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Host preference and population dynamics of a major pest, *Leptocorisa acuta* (Thunb.), for their ecological management

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Abstract
Rice, *Oryza sativa* L., is the most important staple food crop for more than two thirds of the population of India and more than 65 per cent of the world population. In this modern era with increasing human population there is a need to increase rice production per unit of land through sustainable strategies. In fact, a number of insect pests are reported to ravage the rice fields throughout the world. Today spraying of different broad spectrum synthetic chemical insecticides or few botanicals are the general practices for the control of such pests in the field without considering their sustainability. So, there is a need to control or manage populations of these pests through ecologically, environmentally and economically sustainable strategies. Life table study is a central theme in ecological research to understand the temporal and spatial patterns in population dynamics of any pest for their sustainable management. Host phytoconstituents regulate the growth and survival of herbivorous insects. The host preference test of rice bug, *Leptocorisa acuta* (Thunb.) in relation with phytochemical regime of rice (R) [*Oryza sativa* L.; Family: Poaceae, cv. Jamini (IET-12133)] and non-rice weeds (NRW) [*Cyperus rotundus*, Family: Cyperaceae (NRW1) and *Echinochloa colona*, Family: Poaceae (NRW2)] were conducted in the laboratory condition. The different population growth parameters like higher intrinsic (r_m) and finite (λ) rate of increase of *L. acuta* on R and NRW (NRW1 and NRW2) were significantly differed (P< 0.005) from each other and can be arranged as NRW2>R>NRW1 and reverse (NRW2<R<NRW1) in generation time (T_c) and doubling time (DT). These differences were due to better nutritional quality relative to anti-nutritional factors in the respective host plants. Thus, by knowing the host quality one can NRW2 host as a trap plant around the rice agro ecosystem to make sustainable ecological management of this pest (*L. acuta*) population or other such pests in near future.

Keywords: *Leptocorisa acuta*, population dynamics, *Oryza sativa*, *Cyperus rotundus*, *Echinochloa colona*, phytoconstituents, trap plant, sustainable ecological management

1. Introduction

Rice, *Oryza sativa* L. is the most important food crop for more than two thirds of the population of India and more than 65% of the world population [1, 2]. India is the second largest producer of rice in the world [1, 3-5]. In fact, insect pests are among the most important biological constraints limiting rice yield potential and reflect large scale reduction both in quality and quantity throughout the world [6-19]. So, there is a need to control or manage populations of this pest. The rice crops of Asia are dominated by the rice bugs belong to the genus *Leptocorisa* including *L. acuta*, *L. oratorius*, *L. varicornis*, *L. chinensis*, etc. [11, 13, 16-18, 20]. Among them, *L. acuta* (Thunb.) (Hemiptera: Alydidae) has been reported earlier in many tropical countries including India [6, 16, 21-24]. They aggregate on non-rice weeds (*Echinochloa* spp. *Paniculum* spp. *Cyperus* spp. etc.) grown in and around paddy fields before rice flowers [25]. The losses due to this bug may range from 10-20% to total crop failure depending on the degree of infestation [9, 16, 26]. Both their nymphs and adults feed on the milky juice of the developing rice grains which discolours the panicles and reduces yield [9, 16, 26]. The adult bugs emit a pungent smell when disturbed. Growing rice bug nymphs are more active feeders than adults, but adults cause more damage because they feed for a longer period on milk stage which causes reduce grain quality and yield loss [9, 16, 18, 26]. Control strategies in current use against the pest are largely based on chemical insecticides but intensive use creates an ecological imbalance through destruction of non-target beneficial insects, and accumulation of toxic residues in the environment [27-33]. Also the resistant rice varieties and the use of biorationals as well as natural enemies in the management of rice bug population have not been promising [5, 6, 27, 34-36]. Today, the population dynamics along with limiting factors of this pest are very essential for timely adoption of different management practices [37-42].

Life table study is a central theme in ecological research to understand the temporal and spatial patterns in population dynamics [39-47]. Life tables are used to calculate the vital statistics on pest population dynamics and also give a comprehensive description of the survivorship, development, fecundity, mortality and life expectancy [39-42, 45, 48-50]. These tables can describe duration and survival at each life stage which allow prediction of the population size and age structure of a pest insect at any time [39-42, 48]. Life table is widely useful technique in insect pest management, where developmental stages are discrete and mortality rates may vary widely from one life stage to another [16, 39-42]. It is very helpful to determine the key mortality factors responsible in a particular stage within which the maximum mortality of the pest is obtained. Thus, by knowing such most vulnerable stages from life table, one can make time based application of different control measures for proper management of the pest population. A life table based on field data may be used to estimate fitness of a population but unfortunately, it is often difficult to construct because tracing of population survival and reproduction in the open field under variable environmental conditions. To overcome these constrictions a standard cohort life table can easily be constructed in the laboratory conditions. Rizvi *et al.* [51] were conducted both, age-specific (horizontal) and stage-specific (vertical) life-table of cabbage butterfly, *Pieris brassicae* on various cole crops [51]. But, in our current study, we have used only the stage-specifc life table approach similar with the previous study of Roy [39-42] as it is with lower biasness and more useful in the field condition. There are several reports on the life table study of different pest species were conducted [50, 51] but few of them concerned with the influence of different host phytochemicals in their life table parameters [39-42]. Though, few studies have been made in the past to correlate the incidence of rice bug with meteorological factors but all relations were site specific with some extent spatial and temporal variations [37, 52]. So, there is a need to develop a standard cohort life tables on both R and NRW systems to understand their population dynamics for safer and ecologically sustainable management of the pest.

2. Materials and methods

2.1 Host plants

Rice (R)[*Oryza sativa* L.; Family: Poaceae; cv. Jamini (IET-12133) [Aus season] [3-5] and Non-rice weeds (NRW) [*Cyperus rotundus*, Family: Cyperaceae (NRW1) and *Echinochloa colona*, Family: Poaceae (NRW2)] [25] were collected from the fields near Chinsurah Rice Research Centre (22°53' N, 88°23' E), Hooghly, West Bengal, India. The plant was identified by the help of plant taxonomist and voucher specimens (Voucher No. ERU8-10) were kept in Department of Zoology, Ecology Research Unit, MUC Women's College, Burdwan.

2.1 Phytochemical analysis

The freshly harvested rice (R) and non-rice weeds (NRW) were collected randomly from the same fields near Chinsurah Rice Research Centre (22°53' N, 88°23' E), Hooghly, west Bengal, India. These were initially rinsed with distilled water and dried by paper toweling for phytochemical analysis. These were dipped in different solvents for extraction of different primary and secondary chemicals. The chemicals were estimated by various slandered biochemical analyses protocols as described by Roy [53, 39, 40, 42]. Determination of each biochemical analysis was repeated for three times and expressed in µg/mg dry weight basis.

2.2 Insect mass culture and development

The study on population dynamics and life table parameters of gundhi bug, *Leptocorisa acuta*, was carried out in the laboratory condition (27±1°C, 65±5% RH and a photoperiodism of 12:12 [L:D]). The initial population of this notorious insect pest was collected from the field near Chinsurah Rice Research Centre (22°53' N, 88°23' E), Hooghly, West Bengal, India and was taken to the laboratory. Developmental time and survivability of *L. acuta*, was determined on rice (R) and non-rice weeds (NRW) under the same laboratory condition as described by Dutta and Roy [16]. Duration and survival for each molt were recorded in the laboratory condition of three generations for construction of their stage-specific life table as described by Dutta and Roy [16].

2.3 Life table parameters

The construction of life table includes several parameters which were calculated with the formulae of Southwood [43], Ricklefs and Miller [54], Carey [45, 46], Krebs [55], Price [56] and Schowalter [57]. These parameters include probability of survival from birth to age x (l_x), proportion dying each age (d_x), mortality (q_x), survival rate (s_x) per day per age class from egg to adult stages. Using these parameters, the following statistics like, average population alive in each stage (L_x), life expectancy (e_x), exponential mortality or killing power (k_x), total generation mortality (K or GM), generation survival (GS), gross reproductive rate (GRR), net reproductive rate (NRR or R_0), mean generation time (T_c), doubling time (DT), intrinsic rate of population increase (r_m), Euler's corrected r (r_c), finite rate of population increase (λ), weekly multiplication rate (λ^7), increase rate per generation (λ^{Tc}), were also computed, using Carey's formulae [45]. Some other population parameters like potential fecundity (Pf), total fertility rate (F_x), mortality coefficient (MC), population growth rate (PGR), population momentum factor of increase (PMF), expected population size in 2nd generation (PF_2), expected females in 2nd generation (FF_2), general fertility rate (GFR), crude birth rate (CBR), reproductive value (RV), vital index (VI) and trend index (TI) were also determined by using well defined formulae [43, 48, 49, 58].

2.4 Field experiment

A field experiment was conducted for consecutive three years from 2015 to 2017 by growing the Rice (R) [*Oryza sativa*, cv. Jamini (IET-12133)], and Non-rice weeds (NRW) [*Cyperus rotundus*, Family: Cyperaceae (NRW1) and *Echinochloa colona*, Family: Poaceae (NRW2)] [3-5, 25] in RDB to collect *L. acuta* life stages for their life table study as described earlier workers with few modifications [59, 60]. The experiment was done by using a small land area (2 katha or 134 m^2) near CRRC, Chinsurah, 22°53' N, 88°23' E, 13m above sea level, West Bengal, India, with 3 replications for both R and NRW side by side.

2.5 Statistical Analysis

Experimental data of different phytoconstituents of the host plants and the pest population parameters were subjected to one-way Analysis of Variance (ANOVA), regression analysis and correlation analysis [39-42, 53, 60-62]. Effect of the host plants (R and NRW) on the population dynamics of *L. acuta* were analyzed using one-way ANOVA [39-42, 63, 64]. Means of different demographic parameters were compared by Tukey's test (HSD) when significant values were obtained [39-42, 63, 64]. All the statistical analysis was performed using the statistical program SPSS (version 13.0) [63-65].

3. Results

The biochemical constituents of the three types of host plants (R and NRW) are presented in figure 1. The primary metabolites i.e., carbohydrates, proteins, lipids andamino acids including moisture content was varied significantly ($P < 0.001$) in the host plants (Figure 1). Among the secondary metabolites, phenolics concentration was lower in R system than any NRW system (R<NRW2<NRW1) and differed significantly ($F_{1,\ 4}$=11.831, $P < 0.001$) (Figure 1) whereas other secondary metabolites were present in the order of (NRW2>NRW1> R) (Figure 1). Ultimately, the ratio of primary to secondary metabolites was always higher in R system than NRW systems (R>NRW2>NRW1). Thus, the nutritional factors (primary metabolites) along with the anti-nutritional factors (Secondary metabolites) were varied significantly in the R and NRW systems (Figure 1). The biology of *L. acuta* was carried out in the laboratory on R and NRW systems. Three cohorts containing 40 eggs in each were reared separately on R and NRW systems, respectively to construct the life table of this notorious pest, *L. acuta* (Table 1-3). The average life span, overall survival from egg to the death of adults was significantly higher on NRW2 and R system relative to the NRW1 systems (Table 1-3, 5) due to respective host nutritional and anti nutritional constituents (Figure 1). The fecundity of *L. acuta* was significantly ($P < 0.01$) higher on NRW2 (114.783) followed by R (112.862) and NRW1 (102.006) system (Table 5). Thus, the population growth parameters of *L. acuta* were significantly affected by the different host systems due to variation in their respective nutritional constituents (Figure 1). ANOVA result of stage-specific pooled life table on the selected three hosts (R, NRW1 and NRW2) for the three cohorts each were differed significantly ($F_{26,\ 49} \geq 24.383$, $P < 0.0001$) (Table 4). All the population parameters were advandagious in NRW2 host system followed by R and NRW1 (Table 5) due to their respective phytoconstituents (Figure 1). Population dynamics and reproductive parameters of the nine cohorts (3 cohorts on each host) of *L. acuta* also show highly significant differences ($F_{21,\ 44} \geq 3.215$ [3.215-40.504], $P < 0.0001$) in individual and in combined host system (Table 6). The population parameters were positively and negatively correlated with the hosts (R, NRW1 and NRW2) primary and secondary metabolites, respectively. Thus, the population growth parameters of *L. acuta* were significantly affected by the different host systems (Table 1, 2, 3, 5) due to variation in their respective nutritional constituents (Figure 1).

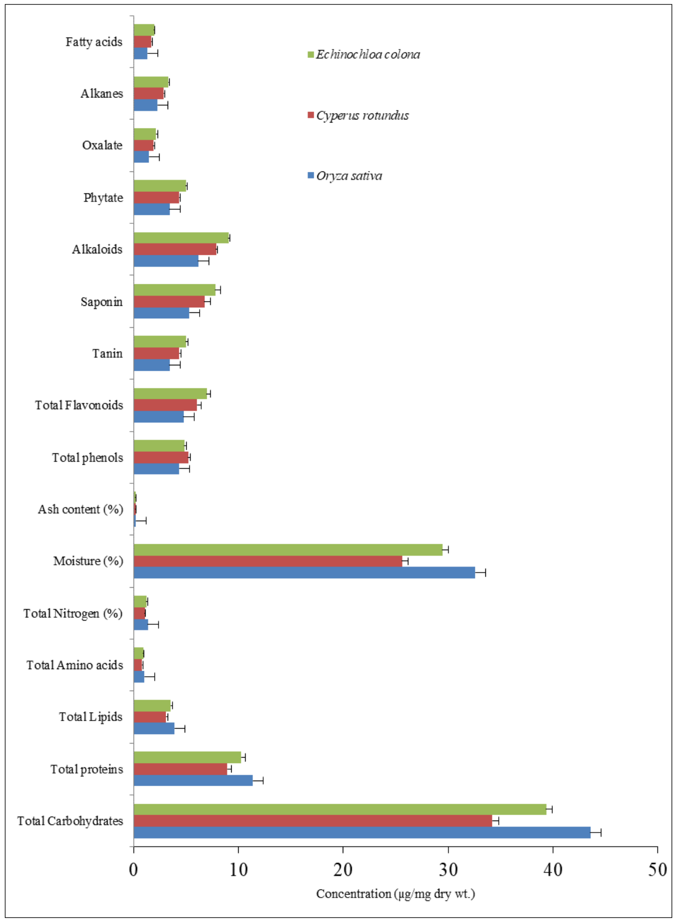

Fig 1: Phytochemical variations of rice (R) [*Oryza sativa*, Family: Poaceae] and non-rice weeds (NRW) [*Cyperus rotundus*, Family: Cyperaceae (NRW1) and *Echinochloa colona*, Family: Poaceae (NRW2)] collected from pesticide free controlled agroecosystem during 2015-2017 (Mean ± SE of 3 observations).

Table 1: Stage-specific pooled life table for 3 cohorts each (Mean of 3 observations) of *L. acuta* on rice [R] (*Oryza sativa*, Family: Poaceae) collected from pesticide free controlled agroecosystem during 2015-2017.

Stage	l_x	d_x	q_x	s_x	L_x	e_x	k_x
Egg 0	1.000	0.302	0.302	0.698	0.849	4.387	0.156
Nymph 1	0.698	0.113	0.162	0.838	0.642	5.068	0.077
Nymph 2	0.585	0.104	0.177	0.823	0.533	4.952	0.085
Nymph 3	0.481	0.057	0.118	0.882	0.453	4.912	0.054
Nymph 4	0.425	0.123	0.289	0.711	0.363	2.500	0.148
Nymph 5	0.302	0.038	0.125	0.875	0.283	2.313	0.058
Nymph 6	0.264	0.057	0.214	0.786	0.236	1.571	0.105
Adult 7	0.208	0.057	0.273	0.727	0.179	0.864	0.138
Stage	**l_x**	**d_x**	**q_x**	**s_x**	**L_x**	**e_x**	**k_x**
Egg 0	1.000	0.302	0.302	0.698	0.849	4.387	0.156
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Adult 7	0.208	0.057	0.273	0.727	0.179	0.864	0.138

Table 2: Stage-specific pooled life table for 3 cohorts each (Mean of 3 observations) of *L. acuta* on *Cyperus rotundus*, Family: Cyperaceae (NRW1) collected from pesticide free controlled agroecosystem during 2015-2017.

Stage	**l_x**	**d_x**	**q_x**	**s_x**	**L_x**	**e_x**	**k_x**
Egg 0	1.000	0.302	0.302	0.698	0.849	4.387	0.156
Nymph 1	0.698	0.113	0.162	0.838	0.642	5.068	0.077
Nymph 2	0.585	0.104	0.177	0.823	0.533	4.952	0.085
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Nymph 1	0.698	0.113	0.162	0.838	0.642	5.068	0.077
Nymph 2	0.585	0.104	0.177	0.823	0.533	4.952	0.085
Nymph 3	0.481	0.057	0.118	0.882	0.453	4.912	0.054
Nymph 4	0.425	0.123	0.289	0.711	0.363	2.500	0.148
Nymph 5	0.302	0.038	0.125	0.875	0.283	2.313	0.058
Nymph 6	0.264	0.057	0.214	0.786	0.236	1.571	0.105
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Nymph 1	0.698	0.113	0.162	0.838	0.642	5.068	0.077
Nymph 2	0.585	0.104	0.177	0.823	0.533	4.952	0.085
Nymph 3	0.481	0.057	0.118	0.882	0.453	4.912	0.054
Nymph 4	0.425	0.123	0.289	0.711	0.363	2.500	0.148
Nymph 5	0.302	0.038	0.125	0.875	0.283	2.313	0.058
Nymph 6	0.264	0.057	0.214	0.786	0.236	1.571	0.105
Adult 7	0.208	0.057	0.273	0.727	0.179	0.864	0.138

Table 3: Stage-specific pooled life table for 3 cohorts each (Mean of 3 observations) of *L. acuta* on *Echinochloa colona*, Family: Poaceae (NRW2) collected from pesticide free controlled agroecosystem during 2015-2017.

Stage	**l_x**	**d_x**	**q_x**	**s_x**	**L_x**	**e_x**	**k_x**
Egg 0	1.000	0.267	0.267	0.733	0.866	5.038	0.135
Nymph 1	0.733	0.100	0.137	0.863	0.682	5.694	0.064
Nymph 2	0.632	0.092	0.145	0.855	0.586	5.517	0.068
Nymph 3	0.540	0.050	0.093	0.907	0.515	5.370	0.042
Nymph 4	0.490	0.109	0.222	0.778	0.436	2.868	0.109
Nymph 5	0.382	0.033	0.088	0.912	0.365	2.542	0.040
Nymph 6	0.348	0.050	0.144	0.856	0.323	1.738	0.068
Adult 7	0.298	0.032	0.107	0.893	0.282	0.947	0.049
Stage	l_x	d_x	q_x	s_x	L_x	e_x	k_x
Egg 0	**1.000**	**0.274**	**0.274**	**0.726**	**0.863**	**4.922**	**0.139**
Nymph 1	0.726	0.103	0.141	0.859	0.675	5.588	0.066
Nymph 2	0.624	0.094	0.151	0.849	0.577	5.424	0.071
Nymph 3	0.530	0.051	0.097	0.903	0.504	5.298	0.044
Nymph 4	0.479	0.111	0.232	0.768	0.423	2.812	0.115
Nymph 5	0.367	0.034	0.093	0.907	0.350	2.511	0.042
Nymph 6	0.333	0.051	0.154	0.846	0.308	1.717	0.073

Adult 7	0.282	0.035	0.123	0.877	0.265	0.939	0.057
Stage	l_x	d_x	q_x	s_x	L_x	e_x	k_x
Egg 0	1.000	0.264	0.264	0.736	0.868	5.105	0.133
Nymph 1	0.736	0.099	0.134	0.866	0.687	5.754	0.063
Nymph 2	0.637	0.091	0.142	0.858	0.592	5.570	0.067
Nymph 3	0.547	0.049	0.090	0.910	0.522	5.410	0.041
Nymph 4	0.497	0.107	0.215	0.785	0.444	2.899	0.105
Nymph 5	0.390	0.033	0.084	0.916	0.374	2.557	0.038
Nymph 6	0.357	0.049	0.138	0.862	0.332	1.747	0.065
Adult 7	0.308	0.032	0.105	0.895	0.292	0.948	0.048

Table 4: ANOVA result of stage-specific pooled life table for the three cohorts each (Mean of 3 observations) of *L. acuta* on rice [R] (*Oryza sativa*, Family: Poaceae) and non-rice weeds (NRW) [*Cyperus rotundus*, Family: Cyperaceae (NRW1) and *Echinochloa colona*, Family: Poaceae (NRW2)] collected from pesticide free controlled agroecosystem during 2015-2017.

HOST	SS	df	MS	F	P-value	F crit
R	63.127	6,49	10.521	24.383	0.0001	2.290
R	63.127	6,49	10.521	24.383	0.0001	2.290
R	63.127	6,49	10.521	24.383	0.0001	2.290
NRW1	63.127	6,49	10.521	24.383	0.0001	2.290
NRW1	63.127	6,49	10.521	24.383	0.0001	2.290
NRW1	63.127	6,49	10.521	24.383	0.0001	2.290
NRW2	80.646	6,49	13.441	25.258	0.0001	2.290
NRW2	77.728	6,49	12.955	25.275	0.0001	2.290
NRW2	82.245	6,49	13.707	25.181	0.0001	2.290

Table 5: Population dynamics and reproductive table of the nine cohorts (Average of 3 observations on each host) of *L. acuta* on rice [R] (*Oryza sativa*, Family: Poaceae) and non-rice weeds (NRW) [*Cyperus rotundus*, Family: Cyperaceae (NRW1) and *Echinochloa colona*, Family: Poaceae (NRW2)] collected from pesticide free controlled agroecosystem during 2015-2017.

Population Parameters	R	NRW1	NRW2	Average	Variance
Potential fecundity (Pf)	112.862	102.006	114.783	109.884	47.462
Total fertility rate (F_x)	771.117	629.679	1386.172	928.989	161763.248
Gross reproductive rate (GRR)	32.833	29.675	40.796	34.434	32.846
Net reproductive rate (NRR)	6.814	6.159	12.070	8.348	10.497
Intrinsic rate of increase (r_m)	0.030	0.031	0.052	0.038	0.000
Euler's corrected r (r_c)	0.113	0.118	0.083	0.105	0.000
Finite rate of increase (λ)	1.031	1.031	1.054	1.039	0.000
Generation time (T_c)	63.264	59.469	47.570	56.768	67.050
Doubling time (DT)	22.854	22.677	13.251	19.594	30.184
Increase rate per generation (λ^{Tc})	6.814	6.159	12.070	8.348	10.497
Generation mortality (GM)	0.821	0.821	0.580	0.741	0.019
Mortality coefficient (MC)	0.060	0.060	0.105	0.075	0.001
Generation survival (GS)	0.297	0.297	0.404	0.333	0.004
General fertility rate (GFR)	16.563	16.563	9.521	14.215	16.528
Crude birth rate (CBR)	2.356	2.356	2.047	2.253	0.032
Population momentum factor of increase (PMF)	11.509	10.914	12.639	11.687	0.767
F_2 Population size (PF_2)	196.330	168.236	381.448	248.671	13419.501
Probable F_2 females (FF_2)	78.532	67.295	152.579	99.469	2147.120
Reproductive value (RV)	65.665	59.349	81.592	68.869	131.384
Population growth rate (PGR)	0.516	0.471	1.585	0.857	0.397
Vital Indwx (VI)	0.151	0.151	0.263	0.188	0.004
Trend index (TI)	13.982	12.637	22.533	16.384	28.812

Table 6: ANOVA result of different population parameters for nine cohorts (Average of 3 observations on each host) of *L. acuta* on rice [R] (*Oryza sativa*, Family: Poaceae) and non-rice weeds (NRW) [*Cyperus rotundus*, Family: Cyperaceae (NRW1) and *Echinochloa colona*, Family: Poaceae (NRW2)] collected from pesticide free controlled agroecosystem during 2015-2017.

ANOVA	df	MS	F	P-value	F crit
R	21,44	528436802.3	40.504	0.0001	1.801
NRW1	21,44	694914675.9	14.526	0.0001	1.801
NRW2	21,44	1.13964E+16	3.215	0.0001	1.801
COMBINED	21,44	119451.0425	14.788	0.0001	1.801

5. Discussion

In this modern era with increasing human population there is a need to increase rice production per unit of land through sustainable strategies [1, 3, 4, 7, 18]. Adult females of *L. acuta* oviposit in single or double rows from the booting stage to the milky stage of rice development similar with *L. oratorius* [17, 20-23, 26]. They also can grow on a number of wild grasses like *L. oratorius*, although as food plants wild grasses were inferior to rice [16, 17, 20]. In our study it is also found that NRW2 system can support the better development of *L. acuta* followed by R and NRW1 system which may be due to relative nutritional and anti-nutritional constituents of the respective host plants as in other cases [39-42]. The nymphs had green body with outstanding long black legs and mimic ants in form and behaviour as described by Dutta and Roy [16]. There were six nymph stages with a total nymph development period of about 22-24 days which were in good agreement with Dutta and Roy [16].

There is a range of innet capacity for individual of a population but the variation in available food quality along with environmental factors (geographic source, RH, temperature, rainfall etc.) always influence the growth, reproduction, longevity and survival of those populations [39-42, 53, 56, 58, 66]. Even, the host plant quality traits are the key determinants of the fecundity of herbivorous insects affecting insect reproductive strategies such as: egg size and quality, allocation of resources to eggs, the choice of oviposition sites, and egg or embryo resorption [39-42, 66]. The effect of different food sources on population parameters were also observed on different host plants [37, 39-42, 51, 66]. The host plant quality during larval growth and development is the key determinant of both fecundity and fertility of adults. Shorter developmental time along with greater total reproduction of insects on a host indicate greater suitability of a host plant [39-42, 51, 66]. In this study, the overall generation survival (GS) of *L. acuta* on R was significantly higher than NRW system whereas total generation mortality (K) was in the reverse order. This difference was probably a result of different food sources taken up by the nymph and adult during their developmental growth similarly in other cases [41, 42, 51, 66]. This difference could be due to the presence of nutritional and anti-nutritional factors that directly affect the pest development and fecundity [39-42, 51, 66].

The r_m is a fundamental ecological parameter to predict the pest population growth under a given condition [43, 58, 67]. It would be a most appropriate index to evaluate the performance of an insect on different host plants as well as the host plant's resistance [42, 43, 51, 58, 66, 67]. Thus high r_m value on NRW2 system indicates that *L. acuta* has a greater reproductive potential and more preference on it relative to the R and NRW1 system. The doubling time (DT) of *L. acuta* was significantly shorter on NRW2 than the other system (NRW2<R<NRW1). Thus, the F_x, R_0, r_m and DT are useful indices of population growth under a given set of conditions. This knowledge is very important when studying insect pest population dynamics for developing efficient pest management tactics. The low number of eggs laid on a plant could have been affected by larval feeding on nutritionally poor host plants. Thus, NRW2 system had the lowest antibiosis resistance against *L. acuta* and was the most favorable one relative to the R and NRW1 systems due to high survival of immature stages as reflected in a higher value of r_m. With this understanding, the population dynamics of *L. acuta* is highly supported by NRW2 system due to high nutritional quality followed by R and NRW1 system. Even it is also predicted that, NRW systems are the alternative source of *L. acuta* growth in absence of R system. So the removal of NRW systems is of course a way to control the pest in field condition. But, this study also informs about the usefulness of NRW2 as trap plant around the rice (R) agro ecosystem for ecological management of the pest as well as it gives complete picture along with vulnerable stage(s) of the pest that may help the farmers to control them with other sustainable measures in the field condition.

6. Conclusion

The IPM has been evolving over the decades to address the deleterious impacts of synthetic chemical pesticides on environment. It is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. Once monitoring, identification, and action thresholds (ETs) indicate that pest control is required, and then less risky sustainable pest controls are chosen first. Recent advancement in IPM has employed molecular techniques including better breeding programmes, genetically modified crops (GMOs), expressing resistant traits and use of synthetic and natural semiochemicals around the world for pest control. Sighting a single pest does not always mean control is needed which actually the first step to remove the possibility of injudicious use of pesticides. But in the modern industrial agricultural system long persistent broad spectrum pesticides (e.g., insecticides and fungicides) are still using indiscriminately in nature to increase agricultural productivity in order to ensure food security. This injudicious application of pesticides obviously leads to the destruction of ecological biodiversity including beneficial natural enemies, essential pollinators and foragers. These also result into secondary pest outbreak and development of pesticide resistance in insect pests and emergence of pest biotypes. At this point population dynamics based eco-friendly approaches would obviously help in the conservation of natural enemies which would bring down the pest load below ET and eventually lower broad spectrum pesticides use which generally brings pest resurgence and pest resistant problems.

The life table study of *L. acuta* on R and NRW system showed three distinct stages with six nymphs and represent similar pattern of development with significant variations ($P< 0.0001$). These differences in the demographic parameters are due to the variation in their nutritional quality of respective kind of host plants. Thus the population dynamics of *L. acuta* is highly supported by NRW2 followed by R and NRW1 system due to their respective phytoconstituents. But it is also predicted that, NRW system is an alternative source of their population growth in absence of R system. So the removal of NRW system is of course a way to control the pest in field condition and even the NRW2 can be used as trap plant around the rice (R) agro ecosystem by habitat manipulation for ecologically sustainable management of the pest. The life table data along with all the stages of *L. acuta* development will make easy to identify this notorious pest for effective management in the field to reduce qualitative and quantitative losses on the yield of rice. There may be few limitations in the methodical scientific study but this particular study somehow has triple- E (Environmental, Ecological and Economical) sustainability for any kind of pest management in near future.

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