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AGE-SPECIFIC SURVIVAL RATES OF THE RICE BROWN PLANTHOPPER, *NILAPARVATA LUGENS* (STAL.) IN THE LABORATORY

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Keywords: Brown planthopper, Age-specific survival, Life table, Survivorship curve.

RINGKASAN

Kadar kemandirian yang berkaitan dengan umur telur, nimfa dan peringkat-peringkat dewasa bena perang betina, *Nilaparvata lugens* (Stal.) dalam keadaan makmal ditentukan. Keluk-keluk kemandirian yang diperolehi dengan menggunakan model BELLOWS dan BIRLEY (1981) telah didapati hampir-hampir sama dengan kadar kemandirian harian pada setiap peringkat. Oleh sebab itu, populasi serangga boleh dimodelkan daripada purata dan sisihan piawai bagi peringkat hidup serangga berkenaan.

INTRODUCTION

Changes in insect population sizes depend on recruitment, mortality and migration. Various techniques to estimate values of these ecological processes have been described in the literature (SOUTHWOOD, 1978). A convenient way to express mortality factors is in an age-specific life table, which consists of a record of the development of individuals through the various life stages from egg to adult. Such data can be used to extract stage specific mortalities or stage recruitments (RICHARDS and WALOFF, 1954; DEMPSTER, 1961) and predict population densities of the various stages (MANLY, 1974; BIRLEY, 1979; BELLOWS and BIRLEY, 1981). The technique of BELLOWS and BIRLEY has several advantages in that it allows for distributed developmental periods of the various stages, it does not assume a constant mortality for successive stages and it does not require the observation of recruitment at each stage. Only the recruitments at the initial stage are needed, subsequent stages are predicted from the estimated development periods and survival rates at each stage.

In this paper, the age-specific survival rates of the egg, nymph and adult stages in the rice brown planthopper (BPH), *Nilaparvata lugens* (Stal.) in the laboratory are determined using the technique of BELLOWS and BIRLEY. Only female adults have been considered and the nymphal stage was not differentiated into different instars in the experiments.

Age-Specific Survival Rates

An age-specific life table can be constructed using the method described by VARLEY, GRADWELL and HASSELL (1973) and SOUTHWOOD (1978). In this case, the stage survival rates may be calculated by comparing the densities of stage *i* and stage *i+1*. For instance, the stage survival rate of the egg stage, *S*, is

$$S = \frac{\text{density of 1st instar nymph}}{\text{initial egg density}}$$

By assuming that the daily survival rates and the stage developments are constant, the daily survival rate, *s*, can be calculated by

$$\ln s = \ln S/d \qquad (1)$$

where *d* is the stage development period.

Alternatively, the stage life span data may be approximated to a truncated normal

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distribution (BELLOWS and BIRLEY, 1981);

$$P_j = 1 - (k\sigma\sqrt{2\pi})^{-1} \int_{-\infty}^{j} \exp\left[-0.5([t-\mu]^2/\sigma^2)^2\right]dt \qquad (2)$$

where, P_j represents the likelihood of the insect surviving to age j, μ and σ^2 are the mean and variance of the adult developmental period, respectively, and k is a constant. As pointed out by BELLOWS (1979), this is only an approximation as the age index j is not permitted to be negative. The approximation is more precise when the mean is much greater than the standard deviation ($\bar{x} >> s$). The constant k is required to ensure that the sum of P_j's over the range of j's approximate unity.

MATERIALS AND METHODS

BPH Cultures

Green house stock cultures of BPH were reared on 60–80 day-old rice plants (var. MR 1). For the experiments, standard BPH cultures were initiated by placing two plots of 60-day-old rice plants into the stock culture for 24 hours. The plants were then removed and placed into a fresh aluminium cage (90 x 60 x 90 cm_3). As soon as the nymphs hatched, the cage was replenished with rice plants.

Experimental Cages

All the experiments were carried out using cages made of mylar sheets. They were 7 cm in diameter and 42 cm high with the top and a cut-out window of 6 cm x 7 cm covered with muslin cloth. Each cage was placed over a 60-day-old rice plant grown in a pot. To avoid experimental insects getting trapped in the mud, the pot was covered with a piece of cling sheet.

Experimental Conditions

The experiments were conducted in the laboratory at a temperature of 25°C ± 4°C, RH 70%–80% and natural illumination of about 12h light and 12h darkness.

Adult Female Survival Rates

A pair of freshly moulted macropterous female adults from the standard BPH culture was placed into each experimental cage with a macropterous male. Thirty pairs of BPH were used in the experiment. At 24-hour intervals, mortality of the adult female was recorded.

Egg Survival Rates

A pot of 60-day-old rice plants was placed in the BPH stock culture for 24 hours to allow eggs to be oviposited. It was then removed and brought into the laboratory for incubation. After four to five days, the tillers of the plants were cut and examined for eggs. Tillers with eggs were cut and placed into petri dishes with moist filter paper. The total number of eggs in each petri dish was counted under the binocular microscope. The petri dishes were examined daily for a week and the first instar nymphs that appeared were recorded and removed. This procedure was repeated five times.

Nymph Survival Rates

The BPH nymphal stage undergoes five instars of two to three days each. For this experiment, the different instars were not differentiated and all the nymphal instars were treated as one nymphal stage.

Freshly hatched first instar nymphs were removed from the standard BPH cultures with a fine camel brush and placed onto rice plants in the experimental cages. To minimize density dependent effects, five nymphs were placed in each cage and ten cages were used. The nymphs were observed daily until they moulted into adults. At each observation, the numbers in each nymphal instar and the adult stage were recorded. The experiment was repeated five times and a total of 250 nymphs was observed.

RESULTS

Adult Survival Rates

The mean female longevity (in days) was found to be 18.87 with a standard

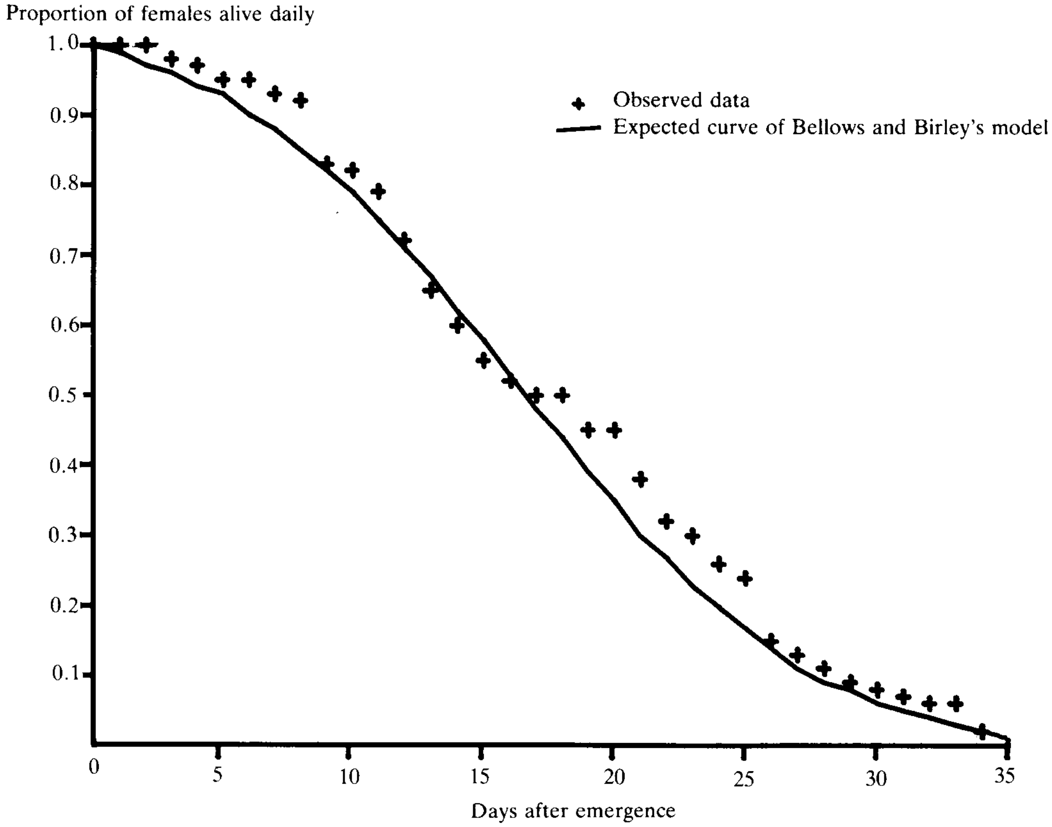

Figure 1. Daily survival rates of the brown planthopper adult female.

Table 1. Egg hatchability and developmental period of the brown planthopper in the laboratory

	Replicates					
	I	II	III	IV	V	Total
Total eggs	297	301	326	352	300	1 577
Eggs hatched	93	79	83	102	91	448
% eggs hatched	31.3	26.3	25.5	28.9	30.3	28.4
Egg development period (days)						
Mean ($\bar{x}$)	15.58	10.75	12.89	11.01	13.54	12.82
Std. dev. (s)	5.69	5.51	5.53	5.77	4.02	5.38

deviation of 7.98 and a range of 2 to 34. Daily survival rates were obtained by computing the proportion of adults alive on each day. This is shown in *Figure 1*. The expected curve of the truncated normal distribution model was generated using the mean and standard deviation with a computer program coded in FORTRAN. The observed data well approximated the predicted values from the model ($r^2 = 0.99$, d.f. = 32).

Egg Survival Rates

The results are shown in *Table 1*. The percentage of eggs hatched was obtained by dividing the number of eggs that hatched and the initial egg numbers. A total of 1 577 eggs was observed and the mean percentage of eggs hatched was 28.4. For egg duration, only the data of the hatched eggs were used. The mean of the five replicates was found to be 12.82 days with a standard deviation of 5.38.

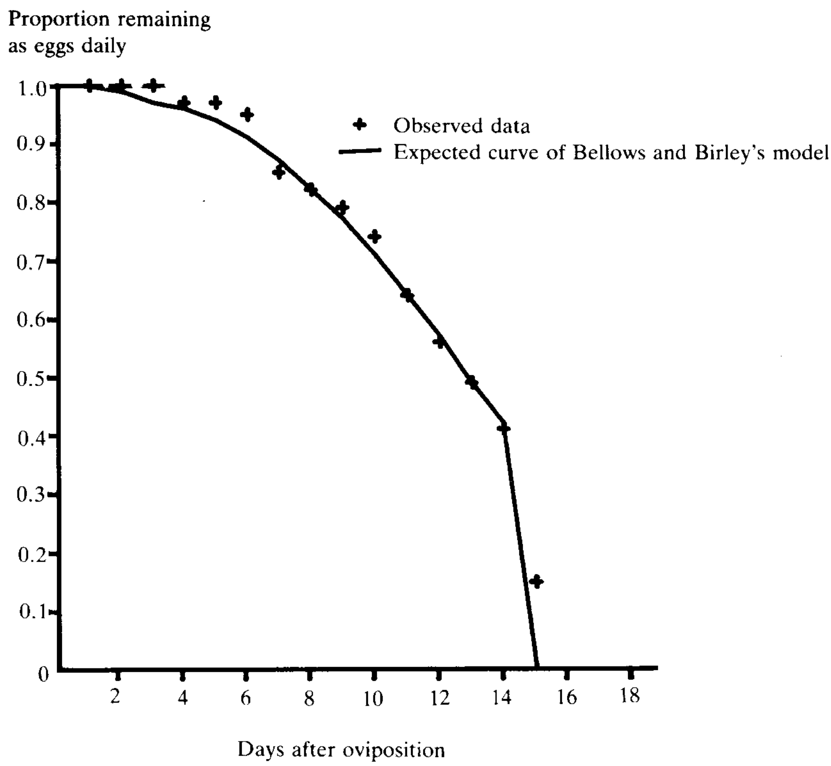

Figure 2. Daily probabilities of brown planthopper eggs remaining in the egg stage.

Table 2. Nymphal survival and developmental period of the brown planthopper in the laboratory

	Replicates					
	I	II	III	IV	V	Total
Total 1st instar nymphs	50	50	50	50	50	250
No. becoming adults	40	40	49	46	47	222
Proportion of survival	0.80	0.80	0.98	0.92	0.94	0.89
Nymphal period (days)						
Mean ($\bar{x}$)	9.60	9.18	8.96	9.40	8.74	9.19
Std. dev. (s)	1.14	1.75	1.11	1.39	1.48	1.40

Daily probabilities of an egg hatching into a nymph was obtained by computing the proportion of nymphs hatched on each day of the experiment. The probability of eggs remaining in the egg stage is thus one minus the probability of hatch. These probabilities are plotted in *Figure 2*, with the expected curve generated using the truncated normal distribution model as discussed earlier. The predicted values appear to closely approximate all the observed points ($r^2 = 0.98$, d.f. = 13).

Nymph Survival Rates

The results are shown in *Table 2*. Mean nymphal survival rate was found to be 89% and the nymphal duration was 9.19 days with a standard deviation of 1.40.

The daily probabilities of a nymph remaining in the nymph stage, computed by comparing the number of nymphs present each day with the initial number, are plotted in *Figure 3*. The predicted curve is obtained

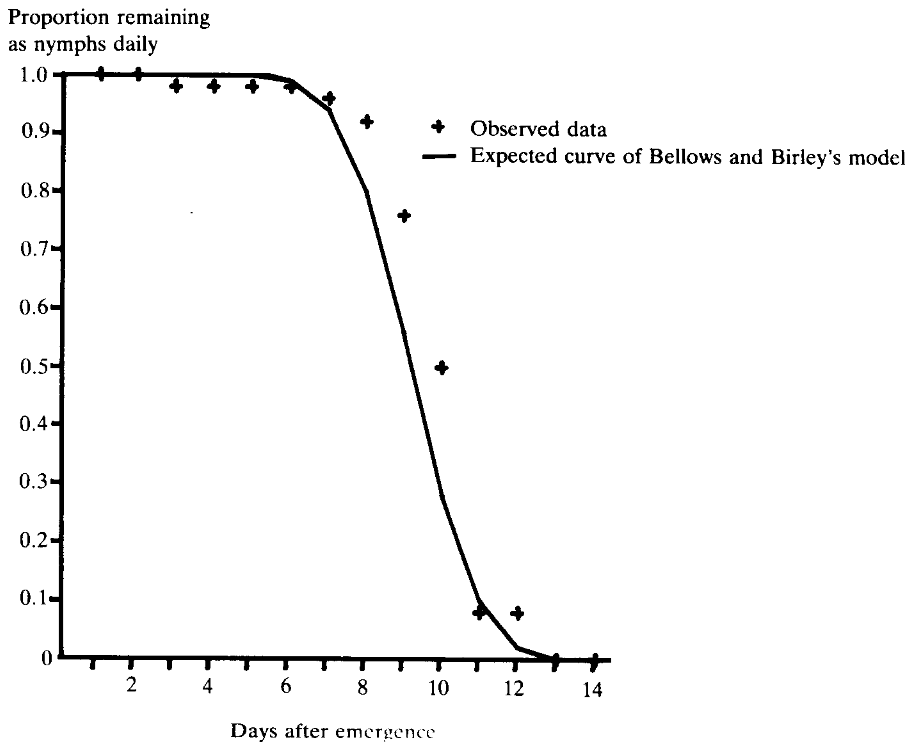

Figure 3. Daily probabilities of brown planthopper individuals remaining in the nymph stage.

Table 3. Comparison of biological parameters of *Nilaparvata lugens* obtained in Japan and in this study

	MOCHIDA & OKADA*	This study
Experimental conditions		
Rice variety	*japonica*	*indica*
Stage of host plants	seedlings	60 days
Egg		
Hatchability (%)	65 – 92.5	28.4
Stage period (days)	8 – 8.5	12.8
Nymph		
Survival rate (%)	96 – 98	88.8
Stage period (days)	12.6 – 13.2	9.2
Adult (Macropterous female)		
Longevity (days)	27.6	18.9

*Data cited are extracted for the range of temperatures used in this study (25°C–29°C) for comparison.

from the mean and standard deviation as discussed earlier. Again, the data are well approximated by the predicted values of the truncated normal distribution (r^2 = 0.96, d.f. = 11).

DISCUSSION

There are considerable differences in the biological data of the BPH obtained from studies done in Japan (MOCHIDA and OKADA, 1979) and this study *(Table 3)*. This may be due to the differences in the experimental conditions used, namely, the rice varieties, stage of the host plants and other experimental conditions. Temperature has a significant effect on the biological parameters. Adult longevity and oviposition may be affected by temperature conditions not only during the adult stage, but also in the nymphal stages (MOCHIDA and OKADA, 1979). Since it is difficult to maintain the temperature at all times in ordinary laboratory and field conditions, variations in the parameters will be inevitable. Other experimental conditions in which the data are obtained should, however, be specified and maintained for each experiment as well as subsequent ones in the series.

The daily survival rates of the adult female, the probabilities of BPH individuals remaining in the egg and nymphal stages can be adequately approximated by the normal distribution, truncated at zero, of BELLOWS and BIRLEY (1981). This survivorship function is based on the premise that individuals have age specific probabilities of daily survivals. These probabilities P_j represent the likelihood of an individual surviving to age *j*. The model was also found to adequately approximate the survival rates of *Plutella xylostella* adults reared under various temperature regimes (SIVAPRAGASAM and HEONG, 1984).

With this approximation, the development of an insect population can be predicted from the means and standard deviations of the stages. Population models that incorporate this approximation function are thus more generalized and can be easily adapted for other related insects. The maximum stage durations, their means and standard deviations often reported in literature describing life histories can now be used as initial parameters to model population developments.

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ABSTRACT

The age-specific survival rates of the egg, nymph and adult female stages of the brown planthopper, *Nilaparvata lugens* (Stal.) under laboratory conditions are determined. Survivorship curves obtained using the model of BELLOWS and BIRLEY (1981) have been found to closely approximate the daily survival rates at each stage. Thus, the insect population can be modelled from the means and standard deviations of the various stage.

REFERENCES

BELLOWS T.S. JR., and BIRLEY, M.H. (1981). Estimating developmental and mortality rates and stage recruitment from insect stage-frequency data. *Res. Popul. Ecol.*, ***23***, 232–44.

BIRLEY, M.H. (1979). Estimating the developmental period of insect larvae with applications to the mosquito *Aedes aegypti* (L.) *Res. Popul. Ecol.*, ***21***, 68–80.

DEMPSTER, J.P. (1961). The analysis of data obtained regular sampling of an insect population. *J. Anim. Ecol.* ***30***, 429–32.

MANLY, B.F.J. (1974). Estimation of stage-specific survival rates and other parameters for insect populations developing through several stages. *Oecologia,* ***15***, 277–85.

MOCHIDA, O. and OKADA, T. (1979). Taxonomy and biology of *Nilaparvata lugens* (Hom., Delphacidae). In *Brown Planthopper: Threat to Rice Production in Asia*, pp. 21–43. Los Banos: International Rice Research Institute.

RICHARDS, O.W. and WALOFF, N. (1954). Studies on the biology and population dynamics of British grasshoppers. *Anti-Locust Bull.*, ***17***, 182pp.

SIVAPRAGASAM, A. and HEONG, K.L. (1984). The effects of temperature on adult survival, oviposition and the intrinsic rate of increase of *Plutella xylostella* (L.). *MARDI Res. Bull.* ***12***(3), 341–7.

SOUTHWOOD, T.R.E. (1978). *Ecological Methods: With Particular Reference to the Study of Insect Populations.* London: Chapman and Hall.

VARLEY, G.C., GRADWELL, G.R. and HASSELL, M.P. (1973). *Insect Population Ecology.* Oxford: Blackwell Scientific Publications.

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