LIFE TABLE AND DEMOGRAPHIC PARAMETERS OF BROWN PLANTHOPPER (BPH), *Nilaparvata lugens* (HOMOPTERA: DELPHACIDAE) ON PADDY FOR POPULATION STUDIES

Siti Noor Hajjar Md Latip[1,2*] & Anis Syahirah Abu Bakar[1]
[1] Faculty of Plantation and Agrotechnology,
Universiti Teknologi MARA,
77300 Merlimau, Melaka, Malaysia
[2] Sustainable Crop Protection Research Group,
Universiti Teknologi MARA,
40450 Shah Alam, Selangor, Malaysia
*Corresponding author: *noorhajar@uitm.edu.my*

ABSTRACT

Brown planthopper (BPH), *Nilaparvata lugens* (Homoptera: Delphacidae) is one of the most economically important insect pests, by posing a threat to paddy production throughout Asia including Malaysia. Plants turn yellow and dry up rapidly due to infestation. At early infestation, round and yellow patches appear, which soon turn brownish due to the drying up of the plants, known as Hopperburn which is reported to cause yield loss up to 80%. Life table and demographic parameters play important role in determining the key factors that responsible for the highest mortality within population. Therefore, the objective of the study was to construct life table and demographic parameters of BPH. A survivorship and fecundity study of BPH was conducted in laboratory using three cohorts consisted of 108, 112 and 145 one-day old eggs. The survival and mortality of every life stage were observed and recorded daily. Five pairs of one-day old BPH adults were used in fecundity study. The laid eggs were observed daily and longevity of adults were recorded. Standard life table parameters and population age structures were calculated from daily records of survival, mortality and fecundity of each cohort. The highest mortality was recorded in second instar nymph (15.45%) indicated that this stage is the key factor in regulating BPH population. A total of 57.33% individuals have successfully reached at adult stage. The emergence of first female was on day 20 whilst the last female died on day 40. The earliest egg was laid on day 23 and continued until day 40 with maximum oviposition was on day 36 and 37 which constitute 57.73% of total eggs. The intrinsic rate of natural increase (rm) was 0.08 per female per day with mean generation time (Tc) of 32.64 days and doubling time (DT) of 8.19 days. This shows that BPH population has increased and builds up rapidly in short time period. Our results suggested that the control program should be done during early stage of nymph in order to suppress the BPH population effectively. Life table study of BPH on other local rice varieties should be conducted in determining its survivorship and reproduction on other host varieties.

Keywords: Brown planthopper, *Nilaparvata lugens,* life table, demographic parameters

ABSTRAK

Bena perang (BPH), *Nilaparvata lugens* adalah salah satu perosak serangga yang paling penting dari segi ekonomi, dengan menimbulkan ancaman kepada pengeluaran padi di seluruh Asia termasuk Malaysia. Tumbuhan bertukar menjadi kuning dan kering dengan cepat kerana jangkitan. Pada awal infestasi, tompok bulat dan kuning muncul, yang segera berubah menjadi kecoklatan akibat pengeringan tanaman, yang dikenal sebagai *Hopperburn* yang dilaporkan menyebabkan kehilangan hasil hingga 80%. Jadual hidup dan parameter demografi memainkan peranan penting dalam menentukan faktor utama yang bertanggungjawab untuk kematian tertinggi dalam populasi. Oleh itu, objektif kajian adalah untuk membina jadual hidup dan parameter demografi BPH. Satu kajian kelangsungan hidup dan kesuburan BPH dilakukan di makmal dengan menggunakan tiga kohort yang terdiri daripada 108, 112 dan 145 telur satu hari. Kelangsungan hidup dan kematian setiap peringkat kehidupan diperhatikan dan dicatat setiap hari. Lima pasang BPH dewasa berusia satu hari digunakan dalam kajian kesuburan. Telur diperhatikan setiap hari dan panjang umur BPH dewasa dicatatkan. Parameter jadual kehidupan standard dan struktur umur populasi dihitung dari catatan harian mengenai kelangsungan hidup, kematian dan kesuburan setiap kohort. Kematian tertinggi dicatatkan pada nimfa instar kedua (15.45%) menunjukkan bahawa tahap ini adalah faktor utama dalam mengatur populasi BPH. Sebanyak 57.33% individu berjaya mencapai tahap dewasa. Kemunculan betina pertama adalah pada hari ke-20 sementara betina terakhir mati pada hari ke-40. Telur paling awal pada hari ke-23 dan berlanjutan hingga hari ke-40 dengan oviposisi maksimum pada hari ke-36 dan 37 yang merupakan 57.73% dari jumlah telur. Kadar pertumbuhan semulajadi intrinsik (rm) adalah 0.08 setiap betina sehari dengan purata masa generasi (Tc) 32.64 hari dan masa penggandaan (DT) 8.19 hari. Ini menunjukkan bahawa populasi BPH telah meningkat dan bertambah dengan cepat dalam jangka masa yang singkat. Hasil kajian kami menunjukkan bahawa program kawalan harus dilakukan pada peringkat awal nimfa untuk menekan populasi BPH dengan berkesan. Kajian jadual hidup BPH pada varieti padi tempatan yang lain harus dilakukan dalam menentukan kelangsungan hidup dan pembiakannya.

Kata kunci: Bena perang, *Nilaparvata lugens*, jadual hidup, parameter demografi

INTRODUCTION

Brown planthopper (BPH), *Nilaparvata lugens* (Homoptera: Delphacidae) is one of the most economically important insects of paddy in most Asian countries (Singh et al. 2019). Both nymphs and adults of the BPH damage paddy directly by removing nutrients and indirectly by transmitting pathogens, namely, ragged stunt virus, striped virus and grassy stunt virus (Madhuri et al. 2017). All the stages of paddy are attacked by this pest. Generally, the pest clusters at the base of the plant and feed on the plant sap (Wu et al. 2018). In the initial stages of infestation, round yellow patches on the plant are seen which later turns brownish due to drying up of the plants, known as Hopperburn (Kumar et al. 2020). The phenomenon of hopperburn was reported to cause 20 – 80% yield loss (Haliru et al. 2020).

As in Malaysia, local rice production has long been threatened by the attack of BPH, which has compromised huge and extensive yield losses (Maisarah & Habibuddin 2018). Starting from a serious outbreak since 1967, where it had destroyed more than 5,000 hectare of rice field in West Malaysia worth of USD0.75 million (Dyck & Thomas 1979), the pest invasion is unstoppable. A very recent BPH attack was reported in MADA in 2020, an estimated 30,000 metric tonnes of paddy yield declined with farmers in the state suffering losses reaching RM36 million a year (Mutalib 2021).

The development of an adequate control strategy, with minimal pesticide use, requires basic knowledge on the pest's population dynamics (Ali & Rizvi 2007; Pascua & Pascua 2002). For an ecologically sound integrated pest management program, it is crucial to thoroughly understand the ecology of the pest (Roseli et al. 2019). The life table generates an integrated and comprehensive description in details of development, survival, fecundity and life expectancy of a population, and is often used by scientists as a means of projecting the growth of populations (Rozilawati et al. 2017). Life-tables constructed using laboratory data collected under controlled conditions are useful in revealing the maximal growth potential of a population (Gabre et al. 2005).

Therefore, in order to contribute with helpful information for the management of this pest species, the aim of this study was the construction of a life table and demographic parameters of BPH on paddy at laboratory conditions.

MATERIALS AND METHODS

BPH Collection and Rearing

BPH used for the experiments was collected from the paddy fields at Tanjong Karang, Selangor, Malaysia and reared at the rain shelter in Faculty of Plantation and Agrotechnology, UiTM Puncak Alam Campus, Selangor on Malaysian local paddy variety, MR219 without exposure to any insecticide.

Survivorship Study

Survivorship study of BPH from egg to adult was conducted using three cohorts consisted of 108, 112 and 145 one-day old eggs. Observations of these eggs were made till they hatched. Date of egg laying and hatching was recorded. After egg hatching, the newly hatched of first instar BPH nymphs were supplied with new paddy leaves and monitored daily for their development. The survival and mortality of eggs, nymphs and adults of BPH were observed and recorded daily until their death.

Fecundity Study

A pair of five-day-old BPH was released to potted paddy plants into the cage for oviposition. The pre oviposition period was calculated by observing the first laying of eggs by female adults of BPH after the completion of nymphal stages. The paddy plants were regularly observed for oviposition scars and these were marked as soon as observed and the paddy plants with eggs were removed from cages to avoid counting overlap and new plants were supplied daily for oviposition. Eggs laid by each female were counted and recorded daily until the death of all individuals. The preoviposition and oviposition period, fecundity of females, and adult longevity for both males and females of BPH were recorded.

Data Analysis

In order to calculate the life demographic growth parameters, the data of survivorship (nymph to adult of BPH) and the daily fecundity of females were used to construct the $l_x m_x$ life tables. The data were analysed following the single sex method. Standard life table parameters and population age structures were calculated from daily records of survival, mortality and fecundity of each cohort. The symbol, formula and definition of parameters were following the procedures outlined by Birch (1948) and Southwood (1978) as follows:

x : age class in units of time (days) / developmental stage
l_x : number surviving individuals at beginning of age class(x)

The number of individuals alive, during a given age interval class as a fraction of an initial population of one

L_x : number of individuals alive between age x and x+1, $L_x = (l_x + l_{x+1})$ ½
d_x : number dying during age interval x
100_{qx} : percent apparent mortality, $100_{qx} = (d_x/l_x)100$
S_x : survival stage rate within stage
T_x : total number of age x units beyond the age x
e_x : life expectancy for individuals of age x, $e_x = T_x/l_x$
m_x : age-specific fertility, the number of living females born per female in each age interval
R_o : net reproductive rate, multiplication rate per generation, $R_o=\Sigma\ l_x m_x$
R_c : innate capacity for increase, $R_c = \ln R_o / T_c$
R_m : intrinsic rate of natural increase or maximum population growth, calculated by iteration of Euler's equation, $\Sigma e^{-rm.x}\ l_x m_x = 1$
T_c : cohort generation time (in day), $T_c = \Sigma\ x\ l_x m_x / \Sigma\ l_x m_x$
T : corrected generation time, $T = \ln R_o / r_m$
λ : Finite rate of increase, the number of female off-springs female^{-1} day^{-1}, $\lambda = e^{rm}$
DT : doubling time, the number of days required by a population to double, $DT= \ln 2 / r_m$
b : intrinsic birth rate, $b = 1 / \Sigma\ e^{-rm.x}\ l_x$
d : intrinsic death rate, $d = b – r_m$

RESULTS

Age-specific Survival Life Table

The survivorships of three cohorts of BPH reared on paddy plants are shown in Figure 1. Cohort 1 recorded the egg hatchability of 98% with 61.21% out of total individuals had successfully survived until adult. First adult female emerged on day 20, whilst the last adult female died on day 45. The highest mortality occurred in first instar of larval stage (11.43%) and gradually decreased throughout the life span of population.

In cohort 2, a total of 95% of eggs has successfully hatched with 50% out of total individuals had successfully survived until adult. First adult female emerged on day 22, whilst the last adult female died on day 46. Similar to cohort 1, first instar larvae (7.38%) recorded the highest mortalities compared to other stages. A similar pattern of mortalities also was recorded in cohort 3 in which first instar larvae (7.87%) recorded the highest mortalities. Egg hatchability in cohort 3 was 97% with the total individuals successfully survived until adult was 60.87%. The first adult female emerged on day 21, whilst the last adult female died on day 44.

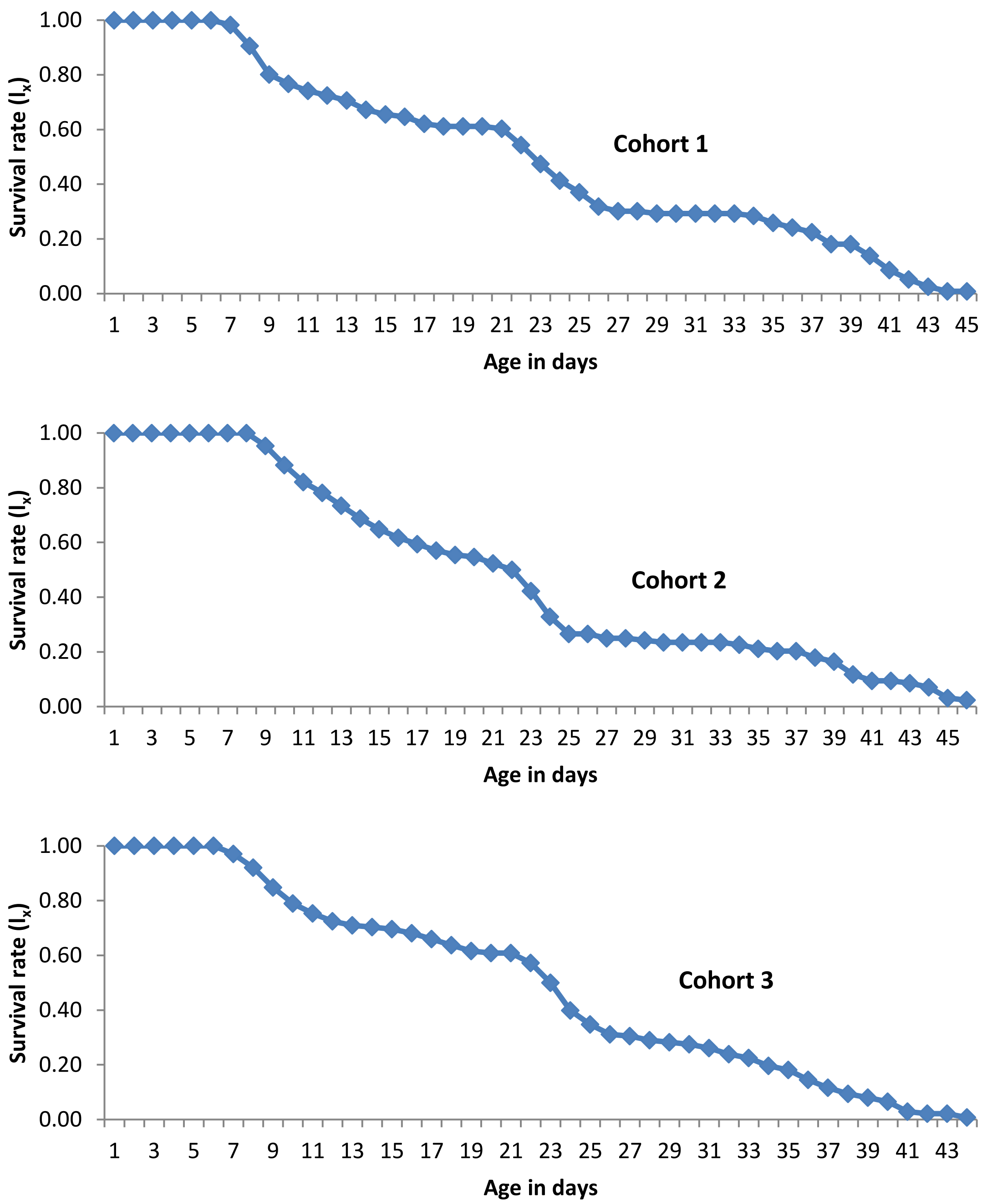

Figure 1. Survivorship curve of three cohorts of brown planthopper reared on paddy plant

Table 1 shows the pooled life table of BPH for three cohorts describing one pathway of population change – mortality. All the surviving nymphs underwent four moults. It indicates that out of 382 eggs of BPH, only 57.33% individuals successfully emerged as adults with high mortality occurring during the early immature stages. Results revealed that the second instar nymph recorded highest mortality (15.45%) followed by first instar (12.30%), fourth instar (7.85%), egg stage (3.14%), third instar (2.09%) and the lowest mortality was recorded in fifth instar nymph (1.83%). Therefore, it can be suggested that second instar nymph of BPH is the ideal stage to be treated with control method in order to suppress the BPH population effectively.

Table 1. Pooled life table of BPH

Age (days)	**l_x**	**L_x**	**d_x**	**$100q_x$**	**s_x**	**T_x**	**e_x**
Egg	382	376.0	12	3.14	96.86	1849.0	4.84
Nymph Instar 1	370	346.5	47	12.70	87.30	1473.0	3.98
Nymph Instar 2	323	293.5	59	18.27	81.73	1126.5	3.49
Nymph Instar 3	264	260.0	8	3.03	96.97	833.0	3.16
Nymph Instar 4	256	241.0	30	11.72	88.28	573.0	2.24
Nymph Instar 5	226	222.5	7	3.10	96.90	332.0	1.47
Adult	219	109.5					

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
100qx: 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 Fecundity Life Table

Age-specific survivorship (l_x) and fecundity (m_x) of BPH are shown in Figure 2. The emergence of first female was on day 20, whilst, the last female died was on day 40. The earliest egg laid was on day 23 which was three days after first female emerged. The number of eggs deposited was less in the earlier stages and higher during the later stages of lifespan. The oviposition had been continued until day 40 with maximum oviposition was on day 36 and 37 which constituted 57.73% of total eggs laid.

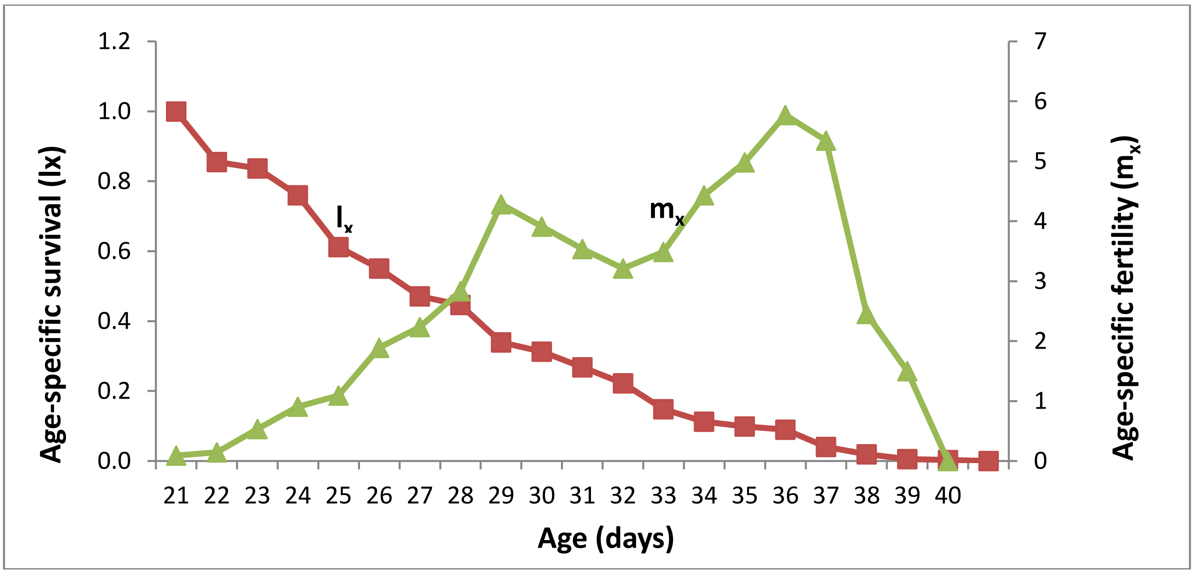

Figure 2. Survivorship curve (l_x) patterns for three cohorts of Brown planthopper (BPH)

The population and reproductive parameters of BPH was summarized in Table 2. The intrinsic rate of natural increase (r_m) was 0.06 per female per day and the net reproductive rate (R_o) was 9.08 which indicated the population had increased because the value was above 0 and

1, respectively (Manikandan et al., 2014). The daily finite rate of increase (λ) was 1.06 for female offsprings per female per day with mean generation time (T_c) of 32.64 days. The population had doubled up in 9.42 days.

Table 2. Population and Reproductive Parameters of BPH

No.	Parameter	Formula	Value
1	Approximate generation time (T_c), (days)	$\Sigma\ l_x m_x x / \Sigma\ l_x m_x$	32.64
2	Corrected generation time (T), (days)	$\ln Ro/r_m$	32.05
3	Innate capacity for increase (r_c)	$\ln R_o/T_c$	0.06
4	Intrinsic rate of natural increase (r_m)	$\Sigma\ e^{-r}m^{x}\ l_x m_x = 1$	0.06
5	Finite rate of increase (λ)	e^{r}	1.06
6	Doubling time (DT), (days)	$\ln 2/r$	9.42
7	Intrinsic birth rate (b)	$1/\Sigma\ e^{-r}m^{x}l_x$	1.17
8	Intrinsic death rate (d)	$b–r_m$	1.02
9	Gross reproduction rate	$\Sigma\ m_x$	52.34
10	Net reproduction rate (R_o)	$\Sigma\ l_x m_x$	9.08

DISCUSSION

The survival of BPH indicated a gradual increased rate of mortality during initial developmental stages and then it relatively decreased in the advanced stages up to adulthood, which may reflect a type-III survivorship curve based on classification made by Schowalter (2016). The curve depicts a population with high mortality occurred in early stages compared to later stages with lower mortality rate and keep decreasing until all individuals died.

These results are also in agreement with the findings of Win et al. (2011) who reported that the survivorship of BPH showed that high mortality was found during nymphal growth of BPH, particularly in the first and second instars stages, followed by a gradual decrease in the population densities throughout its life span over the study period. Results from Roseli et al. (2019) also indicated that survivorship curve pattern of rice leaf folder, *Cnaphalocrocis medinalis* population fall into type III curve as mortality rate was higher in early stages and lower in later stages. So, it is suggested that first and second instars may be critical for the application of control measures.

It indicates the female laid the maximum number of eggs in earlier days of oviposition while much lesser number of eggs were laid in later days of oviposition period which seem to be similar with result of Zhang et al. (2019). Maximum oviposition was recorded on second and third day of oviposition period and then followed by a gradual decline towards the last day of oviposition. This phenomenon also occurred in rice leaf folder, *Cnaphalocrocis medinalis* (Lepidoptera: Pyralidae) which reared on rice host plants (Roseli et al. 2019) and diamondback moth, *Plutella xylostella* which reared on brassicaceous host plants (Golizadeh et al. 2009).

However, the values of the parameters in this study were lower as compared to values reported earlier by Manikandan et al. (2014), Win et al. (2011) and Zhang et al. (2019). Kocourek et al. (1994) stated that the r_m is a reflective of many factors such as fecundity, survival and generation time which adequately summarizes the physiological qualities of an insect in relation to its capacity to increase. In the same time, the R_o value is a reflection of r_m value (Golizadeh et al. 2009). Therefore, the difference of the population growth parameters of BPH between this study and previous studies was contributed by differences in reproduction of population. Southwood and Henderson (2000) had stated that r_m would be a most appropriate index in evaluating insect performance towards different factors and variables.

CONCLUSIONS

In conclusion, survivorship curve pattern of BPH population fall into type III curve as mortality rate was higher in early stages and lower in later stages. Population growth of BPH was rapid and has built up in short time period as the intrinsic rate of natural increase (r_m) was 0.08, net reproduction rate (R_o) of 14.48 and doubling time of 8.19 days. Our results suggested that the control program should be done during early stage of larvae in order to suppress the BPH population effectively. Therefore, it can be suggested that first and second instar is the ideal stage to be treated with control method in order to suppress the BPH population effectively. Life table study of BPH on other local rice varieties that planted by most farmers in Malaysia should be conducted. It is to gain knowledge regarding survivorship and reproduction of BPH on other host varieties.

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