Tropical Life Sciences Research, 22(1), 25–35, 2011

Life Table and Population Parameters of *Nilaparvata lugens* Stal. (Homoptera: Delphacidae) on Rice

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Abstrak: Kadar kemandirian dan fertility benah perang (BPH), *Nilaparvata lugens* telah dibuat di makmal dan di ladang. Jadual hidup dan parameter populasi benah perang dibuat berdasarkan pada keadaan makanan tak terbatas dan bebas dari musuh semula jadi. Mortaliti tertinggi didapati pada peringkat muda, terutama pada peringkat nimfa satu dan dua. Analisis jadual hidup ini menunjukkan densiti populasi *N. lugens* berkurang pada kadar yang perlahan. Nisbah jantina jantan dan betina ialah 0.512:0.488. Betina dewasa dapat hidup maksimum 20 hari. Corak oviposisi dengan pemuncak didapati pada akhir kehidupan betina. Purata telur tertinggi yang dihasikan per betina dewasa per hari ialah 9.63. Kadar pertambahan intrinsik semula jadi (r_m) ialah 0.0677 per betina per hari dan kadar pertambahan finit harian (λ) ialah 1.0688 betina per betina per hari, dengan purata waktu generasi (T) ialah 34.05 hari. Kadar pembiakan net (Ro) untuk populasi bersangkutan ialah 10.02. Waktu penggandaan populasi (DT) ialah 10.42 hari.

Kata kunci: *Nilaparvata lugens*, Jadual Hidup, Padi, Benah Perang

Abstract: Survival and fertility characteristics of the brown planthopper (BPH), *Nilaparvata lugens* were assessed in the laboratory and field. Life tables and population parameters of the BPH were constructed in an environment with unlimited food supply and that was free of natural enemies. The highest mortality occurred in the immature stage, especially in the first and second instars. The life table analysis showed that the population density of BPH decreased gradually. The survival ratio of male to female was 0.512:0.488. The females lived for a maximum of 20 days. The trend of oviposition showed a peak at around the tenth day of the female life. The highest number of eggs produced per female per day was 9.63. The intrinsic rate of increase (r_m) in egg production per female per day was 0.0677 and the daily finite of increase (λ) was 1.0688 females per female per day, with a mean generation time (T) of 34.05 days. The net reproductive rate (Ro) of the population was 10.02. The population doubling time (DT) was 10.42 days.

Keywords: *Nilaparvata lugens*, Life Table, Rice, Brown Planthopper

INTRODUCTION

Pest infestation and related diseases are major constraints in rice production. Insect pests, including the brown planthopper (BPH), can cause serious damage to the rice crop. Particularly, the BPH *Nilaparvata lugens* (Stal) has become more problematic in posing a threat to rice production throughout South and South East Asia since the early 1970s. The crop yield was reduced to 10%–30%. BPH

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causes serious damage during the early stages of plant growth, and the infested plants show hopper burn symptoms due to intensive sucking of the plant (Lim *et al.* 1978; Norton & Way 1990; Dale 1994). The BPH is also a vector in transmitting viral diseases such as grassy stunt, ragged stunt and wilted stunt (Chen *et al.* 1978; Hibino 1979; Chiu *et al.* 1981). In Myanmar, the first outbreak of BPH was recorded in 1970 at the Kyaukse Central Farm (Mandalay Division) and in the Upper Myanmar (Myint 1975). The BPH has since become a major pest of rice in Myanmar. The construction of life tables is an important tool for understanding the population dynamics of an insect. Age-specific life tables serve as a framework for organising data on mortality and natality. Additionally, it provides a detailed transparent description of the actual properties of the cohorts. It generates simple summary statistics including life expectancy and natality rate. It also has a basic form that can be expanded, condensed, or modified for analysing different types of data such as mortality by various factors (Carey 2001). Analysis of life tables is the most suitable method to evaluate natality and reproduction of a population (Southwood 1978; Begon & Mortimer 1981; Price 1997). Deevey (1947) reported that a life table is a concise summary statement for every interval of age, the number of deaths (d_X), the number of survivors at the beginning of the age class X (l_X), the rate of mortality (q_X), and the expectation of life remaining for individuals of age X (e_X). The table also includes numbers living between the ages X and X+1, which is the age structure (L_X). In such studies, developmental times and survival rates of each stage, longevity of adults, and daily fecundity of females are recorded for every individual (Chi 1988). Therefore, the aim of this study was to construct life tables of BPH fed on rice plants for demographic analysis and to determine the survival rate and rate of increase of the planthopper.

MATERIALS AND METHODS

The insects used for the experiments were cultured in the laboratory. The experiments were conducted in the laboratory and in small holder pesticide-free rice fields at Hmaw Be, Upper Myanmar. The rice plants were grown in pots. Five seeds of rice were placed in each pot (10 cm diameter x 5 cm in length). The pots were filled with soil (13 cm height) prior to seeding. Fifteen days after seeding, the excess seedlings were thinned out; only one or two seedlings were left in each pot. The Manawthukha rice variety was used in this experiment. A wooden cage (length 34 cm x breadth 34 cm x height 61 cm) covered with a wire mesh sieve on each site was constructed for rearing purposes, and a pair of five-day-old BPHs was released into the wooden cage. A thirty-day-old rice plant in a pot was placed on the floor of the wooden cage. The life tables were constructed following the procedure described by Birch (1948) and Southwood (1978). To construct the age-specific life table, 23 pairs were placed into the cages. The cages and rice plants used were as described above. This study was conducted in field cages at temperatures ranging from 23°C to 33°C and relative humidity from 58% to 90%.

After 3 days, the adult male hoppers were removed from the wooden cage. Data including the survival rate of eggs, stage 1–5 nymphal instars and the mortality rate at all the stages were recorded daily and analysed. The total numbers of laid eggs were recorded daily until all the released BPH females had died. The eggs were counted using a magnifying glass. Three cohorts were analysed; cohort A, B and C had 108, 112 and 145 eggs, respectively.

Data analysis was carried out following the single-sex method (Birch 1948; Southwood 1978). Life table was constructed using the following column of parameters:

X	:	the pivotal age for the age class in units of time (days)
l_X	:	the number of surviving individuals at the beginning of age class X
L_X	:	the number of living individuals between the ages X and X+1
d_X	:	the number of dying individuals during the age interval X
$100q_X$	:	percent apparent mortality
S_X	:	survival rate during a stage
T_X	:	total number of age X units beyond the age X
e_X	:	life expectancy for individuals of age X
m_X	:	age-specific fertility, the number of living females born per female in each interval class
Ro	:	net reproductive rate, equal to the sum of the l_X m_X products as in the following equation: **$Ro = \sum l_X m_X$**
T_c	:	cohort generation time (in days), approximated by the following formula: **$T_c = \sum Xl_x m_x / \sum l_x m_x$**
r_c	:	innate capacity for increase, calculated by: **$r_c = \ln Ro/T_c$**
r_m	:	the maximum population growth, the intrinsic rate of natural increase or the innate capacity for increase as calculated by iteration of Euler's equation: **$\sum e^{-rm.X} l_X m_X = 1$**

T : the corrected generation time:
$T = \ln Ro/r_m$

λ : the finite rate of increase, the number of female offspring per female per day, calculated by:
$\lambda = e^{r} m$

DT : doubling time, the number of days required by a population to double, calculated by:
$DT = \ln 2/r_m$

b : intrinsic birth rate:
$1/ \sum e^{-r} m^{X} l_X$

d : intrinsic death rate:
$b - r_m$

To estimate the population parameters of BPH, three sets of data from different cohorts were obtained on different dates (July 2, July 12 and July 22, 2007).

RESULTS AND DISCUSSION

Age-specific Survival Life Table

The survival rate (l_X) of the BPH *N. lugens* in three different cohorts (Fig. 1) showed a similar pattern including high mortality occurring during nymphal growth, particularly at the early instar stage, which gradually decreased during the plant life. The first adults appeared on days 22, 23, 24. The maximum life span (from egg hatching until death of the adult) was 45 days for cohort 1 and 41 days for cohorts 2 and 3. The observed survival pattern indicated that the immature BPHs are more susceptible to physical disruptions caused by suitable food quality. The BPH survival curve indicated a modest increased rate of mortality during early life stages but a relatively gradual decrease as they reached adulthood. The BPH population assumed a type III survivorship curve according to the classification of Pearl (Schowalter 2006) and Speight *et al.* (1999).

Table 1 shows the combined life table describing one pathway of population change, mortality. All the surviving nymphs underwent four moults. The life table showed that about 37.26% of 365 BPH eggs successfully emerged as adults with high mortality occurring during the early immature stages. This survivorship is commonly found in most insect species (Begon & Mortiner 1981).

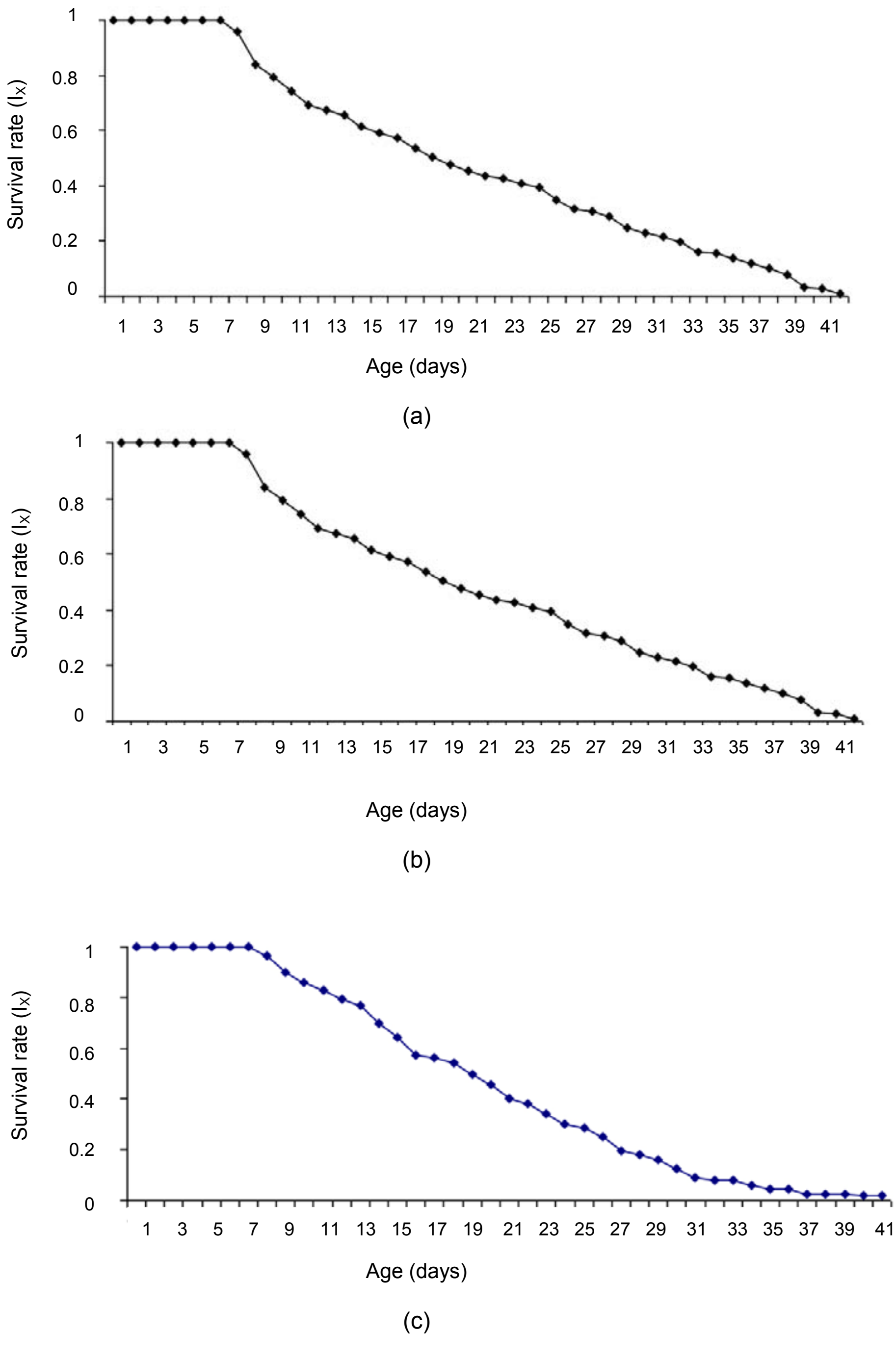

Figure 1: Survivorship curve (l_X) of BPH for three (a, b and c) different cohorts.

Table 1: Pooled life table of BPH on rice.

Age (days)	l_X	L_X	d_X	$100q_X$	S_X	T_X	e_X
Eggs	365	351	28	7.67	92.23	1501	4.11
Nymph							
Instar 1	337	304	66	19.58	80.42	1150	3.41
Instar 2	271	252	38	14.02	85.98	846	3.12
Instar 3	233	214	38	16.31	83.69	594	2.55
Instar 4	195	171	48	24.62	75.38	380	1.94
Instar 5	147	141	11	7.48	92.52	209	1.42
Adult	136	68					

X = developmental stage
l_X = number entering stage
L_X = number alive between stage X and X+1
d_X = number that died in stage X
$100q_X$ = percent apparent mortality
S_X = survival rate within stage
T_X = total number of age X units beyond the age
e_X = life expectancy

Age-specific Fertility Life Table

The survivorship and fecundity of BPH are shown in Figure 2 based on the data in Table 2. The first female emerged on day 21, and the first female died on day 30. The survival rate from egg to adult was 0.92. The proportion of males to females was 0.512:0.488 (Table 2). The last females died on day 41. The females remained alive for a maximum of 20 days. Females started laying eggs from day 24 or within 3 days of emerging as adults. The number of eggs deposited was less in the earlier stages and higher during the later stages of life span. The highest number of eggs per female per day was 9, and this occurred at day 37 when the females were 13 days old.

The population and reproductive parameters of BPH are summarised in Table 3. The intrinsic rate of natural increase (r_m) of BPH was 0.0677 per female per day and the daily finite rate of increase (λ) was 1.0688 female offsprings per female per day with a mean generation time (T_c) of 34.64. The net reproduction rate (Ro) of the population was 10.02, and the doubling time (DT) was 10.42 days. The r_m, T_c and DT are useful indices of population growth under a given set of growth conditions. It is generally presumed that short developmental time and high reproduction rate on a host reflect suitability of the plant tested (van Lenteren & Noldus 1990). Life tables with data on the r_m of a particular species provide insight into the characteristic life patterns of different species (Satpute *et al*. 2005). There is a range of innate capacity for individual of a population (Gill *et al.* 1989). Insect growth, longevity and reproduction can be influenced by the available food sources (host plants or host prey) and also by environmental factors such as temperature (Ellers-Kirk & Fleischer 2006).

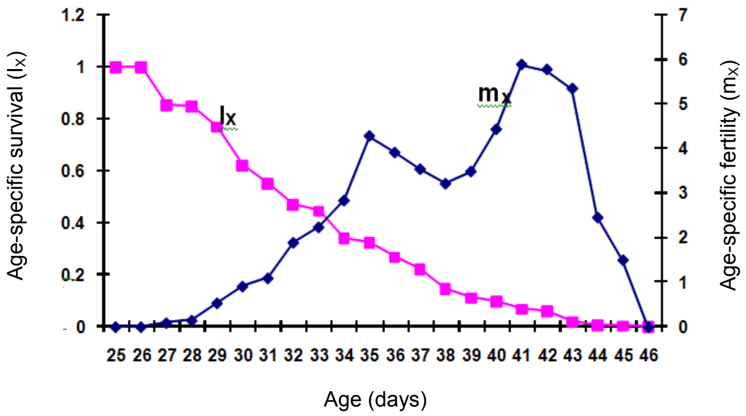

Figure 2: Daily age-specific survival (l_x) and fecundity (m_x) of female BPH fed on rice.

Table 2: Life and age-specific fecundity table of BPH fed on rice.

Age (days)	l_x	Egg per female	m_x	$l_x m_x$	$Xl_x m_x$	$e^{-r}m^X(l_x m_x)$
1	1.00000					
2	1.00000					
3	1.00000					
4	1.00000					
5	1.00000					
6	1.00000					
7	1.00000					
8	1.00000					
9	1.00000					
10	1.00000					
11	1.00000					
12	1.00000					
13	1.00000					
14	1.00000					
15	1.00000					
16	1.00000					

(continued on next page)

Table 2: *(continued)*

Age (days)	l_x	Egg per female	m_x	l_xm_x	Xl_xm_x	$e^{-r}m^X(l_xm_x)$
17	1.00000					
18	1.00000					
19	1.00000					
20	1.00000					
21	1.00000					
22	0.85479	0.14648	0.08950	0.07650	1.75959	0.01613
23	0.84658	0.23758	0.14516	0.12289	2.94936	0.02421
24	0.76986	0.87381	0.53390	0.41103	10.27571	0.07567
25	0.62192	1.48512	0.90741	0.56433	16.92998	0.07407
26	0.55068	1.78697	1.09184	0.60126	18.63900	0.07375
27	0.47123	3.09347	1.89011	0.89068	28.50182	0.10210
28	0.44658	3.65723	2.23457	0.99790	32.93080	0.10690
29	0.33973	4.64094	2.83562	0.96333	32.75331	0.09644
30	0.32329	7.01037	4.28333	1.38475	48.46621	0.12956
31	0.26849	6.40308	3.91228	1.05042	37.81514	0.09185
32	0.22192	5.79126	3.53846	0.78525	29.05416	0.06417
33	0.14795	5.25696	3.21200	0.47520	18.05760	0.03629
34	0.11233	5.70733	3.48718	0.39171	15.27671	0.02796
35	0.09863	7.25586	4.43333	0.43726	17.49041	0.02916
36	0.06849	9.63175	5.88500	0.40308	16.52637	0.02512
37	0.06027	9.44800	5.77273	0.34795	14.61370	0.02027
38	0.01918	8.74795	5.34500	0.10251	4.40779	0.00558
39	0.00548	4.01726	2.45455	0.01345	0.59178	0.00068
40	0.00274	2.45499	1.50000	0.00411	0.18904	0.00018
41	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Total			53.55196	10.02361	347.22850	1.00007

Note: Sex ratio (F:M) = 0.512:0.488.

The survivorship (l_x) of BPH (Fig. 1) showed that high mortality was found during nymphal growth of BPH, particularly in the early stages, followed by a gradual decrease in the population densities throughout its life span over the study period. Velasco and Walter (1993) reported that survival of insects and nymph in the growth and reproductive phase were highly influenced by food quality. The pattern of survivorship of BPH observed indicated that nymphal stages were influenced by food and nutrition quality, and that these insects appeared to be susceptible to the density-dependent factor due to food change during captivity. The effects of different food sources on population parameters were observed in *Earias vitella* (Lepidoptera: Noctuidae) fed on different host plants (Satpute *et al.* 2005), *Diaphorina citri* fed on four different host plants (Tsai

& Liu 2000), and *Orius albidipennis* fed on various arthropod prey (Chyzik *et al.* 1995).

The survivorship curve for BPH was classified as 'Type III' following the criteria described by Speight *et al.* (1999) and Schowalter (2006). According to Schowalter (2006), a poor survivorship trend was observed at the nymphal stage or at a young age, and a higher survivorship trend was observed for the older individuals. In this study, BPH was studied during the rainy season, which is reflected in the mortality rate of the early nymphal stages of BPH. Schowater (2006) reported that insect populations are highly sensitive to changes in abiotic conditions such as temperature, rainfall and relative humidity which, in turn affect their growth and survival.

Table 3: Population and reproductive parameters of BPH fed on rice.

No.	Parameter	Formula	Value
1	Approximate generation time (T_c), (days)	$\sum l_X m_X x / \sum l_X m_X$	34.64
2	Corrected generation time (T), (days)	$\ln Ro/r_m$	34.05
3	Innate capacity for increase (r_c)	$\ln Ro/T_c$	0.0665
4	Intrinsic rate of natural increase (r_m)	$\sum e^{-r}m^X l_X m_X = 1$	0.06769
5	Finite rate of increase (λ)	e^r	1.06876
6	Doubling time (DT), (days)	$\ln 2/r$	10.42
7	Intrinsic birth rate (b)	$1/\sum e^{-r}m^X l_X$	1.25
8	Intrinsic death rate (d)	$b - r_m$	1.18
9	Gross reproduction rate	$\sum m_X$	53.55
10	Net reproduction rate (Ro)	$\sum l_X m_X$	10.02

The combined life table (Table 3) indicates that the population changed according to death and birth rates. It showed that the mortality of eggs of BPH was 7.67%. The mean Ro of BPH was 10.02. However, Birch (1948) stated that comparison of two or more populations by their Ro might be quite misleading unless the mean values of the generation time are same. However, the intrinsic rate of increase, mean generation time and population doubling times are useful indices of population growth under a given set of growing conditions. van Lenteren and Noldus (1990) reported that a short developmental time and high levels of reproduction on a host reflect suitability of the plants tested. If the tested host plants are different, the values of population parameters will vary. Longevity, population fluctuation, reproductive rates and growth rates could be influenced by their food sources (host plants or host preys).

The values of the population parameters can vary under different field and laboratory conditions. It appears that the survival of different stages of BPH in different conditions including cages may vary due to increases in stress among the planthoppers released in the cage during a population study. There is a high degree of environmental variability between field and caged conditions such as temperature, relative humidity, wind speed, solar radiation, and microclimate. The influence of environmental factors on insect population parameters are well exemplified by *Acalymma vittatum* (Coleoptera: Chrysomelidae) fed on cucurbits

(Ellers-Kirk & Fleischer 2006) and *Nasonovia ribisnigri* (Homoptera: Aphididae) fed on lettuce (Diaz & Fereres 2005).

CONCLUSION

The pattern of survivorship that we observed indicated that the young and immature stage was more susceptible to physical disruptions caused by the suitability of the food quality. The survivorship curve indicated a modest rate of mortality during the early life stages and a gradual decrease as it approached adulthood; this curve assumed a near type III survivorship curve. The pooled life table showed that the population changes according to death and birth rates. It showed that mortality of eggs of BPH was 7.67% and the mean net reproductive rate (Ro) was 10.02. The intrinsic rate of natural increase (r_m) of BPH was 0.0677 per female per day and the daily finite rate of increase (λ) was 1.0688 female offspring per female per day with a mean generation time (T_c) of 34.64. The basic reproductive rate of BPH (Ro) was 10.02; the population increased by a factor of 10. Based on these data, at least at the time of data collection, the population was not in any danger of decreasing in size. However, in this study, the cohort life table was constructed based on an unlimited food supply in an environment that was free from natural enemies. The life table data obtained in this study can provide insight into the demographics of planthopper populations. Quantifying age-specific birth and death rates enables us to discern patterns and make predictions about the growth or decline of planthopper populations in the future.

ACKNOWLEDGEMENT

Financial support for this work was from the Third World Organization for Women in Science (TWOWS).

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