Life Table Based ETs and Time Series for Sustainable Management of *Spilosoma obliqua* Walkar on Jute

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Abstract

Stage-specific two-sex pooled life table, nutritional ecology and economic thresholds (ETs) based time series of a major pest of jute, *S. obliqua* Walkar (Lepidoptera: Arctiidae), was investigated on two jute species (*Chorchorus olitorious* and *C. capsularis*) during 2017-2019. The population and feeding indices of *S. obliqua* were significantly ($F_{1,4}$ 8.592,$P<0.05$) affected by the host phytoconstituents in terms of host suitability or susceptibility (*C. olitorious*<*C. capsularis*). The average ET was 3.787±1.539 pests plant-1 on *C. capsularis* which was significantly lower ($F_{1,4}$=9.530, $P<0.05$) than *C. olitorious* (4.323±0.897 pests plant^{-1}) due to higher host preference by *S. obliqua*. For a single pest per plant, the possible time (Tt) to reach ET was 14.781±5.973 days on *C. capsularis* which was lower than that in *C. olitorious* (16.456±2.522 days). Host preference and population dynamics-based ET calculation of *S. obliqua* could thus support time-based management strategy and trap cropping for sustainable pest management.

Keywords: *Chorchorus olitorious*, *C. capsularis*, Life table, Phytoconstituents, *Spilosoma obliqua*.

Introduction

Jute (*C. olitorious*, cv. JRO 524 [tossa jute] and *C. capsularis*, cv. Sonali; JRC-321[white jute]) is the most important economic fiber crop throughout the world after cotton (Kumar et al., 2017). Presently, jute cultivation is gaining importance in India due to its increasing demand as raw material for different industries (Mazumdar et al., 2016; Naik and Karmakar, 2016). However, biotic and abiotic factors regulate production of jute throughout the world (Sarkar and Gawande, 2016). The Bihar hairy caterpillar (BHC) of *S. obliqua* (Syn. *Diacrisia obliqua*) (Lepidoptera: Arctiidae) is one of the predominant pests of jute in West Bengal, India, which causes direct economic damage (Sarkar and Majumdar, 2016). It is also one of the major polyphagous (generalist) pest in India, Bangladesh, Bhutan, Srilanka, Pakistan and south-eastern Afghanistan (Gotyal et al., 2015; Gurung et al.,

2020). Use of high yielding resistant varieties (Hails, 2003), broad-spectrum synthetic pesticides (Carvalho, 2017), biorationals (Mathew, 2016), natural enemies (Damalas and Koutroubas, 2018), etc., are the common forms of pest management (Parui and Roy, 2016). Unfortunately, farmers are using broad-spectrum synthetic pesticides injudiciously (Kim et al., 2017) without considering their ET limit or pest density and growth rate (Higley and Wintersteen, 1992). This results in secondary pest outbreak, pest resurgence and development of pesticide resistance, which ultimately leads to regulatory complications in the agro ecosystem (Kim et al., 2017). To cope up with this ecosystem crisis, smart pest management (SPM) strategies need to be developedthrough environmentally benign approaches (Heeb et al., 2019; Roy, 2019a).

The yield loss assessment data is a primary tool to design a module for insect pest management. The

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economic injury (EI) and economic threshold (ET) are the two points (break-even and action point, respectively) for the application of any control measures (Pedigo and Higley,1992). In addition, life table is a powerful tool for analyzing and understanding the effect of different hosts on feeding, growth, survival and reproduction of an insect pest (Carey, 2001; Kakde et al., 2014). Different host plants can influence the survival, development and fecundity of an insect pest (Genc and Nation, 2004). Thus, pest nutritional ecology, their yield reduction efficiency as well as different demographic parameters will inform about the time-based infestation capability and density of the pest in the crop ecosystem (Pedigo and Buntin,1994). On the other hand, the management cost of the pest depends on the pest density, severity of damage and market value of the control measures against the pest (Pedigo and Higley, 1992). The effect of different food sources on population parameters were observed in *Papiliopolytes* (Shobana et al., 2010), *Spodoptera litura* (Xue et al., 2010), *Diacrisia casignetum* (Roy and Barik, 2013), *Podontia quatuordecimpunctata* (Roy, 2015a), *Helicoverpa armigera* (Liu et al., 2004), *Leptocorisa acuta* (Dutta and Roy, 2016) and *Epilachna vigintioctopunctata* (Roy, 2017) due to differences in host chemical regime (Awmack and Leather, 2002). Similarly, several biological studies were reported for *S. obliqua* on sunflower (Singh and Singh, 1992), sesame (Roy, 2020), jute (Gotyal et al., 2015), black gram (Mohapatra and Gupta, 2018) and green gram (Mobarak et al., 2019). The studies on population dynamics and nutritional ecology-based ET calculation of *S. obliqua* are crucial in order to apply time based sustainable management strategies of jute. The objectives of the present study are to (i) find out the phytochemical basis in host preference of *S. obliqua* through their nutritional ecology and population dynamics, (ii) assess the influence of the hosts on population parameters of *S. obliqua to* suggest suitability or susceptibility of the species including their economic profits, (iii) determine the appropriate ETs and respective time series based on pest density, economic attributes beyond the field and their life table parameters on the jute species.

Materials and Methods

A series of field and laboratory experiments were conducted to study the feeding dynamics and population ecology-based ETs calculation of *S. obliqua* on two species of jute (*C. olitorious*, cv. JRO-524 [tossa jute] and *C. capsularis*, cv. Sonali; JRC-321[white jute]) during 2017-2019.

Host plants
C. olitorious and *C. capsularis* were cultivated in a selected field situated near Chinsurah Rice Research Center (CRRC), Chinsurah, 22°53' N, 88°23' E, 13m above sea level, Hooghly, West Bengal, India, during Pre-Khari to the end of Kharif seasons (April to August) in 2017-2019.The plots [each plot 5m×5m; plot gap 1m, soil organic matter 5.3±0.2%, pH 7.7, photoperiod 13 L:11 D at 30–35°C] were prepared as per standard horticultural requirements for cultivation of the two jute species with three replications for each, as well as for the control (without any pesticide) side by side as in Roy (2019 b). The plots were naturally infested by *S. obliqua* during the early growth stage in the field, and the pests were collected separately for their mass rearing. Mature leaves of 4-5 weeks old plants were provided as food for *S. obliqua* neonates. Leaves from each species were collected separately from the control plot for phytochemical analysis.

Phytochemical analysis
The freshly collected jute leaves (*C. olitorious* and *C. capsularis*) were rinsed with distilled water and dried by paper toweling for phytochemical analysis. The leaves were dipped in different solvents for the extraction of different primary (PMs) and secondary metabolites (SMs) as in Roy (2020). The chemicals were estimated by various standard biochemical analysis protocols described by Harborne (1994) with few modifications, as in Roy (2017). Each biochemical analysis was repeated three times and expressed based on µg/mg dry weight.

Insect mass culture

The initial population of *S. obliqua* eggs was collected from both jute fields near CRRC, Chinsurah, Hooghly, West Bengal, India, during Pre-Kharif to the end of Kharif seasons (April to August) over the three consecutive years from 2017 to 2019. The eggs were incubated in the laboratory at 27±1°C, 65±5% RH and photoperiodism of 12:12 (L:D) on the mature jute leaves separately in glass jars (20 cm × 30 cm) until the emergence of caterpillars. The stock culture of *S. obliqua* was initiated on both kinds of jute leaves with three replications at the same laboratory conditions, i.e., at 27±1°C, 65±5% RH and a photoperiodism of 12:12 (L:D) in a growth chamber for life table and feeding dynamics study as described previously (Roy, 2017). In order to obtain the same aged eggs of *S. obliqua*, six pairs of newly emerged moths from each species were placed in an oviposition cage of fine nylon net (25×25×25 cm) separately with fresh foliage, and the process was replicated three times each year with defined cohort (n=100) as previously described (Roy, 2019b).

Life table parameters

The construction of two-sex life table includes several parameters which were calculated with the formulae of Southwood (1978), Carey (1993), and Schowalter (2006). These parameters include probability of survival from birth to age x (l_x), mortality rate (q_x) and survival rate (s_x) per day per age class from egg to adult stages. Using these parameters, the following statistics like total individuals at age x and beyond k (T_x), 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 by using Carey's formulae(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), Hypothetical females in 2nd generation (HFF_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 (Carey, 1993; Roy, 2020).

Feeding dynamics

Food utilization indices were calculated by the formulae of Waldbauer (1968) with slight modifications (Roy and Barik, 2013) to assess the feeding efficiencies of the BHC of *S. obliqua* at 27±1°C, 65±5% RH and a photoperiodism of 12:12 (L:D) hours in a growth chamber as described previously (Roy, 2017). All the feeding indices like growth rate (GR), consumption rate (CR), relative growth rate (RGR), consumption index (CI), egestion rate (ER), host consumption rate (HCR), approximate digestibility (AD%), efficiency of conversion of ingested food (ECI%), efficiency of conversion of digested food (ECD%) and host utilization efficiency (HUE%) including feeding index (FI), growth index (GI) and pest susceptibility index (PSI%) were estimated as in Roy and Barik (2013) and Roy (2017).

Field experiment

Field experiment was conducted for three consecutive years from 2017 to 2019 by growing *C. olitorious* and *C. capsularis* in a randomized block design (RBD) to determine the ETs of *S. obliqua* as described by earlier workers with few modifications (Parui and Roy, 2016). The experiment was done in the same field near CRRC, Chinsurah, West Bengal, India, with 3 replications for both control and treated plots (5m×5m) with an average plant density of 30±2 plants/m² for three years. The yield potential of jute and ETs were observed over a traditional synthetic pesticide, lambda-cyhalothrin 5% EC @ 1ml/L (Kumar et al., 2014), along with control (without pesticide) side

by side (Parui and Roy, 2016).

Yield losses and ETs calculation

From sowing to harvest, the occurrence of BHC(s) of *S. obliqua was* recorded by random quadrat sampling (RQS) from each treated and control plot. Calculation of EI for *S. obliqua* according to the methodology proposed by Pedigo et al. (1986) expressed as numbers or injury equivalents and governed by four primary variables viz. cost of the management tactic per production unit (C), market value per production unit (V), per cent yield loss per pest *(DÊ)* and the proportional reduction in pest attack (K). If the relationship of these variables is linear or roughly so, the EI can be given as $EI = C/VDÊK$ (Pedigo and Buntin, 1994). On the basis of BHC, infestation and the efficacy of the traditional synthetic pesticide were determined in terms of yield damage reduction (Yr%), proportion of insect controlled (PC%) and percent yield loss per pest per plant (D%) along with the management costs (C) for calculation of EI, ET, time to reach the EI (Ti) and ET (Tt) when a plant is infested by a single insectin the field. A time series was also calculated for each jute cultivar up to reach the ET from population growth data. The benefit cost ratio (BCR) was determined (Roy, 2020) to find the economic yield efficiency as well as resistance of the selected species against *S. obliqua* as the sole pest infestation.

Statistical Analysis

Experimental data of different phyto constituents of the host plants (C. *olitorious* and *C. capsularis*) and *S. obliqua* population parameters were subjected to one-way Analysis of Variance (ANOVA), regression analysis and correlation analysis (Zar, 1999). The field experiment RBD data of the host plants and the RQS data of the pest were analyzed using one-way ANOVA (Zar, 1999). Tukey's test (HSD) compared Means of different demographic parameters when significant values were obtained (Zar, 1999). All the statistical analyses were performed using SPSS, version 16.0 (Roy, 2020).

Results and Discussion

The biochemical constituents of the two jute species, *C. olitorious* and *C. capsularis*, are presented in figure 1. All the primary (PMs) and secondary metabolites (SMs) varied significantly ($F_{1,4} \geq$ 53.620-224.213, $P < 0.001$) in the jute species. Among the PMs total carbohydrates, proteins, lipids andamino acids content were 48.195 ± 0.753, 7.767 ± 0.214, 7.415 ± 0.234, 1.065 ± 0.093 and 59.205 ± 0.572, 9.093 ± 0.158, 8.866 ± 0.222, 1.659 ± 0.046 µg/mg dry weight, respectively in *C. olitorious* < *C. capsularis*. The SMs like total phenols, flavonoids and tannins content were 10.768 ± 0.359, 8.401 ± 0.145, 5.529 ± 0.098 and 9.169 ± 0.124, 7.808 ± 0.078, 4.894 ± 0.061 µg/mg dry weight, respectively in *C. olitorious* > *C. capsularis*. The alkanes and free fatty acids in the cuticular wax were 2.601 ± 0.942, 3.416 ± 0.810 and 3.381 ± 0.447, 3.836 ± 0.958 µg/mg dry weight, respectively in *C. olitorious* > *C. capsularis*. Ultimately, the ratio of PMs and SMs was always significantly higher ($F_{1,4} \geq 55.614$, $P < 0.001$) in *C. capsularis* than *C. olitorious*.
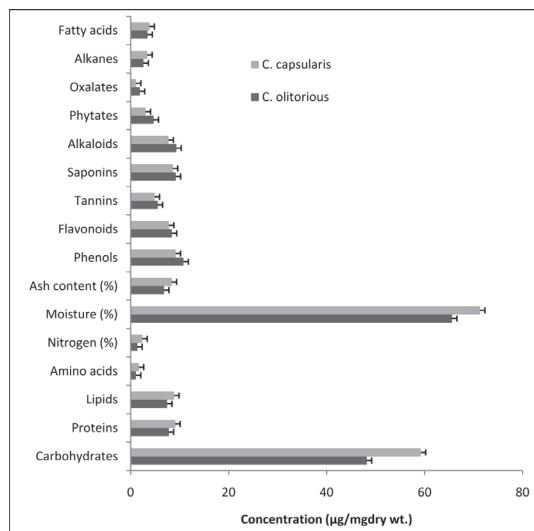

Figure 1. Phytochemical variations (Mean ± SE of 3 observations) in *C. olitorious* and *C. capsularis* cultivated in pre-kharif to Kharif seasons (April to August) during 2017-2019

Pest nutritional ecology and population growth are regulated by host phyto constituents which are highly dynamic (Schoonhoven et al., 2005; Shobana et al., 2010). Host PMs are used only for general vitality, growth and reproduction of the herbivores (Genc and Nation, 2004). While, SMs have a defensive role, and they adversely affect herbivores (War et al., 2012). Among the SMs, plant phenols, flavonoids, tannins, terpenoids, alkaloids, etc., constitute the most common and cosmopolitan group of defensive compounds against insect herbivores (Bernays and Chapman, 2000, Treutter, 2006). The defensive SMs of tomato, tobacco and maize act synergistically on different insects including *Spodoptera spp.* and *Helicoverpa spp.* during ingestion, digestion, and metabolism (Bhonwong et al., 2009). In other instances, herbivore-challenged plants indirectly defend themselves by emitting a blend of volatiles and non-

volatile compounds to resist future threats (Kessler and Baldwin, 2002; War et al., 2012). Similarly, the growth and development of *S obliqua* were also influenced by the respective host phyto constituents. Stage-specific two-sex pooled life table of *S. obliqua* reared on both types of jute (*C. olitorious and C. capsularis*) showed four distinct stages (i.e., egg, larva, pupa, and adult) with six larval instars with significant variations ($F_{9,60} \geq 20.958$, $P<0.001$) in different developmental stages (Table 1-3). The population parameters like, l_x and e_x of *S. obliqua* gradually decreased throughout their developmental stages on both jute plants (*C. olitorious* < C. *capsularis*). They always produce type-III survivorship curves like most of the insects. While, q_x and k_x were in reverse order (*C. olitorious* > C. *capsularis*) with significant ($F_{9,20} \geq 53.664$, $P < 0.001$) variations. The average l_x, e_x, q_x and k_x of *S. obliqua* in adult stage were 0.574 ± 0.013, $0.861 \pm$

Table 1. Stage-specific pooled life table (Mean ± SE of 3 observations) for 9 cohorts (n=100) of *S. obliqua* on tossa jute (*C. olitorious*) cultivated during 2017-2019.

Stages	lx	q_x	s_x	Lx	Tx	ex	Kx
Egg-0	1.000±0.000	0.082±0.006	0.918±0.006	0.959±0.003	7.488±0.052	7.488±0.052	0.037±0.003
lnst- I -1	0.918±0.006	0.044±0.002	0.956±0.002	0.898±0.006	6.528±0.053	7.114±0.089	0.020±0.001
lnst- II-2	0.877±0.005	0.051±0.006	0.949±0.006	0.855±0.003	5.631±0.055	6.417±0.078	0.023±0.003
lnst- III-3	0.833±0.003	0.049±0.007	0.951±0.007	0.812±0.002	4.776±0.056	5.735±0.086	0.022±0.003
lnst- IV-4	0.792±0.004	0.053±0.001	0.947±0.001	0.771±0.004	3.963±0.057	5.006±0.061	0.024±0.001
lnst- V-5	0.750±0.005	0.051±0.007	0.949±0.007	0.730±0.007	3.193±0.054	4.260±0.063	0.023±0.003
lnst- VI-6	0.711±0.009	0.056±0.011	0.944±0.011	0.691±0.011	2.462±0.050	3.462±0.044	0.025±0.005
Prepup-7	0.672±0.014	0.027±0.004	0.973±0.004	0.663±0.015	1.771±0.039	2.637±0.015	0.012±0.002
Pup-8	0.654±0.016	0.122±0.009	0.878±0.009	0.614±0.014	1.108±0.026	1.695±0.023	0.056±0.004
Adult-9	0.574±0.013	0.278±0.024	0.722±0.024	0.494±0.014	0.494±0.014	0.861±0.012	0.142±0.015

Within the column means followed by same letter(s) are not significantly different at P<0.05 by Tukey (HSD) test.

Table 2. Stage-specific pooled life table (Mean ± SE of 3 observations) for 9 cohorts (n=100) of *S. obliqua* on white jute (*C. capsularis*) cultivated during 2017-2019.

Stages	lx	qx	sx	Lx	Tx	ex	Kx
Egg-0	1.000±0.000	0.058±0.019	0.942±0.019	0.971±0.010	7.797±0.148	7.797±0.148	0.026±0.009
lnst- I -1	0.942±0.019	0.041±0.002	0.959±0.002	0.923±0.019	6.827±0.139	7.246±0.065	0.018±0.001
lnst- II-2	0.904±0.018	0.047±0.004	0.953±0.004	0.883±0.017	5.904±0.122	6.533±0.054	0.021±0.002
lnst- III-3	0.861±0.016	0.046±0.007	0.954±0.007	0.842±0.016	5.022±0.108	5.832±0.078	0.021±0.003
lnst- IV-4	0.822±0.017	0.049±0.003	0.951±0.003	0.801±0.018	4.180±0.094	5.087±0.044	0.022±0.001
lnst- V-5	0.781±0.018	0.047±0.006	0.953±0.006	0.763±0.019	3.378±0.077	4.324±0.045	0.021±0.003
lnst- VI-6	0.745±0.019	0.050±0.009	0.950±0.009	0.726±0.017	2.615±0.060	3.511±0.026	0.022±0.004
Prepup-7	0.707±0.017	0.024±0.004	0.976±0.004	0.699±0.018	1.889±0.043	2.671±0.004	0.011±0.002
Pup-8	0.690±0.019	0.110±0.005	0.890±0.005	0.652±0.016	1.190±0.025	1.726±0.012	0.050±0.002
Adult-9	0.614±0.014	0.247±0.013	0.753±0.013	0.538±0.009	0.538±0.009	0.876±0.006	0.123±0.007

Within the column means followed by same letter(s) are not significantly different at P<0.05 by Tukey (HSD) test.

Table 3. Population parameters (Mean ± SE of 3 observations) of *S. obliqua* determined from 18 cohorts (n=100) on *C. olitorious* and *C. capsularis* cultivated during 2017-2019.

Population parameters	*C. olitirious*	*C. capsularis*	*Average*	*Variance*
Potential fecundity (Pf)	332.000±6.741	340.000±11.533	336.000	32.000
Total fertility rate (F_x)	21080.000±1866.625	20318.400±640.890	20699.200	290017.280
Gross reproductive rate (GRR or m_x)	101.840±6.027	103.140±3.162	102.487	0.849
Net reproductive rate (NRR or R_0)	61.200±0.706	62.000±4.086	61.600	0.320
Generation time (T_c)	43.760±0.031	43.660±4.339	43.709	0.005
Doubling time (DT)	7.360±0.648	7.350±0.022	7.352	0.000
Intrinsic rate of natural increase (r_m)	0.090±0.007	0.090±0.001	0.094	0.000
Innet capacity for increase (r_c)	0.030±0.002	0.030±0.001	0.027	0.000
Finite rate of increase (ë)	1.100±0.007	1.100±0.001	1.099	0.000
Weekly multiplication rate ($ë^7$)	1.930±0.004	1.940±0.088	1.935	0.000
Increase rate per generation ($ë^{Tc}$)	61.200±0.706	62.000±4.086	61.600	0.320
Generation mortality (GM)	0.336±0.004	0.341±0.019	0.339	0.000
Mortality coefficient (MC)	0.182±0.007	0.184±0.002	0.183	0.000
Generation survival (GS)	0.629±0.012	0.670±0.018	0.650	0.001
Population growth rate (PGR)	14.418±0.207	14.619±0.663	14.518	0.020
Population momentum factor (PMF)	16.690±0.407	17.258±0.577	16.974	0.161
F_2 population size (PF_2)	2587.008±203.251	2640.480±111.734	2613.744	1429.636
Hypothetical F_2 females (HFF_2)	3745.440±85.713	3844.000±421.314	3794.720	4857.037
Realized F_2 females (RFF_2)	1034.803±81.300	1056.192±44.693	1045.498	228.742
General fertility rate (GFR)	5.425±0.048	5.484±0.261	5.454	0.002
Crude birth rate (CBR)	1.297±0.030	1.323±0.009	1.310	0.000
Reproductive value (RV)	203.671±12.144	206.278±6.323	204.975	3.397
Vital Index (VI)	0.456±0.018	0.461±0.004	0.458	0.000
Trend index (TI)	68.856±3.562	75.064±5.673	71.960	19.273

Within the rows means followed by same letter(s) are not significantly different at P<0.05 by Tukey (HSD) test.

0.012, 0.278 ± 0.024, 0.142 ± 0.015 and 0.614 ± 0.014, 0.876 ± 0.006, 0.247 ± 0.013, 0.123 ± 0.007 per day/age class, respectively (Table 1-2) with significant variations in *C. olitorious* ($F_{9,20}$= 53.664-672.391, *P*<0.001) and C. *capsularis* ($F_{9,20}$=55.759-229.953, *P*<0.001), respectively. Average Pf and F_x of *S. obliqua* on *C. olitorious* and *C. capsularis* were 332.000 ± 6.741, 340.000 ± 11.533 eggs/female and 21080.00 ± 1866.625, 20318.400 ± 640.890 offsprings/female, respectively (Table 3). The average GRR or m_x and NRR or R_0 were 101.840 ± 6.027, 61.200 ± 0.706 and 103.140 ± 3.162, 62.000 ± 4.086 female offsprings/female, respectively on the jute (*C. olitorious* < C. *capsularis*) species. The T_c and DT of *S. obliqua* were 43.760 ± 0.031, 7.360 ± 0.648 and 43.660 ± 0.031, 7.350 ± 0.022 days, respectively on the jute (*C. olitorious* > C. *capsularis*) species without any significant ($F_{1,4}$ ≤ 0.062, *P*>0.05) differences. The average r_m and ë of *S.obliqua* on *C. olitorious* and *C. capsularis* were

0.090 ± 0.007, 1.100±0.001 and 0.090 ± 0.001, 1.100 ± 0.001 female offsprings/ female/day, respectively. The average PGR, GM and GS were 14.418 ± 0.207, 0.336 ± 0.004, 0.629 ± 0.012 and 14.619 ± 0.663, 0.341 ± 0.019, 0.670 ± 0.018 offsprings/individual respectively on *C. olitorious* and *C. capsularis*, respectively. Themean VI and TI of *S. obliqua* were 0.456 ± 0.018, 68.856 ± 3.562 and 0.461 ± 0.004, 75.064 ± 5.673 off springs/ individual respectively, on the jute (*C. olitorious* < C. *capsularis*) species. All the 24 selected population parameters of the 18 cohorts [(3×3)×2=18, n=100] of *S. obliqua* showed significant ($F_{23,24}$=2925.173, *P*<0.001) variations with few exceptions. Thus, the population growth and reproductive parameters of *S. obliqua were* significantly affected by the host phytoconstituents and support the host superiority or susceptibility (*C. capsularis* > *C. olitorious*).

Being a sporadic and polyphagous pest, larval survival and development of *S. obliqua* vary greatly on host plants (Mobarak et al., 2019; Gurung et al., 2020). In this study, the overall development, survival, and reproductive growth of *S. obliqua* on *C. capsularis* was significantly ($F_{9,60} \geq 20.958$, $P < 0.001$) higher than *C. olitorious* due to respective phytoconstituents like other instances (Roy, 2014, 2015a, 2015b). Population growth parameters like GRR, R_0, r_m, ë, etc., were significantly ($F_{23,24} = 2925.173$, $P < 0.001$) higher on *C. capsularis* (103.140 ± 3.162, 62.000 ± 4.086, 0.090 ± 0.001 and 1.100 ± 0.001 female offsprings/female, respectively) than *C. olitorious* (Awmack and Leather, 2002). Similarly, the average CR, GR, FI, GI and PSI of *S. obliqua* were significantly ($F_{1,4} \geq 45.431$, $P < 0.001$) higher on *C. capsularis* than *C. olitorious*. These differences are mainly due to different nutritional (PMs) and anti-nutritional (SMs) factors present in the respective jute (*C. olitorious* and *C. capsularis*) species, including other physical attributes (Slansky and Scriber, 1985). The life table parameters, feeding indices, and yield loss calculations represent similar pattern of biotic resistance (*C. olitorious* > *C. capsularis*) and or susceptibility (*C. olitorious* < *C. capsularis*) towards its defoliator (*S. obliqua*) depending upon host specific chemical regime as mentioned by other workers (Awmack and Leather, 2002; Roy, 2017). In this study, the food utilization indices (GR, CR, RGR, CI, ER, HCR, AD, ECI, ECD, and HUE) varied significantly ($F5,54 \geq 3.401$, $P = 0.009$) within the larval instars on *C. olitorious* and *C. capsularis* (Table 4). The mean GR CR, RGR, and CI were 4.455 ± 2.776, 24.849 ± 12.066, 217.343 ± 189.668, 1024.601 ± 858.300 and 5.923 ± 4.169, 36.487 ± 20.549, 385.991 ± 356.617, 2019.130 ± 1796.695 mg/day, respectively on the jute (*C. olitorious* < *C. capsularis*) species. The average FI (0.092 ± 0.004, 0.106 ± 0.006 mg/mg, respectively) and GI (1.570 ± 0.069, 2.067 ± 0.021 mg/mg, respectively) of *S. obliqua* also significantly ($F_{1,4} \geq 47.841$, $P < 0.001$) varied among the species. Similarly, PSI of *S. obliqua* was also significantly ($F_{1,4} = 94.286$, $P < 0.001$) higher on *C. capsularis* ($62.431 \pm 4.576\%$) than *C. olitorious* (59.323 ± 4.482 %). All the other feeding indices too significantly ($F_{1,4} = 45.431-58.947$, $P < 0.001$) varied. Thus, the feeding indices represented biotic resistance (*C. olitorious* > *C. capsularis*) and or susceptibility of the host (*C. olitorious* < *C. capsularis*) to *S. obliqua* due to variations in their phytoconstituents.

The yield loss is increased with an increase in larval density (Pedigo and Higley, 1992). In the present investigation, the mean EI and ET for *S. obliqua* were 4.09 ± 1.662 and 3.787 ± 1.539 pests/plant, respectively, on *C. capsularis* that were significantly ($F_{1,4} \geq 3.013$, $P < 0.05$) lower than *C. olitorious*

Table 4. Average feeding indices (Mean ± SE of 3 observations) of *S. obliqua* neonates (instar I-VI) of 18 cohorts (n=100) on *C. olitorious* and *C. capsularis* cultivated during 2017-2019.

Parameter	*C. olitorious*	*C. capsularis*	Average	Variance
GR (mg/day)	5.923±4.169	4.455±2.776	5.189	86.921
CR (mg/day)	36.487±20.549	24.849±12.066	30.668	2111.268
RGR (mg/day)	385.991±356.617	217.343±189.668	301.667	635880
CI (mg/day)	2019.130±17.96.695	1024.601±858.300	1521.866	16140561
AD (%)	74.7±601.701	71.266±1.474	73.013	14.470
ECI (%)	8.64±12.816	10.722±3.280	9.681	39.654
ECD (%)	11.91±34.180	14.896±4.490	13.405	87.344
HUE (%)	79.917±1.042	77.732±0.961	78.825	5.426
ER (mg/day)	651.506±600.499	293.795±253.782	472.65	1802996
HCR (mg/day)	2670.637±2396.998	1318.395±1111.969	1994.516	28728006
FI (mg/mg)	0.092±0.004	0.106±0.006	0.099	0.000
GI (%/mg)	1.570±0.069	2.067±0.021	1.819	0.124
PSI (%)	62.431±4.576	59.323±4.482	60.877	69.682

Within the rows means followed by same letter(s) are not significantly different at P<0.05 by Tukey (HSD) test.

Table 5. Average yield losses and economic thresholds (ETs) of *S. obliqua* including production values of *C. olitorious* and *C. capsularis* observed over a traditional synthetic pesticide (lambda-cyhalothrin) along with control (without pesticide) side by side cultivated during 2017-2019.

Crop yield losses and ETs	*C. olitorious*	*C. capsularis*	*Average*	*Variance*
Damage per pest per plant (D%)	3.11±0.219	4.196±0.718	3.653	0.59
Yield damage before treatment (Yd %)	21.643±1.704	21.244±5.307	21.444	0.08
Yield damage after treatment (Ydt %)	3.11±0.219	4.196±0.718	3.653	0.59
Yield damage reduction after treatment (Yr %)	18.533±1.649	17.048±4.697	17.791	1.103
Proportion of insect controlled (PC %)	85.516±1.207	79.444±2.422	82.48	18.435
EI (pest/plant)	4.712±0.977	4.090±1.662	4.401	0.193
ET (pest/plant)	4.323±0.897	3.787±1.539	4.055	0.144
EEI (pest/plant)	4.733±0.985	4.110±1.672	4.422	0.194
Time to reach EI/pest/plant (Ti days)	17.456±2.522	15.781±5.973	16.619	1.403
Time to reach ET/pest/plant (Tt days)	16.456±2.522	14.781±5.973	15.619	1.403
Production values				
Pest control cost [CC] (Rs/ha)	3200.000±50.665	3200.000±50.665	3200	0
Total production cost [TPC] (Rs/ha)	18600.000±57.735	18600.000±57.735	18600	0
Economic yield [EY](Rs/ha)	28234.351±55.445	29780.276±55.445	29007.314	1194942.053
Net Profit [NP] (Rs/ha)	9634.351±55.445	11180.276±55.445	10407.314	1194942.053
Benefit cost ratio (BCR/ha)	0.518±0.002	0.601±0.002	0.56	0.003

Within the rows means followed by same letter(s) are not significantly different at P<0.05 by Tukey (HSD) test.

(4.712 ± 0.977 and 4.323 ± 0.897 pests/plant, respectively) depending on their respective damage potential. The average yield damage (D) by *S. obliqua* were 3.110±0.219 and 4.196±0.718%/ pest/plant on *C. olitorious* and *C. capsularis*, respectively with significant ($F_{1,4}$=2.692, $P < 0.05$) variation (Table 5).The pest control efficacy of the synthetic pesticide (lambda-cyhalothrin) over the control plots represents mean EI and ET of 4.712 ± 0.977 and 4.323 ± 0.897 pests/plant, respectively on *C. olitorious*, which were significantly ($F_{1,4}$= 3.013, $P < 0.05$) higher than *C. capsularis* (4.090 ± 1.662 and 3.787 ± 1.539 pests/plant, respectively) depending on respective damage potential (D%) of the pest. For a single pest per plant, the possible time (Tt) that can be taken to reach the ET were calculated as 16.456 ± 2.522 and 14.781 ± 5.973 days, respectively, on the two jute (*C. olitorious* > *C. capsularis*) species. Thus, all the damage count and ET associated values significantly differed ($F_{7,16}$ ≥ 37.397, $P<0.001$) on both jute species.

Even, ETs based time series were also calculated to find the specific time to reach EI (Ti) and ET (Tt) for any number of pest(s)/plant on the selected jute species (Table 6). The maximum tolerance levels (MTLs) of the pest were 3.900 and 3.400 pests/plant, respectively on the jute (*C. olitorious*>*C. capsularis*) species like ETs. The production values like, EY and BCR were 28234.351±55.445, 29780.276 ± 55.445 Rs/ha and 0.518 ± 0.002, 0.601 ± 0.002, respectively, for the jute (*C. olitorious* < *C. capsularis*) species with significant ($F_{4,5}$ = 582.117, $P < 0.001$) variations according to production of the crop and damage potential of the pest, for average TPC of Rs. 18600.000 ± 57.735 Rs/ha. Thus, the yield loss and ETs also represent biotic resistance (*C. olitorious* > *C. capsularis*) and or susceptibility (*C. olitorious* < *C. capsularis*) of the host plants towards *S. obliqua* due to variation in their nutritional ecology and population growth. In particular, research is needed to obtain improved ETs for IPM towards the better capability to predict pest population trends in the agro-ecosystem.

In a nutshell, the findings represent the variation of different host chemical profiles (PMs and SMs) and their impact on the ecology of *S. obliqua*. Such studies of host preference and population dynamics-based ET calculation of *S. obliqua* could aid in developing time-based application of any sustainable control measures against them. They

Table 6. Time Series for specific time (Ti and Tt days) to reach EI and ET, respectively (Mean of 3 observations) for any number of pest (*S. obliqua*) on *C. olitorious* and *C. capsularis* observed over a traditional synthetic pesticide (lambda-cyhalothrin) along with control (without pesticide) side by side during 2017-2019.

Pest(s)/plant	Ti (days) for *C. olitorious*	Tt (days) for *C. olitorious*	Ti (days) for *C. capsularis*	Tt (days) for *C. capsularis*
0.025	54.064	54.968	52.675	53.482
0.05	46.791	47.695	45.402	46.21
0.1	39.519	40.423	38.13	38.937
0.2	32.246	33.15	30.857	31.665
0.3	27.992	28.896	26.603	27.411
0.4	24.974	25.878	23.585	24.392
0.5	22.632	23.536	21.243	22.051
0.6	20.719	21.623	19.331	20.138
0.7	19.102	20.006	17.713	18.521
0.8	17.701	18.605	16.312	17.12
0.9	16.465	17.369	15.076	15.884
1	15.36	16.264	13.971	14.779
....up to ET ≥1 day remain for manage the pest				
MTL (Pests/plant)	3.9	3.9	3.4	3.4

also support host preference based (*C. olitorious* < *C. capsularis*) trap cropping by using the most preferred jute species (*C. capsularis*) over the less preferred one (*C. olitorious*) as the main crop. These results support the choice of jute cultivar (*C. olitorious* < *C. capsularis*) by considering their biotic resistance and BCR values against *S. obliqua for* their better production. Moreover, the ETs based time series for *S. obliqua* emphasizes the reduction of dependence on pesticide uses for sustainable production of jute in the near future.

Acknowledgments

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