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Trap crop selection and economic threshold based ecological management of *Spilarctia obliqua* (Walker) (Lepidoptera, Erebidae) for sesame

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ABSTRACT: The stage-specific life table and nutritional ecology of a *Spilarctia obliqua* (Walker) along with respective economic thresholds (ETs) on four different crops such as sesame (*Sesamum indicum*), castor (*Ricinus communis*), jute (*Corchorus capsularis*) and sunflower (*Helianthus annuus*) were studied during 2020-2022. The feeding and population dynamics of *S. obliqua* were significantly affected by the hosts in terms of host suitability or susceptibility (sunflower>jute>castor>sesame). The ET of *S. obliqua* on sesame (40.59±2.12 pests m^{-2} area) was significantly ($F_{3,8}=4.72$, $P=0.031$) higher than the other crops (sunflower<jute<castor). Subsequently, the three most suitable hosts (sunflower> jute>castor) were tested in a multi trap cropping system for sesame as main crop in a specific pattern depending on respective susceptibility. Data from the model trap cropping (without pesticide) supported minimum infestation of *S. obliqua* and other pests along with more predators on sesame with higher benefit cost ratio (BCR) and more (11.82%) carbon sequestration (CS) in same area relative to monoculture (with pesticide) of sesame. It supports pesticide free high production and better CS than sole culture of sesame for climate smart agriculture. © 2023 Association for Advancement of Entomology

KEY WORDS: Host suitability, sesame, castor, jute, sunflower, carbon sequestration, phytoconstituents

INTRODUCTION

Spilarctia obliqua (Walker) (Syn. *Diacrisia obliqua*) (Lepidoptera, Erebidae) is a major polyphagous (generalist) pest of different economic crops including sesame, castor, jute and sunflower throughout the South East Asian countries (Gotyal *et al*., 2015; Mobarak *et al.,* 2020). Management of *S. obliqua* is throgh broad-spectrum synthetic pesticides (triazophos, lambda cyahlothrin, indoxacarb, cypermethrin, deltamethrin, etc.) and plant extracts (nimbicidine, ultineem, neemoil, etc.) (Bhardwaj and Kumari, 2016; Mohapatra and Gupta, 2018). The basic information on bio-ecology of an insect pest is necessary before deciding any strategy to combat with the pest (Slansky and Scriber, 1985; Chen *et al*., 2017). Trap crops can attract and divert pests from the main crop by exploiting their different sensory modalities toward most preferred (trap crops) hosts (Rhino *et al*., 2016; Srinivasan *et al*., 2008). But, till date none of the studies has been performed with *S. obliqua* on different crop cultivars using age-stage life table

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and nutritional ecology-based ET calculation along with carbon sequestration efficiencies (CSEs) or trap crop designing.

The objectives of the present study were to (i) find out the biochemical basis of host preference of *S. obliqua* by their food utilization efficiency measures, (ii) unfold the impact of different host plants on their population growth, (iii) find the appropriate ETs of *S. obliqua* for time based application of any control measures for the crops, (iv) selection of trap crops based on host choice and their cropping pattern for optimum management of the pest other than any pesticides, and (iv) suggest new strategy for climate smart agriculture (CSA) in terms of economic profit and sustainable management of *S. obliqua* by using multilayer trap cropping.

MATERIALS AND METHODS

Series of laboratory experiments were conducted during 2020-2022 to study the feeding dynamics and population ecology of *S. obliqua* on four economic crops like, sesame, *Sesamum indicum* (Pedaliaceae) cv. Rama; castor, *Ricinus communis* (Euphorbiaceae) cv. DPC-9; jute, *Corchorus capsularis* (Malvaceae) cv. Sonali, JRC-321 and sunflower, *Helianthus annuus* (Asteraceae) cv. PAC-36. Fieldworks were also conducted to determine ETs for *S. obliqua* and CSEs of respective crop cultivars along with trap crop selection for designing a suitable trap cropping system.

Sesame, castor, jute and sunûower crops were cultivated in a field situated near Chinsurah Rice Research Center (CRRC), Chinsurah, 22°53' N; 88°23' E, 13m above sea level, Hooghly, West Bengal, India, in their growing season during late summer to monsoon (June-September) in 2020-2022. Total twenty four [4 crop×(3 treated+3 control)=24] plots [each plot 10m× 10m; soil organic matter 5.3 ± 0.2%, pH 7.7, average photoperiod of about 13:11 (L:D) at 30–32°C] were prepared for cultivation of sesame, castor, jute and sunûower with average plant density of 30±2, 08±2, 30±2 and 12±2 plants m^{-2}, respectively. Fieldworks were conducted by growing the crop cultivars in randomized block design (RBD) with a gap of 1 m between two plots. The yield potential of the selected crop cultivars was observed over a traditional synthetic pesticide, triazophos 40 EC (@ 40g ai. ha^{-1}) for two times at pre-flowering and flowering stage along with control (without pesticide) side-by-side. The crops were naturally infested by *S. obliqua* in the field and the pests were collected separately for their mass culture. Intact mature leaves from 4-5 weeks old crop plants from respective control plots were collected separately for phytochemical analysis as well as food for *S. obliqua* neonates.

Phytochemical analysis: Freshly collected intact leaves of sesame, castor, jute and sunflower were initially rinsed with distilled water and dried separately for different phytochemical analysis such as total carbohydrates (Dubois *et al*., 1956), total proteins (Miller, 1959), total lipids (Folch *et al*., 1957), total amino acids (Moore and Stein, 1948), total nitrogen (Humphries, 1956), moisture (Nayek and Banerjee, 1987), ash content (Banerjee and Haque, 1984), total phenols (Bray and Thorpe, 1954), total flavonoids (Zhishen *et al*., 1999), Tanins, saponins (Trease and Evans, 1983), alkaloids (Harborne, 1973), phytates (Reddy and Love, 1999) and oxalates (Day and Undrwood, 1986). Determination of each biochemical analysis was repeated three times and expressed in µg mg^{-1} dry weight basis.

Insect mass culture: The initial population of *S. obliqua* larvae were collected from each crop (sesame, castor, jute and sunflower) cultivar separately from the cultivated. The larvae were incubated separately in the laboratory at 26±1°C, 60±5% RH and a photoperiod of 12:12 (L:D) on intact mature leaves of the selected crops in glass jars (20 cm dia. × 30 cm ht.) until their pupation. After emergence of adults from the reared pupae, six pairs of newly emerged male (bipectinate antennae) and female (filiform antennae) were placed in an oviposition cage of fine nylon net (25×25×25 cm) containing a small cotton ball soaked with 10% honey solution for their feeding. The paired moths (male and female) were kept with respective fresh foliage separately for their oviposition. The stock culture of *S. obliqua* was initiated with the F_1 eggs on the selected crop cultivars with three replications at same conditions in a growth chamber [ten eggs in a glass jar (20 cm dia. × 30 cm ht.)] up to three generations. On each crop cultivar, newly laid eggs by the F_3 females were collected in order to obtain the same aged eggs of defined cohort (n=100) for the crops to study population and nutritional ecology with three replications. The petiole of each fresh mature leaf was inserted into a moist piece of cotton, which was wrapped with aluminium foil to prevent moisture loss and replaced daily with fresh ones. Ten larvae were placed in a glass jar containing a particular mature fresh leaves of selected crop cultivars in same condition up to their last instar (6th instar) for pupation. The pupae obtained from each glass jar were placed in separate glass jar (6 cm dia. × 10 cm ht.) covered with fine mesh nylon net in same condition up to their adult emergence on respective crop cultivars. Similarly, newly emerged six pairs of moths (male and female) derived from the respective crop cultivars were kept with respective fresh foliage separately in the same type of oviposition cage. Mortality and developmental durations from egg to adult along with newly emerged female's fecundity were recorded. The feeding dynamics of the neonates and population data throughout their life cycle were recorded separately on the selected crop cultivars.

Feeding ecology: Feeding ecology was determined by taking the F_4 newly emerged first instar larvae that had been reared in the laboratory condition on the selected crops (sesame, castor, jute and sunflower) separately as described in previous experiments. Food utilization indices were calculated by the formulae of Waldbauer (1968). 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%) were estimated on the selected host plants with three replications.

Life table study: The data on survival, developmental duration and oviposition of all individuals on the selected four crop (sesame, castor, jute and sunflower) cultivars were analyzed separately based on age-stage life table. It includes parameters, probability of survival from birth to age x (l_x), proportion of dying (d_x), mortality rate (q_x) and survival rate (s_x) per day per age class from egg to adult stages, which were calculated based on the formulae of Southwood (1978), Carey (1993), Krebs (1994) and Price (1998). Using these parameters, the statistics like total individuals at age x and beyond k (T_x), average population alive in each stage (L_x), life expectancy (e_x), gross reproductive rate (GRR or m_x), net reproductive rate (NRR or R_0), mean generation time (T_c), doubling time (DT), intrinsic rate of population increase (r_m), and finite rate of population increase (ë) were computed, using Carey's formulae (1993).

Yield loss, ET and CSE calculation: The occurrences of *S. obliqua* were recorded by random quadrat sampling (RQS) from each treated and control plots of the selected crop (sesame, castor, jute and sunûower) cultivars. Each plot was considered with 24 quadrats for 3 times (pre-flowering, flowering and post flowering stage) i.e., total 72 quadrats/plot. Economic injury (EI) of *S. obliqua* was determined according to the methodology proposed by Pedigo *et al.* (1986) that expressed as numbers or injury equivalents which governed by four primary variables viz., cost of the management tactic per production unit (*C*), market value per production unit (*V*), percent 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 *et al.,* 1986; Pedigo and Buntin, 1994). The economic threshold (ET) is the population density at which control action should be determined (initiated) to prevent an increasing pest population (injury) from reaching the EI (Pedigo and Higley, 1992). The cost of control (C) includes cost of the insecticide plus application, although others could be added (Higley and Wintersteen, 1992). On the basis of BHCs 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 was infested by a single pest in the field (Roy, 2019). The average management cost was calculated using the cost of the insecticide (triazophos 40 EC) and its application accounted @ Rs. 3500 ha^{-1}. The market value of the produced crops was considered accordingly prevailed in West Bengal, India (Roy, 2020). The benefit cost ratio (BCR) was also determined to find the production efficiency of the selected crop (sesame, castor, jute and sunflower) cultivars over *S. obliqua* as sole pest infestation. The organic biomass production and CSE of the selected crop cultivars were also determined as in Roy (2020) to find the ability of the crops to mitigate the GHGs emission and climate change for CSA (Albrecht and Kandji, 2003; Lal, 2008, 2011; Heeb *et al*., 2019; Roy, 2021).

Trap crop selection and cultivation pattern: Another fieldwork was conducted similarly during 2020-2022 in the same field for designing suitable trap crop and their cultivation pattern. Six plots [each plot 10 m× 10 m; soil organic matter 5.3 ± 0.2%, pH 7.7, average photoperiod of about 13:11 (L:D) at 30–35°C] were prepared similarly in the same field near CRRC for cultivation of sesame as main crop followed by sunflower, jute and castor as trap crop according to preference of *S. obliqua*. The sesame cultivar was grown in the six plots side by side and there was a gap of 0.125 m between two plots which was kept for cultivation of single row (3.184% land area) of sunflower. Surrounding the six plots a border of 0.25m diameter was used for jute (3.815% land area) followed by same diameter of 0.25m for castor (3.872% land area). The land used for main crop cultivation was 8.184 times than the trap crops which occupy only 10.889% of land area. The sesame cultivar (cv. Rama) was also cultivated in the same condition as sole crop (monoculture) in same land area (673.33 m^2) with keeping only 3.889 per cent land area as ecotone. All the six plots of sesame and inter-plot sunflower along with the borders of jute and castor in composite culture as well as only sesame as sole crop (monoculture) with three replications were maintained without pesticide. Different crop parameters were determined in the manipulated crop ecosystem to find the production efficiency of trap crop system (polyculture) in comparison with the monoculture of sesame over BHC of *S. obliqua* along with other pest infestation. Biomass production and CSEs were also determined for both agro ecosystems of sesame.

Statistical Analysis: Experimental data of different phytoconstituents of the selected crop cultivars (sesame, castor, jute and sunflower) and the pest (*S. obliqua*) population parameters feeding indices including ETs related values were homogeneous among treatments as confirmed by Levene's homogeneity test. All the data were normally distributed as determined by Shapiro–Wilk tests and so data were analysed with one-way ANOVA. Means associated with all the data were separated using Tukey's (HSD) test when significant values were obtained. The RBD data of the selected cultivars, respective CSEs and the RQS data from the field with ET values of the pest were analyzed using one-way ANOVA (Zar, 1999). All the statistical analysis was performed by using SPSS, version 16.0.

RESULTS AND DISCUSSION

Host Phytochemicals: All the PMs and SMS were varied significantly ($F_{3,8}$≥6.30, P≤0.017) in the crop cultivars and they were present in reverse order with each other. Among the PMs, total carbohydrates and proteins were in the order of sesame<castor< jute<sunflower. Similarly, total lipids and amino acids were the lowest in sesame followed by castor, jute and sunûower, respectively. All the SMs were in the order of sesame> castor> jute> sunflower. Ultimately, the ratio of PMs to SMs was significantly ($F_{3,8}$≥5.76, P<0.021) varied in the selected crop (sesame<castor< jute<sunflower) cultivars (Table 1).

Feeding dynamics: All the food utilisation indices of *S. obliqua* on the selected crops were displayed significant ($F_{3,8}$≥10.67, P≤0.004) variations within the selected crops. The average GR and CR of *S. obliqua* larvae on sesame, castor, jute and sunûower were 6.72±0.09, 6.73±0.09, 6.83±0.09, 7.09±0.10 and 33.48±0.09, 33.91±0.10, 34.36±0.10, 37.13±0.13 mg per day, respectively. The GR, CR, AD and HUE values were in the order of sesame<castor<jute<sunflower while, ECD and ECI were exactly in reverse order (Table 2).

Population dynamics: The stage-specific life tables of *S. obliqua* were investigated in the laboratory on intact mature leaves of sesame, castor, jute and sunflower cultivars and showed four distinct stages (i.e., egg, larva, pupa and adult) with six larval instars. The l_x, T_x and e_x of *S. obliqua* gradually decreased throughout the developmental stages on the selected crop cultivars and they also produce type-III survivorship curve like most of the insects. Whereas, q_x was varied in different developmental stages and comparatively higher in egg and pupae stage with a rapid surge in adult stage on the selected crop cultivars. The average Pf significantly varied on the crops (sesame< castor<jute<sunflower) ($F_{3,8}=36.75$; $P<0.001$). The F_x, GRR or m_x and NRR or R_0 of *S. obliqua* also differed significantly ($F_{3,8}=13.99-23.23$; $P\leq0.002$). Average T_c for the crop cultivars were without any significant ($F_{3,8}=2.96$; $P=0.098$). Whereas, the average DT for the crop (sesame>castor>jute> sunflower) varied significantly ($F_{3,8}=3.87$, $P=0.031$). The r_m and λ also varied significantly ($F_{3,8}=6.81-7.06$; $P\leq0.012$) like their respective Pf (Table 3).

Yield losses, ETs and CSEs: The efficacy of the synthetic pesticide over the control indicated EI and ET of 25.20 - 42.65 and 20.31- 40.59 pests

Table 1. Phytochemical variations (Mean ± SE of 3 observations /cultivar) of sesame (*S. indicum*; cv. Rama), castor (*R. communis*; cv. DPC-9), jute (*C. capsularis*; cv. Sonali; JRC-321) and sunflower (*H. annuus*; cv. PAC-36)] determined during 2020-2022

Phytochemicals (µg mg^{-1} dry weight)	Sesame	Castor	Jute	Sunflower
Total carbohydrates	49.42±1.43^a	50.12±1.31^b	51.21±1.31^c	54.33±1.49^d
Total proteins	5.62±0.43^a	6.32±0.29^b	6.89±0.37^b	11.53±0.39^c
Total lipids	4.22±0.41^a	4.69±0.23^b	4.92±0.21^b	9.13±0.32^c
Total amino acids	1.38±0.22^a	1.85±0.20^b	2.03±0.15^c	2.18±0.16^d
Total nitrogen (%)	0.69±0.10^a	1.41±0.13^b	1.54±0.12^b	2.24±0.11^c
Moisture (%)	76.13±1.43^a	77.85±1.45^b	77.98±1.38^b	78.68±1.44^b
Ash content (%)	9.05±0.25^a	11.37±0.45^b	11.50±0.47^b	12.20±0.41^c
Total phenols	14.84±0.29^a	13.01±0.49^b	12.14±0.41^c	11.69±0.39^d
Total flavonoids	13.80±0.29^a	12.97±0.42^b	11.10±0.38^c	10.65±0.39^d
Tanins	10.98±0.27^a	8.85±0.40^b	9.28±0.31^c	6.53±0.28^d
Saponins	14.08±0.24^a	11.95±0.44^b	10.38±0.32^c	9.63±0.41^d
Alkaloids	12.48±0.28^a	10.35±0.44^b	9.78±0.36^c	8.03±0.26^d
Phytates	8.78±0.21^a	6.65±0.38^b	5.08±0.28^c	4.33±0.20^d
Oxalates	7.52±0.29^a	5.39±0.24^b	4.82±0.25^c	3.07±0.19^d

Within the rows means followed by same letter(s) are not significantly different at P<0.05 by Tukey (HSD) test along with *F* values (ANOVA)

Table 2. Average feeding indices of *S. obliqua* Walkar (Mean ± SE of 3 observations) on selected host plants [sesame (*S. indicum*; cv. Rama), castor (*R. communis*; cv. DPC-9), jute (*C. capsularis*; cv. Sonali; JRC-321) and sunflower (*H. annuus*; cv. PAC-36)] determined during 2020-2022

Parameter	Sesame	Castor	Jute	Sunflower
GR (mg day^{-1})	6.72 ± 0.09^{a}	6.73 ± 0.09^{a}	6.83 ± 0.09^{b}	7.09 ± 0.10^{c}
CR (mg day^{-1})	33.48 ± 0.09^{a}	33.91 ± 0.10^{b}	34.36 ± 0.10^{a}	37.13 ± 0.13^{c}
RGR (mg day^{-1})	3.41 ± 0.02^{a}	3.43 ± 0.02^{a}	3.37 ± 0.02^{b}	3.21 ± 0.02^{c}
CI (mg day^{-1})	55.57 ± 0.08^{a}	57.84 ± 0.08^{b}	59.95 ± 0.08	57.33 ± 0.08
AD (%)	69.32 ± 0.06^{a}	69.69 ± 0.06^{b}	69.73 ± 0.06^{b}	71.17 ± 0.05^{c}
ECI (%)	12.14 ± 0.08^{a}	11.95 ± 0.07^{b}	11.88 ± 0.08^{b}	11.47 ± 0.07^{c}
ECD (%)	20.07 ± 0.16^{a}	19.60 ± 0.15^{b}	19.56 ± 0.16^{b}	18.29 ± 0.14^{c}
HUE (%)	77.63 ± 0.03^{a}	77.84 ± 0.03^{b}	77.85 ± 0.03^{b}	78.67 ± 0.03^{c}
ER (mg day^{-1})	17.46 ± 0.02^{a}	17.81 ± 0.02^{b}	17.37 ± 0.02^{a}	16.07 ± 0.02^{c}
HCR (mg day^{-1})	73.03 ± 0.09^{a}	75.64 ± 0.09^{b}	77.33 ± 0.09^{c}	73.39 ± 0.09^{d}

Within the row means followed by same letter(s) are not significantly different at $P<0.05$ by Tukey (HSD) test along with *F* values (ANOVA). Here, GR: growth rate, CR: consumption rate, RGR: relative growth rate, CI: consumption index, AD: approximate digestibility, ECI: efficiency of conversion of ingested food, ECD: efficiency of conversion of digested food, HUE: host utilization efficiency, ER: egestion rate, HCR: host consumption rate

m^{-2}, respectively on the crop cultivars (castor< sunflower<jute<sesame) and were significantly ($\boldsymbol{F}_{3,8}$=4.89; *P*=0.032 and $F_{3,8}$=4.72; *P*=0.031, respectively) differed from each other. For a single pest observation per plant the possible time that can be taken to reach EI (Ti) and ET (Tt) were calculated as 36.72-75.38 and 35.72-74.38 days, respectively on the cultivars (sunflower<jute <castor<sesame) and were also significantly ($F_{3,8}$=44.53; *P*<0.001) varied. The benefit cost ratio (BCR per ha) were 0.23-0.58 for the crop cultivars (sesame<castor<jute<sunflower) as in EY and NP with significant ($F_{3,8}$=8824.47; *P*<0.001) variation. The CS were with significant ($F_{3,8}$=34.00; *P*<0.001) variations due to different biomass production ($F_{3,8}$=205.06; *P*<0.001) by the cultivars (sesame<sunflower<jute<castor). The crop parameters including production values and CSEs were changed according to specific pest infestation depending on their host preference, population growth and even on host itself (Table 4).

Efficacy of trap crops over sole crop: The cultivation of sesame as main crop with the most preferred crop cultivars (sunflower> jute> castor) as trap crop (polyculture) in a specific pattern had shown more production efficacy than monoculture of sesame. Different attributes related with the crop production were significantly ($F_{1,4}$= 9.34; *P*d=.037) higher in the said manipulated (designed) agro ecosystem than monoculture system of sesame. The infestation of *S. obliqua* and other pests were 16.23±2.41, 7.44±2.12 and 11.62±2.32, 5.74±2.15 individuals m^{-2}, respectively in mono and poly culture of sesame. Whereas, the occurrence of different predators, mainly Hymenopterans, were significantly ($F_{1,4}$=84.00; *P*<0.05) higher in the defined multi-trap (sunflower>jute>castor) cropping system (8.98±2.06 individuals m^{-2}) of sesame than its monoculture (6.53±2.14 individuals m^{-2}) system.

Table 3. Population dynamics and reproductive table (Mean ± SE of 3 observations) of the 12 cohorts (n=100) of *S. obliqua* Walker on selected four host plants [Sesame (*S. indicum*; cv. Rama), castor (*R. communis*; cv. DPC-9), jute (*C. capsularis*; cv. Sonali; JRC-321) and sunflower (*H. annuus*; cv. PAC-36)] cultivated during 2020-2022.

Population parameters	Sesame	Castor	Jute	Sunflower
Potential fecundity (Pf)(eggs/female)	172.67 ± 9.53^{a}	210.15 ± 8.42^{b}	270.64 ± 8.12^{c}	300.57 ± 6.41^{d}
Total fertility rate (F_x) (offspring/total mature females)	1914.40 ± 758.64^{a}	1982.67 ± 888.09^{b}	9022.67 ± 1345.17^{c}	13622.67 ± 1573.77^{d}
Gross reproductive rate (GRR or mx) (offspring/ individual)	26.98 ± 9.68^{a}	62.89 ± 5.89^{b}	70.43 ± 5.35^{c}	86.37 ± 4.81^{d}
Net reproductive rate (NRR or R_0) (offspring/ individual)	9.07 ± 3.81^{a}	10.67 ± 3.81^{b}	33.07 ± 3.81^{c}	45.07 ± 3.81^{d}
Generation time (T_c) (days)	44.49 ± 0.29^{a}	44.73 ± 0.31^{b}	45.39 ± 0.37^{c}	44.13 ± 0.26^{d}
Doubling time (DT) (days)	20.03 ± 1.45^{a}	15.41 ± 1.49^{b}	9.05 ± 0.38^{c}	8.05 ± 0.14^{d}
Intrinsic rate of increase (r_m) (per day)	0.04 ± 0.01^{a}	0.05 ± 0.01^{b}	0.08 ± 0.00^{c}	0.09 ± 0.00^{d}
Finite rate of increase (ë) (per day)	1.05 ± 0.01^{a}	1.05 ± 0.01^{a}	1.08 ± 0.00^{b}	1.09 ± 0.00^{c}

Within the row means followed by same letter(s) are not significantly different at P<0.05 by Tukey (HSD) test along with *F* values (ANOVA)

The BCR ha^{-1} was 0.23±0.00 and 0.34±0.00, respectively for sesame as sole crop (monoculture) and main crop (polyculture) depending on respective production cost and profit. Habitat manipulation by the trap crops (sunflower>jute>castor) leads more carbon sequestration (11.82%) due to significantly ($F_{1,4}$=40.22, P=0.003) higher biomass production than sesame as sole crop.

Sunflower (cv. PAC-36) leaves were noted with good nutritional (PMs) quality compared to other three crops (jute> castor> sesame) and anti-nutritional factors (SMs) were in reverse order. The PMs (carbohydrates, proteins, lipids, amino acids) including moisture content was used for their general growth and reproduction like other animals (Turunen, 1990; Genc and Nation, 2004). Such variations in host plants were directly affected the potential and achieved development and growth of *S. obliqua* as in other insects (Awmack and Leather, 2002; Roy and Barik, 2012). The GR, CR, AD and HUE of *S. obliqua* were higher on sunflower leaves followed by jute, castor and sesame, while ECI and ECD were in reverse order (sesame>castor>jute>sunflower) due to respective host chemical regime. Trap cropping by habitat manipulation is an attractive option to reduce dependency on conventional pest management practices through insecticides (Srinivasan *et al.*, 2008; Rhino *et al.,* 2016). In this finding, all these parameters (GRR or m_x, NRR or R_0, r_m, T_c, DT and ë) were higher in sunflower followed by jute, castor and sesame like most of the insects (Roy and Barik, 2013; Mobarak *et al.*, 2020; Roy, 2020).

Table 4. Different crop parameters and ETs (Mean ± SE of 3 observations) of *S. obliqua* Walkar on selected four host plants [sesame (*S. indicum*; cv. Rama), castor (*R. communis*; cv. DPC-9), jute (*C. capsularis*; cv. Sonali; JRC-321) and sunflower (*H. annuus*; cv. PAC-36)] including their CSEs observed over a traditional synthetic pesticide (Triazophos 40 EC) along with control (without pesticide) side by side during 2020-2022

Crop Parameter	Sesame	Castor	Jute	Sunflower
Yield damage without treatment (Yd %)	21.77±2.89^{a}	31.71±0.83^{b}	23.93±2.15^{c}	25.39±3.81^{d}
Proportion of insect controlled (PC %)	80.24±3.09^{a}	83.61±2.17^{b}	83.02±1.66^{c}	80.24±3.09^{a}
Yield damage reduction after treatment (Yr %)	17.63±2.92^{a}	26.52±1.12^{b}	19.93±2.13^{c}	20.57±3.62^{d}
Damage per pest per plant (D%)	4.13±0.32^{a}	5.19±0.68^{b}	3.99±0.15^{c}	4.83±0.56^{d}
Economic injury (EI) (pests/m^2)	42.65±2.54^{a}	21.22±1.13^{b}	32.16±1.07^{c}	25.20±1.47^{d}
Economic threshold (ET) (pests/ m^2)	40.59±2.13^{a}	20.31±1.04^{b}	29.78±1.77^{c}	23.12±1.94^{d}
Time to reach EI/pest/ m^2 (Ti days)	75.38±3.83^{a}	69.55±2.41^{b}	44.98±1.57^{c}	36.72±2.92^{d}
Time to reach ET/pest/ m^2 (Tt days)	74.38±3.83^{a}	68.54±2.41^{b}	43.98±1.57^{c}	35.72±2.92^{d}
Production value				
Total production cost [TPC] (Rs/ha)	21900.00±57.74^{a}	21900.00±57.74^{a}	21900.00±57.74^{a}	21900.00±57.74^{a}
Economic yield [EY](Rs/ha)	26783.95±57.74^{a}	27287.42±52.35^{b}	31063.45±50.66^{c}	34587.75±55.45^{d}
Net Profit [NP] (Rs/ha)	4983.95±57.74^{a}	5487.42±52.35^{b}	9263.45±50.66^{c}	12787.75±55.45^{d}
Benefit cost ratio (BCR/ha)	0.23±0.00^{a}	0.25±0.00^{b}	0.42±0.00^{c}	0.58±0.00^{d}
Carbon sequestration efficiency (CSE)				
Biomass produced (lbs dry wt/ m^2)	2.26±0.04^{a}	3.48±0.05^{b}	3.052±0.04^{c}	2.381±0.05^{a}
Carbon sequestration (lbs/ m^2)	0.97±0.04^{a}	1.47±0.05^{b}	1.298±0.04^{c}	1.024±0.05^{a}
Equivalent CO$_2$ sequestration (lbs/ m^2)	3.36±0.04^{a}	5.19±0.05^{b}	4.547±0.04^{c}	3.540±0.05^{d}
Carbon sequestration (Kg/ha)	4136.87±40.17^{a}	6406.96±40.29^{b}	5611.504±40.02^{c}	4364.001±40.68^{d}
Equivalent CO$_2$ sequestration (kg/ ha)	14954.31±40.17^{a}	23277.98±40.29^{b}	20361.291±40.02^{c}	15787.115±40.68^{d}

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

Table 5. Different attributes of the selected trap crops [sunflower (*H. annuus*; cv. PAC-36), jute (*C. capsularis*; cv. Sonali; JRC-321) and castor (*R. communis*; cv. DPC-9)] for sesame (*S. indicum*; cv. Rama) cultivation as main crop for ecosystem service-based management of *S. obliqua* Walker and or other such pest species

Parameters	Sole crop Sesame	Main crop Sesame
Plant density (number/m^2)	30±2^{a}	30±2^{a}
Trap crop density (number/m^2)	-	Sunflower:12±2; Jute:30±2; Castor:8±2
Land area used for sesame (%)	96.11±0.00^{a}	89.11±0.00^{b}
Land area used for others (%)	3.89 (Boundary gap)^{a}	10.89 (Trap crop)^{b}
S. obliqua infestation (number/m^2)	16.23±2.41^{a}	7.44±2.12^{b}
Other pests infestation (number/m^2)	11.62±2.32^{a}	5.74±2.15^{b}
Occurrence of predators (number/m^2)	6.53±2.14^{a}	8.98±2.06^{b}
Production cost (Rs/ha)	21900.00±57.74^{a}	22500.00±52.44^{b}
Seed produced (kg/ha)	635.33±6.43^{a}	712.23±7.22^{b}
Net profit (Rs/ha)	4983.95±57.74^{a}	7613.45±52.44^{b}
Benefit cost ratio (BCR/ha)	0.23±0.00^{a}	0.34±0.00^{b}
Biomass produced (lbs dry wt/ m^2)	2.26±0.04^{a}	2.62±0.06^{b}
Carbon sequestration (lbs/ m^2)	0.97±0.04^{a}	1.12±0.06^{b}
Equivalent CO_2 sequestration (lbs/ m^2)	3.36±0.04^{a}	3.89±0.06^{b}
Carbon sequestration (kg/ha)	4136.87±40.17^{a}	4807.32±42.03^{b}
Equivalent CO_2 sequestration (kg/ ha)	14954.31±40.17^{a}	17412.60±42.03^{b}

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

Thus, relatively low food quality of sesame was made it less preferred host to *S. obliqua* than other crops and which was ultimately supported trap crops (sunflower> jute>castor) selection for sustainable production of sesame. In the present investigation, the mean EI and ET values of *S. obliqua* were in the order of sesame> jute>sunflower>castor with significant variations due to their respective damage potential. Even, trap cropping had also supported CSA of sesame because of lower pest infestation without any pesticide use as well as higher BCR value and CSEs than its monoculture. This study will also inform about the susceptibility and or severity of host cultivars towards *S. obliqua* for their judicious management by using ETs as well as defined trap cropping system of sesame or other such crops.

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REFERENCES

Albrecht A. and Kandji S.T. (2003) Carbon sequestration in tropical agroforestry systems. Agriculture. Ecosystems and Environment 99: 15–27.

Aryal J.P., Jat M.L., Sapkota T. B., Chhetri A.K., Kassie M., Rahut D.B. and Maharjan S. (2018) Adoption of multiple climate smart agricultural practices in the Gangetic plains of Bihar, India. International Journal of Climate Change Strategies and Management 10 (3): 407–427. doi:10.1108/IJCCSM-02-2017-0025.

Awmack C.S. and Leather S.R. (2002) Host plant quality and fecundity in herbivorous insects. Annual Review of Entomology 47: 817–844. doi: 10.1146/annurev.ento.47.091201.145300.

Banerjee T.C. and Haque N. (1984) Dry-matter budgets for *Diacrisia casignetum* larvae fed on sunflower leaves, Journal of Insect Physiology 30: 861 – 866. doi:10.1016/0022-1910(84)90059-3.

Bhardwaj D.K. and Kumari S. (2016) To study the antifeedant activity of Nimbicidine and Ultineem against IInd Instar larvae of *Spilosoma obliqua* (Walker) (Lepidoptera: Arctiidae). European Journal of Biotechnology and Bioscience 4(1): 35–37.

Bray H.G. and Thorpe W.V. (1954) Analysis of phenolic compounds of interest in metabolism. Methods of Biochemical Analysis 1: 27–52. doi:10. 1002/9780470110171.ch2.

Carey J.R. (1993) Applied demography for biologists with special emphasis on insects, Oxford University Press, New York, NY, USA, pp. 211.

Chen Q., Li N., Wang X., Ma L., Huang J.-B. and Huang G.-H. (2017) Age-stage, two-sex life table of *Parapoynx crisonalis* (Lepidoptera: Pyralidae) at different temperatures. PLoS ONE 12(3): e0173380. doi:10.1371/journal.pone.0173380.

Chhetri A.K., Aggarwal P.K., Joshi P.K. and Vyas S. (2017) Farmers' prioritization of climate-smart agriculture (CSA) technologies. Agricultural Systems 151: 184–191. doi: 10.1016/j.agsy.2016.10.005.

Day R.A. and Underwood A.L. (1986) Quantitative analysis, 5th edn., Prentice-Hall publication. pp 701.

Dubois M., Gilles K.A., Hamilton J.K., Rebers P.A. and Smith F. (1956) Colorimetric method for determination of sugars and related substances. Analytical Chemistry 28: 350–356. doi:10.1021/ac60111a017.

Folch J., Lees M. and Sloane Stanley G.H. (1957) A simple method for the isolation and purification of total lipides from animal tissues. Journal of Biological Chemistry 226: 497–509.

Genc H. and Nation J.L. (2004) Influence of dietary lipids on survival of *Phyciodes phaon* butterflies (Lepidoptera: Nymphalidae). Journal of Entomological Sciences 39: 537–544.

Gotyal B.S., Selvaraj K., Meena P.N. and Satpathy S. (2015) Host plant resistance in cultivated jute and its wild relatives towards jute hairy caterpillar *Spilosoma obliqua* (Lepidoptera: Arctiidae). Florida Entomologist 98(2): 721–727. doi:10.1653/024.098.0248.

Harborne J.B. (1973) Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis, Edn. 2, Chapman and Hall, New York. pp 88–185.

Heeb L., Jenner E. and Cock M.J.W. (2019) Climate-smart pest management: building resilience of farms and landscape to changing pest threats. Journal of Pest Science 92: 951–969. doi:10.1007/s10340-019-01083-y.

Higley L.G. and Wintersteen W.K. (1992) A novel approach to environmental risk assessment of pesticides as a basis for incorporating environmental costs into economic injury levels. American Entomologist 38: 34–39.

Holden M.H., Ellner S.P., Lee D.H., Nyrop J.P. and Sanderson J.P. (2012) Designing an effective trap cropping strategy: The effects of attraction, retention and plant spatial distribution. Journal of Applied Ecology 49: 715–722.

Humphries E.C. (1956). Nitrates. In: Peach K., and Tracey M.V., Modern methods of plant analysis, Eds., Springer Verlag, Berlin. pp 48–483.

Krebs C.J. (1994) Ecology: The experimental analysis of distribution and abundance, 4th edn. Harper

Collins College Publishers, New York.

Lal R. (2008) Sequestration of atmospheric CO_2 into global carbon pool. Energy and Environmental Science 1: 86–100.

Lal R. (2011) Sequestering carbon in soils of agro-ecosystems. Food Policy 36: 33–39.

Miller G.L. (1959) Protein determination for large number of samples. Analytical Chemistry 31: 964–967. doi: 10.1021/ac60149a611.

Mobarak S.H., Roy N. and Barik A. (2020) Two-sex life table and feeding dynamics of *Spilosoma obliqua* Walker (Lepidoptera: Arctiidae) on three green gram cultivars. Bulletin of Entomological Research 1–13. doi:10.1017/S0007485319000452.

Mohapatra M.M. and Gupta P.K. (2018) Evaluation of insecticides against Bihar Hairy Caterpillar, *Spilosoma obliqua* Walk. on black gram, *Vigna mungo* (Linn.). International Journal of Current Microbiolog and Applied Sciences 7(6): 605–608. doi: 10.20546/ijcmas.2018.706.069.

Moore S. and Stein W.H. (1948) Photometric ninhydrin method for use in the chromatography of amino acids. Journal of Biological Chemistry 176: 367–388.

Nayek T.K. and Banerjee T.C. (1987) Life history and host specificity of *Altica cyanea* (Coleoptera: Chrysomelidae), a potential biological control agent for water primrose, *Ludwigia adscendens*. Entomophaga 32: 407–414. doi:10.1007/BF02372450.

Pedigo L.P. and Buntin G.D. (1994) Handbook of sampling methods for arthropods in agriculture. CRC Press, Boca Raton, FL.

Pedigo L.P. and Higley L.G. (1992) A new perspective of the economic injury level concept and environmental quality. American Entomology 38: 12-–21.

Pedigo L.P., Hutchins S.H. and Higley L.G. (1986) Economic injury levels in theory and practice. Annual Review of Entomology 31: 341-–368.

Price P.W. (1998) Insect Ecology, Wiley, New York.

Reddy M.B. and Love M. (1999) The impacts of food processing on the nutritional quality of vitamins and minerals, Advances in Experimental and Medical Biology 459: 99-106. doi:10.1007/978-1-4615-4853-9-7.

Rhino B., Verchère A., Thibaut C. and Ratnadass A. (2016) Field evaluation of sweet corn varieties for their potential as a trap crop for *Helicoverpa zea* under tropical conditions. International Journal of Pest Management 62: 3–10.

Roy N. (2019) Life table and economic threshold concept for ecologically sustainable management of *Diacrisia casignetum* Kollar (Lepidoptera: Arctiidae) on jute. ENTOMON 44(2): 103–110. doi:10.33307/entomon.v44i.436.

Roy N. (2020) Population ecology and ETs based time series for climate smart pest management of *Spilosoma obliqua* Walker. ENTOMON 45(1): 15–30. https://doi.org/10.33307.

Roy N. (2021) Population dynamics and economic thresholds-based time series for smart pest management of sesame. International Journal of Tropical Insect Science PP1-12. doi:10.1007/s42690-021-00437-3.

Roy N. and Barik A. (2012) The impact of variation in foliar constituents of sunflower on development and reproduction of *Diacrisia casignetum* Kollar (Lepidoptera: Arctiidae). Psyche 9, Article ID 812091. doi:10.1155/2012/812091.

Roy N. and Barik A. (2013) Influence of four host plants on feeding, growth and reproduction of *Diacrisia casignetum* (Lepidoptera: Arctiidae). Entomological Science 16(1): 112–118. doi:10.1111/j.1479-8298.2012.00546.x.

Slansky F. and Scriber J.M. (1985) Food consumption and utilization. In: Kerkot G.A. and Gillbert L.I. (eds), Comprehensive insect physiology, biochemistry and pharmacology, Pergamon, Oxford, England. pp 87–113. doi:10.1016/b978-0-08-030805-0.50009-2.

Southwood T.R.E. (1978) Ecological methods particular reference to study of insect population, The English Language Book Society and Chapman and Hall, London. pp 524.

Southwood T.R.E. and Henderson P.A. (2000) Ecological Methods. 3rd edn., Blackwell Science, Oxford. pp 575.

Srinivasan K., Moorthy P.K. and Raviprasad T.N. (2008) African marigold as a trap crop for the management of the fruit borer *Helicoverpa armigera* on tomato. International Journal of Pest Management 40: 56–63.

Trease G.E. and Evans W.C. (1983) Textbook of pharmacognosy, 12th edn., Balliese Tindall and Company Publisher, London. pp 343–383.

Turunen S (1990) Plant leaf lipids as fatty acid sources in two species of Lepidoptera. Journal of Insect Physiology 36: 665–672. doi:10.1016/0022-1910(90)90071-M.

Waldbauer G.P. (1968) The consumption and utilization of food by insects. Advances in Insect Physiology 5: 229–288. doi:10.1016/S0065-2806.

Zar J.H. (1999) Biostatistical Analysis. Prentice Hall, Upper Saddle River, New Jersey, USA.

Zhishen J., Mengcheng T. and Jianming W. (1999) The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chemistry 64 (4): 555–559. doi:10.1016/S0308-8146(98)00102-2.

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