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Life Table and Demographic Parameters of the Lesser Wax Moth, *Achroia grisella*, Reared on Natural Honey Bee Wax

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Abstract Life table is one of the useful procedures to understand the population dynamic of a specie. The population growth of the insect can be studied by using the demographic studies of insect species and summarize the data collected from the population as well as understanding the dynamics. This study was carried out to track the demographic processes, such as birth, death, and fecundity, as these affect the size and composition of the population of *A. grisella* in laboratory conditions. In addition, a life table on honey bee wax is constructed to estimate the rate of population growth and survival of this pest. A stock culture was started by 30 pairs of adult moths to lay eggs. The newly hatched larvae were raised on sanitized combs, and the culture was placed and allowed to reproduce at a room temperature of 31±1°C and 66.28±3% RH with 12L: 12D photoperiod in a closed aquarium tank (9.2×16×9.2 cm). The aquarium was covered with muslin cloth for good aeration in the laboratory. The results show that, the net reproductive rate (R_o) was 29.81 females per female cohort per day. This indicates that within two months (Ro > 1), the population will increase and multiply by this value in the next generation. The infinite rate of natural increase (λ) value was 2.55 female per female per day. This study shows that the estimated intrinsic rate of increase equals to the positive value of 0.94 females per female per day, which indicates that the population of *A. grisella* will increase under laboratory conditions and could be successfully cultured in mass production.

Keywords: *population dynamic, intrinsic rate, net reproductive rate*

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1. Introduction

The life table development for a specific insect is a very useful procedure to understand the population dynamic of a species, and has been used for a long time in insect and animal ecology studies [1]. The demographic studies of insect species have been carried out to help understand the population growth of the insect and summarize the data collected from the population as well as understanding the dynamics [2]. The life table population parameters, such as intrinsic rate of natural increase (r_m) and infinite rate of increase (**λ**), can be used to determine the degree of mortality caused by parasitiods or predators attacking a species in the field conditions [3]. The intrinsic rate of increase can be used to compare between different groups of insect living in different conditions [4]. However, information about the demographics and population growth for predicting insect outbreaks, and developing suitable plans for moth control, are inadequate for the lesser wax moth, *Achroia grisella*.

A. grisella is seriously damages beehives by attacking and consuming the base pillar of the beehive. Bee wax is used to construct the hive cells, which they use for rearing bee broods and the storage of honey [5]. Bee wax is consumed by the larvae of the lesser wax moth to complete the stage development, which threatens the well-being of the honey bee population. *A. grisella* is common in tropical, subtropical and temperate regions, and is more widely distributed than its relative, the greater wax moth, *Galleria mellonella* [6]. The perilous threat presented by this pest is on the stored or unprotected combs in the weak honey beehives [7]. Moreover, it has been reported that *A. grisella* attacks stingless honey bee combs [8]. The lesser wax moth has also been observed attacking bamboo reed, *Ochlandra ebracteata,* as a seed pest [9]. The larval stage is the most destructive stage among the developmental stages of *A. grisella*. The adults do not feed, i.e. consume wax or drink any kind of liquid, until the end of their life after mating and the female lays her eggs [10].

Therefore, this study aims to study the demographic processes, such as birth, death, and fecundity, as these affect the size and composition of the population of *A.*

grisella in laboratory conditions. In addition, a life table on honey bee wax is constructed to estimate the rate of population growth and survival of this pest.

2. Materials and Methods

2.1. Insect Sourcing and Collection

The lesser wax moth, samples were collected from a local honey bee apiary located at Batu Pahat 1°51′N 102°56′E, Johor, Malaysia. The infested honey bee wax combs that contained all stages of the insect were used to establish the laboratory stock culture for further studies.

2.2. Insect Rearing

Natural honey bee combs were pre-treated by freezing at -20°C by placing them in a freezer for 2 days to disinfest the bee wax from the moth developmental stages. A stock culture was started by 30 pairs of adult moths to lay eggs. The newly hatched larvae were raised on sanitized combs, and the culture was placed and allowed to reproduce at a room temperature of 31±1°C and 66.28±3% RH with 12L:12D photoperiod in a closed aquarium tank (9.2×16×9.2 cm). The aquarium was covered with muslin cloth for good aeration in the laboratory to study the biology and life table parameters.

2.3. Life Table Experiments in Laboratory

The eggs were collected to establish the life table experiment. The life table was constructed from two cohorts; one hundred eggs for each cohort. The larvae hatched from these eggs were fed separately on two grams of sterilized natural honey bee wax in 9 cm Petri dishes until pupation. Pupation occurred after the larvae spun the cocoon from silk, frass and wax impurities; the remaining bee wax was removed after pupation. The data obtained from two cohorts of lesser wax moth, A. grisella, were used to construct the life table and age-specific fertility life table.

The following parameters were used to create the life table and fecundity table of (LWM) *A. grisella*, as described by Southwood [12], and Alasady *et al.* [13]

2.4. Life Table Parameters

X: The age class in units of time (days).
L_x: The number of individuals alive between age x and x+1.
T_x: Total number of individual x age units beyond the age x.
d_x: The number of individuals dying during the age interval x.
ex: The expectation of life remaining for individuals of age x.
100 q_X: Apparent mortality percentage RM%: percentage of real mortality calculated based on the population density at the beginning of the generation RM = (d_x/lo) 100.

2.5. Fecundity Schedule

X: pivotal age for the age class in units of time.
l_x: The ratio of individuals surviving at beginning of age class x.
m_x: Age specific fertility .The number of female eggs laid by age class x.
$l_x m_x$: Total number of female eggs laid in age class x.
R_o: Net reproductive rate. Defined by Carey [11] as the average number of offspring females produced by each female during its whole lifetime. It is equal to the summation of the lxmx. It was calculated through the equation:

$$R_{o^\circ} = \Sigma\, l_{x.} m_x$$

T: Cohort generation time (in days), approximated by:

$$T = \Sigma\, X l_x m_x / \Sigma l_x m_x .$$

r_c: Innate capacity for increase, calculated by:

$$r_c = lnR_o / T_c .$$

r_m: The maximum population growth, the intrinsic rate of natural increase or the innate capacity for increase, calculated by iteration of Euler's equation:

$$\Sigma e^{-r.x} l_x m_x .$$

λ: The finite rate of increase, number of female offspring per female per day, calculated by: $\lambda = e^r$.
DT: oubling time, the number of days required by a population to double, calculated by: $DT = ln2 / r$.
b: Intrinsic birth rate calculated by: $1/\Sigma e^{-r} I_x$.
d: Intrinsic death rate calculated by equation: $b - r_m$.
GRR: Gross reproduction rate calculated by: Σm_x.

3. Results and Discussion

3.1. Life Table of Lesser Wax Moth

The lesser wax moth, *A. grisella*, is a true semelparous organism, according to the classification of living organisms [14]. The moth adults neither eat nor drink during adulthood and the individuals have a short limited period of reproduction. After mating and laying eggs for the new generation, the adults die immediately or after a short time. This results in non-overlapping generations. The life and age-specific fecundity results of *A. grisella* show that the first adult emergence occurred at day 40 and 33, and the maximum life span was 61 and 62, respectively. The life table describes the pre-reproductive period of the female, which was 39 days, as well as the reproductive period, which started from day 40 and continued for 12 days until day 52 of the female life span.

The following values obtained from the life and age-specific fecundity table displayed in Table 1, show the estimated generation time T_C of 27.16 days. This indicates the mean elapsed time between the cohort female birth and the offspring female birth. The net reproductive rate (R_o) explains the population growth and describes the number of new individuals produced by the cohort female for the next generation. The (R_o) was 29.81 females per female cohort per day. This indicates that within two months (Ro > 1), the population will increase and multiply by this value in the next generation. The infinite rate of natural increase (λ) value of 2.55 female per female per day shows the change in the net reproductive rate over time. It is a suitable indicator of the population growth for *A. grisella* due to the short reproductive period. The intrinsic rate of natural increase (r_m) reflects the change in population size according to the effect of the female cohort in the time interval. This study shows that the estimated intrinsic rate of increase equals to the positive value of 0.94 females per female per day, which indicates that the population of A. grisella will increase under laboratory conditions. The gross reproduction rate (GRR) shows that the female eggs produced per female cohort in the A. grisella population reared on natural bee wax in laboratory conditions, amount to 159.67 female per female per generation. This also shows that the calculated natural birth rate was 1.06 and that the natural death rate was 0.12 (Table 1).

Table 1. Population and reproductive parameters of *A. grisella*

Parameters	Formula	Values
GRR	Σmx	159.67
R_o	$\Sigma lxmx$	29.81
T_C	$\Sigma\, xl_xm_x/\Sigma\, l_xm_x$	27.16
r_c	$\ln R_o/T_C$	0.12
r_m	$\Sigma e^{-rx}\, l_xm_x$	0.94
Λ	e^r	2.55
DT	Ln2/r	0.74
B	$1/\Sigma e^{-rx}\, l_xm_x$	1.07
D	$b-r_m$	0.13

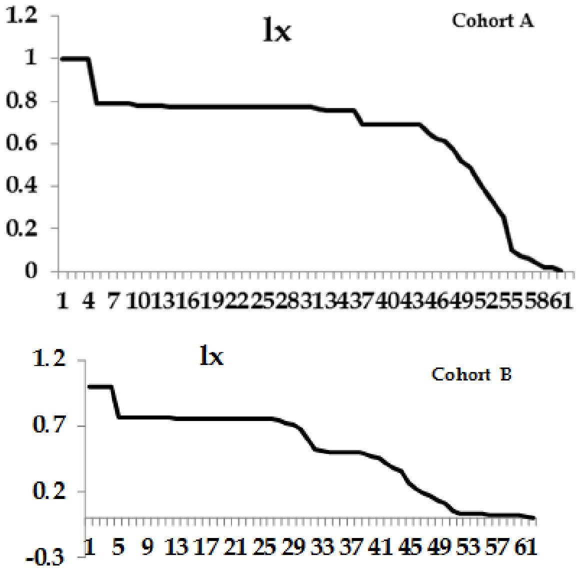

Figure 1. Patterns of survivalship (l_x) curves for the first cohort (A) and second cohort (B) of *A. grisella*

The survival (lx) of *A. grisella*, shown in Figure 1 A and Figure 1 B, for two different generations demonstrate the natural mortality and survival pattern of the individuals plotted through the time (age X). The findings show that when the mortality is concentrated in the late larval and pupal stages, the population survival curve pattern generally becomes an inverted type and near to type 3 pattern following the classification of Pearl [15], Speight *et al.* [16] and Henderson [2] in which moderate survival is observed in the young stages, while moderate survival is seen in the late stages this due to abundant food provided to the young larvae under laboratory conditions.

3.2. Survival and Fecundity of *A. grisella*

The survival and fecundity of *A. grisella* is displayed in Figure 2. The first egg was deposited after one day from female emergence; the highest number of eggs layed was 1,630 eggs, which were laid by 34 females at day 48 of the insect life with an average of 47.90 eggs/female.

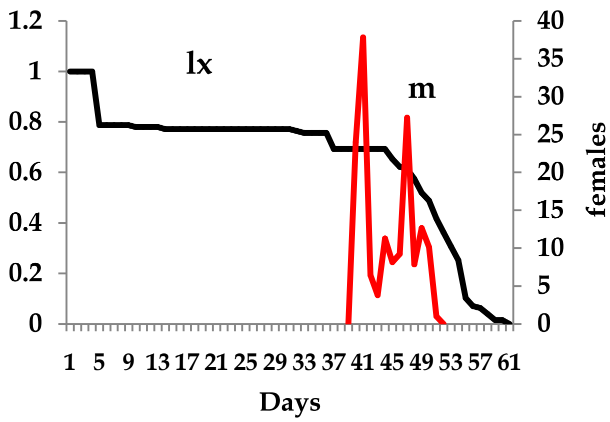

Figure 2. Daily age–specific survivalship (lx) and fecundity (mx) of *A. grisella* females

3.3. Analysis of Immature Mortality

The results on stage specific mortality of the immature stage of *A. grisella* reared on natural honey bee wax are presented in Table 2. The highest mortality, which occurred in the first stage and last larval instar, was 8.33%, 21.26%; it failed to enter the pupal stage. The lowest mortality was observed in the second and 4th instars, which was 2.04% and 2%; relatively moderate mortality 3.41% was observed in the pupal stage.

Table 2. Life table of *A. grisella* reared on natural bee wax

X	lx	dx	Lx	Tx	ex	100qx	RM%	IM%
Egg	127	27	113.5	726.5	5.72	21.26	21.26	22.95
instar I	100	2	99	613	6.13	2.00	1.57	1.73
instar II	98	0	98	514	5.24	0.00	0.00	0.00
instar III	98	0	98	416	4.24	0.00	0.00	0.00
instar IV	98	2	97	318	3.24	2.04	1.57	1.77
instar V	96	8	92	221	2.30	8.33	6.30	7.73
Pupa	88	3	86.5	129	1.47	3.41	2.36	3.00
Adult	85	85	42.5	42.5				

4. Conclusion

Achroia grisella, could be successfully cultured in mass production under suitable laboratory conditions. The high value of r_m 0.9 and low mortality observed among old stages in the absence of predators and larval parasitoids indicates the appropriateness of the natural bee wax diet provided for the larvae; the survival curve pattern generally becomes an inverted type 3 pattern, the result showed high fertility of the first cohort females, and thereby contributed to the population growth of this insect.

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