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Studies on Some Life Table Parameters of *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) in Maize under Field Condition in Western Ethiopia

Tifsehit Solomon[1] and Emana Getu[2*]

[1]Department of Biology, College of Natural and Computational Science, Wollega University, Ethiopia.
[2]Department of Zoological Science, Faculty of Science, Addis Ababa University, Ethiopia.

Authors' contributions

Author TS designed and executed the experiment, collected data, analyzed data and wrote the manuscript. Author EG checked the experiment, checked the execution of the experiment and corrected the manuscript. The first author was Ph.D. student and this manuscript is one chapter of the thesis. The second author was the supervisor. Both authors read and approved the final manuscript.

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ABSTRACT

Field Life Tables were constructed for *Busseola fusca* (Fuller) (Lepidoptera: Noctuidae) at Boneya and Haru during 2012 and 2013. The analysis of the life tables were done to determine the role of each factor such that density dependent factors (Predators and parasitoids) and density independent factors (wind) in the developmental stages of the insect. Meanwhile, key mortality factor was determined using Podoler and Rogers [1] regression method. The life table analyses showed that *B. fusca* has two generations per season at both locations. The highest population reduction of *B. fusca* was recorded at small larval stage which was caused by disappearance that could be due to predation and/or mobility to other plants or locations with the aid of wind in Boneya and Haru. Population reduction of small larvae and medium larvae caused by disappearance and/or migration were the key factor in changing the population of *B. fusca* in Boneya and Haru, respectively. The detection of density dependence result showed inverse density dependence

**Corresponding author: E-mail: egetudagaga@yahoo.com;*

between kparasitism of pupal stage and *B. fusca* population and no density dependence was detected for the other population reduction factors at Boneya. So the parasitoid couldn't increase with the increasing population of *B. fusca*. At Haru the result was not significant for all population reduction factors, so there was no density dependence detected for all population reduction factors implying that population reduction factors acted irrespective of the population of *B. fusca*.

Keywords: Busseola fusca; density relationship; key factor; population reduction factors.

1. INTRODUCTION

Maize suffers from the attack of insect pests from seedling to maturity and *Busseola fusca* (Fuller) (Lepidoptera: Nocutidae) is a major constraint to maize production in Africa [2-4]. The destructive stage of *B. fusca* is the larval stage. Larvae cause damage by feeding on all parts of maize plant except roots. On hatching, the larvae migrate to the whorl of the plant where they first feed on the leaves or balloon off of the plant. The medium larvae bore into the central shoot resulting in drying up of the growing point and formation of dead hearts in young plants. It also form tunnels filled with excreta inside the stem and show exit holes on the surface. Severe damage results in breaking of the stem [5]. It pupates inside the stem and makes holes before pupation for emergence of adults. Sometimes, the larvae inside the stem enter the ears through the shank and damage the ears [6].

Designing effective management method needs detailed understanding of population dynamics of the stem borer. Ecological life tables are one of the tools most useful in the study of insect population dynamics. Such tables record a series of sequential measurements that reveal population change throughout the life cycle of a species in its natural environment. When these measurements are related to several causes of mortality, the life tables form a budget of the successive processes that operate in a given population [7].

Study on population, life table and mortality factors of *B. fusca* in eastern and western Wollega are lacking. Therefore, the purpose of the present investigation was to study population processes, and the role of mortality factors in population changes of *B. fusca*, by constructing life tables and conducting key factor analysis.

2. MATERIALS AND METHODS

The studies were conducted in Haru agricultural research sub center and Boneya experimental station of agricultural office. Haru agricultural research sub center is found in West Wollega and is 464 km away from Addis Ababa. Haru is found at 8°58.992N and 35°47. 746E having an average elevation of 1672 m. Boneya is found in East Wollega zone and is 320 km away from Addis Ababa. Boneya has coordinates of 8°58.614N and 36°40.206E and an altitude of 1680 m. The experiment was conducted in 2012 and 2013. Maize was planted in mid May to determine field life tables of *B. fusca* in the rainy season. Maize was planted at the spacing of 30 cm between plants and 70 cm between rows on a plot of 4.9 m x 4.8 m (23.52 m^2). The experiment was replicated three times. Two seeds were sown per hole and then thinned to one after two weeks of emergence. Di Ammonium phosphate (DAP) was applied at planting at the rate of 100 kg/ha and UREA as a side dressing at knee height stage at the rate of 100 kg/ha. The plot was hand weeded when necessary.

Every 15 days destructive sampling was done in which ten plants from each plot were randomly selected and cut at ground level. Stems were carefully dissected longitudinally and discovered larvae and pupae were kept in glass vials (2.5 cm diameter and 8 cm height) and taken to laboratory and were given fresh maize every three days till they pupate or die. The larvae were also checked for parasitoid emergence observed if there is any parasitoid emergence or pathogen infection. The pupae were also kept till the adult or parasitoid emerges.

The egg data were not used in the life table analysis because it was not possible to get sufficient number to account for the number of larvae and pupae recovered during subsequent sampling occasions mainly because of its cryptic nature. Larval instars were categorized in to small, medium and large for the study.

2.1 Construction of Life Table

The graphical method described by Southwood [8] was used to determine the number of individuals entering a specific stage denoted as lx. The density of each life stage was plotted against sample date for successive census data. The points were joined up and the number of squares under the line counted, then the total was divided by mean developmental time. Developmental time (Tx) for each stage was obtained from field and laboratory studies. Therefore, partial ecological life table was constructed for *B. fusca* according to Harcourt [7] and Elkinton [9].

2.2 Key Factor Analysis and Density Relationships

The analysis of life table was done to determine the role of each factor in the developmental stages of the insect. Identification of the key mortality factors provides a rational and predictive basis for pest control. The series of age-specific mortalities were calculated by subtracting each log population from the previous one. After log transformation, the lx values were subtracted successively to give k values (total mortality occurring in the stage) as follows:

k1 = log (small larvae) - log (medium larvae),
k2 = log (medium larvae) - log (large larvae),
k3 = log (large larvae) - log (pupae)

The sum of the individual mortality factors (ki) gives total generation mortality (K) as:

K= k1 + k2 +…+ ki

For individual causes of mortality ki was calculated as Ki= $\log_{10} (1/_{1-qx})$

The Podoler and Rogers [1] regression method of key factor analysis was used to determine the key factor in the population process of *B. fusca*. The individual mortality factors (ki) were regressed against generation mortality K and the one with the greatest value of the slope (b) was considered as key factor.

For detection of density dependence, individual k values were regressed against the $\log_{10}$ up on which they acted. The relationship between the stage specific mortality and *B. fusca* density was determined by regressing kx on log density of lx.

3. RESULTS

3.1 Life Table

Life tables were constructed for *B. fusca* population on maize during 2012 and 2013 at Boneya and Haru and it is presented in Tables 1 to 4. The real generation mortalities for both locations are summarized on Table 5 for each stage. For small larvae, mortality ranged from 17.9% to 36.6% with mean mortality of 28.3±3.9 at Boneya and from 23.9% to 44.9% with mean 31.6±4.6 at Haru and it was the highest of all stages. The cause of mortality for small larvae was disappearance which could be due to predators, migration or abiotic factors like rain fall and wind. Medium sized larvae mortalities were caused by death and disappearance which resulted in 17.6±1.5 and 21.2±2.8 mean percent mortality at Boneya and Haru, respectively. For large sized larvae death, parasitism and disappearance were causes of mortality. These have resulted in 12.5±1.4 and 12.7±3.0 mean percent mortality at Boneya and Haru, respectively. Mortalities caused to pupae at Haru were the lowest (6.4±2.2) when compared to the other stages and at Boneya it was 13.2±1.4 percent. The causes for pupal mortalities were parasitism and failure to emerge. The total generation mortality ranged from 61% to 79% with mean of 72% at Boneya and from 70% to 73% with mean of 72% at Haru.

3.2 Key Factor Analysis and Density Relationships

K values were calculated from life table data and presented in Table 6. The regression of ki on generation mortality showed that small larvae mortality has the highest positive slope (0.26) for Boneya. At Haru the highest positive slope (0.62) was observed from medium larvae by regression of ki against generation mortality (Table 7). Mortality of small larvae and medium larvae caused by disappearance was the key factor in changing population in Boneya and Haru, respectively. Mortality caused by parasitism to large larvae and pupae didn't contribute much to the population change.

From the result of density dependence detection showed that only Kparasitism (for pupal stage) was significant (b= -0.46 and p=0.012) at Boneya, which was in an inverse density dependence manner (Tabe 8). This indicates that mortality caused to *B. fusca* by parasitism decreased with an increase in the population of *B. fusca*. For the other mortality factors no density dependence was detected. At Haru the result was not significant for all mortality factors and there was no density dependence detected between the mortality factors and the *B. fusca* population.

4. DISCUSSION

The life table studies have shown that *B. fusca* has two generations per year at both locations. This is in line with the study conducted in eastern Ethiopia (Alemaya area) which recorded two generations of *B. fusca* per year [10]. More number of generations was observed in Eritrea by Adugna and Hofsvang [11] which was three per year in one location and two per year on another location.

Table 1. Life table of *B. fusca* at Boneya in 2012

Stage	Lx	DxF	Dx	100qx	Sx
Generation I					
Small Larvae	71	Disappearance	26	36.6	0.63
Medium Larvae	45	Disappearance	13	28.9	0.71
Large Larvae	32	Parasitism	3	9.4	0.78
		Disappearance	4	12.5	
		Total	7	21.9	
Pupae	25	Parasitism	5	20	
		Disappearance	4	16	
		Total	9	36	
Generation II					
Small Larvae	84	Disappearance	24	28.6	0.71
Medium Larvae	60	Death	3	5	0.7
		Disappearance	15	25	
		Total	18	30	
Large Larvae	42	Parasitism	2	4.8	0.71
		Disappearance	10	23.8	
		Total	12	28.6	
Pupae	30	Parasitism	4	13.3	
		Disappearance	8	26.7	
		Total	12	40	

Lx= number entering stage x; DxF=mortality factor; Dx= number dying during the stage; 100qx apparent generation mortality; Sx= survival rate of stage x

Table 2. Life table of *B. fusca* at Boneya in 2013

Stage	Lx	DxF	Dx	100qx	Sx
Generation I					
Small Larvae	67	Disappearance	12	17.9	0.82
Medium Larvae	55	Disappearance	10	18.2	0.82
Large Larvae	45	Death	1.5	3.3	0.84
		Parasitism	2	4.4	
		Disappearance	3.5	7.8	
		Total	7	15.5	
Pupae	38	Disappearance	12	31.6	
Generation II					
Small Larvae	96	Disappearance	29	30.2	0.69
Medium Larvae	67	Death	5	7.5	0.78
		Disappearance	10	14.9	
		Total	15	22.4	
Large Larvae	52	Death	1	1.9	0.71
		Parasitism	4	7.7	
		Disappearance	10	19.2	
		Total	15	28.8	
Pupae	37	Parasitism	3	8.1	
		Disappearance	8	21.6	
		Total	11	29.7	

Lx= number entering stage x; DxF=mortality factor; Dx= number dying during the stage; 100qx apparent generation mortality; Sx= survival rate of stage

Table 3. Life table of *B. fusca* at Haru in 2012

Stage	Lx	DxF	Dx	100qx	Sx
Generation I					
Small Larvae	87	Disappearance	27	31	0.57
Medium Larvae	50	Death	4	8	0.52
		Disappearance	20	40	
		Total	24	48	
Large Larvae	26	Death	2	7.7	0.69
		Parasitism	1.5	5.8	
		Disappearance	4.5	17.3	
		Total	8	30.7	
Pupae	18	Parasitism	2	0.11	
Generation II					
Small Larvae	112	Disappearance	30	26.7	0.73
Medium Larvae	82	Disappearance	22	26.8	0.73
Large Larvae	60	Death	3	5	0.6
		Parasitism	2	3.3	
		Disappearance	19	31.7	
		Total	24	40	
Pupae	36	Disappearance	5	13.9	

Lx= number entering stage x; DxF=mortality factor; Dx= number dying during the stage; 100qx apparent generation mortality; Sx= survival rate of stage

Table 4. Life table of *B. fusca* at Haru in 2013

Stage	Lx	DxF	Dx	100qx	Sx
Generation I					
Small Larvae	98	Disappearance	44	44.9	0.55
Medium Larvae	54	Death	6	11.1	0.74
		Disappearance	8	14.8	
		Total	14	25.9	
Large Larvae	40	Parasitism	3	7.5	0.8
		Disappearance	5	12.5	
		Total	8	20	
Pupae	32	Disappearance	6	18.7	
Generation II					
Small Larvae	142	Disappearance	34	23.9	0.76
Medium Larvae	108	Death	5	4.6	0.69
		Disappearance	28	25.9	
		Total	33	30.5	
Large Larvae	75	Death	3	4	0.77
		Parasitism	3	4	
		Disappearance	11	14.7	
		Total	17	22.7	
Pupae	58	Parasitism	8	13.8	
		Disappearance	10	17.2	
		Total	18	31	

Lx= number entering stage x; DxF=mortality factor; Dx= number dying during the stage; 100qx apparent generation mortality; Sx= survival rate of stage

The highest mortality of *B. fusca* was recorded at small larval stage, which was caused by disappearance at Boneya and Haru. Adugna and Hofsvang [11] have also recorded the highest mortality at small larval stage in Eritrea. Study conducted by Midega et al. [4] under different cropping system at the Kenyan coast, have also showed similar result, in which the highest mortality was recorded from small and medium larvae. The reason for high mortality of small larvae could be due to migration or dispersal of the small larvae from hatching site to the other parts of the plant. At this stage, the larvae were prone to adverse environmental factors. They are also unprotected and they can easily be attacked by predators. It could also be difficult to find host at this early stage and expose them to disappearance. Parasitoids have caused mortality to large larvae and pupae; even if their contribution to the population regulation was low. The death caused to medium and large larvae was not clear because pathogens were not found on the larvae. However, it needs further investigation.

Table 5. Real generation mortality (100rx) for *B. fusca* at Boneya and Haru in 2012-2013

Boneya	**Generation**				
Stage	**1**	**2**	**3**	**4**	**Mean±SE**
Small larvae	36.6	28.6	17.9	30.2	28.3±3.9
Medium larvae	18.3	21.4	14.9	15.6	17.6±1.5
Large larvae	9.8	14.3	10.4	15.6	12.5±1.4
Pupae	12.6	14.3	17.9	11.4	13.2±1.4
Total generation mortality	77.3	78.6	61.1	72.8	72.4±4
Haru					
Stage	**1**	**2**	**3**	**4**	**Mean±SE**
Small larvae	31	26.7	44.9	23.9	31.6±4.6
Medium larvae	27.6	19.6	14.3	23.2	21.2±2.8
Large larvae	9.2	21.4	8.2	11.9	12.7±3.0
Pupae	2.3	4.5	6.1	12.7	6.4±2.2
Total generation mortality	70.1	72.2	73.5	71.7	71.9±0.7

Table 6. Summary of K-values from life table of *B. fusca* for Boneya and Haru

Boneya		**Generational mortality**			
Stage	**Mortality factor**	**1**	**2**	**3**	**4**
Small larvae	K1 Disappearance	0.20	0.15	0.08	0.16
Medium larvae	K2 Death	0	0.02	0	0.04
	K2 Disappearance	0.15	0.13	0.09	0.07
	K2-total	0.15	0.15	0.09	0.11
Large larvae	K3 Death	0	0	0.01	0.01
	K3 Parasitism	0.04	0.03	0.02	0.04
	K3 Disappearance	0.06	0.12	0.04	0.10
	K3-total	0.10	0.15	0.07	0.15
Pupae	K4 parasitism	0.10	0.06	0	0.03
	K4 disappearance	0.10	0.15	0.05	0.11
	K4 total	0.20	0.21	0.05	0.14
Total	**K-total**	**0.65**	**0.66**	**0.29**	**0.56**
Haru					
Stage		**1**	**2**	**3**	**4**
Small larvae	K1 Disappearance	0.24	0.14	0.26	0.12
Medium larvae	K2 Death	0.05	0	0.06	0.02
	K2 Disappearance	0.23	0.14	0.07	0.14
	K-total	0.28	0.14	0.13	0.16
Large larvae	K3 Death	0.04	0.03	0	0.02
	K3 Parasitism	0.03	0.02	0.04	0.02
	K3 Disappearance	0.09	0.17	0.06	0.07
	K-total	0.16	0.22	0.10	0.11
Pupae	K4 parasitism	0.05	0	0	0.06
	K4 disappearance	0	0.06	0.09	0.10
	K total	0.05	0.06	0.09	0.16
Total	**K- total**	**0.73**	**0.56**	**0.58**	**0.55**

Table 7. Key factor analysis for *B. fusca* using Podoler and Rogers [1] at Boneya and Haru in 2012 and 2013

Stage	Morality factor	Ki	Boneya		Haru	
			r^2	B	r^2	B
Small larvae	Disappearance	K1	0.80	0.26	0.36	0.48
Medium larva	Death	K2a	0.10	0.02	0.27	0.17
	Disappearance	K2b	0.33	0.12	0.62	0.61
	Total	K2c	0.83	0.16	0.90	0.78
Large larvae	Death	K3a	0.83	-0.03	0.35	0.12
	Parasitism	K3b	0.56	0.03	0.1	0.03
	Disappearance	K3c	0.51	0.16	0.02	-0.08
	Total	K3d	0.48	0.15	0.01	0.07
Pupae	Parasitism	K4a	0.72	0.21	0.13	0.14
	Disappearance	K4b	0.77	0.21	0.84	-0.49
	Total	K4c	0.97	0.41	0.36	-0.35

Table 8. Regression analysis and density relationship of *B. fusca* at Boneya and Haru during 2012 and 2013

Stage	Morality factor	Boneya		Haru	
		B	P	B	P
Small larvae	KDisappearance	0.23	0.673	-0.68	0.122
Medium larva	KDeath	0.22	0.138	-0.14	0.212
	KDisappearance	-0.37	0.238	-0.07	0.838
	KTotal	-0.15	0.622	-0.21	0.535
Large larvae	KDeath	0.05	0.214	-0.02	0.746
	KParasitism	-0.02	0.786	-0.03	0.342
	KDisappearance	0.12	0.685	0.05	0.768
	KTotal	0.15	0.645	0.004	0.983
Pupae	KParasitism	**-0.46***	0.012	0.01	0.942
	KDisappearance	-0.22	0.515	0.19	0.111
	KTotal	-0.68	0.154	0.2	0.156

**-significant at P<0.05*

Lowest mortality occurred at pupal and large larval stage at Haru and Boneya, respectively. Midega et al. [4] and Adugna and Hofsvang [11] have also recorded the lowest mortality at pupal stage in the Kenyan coast and Eritrea, respectively. This could be because of the fact that pupa and large larva are protected inside the stem of maize and not exposed to the different mortality factors.

The parasitoid couldn't increase with the increasing population of *B. fusca* as it was possible to determine from the density relationship which was inverse density dependent at Boneya. At Haru the mortality factors acted irrespective of the population of *B. fusca,* because there was no density dependence detected for all the mortality factors.

5. CONCLUSION

From the study two generations of *B. fusca* per year at both locations were recorded. At Boneya and Haru it became clear that natural mortality factors' contribution is very low to put *B. fusca* under control or to a level that it does not cause economic loss. Some natural enemies were recorded on *B. fusca* though their contribution in suppressing the population of the pest was insignificant. Hence, looking for other option (s) of pest management against *B. fusca* in the study areas is inevitable. Creating favorable environment for the existing natural enemies could bring good result since they are in the environment already and unable to act effectively because of several reasons which needs to be investigated. Creating environment that can help them reproduce well and survive better could be good option. Integrating different management practices like cultural control methods, diversifying cropping system and others are needed for effective management of *B. fusca* in western part of Ethiopia.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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