fecundity (m_x). K-values and the intrinsic rate of increase (r) were calculated according to Titmarsh (1985).

Results

Egg development

The eggs of the cotton bollworm are creamy-white shortly after being laid and as the embryo develops; the egg turns reddish-brown in the second day and darkens to a grayish-brown before hatching. The duration (Mean $\pm$ SE) of white freshly laid eggs to change to brown lasted 1-1.5 days (d) with the average length of 1.25 $\pm$ 0.21d. Development from brown to black took from 0.35-1d (0.62 $\pm$0.25d). Black eggs hatched to first instar larvae within 0.21 - 0.67d (0.4 $\pm$ 0.19d) (Table 1). Generally, egg development period lasted from 2 - 3 day's (2.25 $\pm$ 0.0.29d). Recorded mean egg infertility was 47.2% for Werer population.

Larval development

The color of developing larvae ranged from olive green to varying shades of pine, green, dark, gray, reddish brown, but it was best distinguished by the tiny spines that covered most of the body. The development period for 1st, 2nd, 3rd and 4th instars took on average 2.17 $\pm$ 0.18, 2.14 $\pm$ 0.18, 1.58 $\pm$ 0.15 and 1.94 $\pm$ 0.13 days, respectively. The 5th instar lasted (2.07 $\pm$ 0.23d), while the 6th lasted 3.15$\pm$ 0.31days. The pre-pupal period was the shortest one and lasted (1.5 $\pm$ 0.4d). Total larval development period lasted 12 -16 days with the average being 14.71$\pm$ 0.81 (Table 1).

Table 1. Development period (days) for age classes of *H. armigera* under laboratory conditions at Werer Agricultural Research Center, 2001-2002.

Developmental Stages		Duration (days)	
		Range	Mean+SE
Egg	White	1.0-2.0	1.21±0.21
	Brown	0.5-1.5	0.62+0.25
	Black	0.2-1.0	0.4+0.19
Larvae	1st instar	1.5-2.5	2.17+0.18
	2nd instar	1.8-25	2.14+0.18
	3rd instar	1.5-2.0	1.58+0.15
	4th instar	2.0-2.5	1.94+0.13
	5th instar	2.0-3.0	2.07+0.23
	6th instar	3.0-4.0	3.15+0.31
Prepupa		1.0-2.0	1.5+0.40
Pupa		7.0-12.0	9.92+1.05
Adult		6.0-10.0	7.35+1.73
Total period		27.5-45.0	34.05+0.48

Body length measurement of (Table 2) indicated, first instar larvae was (mean ± SE) (1.915 ± 0.06) mm, while 2nd instar larvae ranged between 4 – 6.5mm (5.64 ± 0.83). The rate of length increment of the 2nd over the 1st instar was 3 fold. Third intar larvae length increased 2.6 fold while 4th instar increased only 1.5 times that of the 3rd (Table 2). Growth of 6th instar was very low as compared to previous instars and 1day after moulting the range was between 32 - 35mm (33.6 ± 0.64). Length reduction (8.51%) was observed on the 3rd day after moulting and reached on average 30.74mm. The prepupal length showed 36.42% contraction and measured between 20.4 – 22.2mm (21.36 ± 0.73). The pupae measured between 15.8 – 17.2mm (16.72 ± 0.46) (Table 2).

Considering weight, 1st instar larvae weigh between 0.175 – 0.375mg (0.255 ± 0.21), while 2nd weigh between 1.66 – 2.67mg (2.00 ± 0.34). Weight of the 3rd instar has increased 16 fold over the 2nd instar. The weight increase of 4th instar larvae was 4 times higher than that of 3rd instar. Fifth instars weighed on average 283.56mg one day after moulting and 375.12mg on the 2nd day. The 6th instar has only gained 6.7% (27.64mg) weight increase with the mean weight of 391.99 ± 12.45mg. Developing to prepupal stage the insect has lost 30.84% (120.89mg) weight with an average of 271.09 ± 27.81mg. The pupal weight ranged between 223.18 – 257.76mg (237.18 ± 10.58mg) (Table 2).

Table 2. Average weight (mg), length (mm) and rate of increase/decrease for *H. armigera* age classes.

Development stages	Weight	Rate of increase/decrease	Length	Rate of increase/decrease
1st instar	0.25 + 0.21	-	1.92 + 0.06	-
2nd instar	2.0 + 0.34	8.0	5.64 + 0.83	2.94
3rd instar	31.90 + 2.90	15.95	14.86 + 1.03	2.63
4th instar	125.53 + 13.63	3.94	22.09 + 0.87	1.49
5th instar	329.30 + 15.98	2.62	31.42 + 0.95	1.42
6th instar	392.00 + 12.45	1.20	33.6 + 0.64	1.07
Prepupa	271.10 + 27.81	-1.45	21.36 + 0.73	-1.57
Pupa	237.2 ± 10.58	-1.14	16.72 ± 0.46	-1.28

Pupation

The new pupae are reddish brown in color and slowly change to dark brown. Pupation took place in the soil, 1-3cm depths from the surface and lasted 7 - 12 healthy moths. 16.25% of accounts for deformed insects, while 4.14% die before emergence. Disease (unidentified) and desiccation recorded 15.58% and 15.72% of the pupal mortality, respectively. days (9.92 ± 1.05) (Table 1). As results of development study under taken on 1883 pupae show that only 46.31% emerged as

Adult emergence

Adult moths emerged from pupation within 7 - 12 days and the average period in days was (9.92 ± 1.05) (Table 1). As emergence pattern study indicated 12% of the adults emerged within 7 days after pupation while 31% emerged 8 days after pupation. Pupation lasted 9 days for 48% and 10 days for 5% of the population. Only 4% emerged after 11-12 days of pupation. Observed Male to Female ratio was 1:1.11.Fully expanded wingspan of male moths was 30.6 ± 1.5mm while the female measured 32.6 ± 1.35mm. Body length of adult moths was 14.2 ± 1.16 mm for males and 14.9 ± 0.74mm for females. According to life span study adults survived for 6 - 10 days with an average adult longevity period of (7.35 ± 1.73) days (Table 1).

Fecundity

Egg laying started 3-4 days (2.75 ± 0.25) after adult emergence and it was extended from 4-5 days. The maximum number of eggs laid per female was 980, while the lowest was only 8 eggs. The average number of eggs was 256. The total reproductive period was found to be 4-5 days with average reproductive rate of 50 eggs/day/female.

Mortality factors

Major mortality factors recorded during the study period under laboratory condition were infertility, disease and desiccation (Table 3). Among the mortality factors infertility and desiccation were estimated to contribute 20-30% of egg population reduction. Unidentified disease infection was the major factor for larval, perpupal, and pupal death. Desiccation decreased pupal survival by 15-30% (Table 3), which increased to 40% when the room temperature rose to 37^0C and above. Under temperatures above 35°C, fecundity decreased and the surviving adults could not even depart after mating and died while fixed.

Table 3. Percent mortality of *H. armigera* under laboratory condition.

Mortality factors	Age class			
	Egg	Larvae	Pre-pupa	Pupa
Infertility	41.6	-	-	-
Disease	-	7.4	18.3	7.7
Desiccation	-	-	-	14.1
Unknown	6.0	2.6	1.7	-
Total	47.2	10.0	20.0	21.76

Life table statistics

The calculated net reproductive rate (R_o) of cotton bollworm was 77.98 while the intrinsic rate of increase (r) was 0.78. The total K-value was 0.85 (Table 4), while recorded generation time was 26.5 days.

Table 4. Cumulative cohort life table of *H. armigera* at WARC under controlled condition (30 ± 3°C).

Age class (x)	a_x	d_x	$100q_x$	l_x	$100r_x$	k_x (loglx)
White egg	655	0	0	1	0	-
Brown egg	583	72	10.99	0.89	10.99	0.0510
Black egg	553	30	5.15	0.95	4.58	0.0223
Larvae I	506	47	8.50	0.92	7.18	0.0362
Larvae II	492	14	2.77	0.97	2.14	0.0132
Larvae III	468	24	4.88	0.95	3.66	0.0223
Larvae IV	407	61	13.03	0.87	9.31	0.0605
Larvae V	385	22	5.40	0.95	3.36	0.0223
Larvae VI	326	59	15.32	0.85	9.00	0.0706
Prepupa	272	54	16.56	0.83	8.24	0.0809
Pupa	202	70	25.73	0.74	10.69	0.1308
Adult	103	99	49.00	0.51	15.11	0.2924
						K= 0.85

Note: x - age class or development stages; a_x - number entering each class; d_x - number dying during x; $100q_x$ - d_x as a percentage of a_x, l_x - survival rate within x; $100r_x$ - real mortality d_x, k_x - the difference between successive values of l_x

Discussion

About half of *H. armigera* eggs deposited on cotton leaves in the rearing cages failed to hatch for unknown reasons. Possible causes of this egg stage mortality could be infertility; desiccation or the eggs laid by unmated females. Buranapanichpan (1989) studied the biology and partial ecological life tables of *H. armigera* in Thailand under controlled condition and found that mortality was low during the egg to pupal stages, but high in the adult stage. The low larval mortality is in agreement with the studies of Buranapanichpan (1989) and Choasong (1994). However, the high percent egg mortality in this study contrasted the low egg mortality reported by Buranapanichpan (1989). According to the results of this study, early instar mortality was very low and late instar death was found high. The low level of early larval instar mortality in this study was attributed to protected cage environment and separation of larvae after second instar. The high number of late instar death is due to infection by disease (unidentified). Bilapate et al. (1979) found pupal mortality to be responsible for generation survival on both sorghum and pigeon pea. This study also revealed the high contribution of prepupal and pupal death by disease and desiccation for population survival in the next generation.

The total and each larval instar development period in this study is in agreement with the findings of Alemayehu (1992) and Patel & Talati (1987).

Life tables have been built for *H. armigera* by Buranapanichpan (1989) and Choasong (1994). Buranapanichpan (1989) showed the net reproductive rate of increase (R_o) = 499.7392, the capacity for increase (R_c) = 0.1849, the finite rate of increase (λ) = 1.2031 and cohort generation time (T_c) = 33.60 days. The present study has recorded the net reproductive rate of increase (R_o) = 77.98, the intrinsic rate of increase (r) = 0.78 and cohort generation time (T_c) = 26.5 days. The difference in R_o compared to the results of Buranapanichpan (1989) may be attributed to differences in oviposition potential of strains, temperature, and geographical location. Therefore, results of the present studies have indicated the specificity of life table parameters and their apparent dependence on biotic and abiotic factors. Thus, results obtained under controlled environment should be amended with field experiments before being utilized for management interventions.

Data on utility of the results for *H. armigera* management provide information that can be useful in predicting development of *H. armigera* and major mortality factors. The present results have shown that *H. armigera* larvae, prepupae, and pupae suffer considerable mortality due to disease. The causal pathogen (either bacterium or virus) should be identified and exploited for augmenting biological control of the pest. Combined with the information from biology study, estimated life table parameters and biotic and abiotic factors acting on the population processes, it is possible to plan management strategy for *H. armigera* control.

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