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Population Dynamics of Rice Brown Planthopper (*Nilaparvata lugens* Stal.) in Field and Natural Enemy-Free Condition: Life Table Parameters

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The life table of rice BPH was studied under field and natural enemy free condition on three rice varieties *viz*., PTB33, Udaya and TN1 representing resistance, moderate resistance and susceptibility to BPH respectively. Under field condition, BPH mortality was very high in all the three varieties and all the growth stages starting from egg to adult stage due to high predation of spiders and to lesser extent by mesovelid bugs and Dryinids. The population trend index was low, recording 0.72, 2.11 and 2.15 respectively for PTB33, Udaya and TN1, whereas, it was higher recording 13.20, 22.28 and 25.55 respectively under natural enemy free condition. BPH population assumed a near type II diagonal survivorship curve. Mortality survival ratio (MSR) was the highest for the 1st and 2nd instar BPH and as the insects grew, MSR values gradually dwindled and again at 5th instar stage there was a rise. Indispensable mortality (IM), at egg stage was maximum followed by early instars in all the three varieties examined and was minimum during late instars and adult stages.

Key words: Life table, brown planthopper, *kharif*, spiders, survivorship curve

Rice brown planthopper, *Nilaparvata lugens* Stal. is a threat to rice production throughout South and South East Asia since 1960s. Recently, outbreaks have been noticed in several parts of world and the year 2009 was the worst year for BPH outbreaks (Anonymous, 2010). It has been observed since long that natural biological control in irrigated rice at the early crop stages can mainly be attributed to spiders. The construction of life tables is an important tool for understanding the population dynamics of an insect and it is the most important conceptual and analytical tool in entomological research. Life tables are suited for comparing performance of arthropod pest on different cultivars and can provide standard sets of life history data to measure the degree of host plant resistance (Ruggle and Gutierrez, 1995). A life table developed from field data may be used to estimate fitness of a population as influenced by biotic and abiotic factors. On the other hand, life tables constructed using laboratory data are useful in revealing the maximal growth potential of a population. The objective of the current work is to determine the types and rates of BPH mortality that occur at different life stages on different rice varieties and also to determine the key factors associated with such mortality.

Materials and Methods

Three rice varieties were selected to study the life table of BPH *viz*., PTB33, Udaya and TN1 representing resistance, moderate resistance and susceptibility to BPH respectively. Seedlings were transplanted in pots 15 days after sowing and in field 30 days after sowing. For natural enemy free condition, each plant was grown in 13 cm diameter mud pots and covered with insect proof cages to prevent entry of predators as well as moving of insects from one plant to another and care was taken to provide sufficient nutrients to plants. Fifty days-old plants were utilized for life table construction studies. The BPH used for the life table studies were obtained by culturing continuously on susceptible TN1 plants in the net house.

The field study was conducted in a demarcated micro plot size of 1x1x1m made in irrigated field with pegs in five locations in the plot of each variety, where each location represents each replication. Simultaneously, a potted plant of each variety was released with ten three days old BPH females and three males and covered with Mylar film® in laboratory. The adult hoppers were taken out a week after release and those plants laden with eggs were kept at middle of respective field micro plots so as to allow natural exposure. After hatching of all nymphs, the nymphs were distributed carefully among the plants in the micro plot using a mouth aspirator. After this, the eggs laden plants were examined for number of eggs laid totally, unhatched and parasitized eggs. Five such replications were maintained for each variety.

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For the natural enemy free condition, single sex method was followed (Southwood, 1978 and Win *et al*., 2009) *i.e*., a plant of particular variety was confined with a single female and male insect and the emerging nymphs were observed to construct life table. Data on survival rate of eggs, 1st to 5th nymphal instar and adults were recorded daily for calculations. Mortality associated factors were investigated at the eggs, larval and adult stages. The stage specific survival life table was constructed using the following parameters.

X : the pivotal age for the age class in units of time (days).

lx : the number of surviving individual at the beginning of age class x.

Lx : the number of individual alive between age x and x+1.

Tx : total number of individual x age units beyond the age x.

dx : number of individuals dying during the age interval x.

ex : expectation of life remaining for individuals of age x.

Survivorship curve was fitted in a graph taking different insect stages in x-axis and the number of individuals surviving at each age in y-axis.

Apparent Mortality (100 qx): It gives the information on number dying as percentage of number entering that stage and was calculated by using the formula:

Apparent Mortality = [dx / lx] x 100

Survival Fraction (Sx): Data obtained on apparent mortality was used for the calculation of the stage specific survival fraction (Sx) of each stage by using the equation:

Sx of particular stage = [lx of subsequent stage] / [lx of particular stage].

Mortality Survivor Ratio (MSR): It is the increase in population that would have occurred if the mortality in the stage, in question had not occurred and was calculated as follows:

MSR of particular stage = [Mortality in particular stage] / [lx of subsequent stage]

Indispensable Mortality (IM): The number of BPH that reached adult stage on each variety was averaged both under field and laboratory condition. Indispensable (irreplaceable) mortality is the portion of generation mortality that would not occur if the apparent mortality (qx) of an age interval was removed from the life system. It is assumed that the subsequent mortality factors will destroy the same percentage of the population independent of the change in population density.

Indispensable Mortality

IM = [Number of adults emerged from each variety] x [M.S.R. of particular stage]

Trend index

Population trend index measures the potential of population growth between next generation and current generation. Trend index was calculated as N_2/N_1.

Where, N_1- number of eggs during the start of experiment (0 generation)

N_2- number of eggs produced by F1 generation.

k-values: It is the key factor, which is primarily responsible for increase or decrease in number from one generation to another and was computed as the difference between the successive values for “log lx “. However, the total generation mortality was calculated by adding the k values of different development stages of the insect, which is designated/ indicated as “K”.

K = k1 + k2 + k3 + k4 + k5 + k6

Where, k1, k2, k3, k 4, k5 and k6 are the k-values at egg, first instar, second instar, third instar, fourth instar and fifth instar stages of BPH respectively.

Results and Discussions

The efficiency of spiders in regulating BPH population was studied at CRRI under pesticide free environment both in field and laboratory condition during Kharif 2010 during which period, the pest population was very low except BPH. Under field condition, BPH mortality was very high during all the growth stages starting from egg to adult stage due to high predation especially by an array of spiders and to lesser extent by mesovelid bugs besides parasitization by Dryinids. Though the mortality factors during early growth stages include mesovellid bugs and unknown factors (environmental and host plant associated) in later stages the key mortality factor was a wide array of spiders (*viz*., *Lycosa* sp., *Marpissa* sp., *Cheiracanthium* sp., *Pardosa* sp., *Oxyopes* sp., *Neoscona* sp. and *Tetragnatha* sp.). Among the different spider species, *Oxyopes, Lycosa, Pardosa* and *Tetragnatha* were predominant. BPH population was brought to even less than 2/hill from the initial population of 20-25 /hill within 20 days without any pesticide and the spider population ranged between two and eight /hill. Hence, the predatory capacity of spiders as a control measure is worth investigating.

The survival rate during the nymphal period tended to decrease. As reported by Ali and Rizvi, (2007) the early larval instars were much delicate than the later instars and hence, showed higher mortality at first instar stage. Besides, decreasing survival may also be due to the higher density of spiders. As reported earlier, the density of spiders

Table 1. Stage specific life-table of brown planthopper in PTB 33 under field condition

x	lx	Lx	dx	100qx	Sx	Tx	exk-value		MSR	IM	Mortality factors
Egg	1114.00	984.50	259.00	23.25	0.77	1902.00	1.71	0.11	0.30	59.42	Unable to hatch; unknown
1st instar	855.00	582.00	546.00	63.86	0.36	917.50	1.07	0.44	1.77	10.19	Predation by spiders; Mesoveliid bugs; unknown
2 nd instar	309.00	199.50	219.00	70.87	0.29	335.50	1.09	0.54	2.43	7.40	Predation by spiders; Parasitization by dryinids
3 nd instar	90.00	66.00	48.00	53.33	0.47	136.00	1.51	0.33	1.14	15.75	predation by spiders & mesoveliid bugs
4 nd instar	42.00	36.50	11.00	26.19	0.74	70.00	1.67	0.13	0.35	50.73	Predation by spiders, rove beetle & mesoveliid bugs
5 nd instar	31.00	24.50	13.00	41.94	0.58	33.50	1.08	0.24	0.72	24.92	Predation by spiders & mesoveliid bugs
Adult	18.00	9.00	-	-	-	-	-	-	-	-	Predation by spiders
F1 eggs	801.00										

Trend index= 0.72
K value = 1.79

gradually increased after transplanting in paddy fields (Widiarta *et al*., 1991). From a separate study to work out the predatory capacity of spiders on BPH under confinement, it was revealed that spiders prefer late instars compared to early ones. Similarly, in the mixed BPH population, the preference of spiders was more towards brachypterous female insects followed by macropterous females, and the least preference was brachypterous males followed by macropterous male insects. It was noticed that in most species, a single spider can be capable to devour up to ten female insects in a single day. Apart from these, other key factors responsible for mortality may also include environmental factors like rainfall, low temperature and relative humidity. Similar reports were found with *Anopheles* spp. who reported along with predators, environmental factors controlled larval populations to a large extent (Okogun, 2005).

Table 2. Stage specific life-table of brown planthopper in Udaya under field condition

x	lx	Lx	dx	100qx	Sx	Tx	exk-value		MSR	IM	Mortality factors
Egg	1415.00	1200.50	429.00	30.32	0.70	2492.50	1.76	0.16	0.44	41.37	Unable to hatch; unknown
1st instar	986.00	689.50	593.00	60.14	0.40	1292.00	1.31	0.40	1.51	11.93	Predation by spiders; mesoveliid bugs; unknown
2 nd instar	393.00	273.00	240.00	61.07	0.39	602.50	1.53	0.41	1.57	11.48	Predation by spiders
3 nd instar	153.00	135.00	36.00	23.53	0.76	329.50	2.15	0.12	0.31	58.50	predation by spiders & mesoveliid bugs
4 nd instar	117.00	107.50	19.00	16.24	0.84	194.50	1.66	0.08	0.19	92.84	predation by spiders, rove beetle & mesoveliid bugs
5 nd instar	98.00	78.00	40.00	40.82	0.59	87.00	0.89	0.23	0.69	26.10	Predation by spiders & mesoveliid bugs
Adult	58.00	9.00	-	-	-	-	-	-	-	-	Predation by spiders
F1 Eggs	2987.00										

Trend index = 2.11
K value = 1.4

In general, irrespective of plant resistance, the survivorship curves (lx) of BPH on three different varieties examined, showed similar pattern with higher mortality occurring during nymphal growth stages particularly in the early three instars (due to mesovellids, spiders and unknown factors) which gradually decreased throughout the life span under field condition. Hence, the survivorship curve reflected a modest rate of mortality during the early life stages and a gradual reduction when approaching adulthood (Fig 1.). It is found that the BPH population assumed a near type II diagonal

Table 3. Stage specific life-table of brown planthopper in TN1 under field condition

x	lx	Lx	dx	100qx	Sx	Tx	exk-value		MSR	IM	Mortality factors
Egg	1405.00	1321.50	167.00	11.89	0.88	2959.00	2.11	0.05	0.13	133.44	Unable to hatch; unknown
1st instar	1238.00	839.50	797.00	64.38	0.36	1637.50	1.32	0.45	1.81	9.96	Predation by spiders; mesoveliid bugs; unknown
2 nd instar	441.00	343.50	195.00	44.22	0.56	798.00	1.81	0.25	0.79	22.71	Predation by spiders
3 nd instar	246.00	208.50	75.00	30.49	0.70	454.50	1.85	0.16	0.44	41.04	predation by spiders & mesoveliid bugs
4 nd instar	171.00	144.00	54.00	31.58	0.68	246.00	1.44	0.16	0.46	39.00	predation by spiders, coccinellid & mesoveliid bugs, parasitization by dryinids
5 nd instar	117.00	93.00	48.00	41.03	0.59	102.00	0.87	0.23	0.70	25.88	Predation by spiders & mesoveliid bugs
Adult	69.00	9.00	-	-	-	-	-	-	-	-	Predation by spiders
F1 eggs	3018.00										

Trend index= 2.15
K value = 1.30

survivorship curve following the classification of Speight *et al*. (1999). Whereas, in natural enemy free condition, though the same pattern was present, it was not that perceptible.

Under field condition, about 75%, 70 % and 88 % of eggs generated by each of the cohort population investigated, developed into Ist instar nymph stage respectively in PTB33, Udaya and TN1. Whereas,

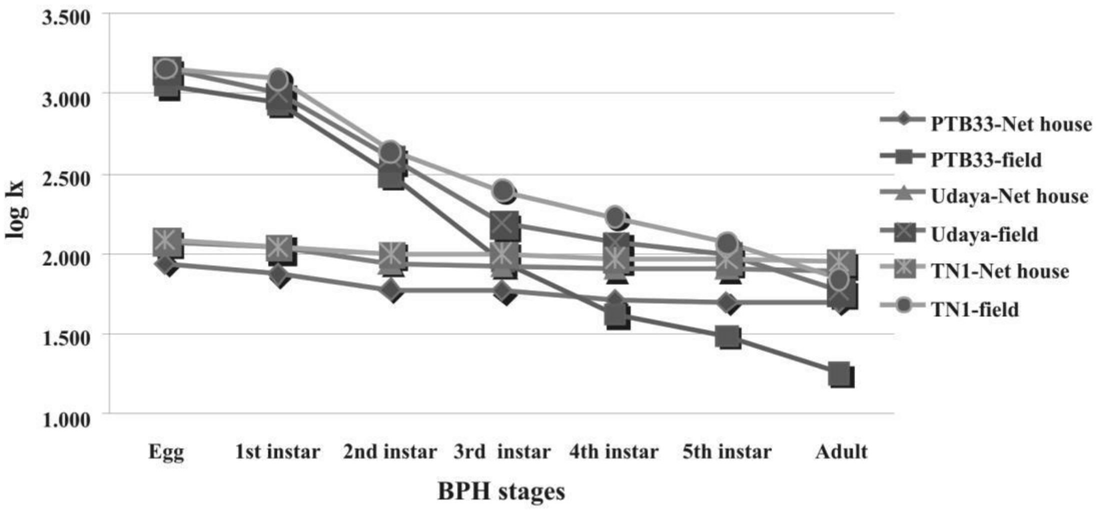

Fig. 1. Pooled survivorship curves of brown planthopper in field and natural enemy free condition on three rice varieties

hatching percentage was higher recording 85 %, 92 % and 93 % respectively under natural enemy free condition. A wide range of factors were responsible for poor hatching including eggs infertility and unable to hatch. Among the varieties examined, k value was high for PTB33 and Udaya compared to TN1 both under field and natural enemy free conditions, which might be because of host plant related resistance mechanisms operation in the plant varieties (Table 1, 2 and 3). The effects of three different sorghum varieties on the fertility life parameters of *Schizaphis graminum* (Rondani) was reported by Khodabandeh *et al*. (2011).

Table 4. Stage specific life table of brown planthopper on PTB33 under natural enemy free condition

x	lx	Lx	dx	100qx	Sx	Tx	ex	k-value	MSR	IM	Mortality factors
Egg	88.50	81.75	13.50	15.25	0.85	372.75	4.21	0.07	0.18	100.00	Unable to hatch; unknown
1st instar	75.00	67.50	15.00	20.00	0.80	291.00	3.88	0.10	0.25	72.00	unknown
2 nd instar	60.00	59.00	2.00	3.33	0.97	223.50	3.73	0.01	0.03	522.00	unknown
3 nd instar	58.00	54.75	6.50	11.21	0.89	164.50	2.84	0.05	0.13	142.62	unknown
4 nd instar	51.50	50.75	1.50	2.91	0.97	109.75	2.13	0.01	0.03	600.00	unknown
5 nd instar	50.00	50.00	0.00	0.00	1.00	59.00	1.18	0.00	0.00	0.00	unknown
Adult	50.00	9.00	-	-	-	-	-	-	-	-	
F1 eggs	1168.00										

Trend index = 13.20
K value = 0.24

The values of the population parameters varied according to field and laboratory conditions. It appears that the survival of different stages of planthoppers under field conditions and laboratory

Table 5. Stage specific life table of brown planthopper on Udaya under natural enemy free condition

x	lx	Lx	dx	100qx	Sx	Tx	ex	k-value	MSR	IM	Mortality factors
Egg	118.00	113.25	9.50	8.05	0.92	545.50	4.62	0.04	0.09	205.58	Unable to hatch; unknown
1st instar	108.50	98.50	20.00	18.43	0.82	432.25	3.98	0.09	0.23	79.65	unknown
2 nd instar	88.50	85.75	5.50	6.21	0.94	333.75	3.77	0.03	0.07	271.64	unknown
3 nd instar	83.00	81.50	3.00	3.61	0.96	248.00	2.99	0.02	0.04	480.00	unknown
4 nd instar	80.00	79.50	1.00	1.25	0.99	166.50	2.08	0.01	0.01	1422.00	unknown
5 nd instar	79.00	78.00	2.00	2.53	0.97	87.00	1.10	0.01	0.03	693.00	unknown
Adult	77.00	9.00	-	-	-	-	-	-	-	-	
F1 eggs	2628.00										

Trend index = 22.28
K value = 0.20

conditions may be varied due to variation in stress, because the overall microclimate varies considerably between field and net house condition. Similar reports were found with *Acalymma vittatum* fed on cucurbits (Ellers-Kirk and Fleischer, 2006), *Nasonovia ribisnigri* on lettuce (Diaz and Fereres, 2005) and WBPH on rice (Win *et al*., 2009). Host plant and naturally occurring resistance (different between varieties) are known to influence reproductive performance of insects (Jackai *et al*., 2001, Obopile and Ositile, 2010). In addition to other factors, host plant's nutritional value was also known to affect survival and fecundity of the insects (Pereyra and Sanchez 2006). The survival rate from hatching of 1st instar nymph to emergence of adults was lower on PTB33 even in natural enemy free condition which was not the case on Udaya and TN1 which further confirms the influence of host plant resistance.

The life table showed that only 1.6 % of the eggs successfully emerged as adults in PTB33 under field condition and the values were 4.1 % and 4.9 % for Udaya and TN1 respectively, where higher mortality occurred during early stages. This type of survivorship is commonly found in most insect species (Begon and Mortimer, 1981) and also in WBPH (*Sogatella furcifera*) (Win *et al*., 2009). Whereas, under natural enemy free condition, percentage of eggs that developed as adults were appreciably high with 56.5, 65.3 and 73.9 respectively in PTB33, Udaya and TN1 plants (Table 4,5 and 6). Velasco and Walter (1993) reported that survival of insects, growth of nymphs and reproductive phase were highly influenced by food quality.

Table 6. Stage specific life table of brown planthopper on TN1 under natural enemy free condition

x	lx	Lx	dx	100qx	Sx	Tx	ex	k-value	MSR	IM	Mortality factors
Egg	120.50	116.25	8.50	7.05	0.93	613.75	5.09	0.03	0.08	237.18	Unable to hatch; unknown
1st instar	112.00	107.00	10.00	8.93	0.91	497.50	4.44	0.04	0.10	183.60	unknown
2 nd instar	102.00	101.00	2.00	1.96	0.98	390.50	3.83	0.01	0.02	900.00	unknown
3 nd instar	100.00	97.50	5.00	5.00	0.95	289.50	2.90	0.02	0.05	342.00	unknown
4 nd instar	95.00	93.00	4.00	4.21	0.96	192.00	2.02	0.02	0.04	409.50	unknown
5 nd instar	91.00	90.00	2.00	2.20	0.98	99.00	1.09	0.01	0.02	801.00	unknown
Adult	89.00	9.00	-	-	-	-	-	-	-	-	
F1 eggs	3079.00										

Trend index= 25.55
K value = 0.13

Thus, it would appear that, in the absence of an extrinsic source of mortality, BPH could have greater potential for population increase. This is very evident with the trend index values in field and natural enemy free condition for all three varieties. The trend index was low 0.72, 2.11 and 2.15 in field for PTB33, Udaya and TN1, whereas, it was many times higher recording 13.20, 22.28 and 25.55 respectively under natural enemy free condition. This was in accordance with *T. cinnabarinus* populations as reported by Mo and Liu (2006). The life expectancy (eij) of each stage is showing the estimates of individuals at age i and stage j are expected to live. There was a gradual decrease in life expectancy in the BPH populations on all three varieties tested under Natural enemy free condition. In field condition also, though life expectancy was low in adult stage compared to 1st instar stage, there were ups and downs among other instars.

Mortality survival ratio (MSR) was highest for the 1st and 2nd instar BPH and as the insect grows, MSR values were gradually falling and again at 5th instar stage there was a raise. The observations on the mortality performance of BPH was in accordance with some coccinellid species (Rai *et al*., 2002).

Indispensable mortality (IM) was maximum at egg stage followed by early instar stages in all the three varieties examined and was minimum during late instars and adult stages. Moreover, it was noticed that IM was higher in natural enemy free condition, while it was less in field in all three varieties. Comparable results were observed earlier for *Coccinella septempunctata* (Ali and Rizvi, 2010). The experiments were conducted during Kharif 2010 (September-October) coinciding with rainy season which could also influence the mortality of the early instars of BPH. Schowalter (2006) reported that the insect populations are highly sensitive to changes in abiotic conditions, such as temperature, rainfall and RH. Thus, any changes in these parameters could influence the growth of insects and their survival.

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