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Population dynamics and host preference of a major pest, *Scirpophaga incertulas* Walker (Pyralidae: Lepidoptera)

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Abstract
In this modern era with increasing human population there is a need to increase rice production per unit of land through sustainable management strategies. The stage-specifc life table study of this notorious rice pest, *Scirpophaga incertulas*, also known as yellow stem borer (YSB), will be useful for their sustainable ecological management in the field. It helps to understand their population dynamics for safer and ecofriendly management of the pest. The life table study of *S. incertulas* on rice (*Oryza sativa* [R]) and non rice [NR] weed (*Echinochloa colona*) showed four distinct stages with five larval instars and represent similar pattern of development with significant variations ($P< 0.001$). The gross reproductive rate (GRR) and net reproductive rate (R_0) on R was significantly higher than NR weed which ultimately influence the fecundity. The r_m, λ, Tc and DT of *S. incertulas* on R plant was significantly higher than NR weed. These differences in the demographic parameters are due to the variation in their nutritional quality of respective kind of host plants. So, for first step management of the notorious insect pest, *S. incertulas*, is very essential to weed the NR areas which ultimately would reduce the population size of the pest in the field condition. Their further management strategies may include different ecofriendly control measures guided by their population parameters. At this point population dynamics based ecofriendly approaches would obviously help in the conservation of natural enemies which would bring down the pest load below economic threshold (ET) and eventually lower broad spectrum pesticides use which generally brings pest resurgence and pest resistant problems. There may be few limitations in the methodical scientific study but this particular population dynamics based study somehow has triple- E (Environmental, Ecological and Economical) sustainability for any kind of pest management in near future.

Keywords: *Scirpophaga incertulas* walker, YSB, *Oryza sativa*, *Echinochloa colona*, nutritional quality, life table, population dynamics, ecological management.

1. Introduction

Rice, *Oryza sativa* L. (Family: Poaceae) is the most important food crop for more than two thirds of the population of India and more than fifty percent of the world population [1-3]. India is the second largest producer of rice in the world. Rice consumes almost 50 per cent of irrigation water and the water crisis is the greater threat to rice cultivation in India [4]. Another threat is the various types of insect pests those ravage the rice fields throughout the world including tropical and subtropical Asia [5-10]. They are the most important biological constraints limiting rice yield potential and reflect large scale reduction both in quality and quantity [5, 11]. The rice crops of Asia are dominated by the rice bugs belong to the genus *Leptocorisa* [5, 10-13] and yellow stem borer (YSB) or paddy stem borer (PSB) belong to the genus *Scirpophaga* [6, 7, 14-20]. They also aggregate on non rice (NR) weeds (*Echinochloa* spp. *Paniculum* spp. *Cyperus* spp. etc.) grown in and around paddy fields [21]. As rice is the staple food of most Asians, there is a need to control or manage populations of those pests. The YSB, *Scirpophaga incertulas* Walker (Pyralidae: Lepidoptera) is one of the major pests in all rice producing areas particularly in south East Asia [7, 15, 19, 22-31]. Only YSB shares about 89.50% of the total rice borer population in West Bengal, India [14, 18, 32]. Recurrent rice grain yield loss due to this pest attack by larval feeding and subsequent inter-nodal penetration during vegetative and reproductive stage and finally results in the characteristic symptom of dead heart (DH) and whitehead (WH) at vegetative and reproductive growth stage of rice plant respectively [18, 33]. 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 [34-40]. Also the resistant rice varieties and the use of pheromones as well as natural enemies like predators and parasites in the management of YSB population have not been promising [17, 19, 25, 26, 30, 31, 41].

In this modern era with increasing human population there is a need to increase rice production per unit of land through economically and environmentally sustainable strategies. Today, the population dynamics based ecological pest management (EPM) are very essential for timely adoption of different IPM strategies. Life table study is a central theme in ecological research to understand the temporal and spatial patterns in population dynamics which can be used for modern EPM [42-49]. 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 [43, 44, 46-50]. This can also 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 [42, 45-49]. 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 [46-49, 51]. 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 [43, 44, 46-50]. 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. Rizvi *et al*. [52] were conducted both, age-specific (horizontal) and stage-specific (vertical) life-table of cabbage butterfly, *Pieris brassicae* on various cole crops. But, in my current study, I have used only the stage-specifc life table approach as it is with lower biasness and more useful in the field condition [46-49]. There are several reports on the life table study of different pest species were conducted [50, 52] but few of them concerned with the influence of host phytochemicals in their life table parameters [46, 47, 49]. Only few studies have been made in the past to correlate the incidence of YSB with environmental factors as well as their population dynamics and ecofriendly management practises [7, 15, 16, 19, 22-31]. So, there is a need to develop a standard cohort life tables on both R and NR weed 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. Shatabdi, IR-36 (Boro season)] [1, 2] and Non-rice (NR) weed [*Echinochloa colona*, Family: Poaceae] [21] were collected randomly from the pesticide free controlled agroecosystem during 2016 and 2017 near Chinsurah Rice Research Center (22°53' N, 88°23' E), Hooghly, West Bengal, India.

2.2 Phytochemical analysis

The freshly harvested rice (R) and non-rice (NR) weed were collected randomly from the same fields. The plants were initially rinsed with distilled water and dried by paper toweling for phytochemical analysis. They 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 [46, 47, 49] as well as by Roy and Barik [63, 64]. Determination of each biochemical analysis was repeated for three times and expressed in µg/mg or percent dry weight basis.

2.3 Insect mass culture and development

The study on population dynamics and life table parameters of YSB, *Scirpophaga incertulas* Walker (Pyralidae: Lepidoptera), 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 same field near Chinsurah Rice Research Center, Hooghly, West Bengal, India. The studies were undertaken in the laboratory at the Department of Zoology in Rabindra Mahaviyalaya, Champadanga, Hooghly and stepwise examine the pest population data during Boro season in 2016 and 2017. Primary culture was established by collecting the pupae of *S. incertulas* from the same paddy field and was kept in a mating cage of 20×10×2 cm. After the emergence, the male and female adults were allowed for mating and the mated females were released into the cage of size 90×210×150 cm containing selected R and NR weed separately. After oviposition, the R and NR weed leaves containing the egg masses were clipped off and their bases were wrapped in moist cotton to keep them fresh until hatching. These were then placed on a moist filter paper in the Petri dishes of diameter 10.5 cm, and were exposed for embryonic development in laboratory condition (27±1°C, 65±5% RH and a photoperiodism of 12:12 [L:D]). The dates at which eggs hatched were recorded. On hatching, first instar larvae were detected from the egg mass with the help of hand lens and collected with the help of camel hairbrush and the immature stages of the borer were reared on the selected host plants separately for the constraction of their respective life table. Developmental time and survivability of *S. incertulas* was determined on rice (R) and non-rice (NR) weed under the same laboratory condition as described by Dutta and Roy [5]. Duration and survival for each stage were recorded in the laboratory condition of three generations for construction of their stage-specific life table as described by Roy [46-49] as well as Dutta and Roy [5].

2.4 Life table parameters

The construction of *S. incertulas* life table includes several parameters which were calculated with the formulae of Southwood [42, 43], Ricklefs and Miller [53], Carey [44, 45], Krebs [54], Price [55], and Schowalter [56]. 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 [44] (1993). 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 [42, 43, 57, 58].

2.5 Field Experiment

A field experiment was conducted for consecutive three years from 2015 to 2017 by growing the Rice (R) [*Oryza sativa*, cv. Shatabdi, IR-36 (Boro season)], and Non-rice (NR) weed [*Echinochloa colona*, Family: Poaceae] [1, 2, 21, 59] in RDB to collect different life stages of *S. incertulas* for laboratory mass culture as described earlier workers with few modifications [60, 61]. 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 NR weed plants side by side.

2.6 Statistical Analysis
Experimental data of different phytoconstituents of the host plants and the pest (*S. incertulas*) population parameters were subjected to one-way Analysis of Variance (ANOVA), regression analysis and correlation analysis [46-49, 61-64]. Effect of the host plants (R and NR) on the population dynamics of *S. incertulas* were analyzed using one-way ANOVA [46-49, 65, 66]. Means of different demographic parameters were compared by Tukey's test (HSD) when significant values were obtained [46-49, 65, 66]. All the statistical analysis was performed using the statistical program SPSS (version 13.0) [65-67].

3. Results
The biochemical constituents of the host plants (R and NR) are presented in figure 1. The primary metabolites i.e., carbohydrates, proteins and lipids including amino acids and moisture content was significantly (P<0.001) higher in R (43.56±0.59, 11.36±0.42, 3.93±0.17, 1.01±0.08 µg/mg dry weight and 32.57±0.60%, respectively) relative to NRW (39.36±0.58, 10.29±0.41, 3.56±0.17, 0.92±0.07 µg/mg dry weight and 29.43±0.59%, respectively) (Figure 1). Among the secondary metabolites, phenols, flavonoids, tannin, alkaloids, phytate and oxalate concentrations were lower in R system (4.35±0.24, 4.75±0.41, 3.41±0.16, 6.17±0.16, 3.42±0.10 and 1.47±0.16 µg/mg dry weight, respectively) than NR weed system (4.83±0.24, 6.97±0.40, 5.00±0.17, 9.04±0.16, 5.00±0.10 and 2.15±0.16 µg/mg dry weight, respectively) and differed significantly (P<0.001) (Figure 1). Ultimately, the ratio of primary to secondary metabolites was always higher in R system than NR weed system. Thus, the nutritional factors (primary metabolites) along with the anti-nutritional factors (Secondary metabolites) were varied significantly (P < 0.001) in the R and NR weed system (Figure 1).
The biology of *S. incertulas* was carried out in the laboratory on both R and NR weed system separately and the developmental stages were photographed in order to present a pictorial demonstration of their different life stages (Figure 2). The three cohorts containing 100 eggs in each were reared separately on R and NR weed system, respectively to construct the life table of this notorious pest, *S. incertulas* (Table 1 and 2). The life table parameters (l_x, d_x, q_x, s_x, L_x, e_x and k_x) were varied significantly (df=6,42, P < 0.001) within the host plants (F=31.618-31.936 and 31.879-32.199 for R and NR weed, respectively) (Table 3). The adult e_x values range from 0.95-0.96 on NR weed system and which is higher than R (0.93-0.94) system whereas reverse is found in k_x value i.e., 0.48-0.64 in R > 0.36-0.51 in NR system for the 3 cohorts on each host (Table 1 and 2). Reproductive parameters of the population on R system were always significantly (P < 0.001) higher than NR weed system with few variations (Table 4) and also varied significantly within (df=21,44, P < 0.0001) and between (df=21,22, P < 0.0001) the host plants (F=253.516, 302.921 and 133.823 for R, NR weed and R-NR host respectively) (Table 5). Among the determined population parameters, the average Pf, GRR, NRR, r_c, λ, T_c, DT, FF_2, RV, PGR and TI were significantly (P < 0.0001) higher in R system (163.969, 57.634, 14.221, 0.075, 1.059, 46.499, 12.138, 237.688, 115.269, 2.030 and 18.235, respectively) than the NR weed system (148.198, 53.650, 13.238, 0.078, 1.061, 43.710, 11.726, 216.77, 107.300, 1.958 and 16.974, respectively) except r_m value (0.057 and 0.059 in R and NR weed, respectively) which was reverse in the selected host plants (Table 4). The mean value of r_m, r_c, λ, GM, MC, GS, CBR and VI were non significantly (P>0.05) differed between the host plants (Table 4). The population parameters of *S. incertulas* were positively and negatively correlated with the host (R and NR) primary and secondary metabolites, respectively. Thus, the population growth parameters of *S. incertulas* were significantly affected by the different host system and here the R system was favoured by the pest than NR due to variation in their nutritional and anti-nutritional constituents (Figure 1).

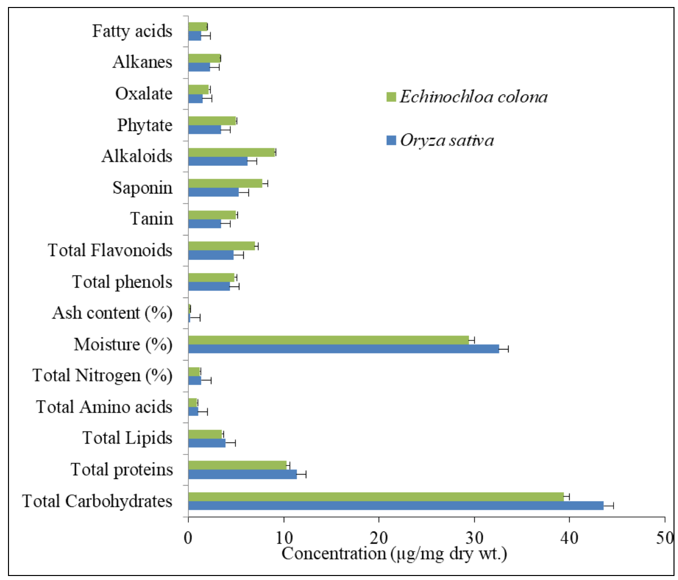

Fig 1: Phytochemical variations of rice [R](*Oryza sativa*, Family: Poaceae) and non-rice [NR] weed (*Echinochloa colona*, Family: Poaceae) collected from pesticide free controlled agroecosystem during 2016 and 2017 (Mean ± SE of 3 observations).

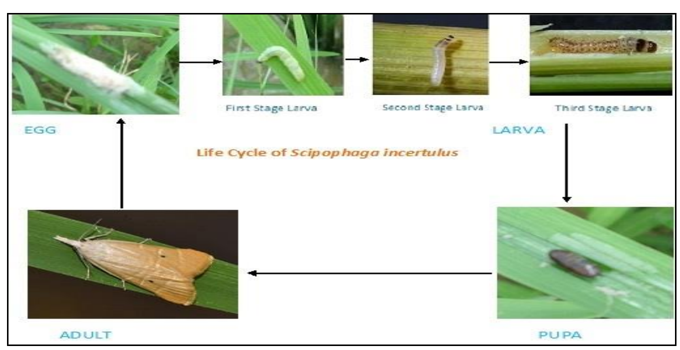

Fig 2: Schematic representation of the life cycle of *S. incertulas* on rice (R) system.

Table 1: Stage-specific pooled life table for 3 cohorts each (Mean of 3 observations) of *S. incertulas* on rice [R] (*Oryza sativa*, Family: Poaceae) collected from pesticide free controlled agroecosystem during 2016 and 2017.

Stage	**l_x**	**d_x**	**q_x**	**s_x**	**L_x**	**e_x**	**k_x**
Egg 0	1.000	0.117	0.117	0.883	0.942	5.377	0.054
Larva 1	0.883	0.156	0.176	0.824	0.805	5.022	0.084
Larva 2	0.727	0.091	0.125	0.875	0.682	4.991	0.058
Larva 3	0.636	0.091	0.143	0.857	0.591	4.633	0.067
Larva 4	0.545	0.078	0.143	0.857	0.506	3.321	0.067
Larva 5	0.468	0.091	0.194	0.806	0.422	2.792	0.094
Prepupa 6	0.377	0.039	0.103	0.897	0.357	2.345	0.047
Pupa 7	0.338	0.091	0.269	0.731	0.292	1.558	0.136
Adult 8	0.247	0.026	0.105	0.895	0.234	0.947	0.048
Stage	**l_x**	**d_x**	**q_x**	**s_x**	**L_x**	**e_x**	**k_x**
Egg 0	1.000	0.117	0.117	0.883	0.942	5.375	0.054
Larva 1	0.883	0.156	0.176	0.824	0.805	5.020	0.084
Larva 2	0.727	0.091	0.125	0.875	0.682	4.989	0.058
Larva 3	0.636	0.091	0.143	0.857	0.591	4.630	0.067
Larva 4	0.545	0.078	0.143	0.857	0.506	3.318	0.067
Larva 5	0.468	0.091	0.194	0.806	0.422	2.788	0.094
Prepupa 6	0.377	0.039	0.103	0.897	0.357	2.340	0.047
Pupa 7	0.338	0.091	0.269	0.731	0.292	1.552	0.136
Adult 8	0.247	0.030	0.120	0.880	0.232	0.940	0.056
Stage	**l_x**	**d_x**	**q_x**	**s_x**	**L_x**	**e_x**	**k_x**
Egg 0	1.000	0.117	0.117	0.883	0.942	5.373	0.054
Larva 1	0.883	0.156	0.176	0.824	0.805	5.018	0.084
Larva 2	0.727	0.091	0.125	0.875	0.682	4.986	0.058
Larva 3	0.636	0.091	0.143	0.857	0.591	4.627	0.067
Larva 4	0.545	0.078	0.143	0.857	0.506	3.314	0.067
Larva 5	0.468	0.091	0.194	0.806	0.422	2.783	0.094
Prepupa 6	0.377	0.039	0.103	0.897	0.357	2.335	0.047
Pupa 7	0.338	0.091	0.269	0.731	0.292	1.546	0.136
Adult 8	0.247	0.034	0.136	0.864	0.230	0.932	0.064

Table 2: Stage-specific pooled life table for 3 cohorts each (Mean of 3 observations) of *S. incertulas* on non-rice [NR] weed (*Echinochloa colona*, Family: Poaceae) collected from pesticide free controlled agroecosystem during 2016 and 2017.

Stage	**l_x**	**d_x**	**q_x**	**s_x**	**L_x**	**e_x**	**k_x**
Egg 0	1.000	0.117	0.117	0.883	0.942	5.380	0.054
Larva 1	0.883	0.156	0.176	0.824	0.805	5.026	0.084
Larva 2	0.727	0.091	0.125	0.875	0.682	4.995	0.058
Larva 3	0.636	0.091	0.143	0.857	0.591	4.638	0.067
Larva 4	0.545	0.078	0.143	0.857	0.506	3.327	0.067
Larva 5	0.468	0.091	0.194	0.806	0.422	2.799	0.094
Prepupa 6	0.377	0.039	0.103	0.897	0.357	2.353	0.047
Pupa 7	0.338	0.091	0.269	0.731	0.292	1.567	0.136
Adult 8	0.247	0.020	0.079	0.921	0.237	0.960	0.036
Stage	**l_x**	**d_x**	**q_x**	**s_x**	**L_x**	**e_x**	**k_x**
Egg 0	1.000	0.117	0.117	0.883	0.942	5.376	0.054
Larva 1	0.883	0.156	0.176	0.824	0.805	5.021	0.084
Larva 2	0.727	0.091	0.125	0.875	0.682	4.990	0.058
Larva 3	0.636	0.091	0.143	0.857	0.591	4.632	0.067
Larva 4	0.545	0.078	0.143	0.857	0.506	3.320	0.067
Larva 5	0.468	0.091	0.194	0.806	0.422	2.790	0.094
Prepupa 6	0.377	0.039	0.103	0.897	0.357	2.343	0.047
Pupa 7	0.338	0.091	0.269	0.731	0.292	1.556	0.136
Adult 8	0.247	0.027	0.111	0.889	0.233	0.945	0.051
0	**l_x**	**d_x**	**q_x**	**s_x**	**L_x**	**e_x**	**k_x**
Egg 0	1.000	0.117	0.117	0.883	0.942	5.378	0.054
Larva 1	0.883	0.156	0.176	0.824	0.805	5.024	0.084
Larva 2	0.727	0.091	0.125	0.875	0.682	4.993	0.058
Larva 3	0.636	0.091	0.143	0.857	0.591	4.635	0.067
Larva 4	0.545	0.078	0.143	0.857	0.506	3.324	0.067
Larva 5	0.468	0.091	0.194	0.806	0.422	2.795	0.094
Prepupa 6	0.377	0.039	0.103	0.897	0.357	2.349	0.047
Pupa 7	0.338	0.091	0.269	0.731	0.292	1.562	0.136
Adult 8	0.247	0.023	0.093	0.907	0.235	0.954	0.042

Table 3: ANOVA result of stage-specific pooled life table for the three cohorts each (Mean of 3 observations) of *S. incertulas* on rice [R] (*Oryza sativa*, Family: Poaceae) and non-rice [NR] weed (*Echinochloa colona*, Family: Poaceae) collected from pesticide free controlled agroecosystem during 2016 and 2017.

Host (Cohort)	SS	df	MS	F	P-value	F crit.
R(1)	77.028	6,42	12.838	31.936	0.0001	2.266
R(2)	76.812	6,42	12.802	31.784	0.0001	2.266
R(3)	76.576	6,42	12.763	31.618	0.0001	2.266
NR(1)	77.406	6,42	12.901	32.199	0.0001	2.266
NR(2)	76.946	6,42	12.824	31.879	0.0001	2.266
NR(3)	77.208	6,42	12.868	32.062	0.0001	2.266

Table 4: Population dynamics and reproductive table of the six cohorts (Average of 3 observations on each host) of *S. incertulas* on rice [R] (*Oryza sativa*, Family: Poaceae) and non-rice [NR] weed (*Echinochloa colona*, Family: Poaceae) collected from pesticide free controlled agroecosystem during 2016 and 2017.

Population Parameters	R	NR	Average	Variance
Potential fecundity (Pf)	163.969	148.198	156.083	124.361
Total fertility rate (F_x)	2336.328	1965.017	2150.673	68935.958
Gross reproductive rate (GRR)	57.634	53.650	55.642	7.937
Net reproductive rate (NRR)	14.221	13.238	13.730	0.483
Intrinsic rate of increase (r_m)	0.057	0.059	0.058	0.000
Euler's corrected r (r_c)	0.075	0.078	0.077	0.000
Finite rate of increase (λ)	1.059	1.061	1.060	0.000
Generation time (T_c)	46.499	43.710	45.104	3.891
Doubling time (DT)	12.138	11.726	11.932	0.085
Increase rate per generation (λ^{Tc})	14.221	13.238	13.730	0.483
Generation mortality (GM)	0.664	0.651	0.657	0.000
Mortality coefficient (MC)	0.087	0.089	0.088	0.000
Generation survival (GS)	0.279	0.279	0.279	0.000
General fertility rate (GFR)	11.524	11.189	11.356	0.056
Crude birth rate (CBR)	1.833	1.833	1.833	0.000
Population momentum factor of increase (PMF)	16.708	16.366	16.537	0.058
F_2 Population size (PF_2)	594.220	541.768	567.994	1375.605
Probable F_2 females (FF_2)	237.688	216.707	227.198	220.097
Reproductive value (RV)	115.269	107.300	111.284	31.748
Population growth rate (PGR)	2.030	1.958	1.994	0.003
Vital Indwx (VI)	0.217	0.223	0.220	0.000
Trend index (TI)	18.235	16.974	17.605	0.795

Table 5: ANOVA result of different population parameters for nine cohorts (Average of 3 observations on each host) of *S. incertulas* on rice [R] (*Oryza sativa*, Family: Poaceae) and non-rice [NR] weed (*Echinochloa colona*, Family: Poaceae) collected from pesticide free controlled agroecosystem during 2016 and 2017.

Host plant	df	MS	F	P-value	F crit
O. sativa (R)	21, 44	758727.217	253.516	0.0001	1.801
E. colona (NR)	21, 44	540827.430	302.921	0.0001	1.801
Between R and NR	21, 22	430067.118	133.823	0.0001	2.059

4. Discussions

Today insects are one of the major constraints in the production of rice throughout the world and there is a need to increase rice production per unit of land through economically and environmentally sustainable strategies. *S. incertulas* is one of most notorious cosmopolitan pest. There are several reports on comparative biology of YSB and consequences of their feeding damage on both aerobic and transplanted rice were studied [7, 14, 18, 32, 33]. The influence of different agro-climatic factors on population fluctuation of YSB was studied by many researchers [6, 22-24, 27]. Population dynamics and management of the YSB by using different insecticides including synthetic chemicals, biorationals, insect pheromones were also applied by several workers [16, 19, 25, 28-31, 68]. In our study it was also found that R system can support the better development of *S. incertulas* relative to the NR weed system which may be due to nutritional quality of the respective host plants. The life table data of *S. incertulas* will make easy for effective management of this notorious pest in the field to reduce qualitative and quantitative losses of rice. The extent of borer induced yield losses have been estimated by Satpathi *et al*. [18] and by physiological compensatory mechanism rice plant can tolerate a low level of dead heart (DH) formation without any final yield loss.

Our study 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. It will be very helpful to determine the different mortality stage as well as pattern of population growth on both R and NR weed system. There is a range of in net 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 [46, 47, 49, 55, 57, 62, 69, 70]. The effect of different food sources on population parameters were also observed in different insect pests on different host plants [46, 47, 49, 52, 62-64, 69]. The host plant quality during larval growth and development is a key determinant of both fecundity and fertility of adults [52, 62-64, 69]. Shorter developmental time along with greater total reproduction of insects on a host indicate greater suitability of a host plant [52, 62, 64]. In this study, the overall generation survival (GS) of *S. incertulas* on R was significantly higher than NR weed 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 larvae during their developmental growth similarly in other cases [62, 46, 47, 49]). The overall survival rates suggest that the survival curve of *S. incertulas* is of type III, with high mortality during the immature stages as found in most insect species [46-49, 52]. 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. It represents the rate of potential increase of a population under optimal environmental conditions when fecundity and survival are maximal and adequately summarizes the physiological qualities of an animal in relation to its capacity to increase [52, 55, 57, 69]. The high r_m value on R system indicates that *S. incertulas* has a greater reproductive potential and more preference on it relative to the NR weed system. The doubling time (DT) of *S. incertulas* was significantly shorter on R than the NR weed system. 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 plants. Thus, R system had the lowest antibiosis resistance against *S. incertulas* and was the most favorable one relative to the NR weed system due to high survival of immature stages as reflected in a higher value of r_m. With this understanding, the population dynamics of *S. incertulas* is highly supported by R system due to high nutritional quality relative to the NR weed system. But it is also predicted that, NR weed system is an alternative source of their population growth in absence of R system. So the removal of NR weed is of course a way to control the pest in field condition. Lastly, this study also informs the vulnerable stage of the pest, *S. incertulas*, and which may help the farmers to control them with proper sustainable measures in the field condition.

5. Conclusions

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. This actually hampers the sustainability and normal functioning of the food chains by toxic effect and biomagnifications through trophic interactions in our ecosystem. These also result into secondary pest outbreak and development of pesticide resistance in insect pests and emergence of pest biotypes. Recent advancement in integrated pest management (IPM) programmes have 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. The life table study of *S. incertulas* on R and NR weed represent similar pattern of development with significant variations ($P< 0.005$). These differences in the demographic parameters are due to the variation in their nutritional quality of respective kind of host plants. So for first step management of the notorious insect pest, *S. incertulas*, is very essential to weed the NR weed areas which ultimately would reduce the population size of the pest in the field condition. Their further management strategies may include different ecofriendly and sustainable control measures following their population parameters. 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 economic threshold (ET) and eventually lower broad spectrum pesticides use which generally brings pest resurgence and pest resistant problems. 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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