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Population growth potential of *Epilachna vigintioctopunctata* (F.) (Coleoptera: Coccinellidae) on some solanaceous medicinal plants

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ABSTRACT

The spotted ladybird beetle, *Epilachna vigintioctopunctata* (F.) (Coleoptera: Coccinellidae), is an important pest of solanaceous medicinal plants in India. In this study, we investigated population growth potential of *E. vigintioctopunctata* in the laboratory at 28 ± 1°C with 80% ± 5% RH and 14:10 L:D photoperiod on seven solanaceous medicinal plants, viz. *Solanum nigrum* (L.), *Datura metel* (L.), *Datura alba* (L.), *Solanum surattense* Burm. (F.), *Withania somnifera* (L.) Dunal (wild) and cultivars of *W. somnifera*, viz. "JA 20" and "JA 134". The lowest rate of population growth occurred on *D. metel*, where immature development time, immature survival and pre oviposition period were highest, and fecundity was lowest (183.96 eggs per female). The highest growth rate occurred on *S. surrattense* and fecundity was also highest (637.08). The lowest net reproductive rate (*Ro*) (56.60) and the intrinsic rate of population increase (r_m) (0.07) were obtained on *D. metel* and were highest on *S. surattense* (305.90 and 0.14 respectively). The mean generation time (*T*) was shortest on *S. surattense* (40.95 days). Using these measures, it is recognized that *E. vigintioctopunctata* performance was best on *S. surattense* and worst on *D. metel*. The findings of this study will contribute to the development of effective integrated pest management strategies for *E. vigintioctopunctata* on cultivated *W. somnifera*.

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Withania somnifera; *Solanum surattense*; *Datura metel*; host plants; development; fecundity; survival; population parameters

1. Introduction

Several solanaceous medicinal plants such as *Withania somnifera* (L.) Dunal, *Solanum nigrum* (L.), *S. surattense* Burm. (F.), *S. indicum*, *Datura* spp., etc. are commonly used in India from ancient times as a cure of many ailments. Among them, *W. somnifera*, also known as Indian ginseng, is an important plant, the roots of which have been employed in Indian traditional systems of medicine, *Ayurveda* and *Unani*. It is cultivated commercially in marginal and low fertility soils of Madhya Pradesh and Rajasthan States in India (Manjoo & Swaminathan 2007). This crop is quite often encountered with heavy infestation of spotted leaf beetle, *Epilachna vigintioctopunctata* (Fabricius) (Coleoptera: Coccinellidae) (Mitra & Biswas 2002; Tripathi et al. 2005; Venkatesha 2006; Manjoo & Swaminathan 2007; Ravikumar et al. 2008; Ramanna et al. 2010). It is a polyphagous pest causing serious damage to solanaceous, cucurbitaceous and leguminous crop plants (Mathur & Srivastava 1964; Ghosh & Senapati 2001; Venkatesha 2006; Varma & Anandhi 2008), and several wild solanaceous medicinal plants such as *Physalis* spp., *Datura stramonium* (L.), *Datura metel* (L.), *D. innoxia* (L.), *S. nigrum* (L.) and *W. somnifera* (Mathur & Srivastava 1964; Mohanasundaram & Uthamaswamy 1973; Sharma & Chandel 2009; Ramanna et al. 2010). It is widely distributed in South-East Asia, Australia, Sri Lanka, China, Japan and India (Richards 1983). Both larvae and adults of the beetle feed characteristically by scraping the leaf cuticle and reducing the leaves to a fibrous skeleton. The damaged leaves dry and drop down prematurely, thus affecting plant growth, vigour and yield (Krishnamurti & Appanna 1951; Tripathi et al. 2005).

Outbreaks of *E. vigintioctopunctata* in commercial cultivars of *W. somnifera*, viz. "JA 20" and "JA 134" are often associated with abundance and proximity of cultivated and wild potential host plants in the field. Development of efficient strategies for managing *E. vigintioctopunctata* will require knowledge of its biological relationship with various host plants. Among these, an important component would be an understanding of host suitability. Despite extensive literature documenting the effects of different host plants on the biological parameters of *E. vigintioctopunctata* (Subbaratnam & Butani 1981; Nakamura et al. 1988; Richards & Filewood 1988; Ramzan et al. 1990; Kahono & Purwantoro 1993; Kaur & Mavi 2005; Sushilkumar et al. 2007; Varma & Anandhi 2008), studies on its development, survival and population growth parameters on plants of medicinal importance are scanty. Therefore, the goal of this investigation was to know the effect of different solanaceous medicinal plants on

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development, survival, reproduction and population growth potential of *E. vigintioctopunctata*, with the final objective to recommend appropriate control tactics for the benefit of growers.

2. Materials and methods

2.1. Host plants

Host plants belonging to the family Solanaceae such as *S. nigrum* (L.), *D. metel* (L.), *Datura alba* (L.), *S. surattense* Burm. (F.), *W. somnifera* (L.) Dunal (wild) and commercial cultivars of *W. somnifera* such as "JA 20" and "JA 134" used in the study were grown in Herbal Garden and Farm at Directorate of Medicinal and Aromatic Plants Research (DMAPR), Gujarat, India (22° 32' N, 73° 00' E and an altitude of 39 m above the sea level). The host plants were selected based on their importance as medicinal and commercial value, distribution and their role as alternate hosts of *E. vigintioctopunctata*.

2.2. Insect stock culture

The egg masses of *E. vigintioctopunctata* were collected from respective host plants and the newly hatched larvae were carefully released on the leaves of respective host plant kept in transparent plastic Petri dishes (90 mm diameter) having lined with moistened blotting paper at bottom to maintain the turgidity of the leaves. Fresh leaves were provided to the larvae regularly till pupation. For mating and subsequent egg laying, newly emerged male and female adults were transferred into transparent plastic jars (10 × 8 cm) having an intact twig of 4–5 leaves of same host fixed in a small vial containing water with the help of cotton. The mouth of plastic jar was covered by a piece of muslin cloth. All the cultures were maintained in biological oxygen demand incubator at 28 ± 1 °C with 80% ± 5% relative humidity (RH) and 14:10 L:D photoperiod.

2.3. Development and survival of immature stages of E. vigintioctopunctata

Newly hatched larvae from the respective insect stock culture were released individually on the fresh leaves of same host plants kept in transparent plastic Petri dishes (60 mm diameter) lined with moistened blotting paper at bottom to maintain turgidity of the leaves. Fresh foliage was provided regularly until pupation. All the treatments were replicated three times with 10 larvae per replication. Each developmental stage was recorded daily. Instars of larvae were confirmed by examining for released exuviae and head capsule. The data were used to calculate mean duration and survival of each stage. To determine the duration and survival of egg stage, egg masses were randomly selected from the culture. The number of eggs per egg mass was also recorded. The egg masses were examined at 12 hours interval and the time to hatch was recorded. The number of eggs producing larvae was counted for each egg mass to determine egg survival. The developmental rate of immature stages were analysed by the equation $1/D$ (1/duration of life stage) to know the per day development of a particular stage of *E. vigintioctopunctata*.

2.4. Oviposition, fecundity, adult weight and adult longevity

Newly emerged male and female adults were sexed following the guidelines given by Gupta and Kumar (1982) and were paired. Each pair was then individually confined to transparent plastic jars (10 × 8 cm) having an intact twig of the test plant for feeding and oviposition. The mouth of jars was covered with a piece of muslin cloth. Fresh twigs were replaced daily. Each treatment was replicated three times and each replicate comprised of eight pairs of adults. Adult survival, number of egg masses and number of eggs/mass were recorded daily. Pre-oviposition and oviposition periods were calculated from these data for fecund females. The body weight of newly emerged male and female adults from each test plant was measured.

2.5. Estimation of population parameters

The data obtained from the studies on developmental period, survival and reproduction were used to determine the following population parameters:

(1) Net reproductive rate (Ro): Referred as number of female offspring produced by each female during its entire life time using the equation (Birch 1948).

$$\mathrm{Ro} = \sum (l_x m_x)$$

where Ro is net reproductive rate, x is the age of the insect (in days), l_x is the age specific survival at time x of a cohort and m_x is the average number of female offspring produced per female during the age interval x. Values of m_x were obtained by dividing the mean number of eggs laid per female per day by two, assuming that females were laying eggs at more or less 1:1 sex ratio for adults.

(2) Mean length of generation (T): Referred as the mean period between the birth of the parent and

their offspring. It is calculated as per the methodology suggested by Dublin and Lotka (1925).

$$T = \sum (X\, l_x m_x) / \sum (l_x m_x)$$

where x is the age of the insect (in days). The result is a weighed approximate value, since the progeny is produced over a period of time and not a definite time.

(3) Intrinsic rate of increase (r_m): Defined as the instantaneous rate of increase of a population in a unit time under a set of ecological condition (Birch 1948). The r_m was computed using the life table statistics Ro and T as calculated above using the following equation:

$$r_m = (\ln \mathrm{Ro}) / T$$

where T = mean length of generation.

The intrinsic rate of natural increase (r_m) is one of the most important parameters for describing the growth potential of a population under given climate and food conditions. The value of r_m determines whether a population increases exponentially ($r_m > 0$), remains constant in size ($r_m = 0$) or declines to extinction ($r_m < 0$) (Gotelli 1998; Southwood & Handerson 2000; Kafil et al. 2007). Differences in r_m and other life table statistics were tested for significance by estimating variances through the Jackknife technique.

(4) Growth index (GI): It is computed as the ratio between percentage of larvae pupating divided by the average larval development time in days (Saxena et al. 1974).

2.6. Statistics

The data of effects of host plants on the life history parameters were subjected to one way analysis of variance by using IBM SPSS 21 software published by IBM Corporation, Armonk, NY, USA. Means associated with host plants for each variable were separated using the Tukey's honestly significant difference (HSD) test when significant F values were obtained. For each host plant, simple linear regression analyses were used to examine the relationship between the insect body weight and fecundity.

3. Results

3.1. Development of E. vigintioctopunctata

The duration of developmental stages of *E. vigintioctopunctata* on different host plants is given in Table 1. Host plants significantly influenced incubation period of eggs ($F = 14.84$, df = 6, 34, $p \leq 0.001$). Eggs laid by

Table 1. Effect of host plants on duration of developmental stages of *E. vigintioctopunctata*.

Hosts	Incubation period (days)		Larval period (days)								Total larval period (days)		Pre-pupal period (days)		Pupal period (days)		Total duration of immature stages (days)	
			First instar		Second instar		Third instar		Fourth instar									
	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE
S. nigrum	3.73^{b}	0.08	4.07^{c}	0.07	2.03^{a}	0.06	2.60^{ab}	0.09	2.60^{a}	0.09	11.29^{ab}	0.15	1.11^{a}	0.06	2.93^{a}	0.05	19.60^{a}	0.21
D. metel	4.00^{b}	0.08	5.35^{d}	0.13	4.30^{c}	0.38	6.17^{d}	0.23	4.73^{d}	0.25	20.60^{e}	0.71	1.47^{b}	0.13	4.13^{c}	0.24	30.27^{c}	0.86
D. alba	3.74^{b}	0.07	3.76^{c}	0.09	3.52^{b}	0.17	5.90^{d}	0.23	5.20^{d}	0.26	18.15^{d}	0.42	1.70^{b}	0.11	5.15^{d}	0.22	29.35^{c}	0.48
S. surattense	3.14^{a}	0.07	2.80^{a}	0.10	2.00^{a}	0.09	2.57^{ab}	0.09	3.30^{b}	0.09	10.67^{a}	0.15	1.70^{b}	0.11	4.03^{bc}	0.90	19.27^{a}	0.29
W. somnifera	3.32^{a}	0.09	3.20^{b}	0.10	3.07^{b}	0.16	3.32^{c}	0.13	3.76^{bc}	0.19	13.24^{c}	0.41	1.58^{b}	0.10	3.92^{bc}	0.18	21.77^{b}	0.45
"JA 20"	3.89^{b}	0.07	2.78^{a}	0.08	2.22^{a}	0.08	3.04^{bc}	0.06	4.00^{c}	0.08	12.04^{bc}	0.04	1.00^{a}	0.00	4.15^{c}	0.07	21.30^{b}	0.17
"JA 134"	4.90^{c}	0.09	3.03^{ab}	0.06	2.07^{a}	0.05	2.30^{a}	0.09	3.50^{bc}	0.09	10.90^{ab}	0.10	1.03^{a}	0.33	3.53^{b}	0.09	20.23^{ab}	0.20

Note: In a column, mean values followed by same letter (s) are not significantly different (Tukey's HSD test at $p \leq 0.001$ $F = 14.84$, df = 6, 34).

Table 2. Development rate of (1/duration of life) life stages of *E. vigintioctopunctata* on different host plants.

S. No.	Developmental stages	1/Duration of life in days						
		S. nigrum	*D. metel*	*D. alba*	*S. surattense*	*W. somnifera* (wild)	"JA 20"	"JA 134"
1	Egg	0.268	0.250	0.267	0.318	0.301	0.257	0.204
2	Larva							
3	First instar	0.245	0.187	0.265	0.357	0.313	0.360	0.330
4	Second instar	0.493	0.233	0.284	0.500	0.326	0.450	0.483
5	Third instar	0.385	0.162	0.169	0.389	0.301	0.329	0.435
6	Fourth instar	0.385	0.211	0.192	0.303	0.266	0.250	0.286
7	Pre pupa	0.900	0.680	0.588	0.588	0.633	1.000	0.971
8	Pupa	0.341	0.242	0.194	0.248	0.255	0.241	0.283
9	Overall immature stages	0.051	0.033	0.034	0.052	0.046	0.047	0.049

adults fed on *S. surattense* and *W. somnifera* (wild) hatched faster (3.14 ± 0.07 and 3.32 ± 0.09 days, respectively) than other hosts. This period was longest on "JA 134" (4.9 ± 0.09 days). Although uniformly four larval instars were observed on all host plants, their duration differed among them. Overall, larval development was significantly affected by host plants ($F = 34.51$; df = 6, 167; $p \leq 0.001$). Total larval development time was shortest on *S. surattense* (10.67 ± 0.15 days) followed by "JA 134" and *S. nigrum* (10.90 ± 0.10 and 11.29 ± 0.15 days, respectively), longest on *D. metel* (20.60 ± 0.71 days) and intermediate on "JA 20" and *W. somnifera* (wild). Pre-pupal period was relatively shorter on "JA 20", "JA 134" and *S. nigrum* than other plant species. Host plants significantly affected pupal development time ($F = 29.98$; df = 6, 167; $p \leq 0.001$). It was shortest on *S. nigrum* (2. 93 ± 0.05 days) and longest on *D. alba* (5.15 ± 0.22 days) followed by "JA 20" and *D. metel* (4.15 ± 0.07 and 4.13 ± 0.24 days, respectively). Overall development time from egg to adult eclosion was significantly shortest when *E. vigintioctopunctata* was fed on *S. surattense* (19.27 ± 0.29 days), followed by *S. nigrum* (19.60 ± 0.21 days), intermediate on "JA 134", "JA 20" and *W. somnifera* (wild) (20.23 ± 0.20 to 21.77 ± 0.45 days) and longest on *D. metel* (30.27 ± 0.86 days), followed by *D. alba* (29.35 ± 0.48 days) ($F = 139.69$; df = 6, 167; $p \leq 0.001$). Accordingly, per day development (i.e. development rate) of immature stages (egg to pupa) was fastest on *S. surattense* and *S. nigrum* (0.052 and 0.051, respectively), intermediate on "JA 134", "JA 20" and *W. somnifera* (wild) and slowest on *D. metel* (0.033), followed by *D. alba* (0.034). The rate of development per day in first, second, third and fourth instar larvae was faster on "JA 20", *S. surattense*, "JA 134" and *S. nigrum* compared to *D. metel* and *D. alba* (Table 2).

3.2. Stage specific survival of immature stages

Host plants significantly affected survival of *E. vigintioctopunctata* in egg ($F = 39.74$; df = 6, 793; $p \leq 0.001$) and larval stages ($F = 48.74$, df = 6, 168, $p \leq 0.001$). The survival of pupae was not influenced by any of the host plants and all the survived larvae entered pupal stage (Table 3). Higher survival of eggs

Table 3. Stage specific survival of *E. vigintioctopunctata* on different host plants.

Hosts	No. of egg masses	% Eggs survival		% Larva survival		% Pupa survival	
		Mean	±SE	Mean	±SE	Mean	±SE
S. nigrum	114	90.23^{b}	1.19	94.0^{de}	1.63	100.0^{a}	0.0
D. metel	109	75.70^{a}	1.55	51.0^{a}	3.14	100.0^{a}	0.0
D. alba	118	90.51^{b}	0.96	67.0^{b}	2.13	100.0^{a}	0.0
S. surattense	126	97.48^{d}	0.48	100.0^{e}	0.00	100.0^{a}	0.0
W. somnifera	107	91.11^{bc}	1.22	80.0^{c}	2.58	100.0^{a}	0.0
"JA 20"	108	94.96^{cd}	0.73	90.0^{d}	2.58	100.0^{a}	0.0
"JA 134"	118	95.98^{d}	0.53	100.0^{e}	0.0	100.0^{a}	0.0

Note: In a column mean values followed by same letter (s) are not significantly different (Tukey's HSD test at $p \leq 0.001$).

(percentage of hatching) in an egg mass was recorded on *S. surattense* (97.48%) followed by "JA 134" (95.90%) and lowest on *D. metel* (75.70%). Survival of larvae was 100.0% on *S. surattense* and "JA 134". Lowest larval survival was recorded on *D. metel* (51.00%), followed by *D. alba* (67.00%). A ranking of larval survival in order of descending is *S. surattense* = "JA 134" > *S. nigrum* > "JA 20" > *W. somnifera* (wild) > *D. alba* > *D. metel*. On all the test plants, all larvae pupated have reached adult stage.

3.3. Oviposition, fecundity, adult weight and adult longevity

Host plants exerted significant influence on the pre-oviposition period of female adults ($F = 9.93$, df = 6, 161, $p \leq 0.001$) (Table 4). Female adults fed on *S. surattense* started laying eggs in 5.29 ± 0.30 days after eclosion. While those fed on *D. metel* and *D. alba* took relatively longer time (13.91 ± 0.58 and 12.71 ± 0.74 days, respectively). This period was intermediate on "JA 20", *W. somnifera* (wild), *S. nigrum* and "JA 134" (6.67 ± 1.17 to 9.20 ± 1.63 days). Similarly, oviposition period was also significantly influenced by host plants ($F = 11.58$; df = 6, 161; $p \leq 0.001$). Oviposition period was longest when adults were fed on "JA 20" (53.40 ± 3.97 days), followed by *S. nigrum* (52.31 ± 4.40 days) and *W. somnifera* (wild) (50.20 ± 4.77 days), whereas, it was shortest on *D. metel* (18.17 ± 2.04 days) followed by *D. alba* (26.29 ± 3.00 days). Post-oviposition period was longest on "JA 134" (12.42 ± 1.64 days) and shortest on *D. metel* (5.21 ± 0.68 days).

Table 4. Effect of different host plants on oviposition and adult longevity of *E. vigintioctopunctata.*

								Adult longevity			
		Pre-oviposition period		Oviposition period		Post-oviposition period		Male		Female	
Host	*N*	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE	Mean	±SE
S. nigrum	24	8.91^{ab}	0.96	52.18^{d}	4.40	7.25^{a}	0.85	67.42^{b}	4.15	68.8^{d}	3.80
D. metel	24	13.91^{c}	0.58	18.17^{a}	2.04	5.21^{a}	0.68	39.75^{a}	2.21	37.29^{a}	2.36
D. alba	24	12.71^{c}	0.74	26.29^{ab}	3.00	6.29^{a}	1.02	36.71^{a}	2.94	45.29^{ab}	2.71
S. surattense	24	5.29^{a}	0.30	35.50^{bc}	2.58	9.67^{ab}	1.07	55.92^{b}	2.25	50.38^{cd}	2.53
W. somnifera	24	7.54^{ab}	0.73	50.20^{bcd}	4.77	7.67^{ab}	1.45	58.88^{b}	4.03	65.04^{cd}	4.65
"JA 20"	24	6.67^{ab}	1.17	53.40^{d}	3.97	7.50^{ab}	1.27	64.33^{b}	3.59	68.71^{d}	3.28
"JA 134"	24	9.20^{ab}	1.63	45.67^{bcd}	5.18	12.42^{b}	1.64	65.79^{b}	3.95	67.21^{d}	3.84

Note: In a column mean values followed by same letter (s) are not significantly different (Tukey's HSD test at $p \leq 0.001$).

Fecundity of *E. vigintioctopunctata* differed significantly depending on host plants ($F = 14.77$; df = 6, 167; $p \leq 0.001$). Females fed on *S. surattense* laid maximum eggs (637.08 ± 38.70 eggs per female) followed by "JA 20", *S. nigrum*, *W. somnifera* (wild) and "JA 134", whereas minimum was recorded on *D. metel* (183.96 ± 16.43 eggs per female) (Figure 1).

Longevity of adults were significantly affected by host plants ($F = 14.93$; df = 6, 161; $p \leq 0.001$). Adults lived for longest period on *S. nigrum* (67.42 ± 4.15 and 68.80 ± 3.80 days for male and female, respectively), shortest on *D. metel* (39.75 ± 2.21 and 37.29 ± 2.36 days for male and female, respectively) followed by *D. alba* and intermediate on "JA 20" "JA 134", *W. somnifera* (wild) and *S. surattense* (Table 4).

Adult body weight also differed significantly depending on host plants ($F = 25.60$; df = 6, 98; $p \leq 0.001$). The mean body weight was heaviest on "JA 20" (26.8 ± 0.41 mg) slightest on *D. metel* (20.1 ± 0.71 mg) and intermediate on other hosts (Figure 2).

Simple linear regression analysis indicated significant relationship between adult body weight (female) and fecundity for each host plant ($p \leq 0.001$) (statistics are presented in Figure 3). Body weight strongly influenced the fecundity and exhibited 70%–80% variance in fecundity when reared on various test host plants (Figure 3(a–g)). *E. vigintioctopunctata* laid more eggs per mg of adult weight (190.0 eggs) when fed on *W. somnifera* (wild) followed by "JA 134" (177.6 eggs) and *S. nigrum* (167.1 eggs). Lowest adult weight to fecundity ratio was recorded on *D. metel* (23.18 eggs). The ratio was intermediate on *S. surattense*, *D. alba* and "JA 20" (Figure 3(a–g)).

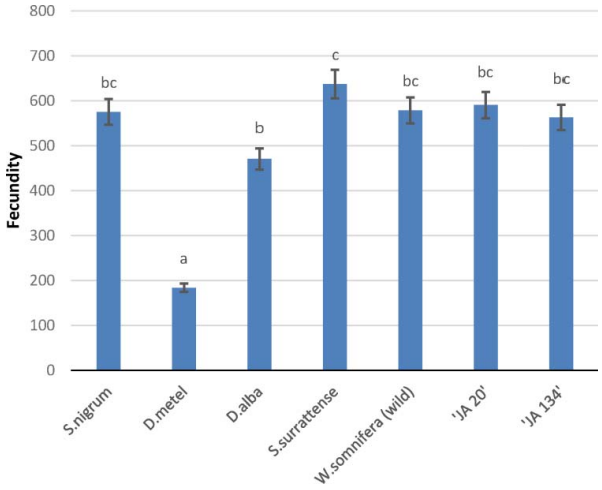

Figure 1. Mean fecundity of *E. vigintioctopunctata* on host plants.

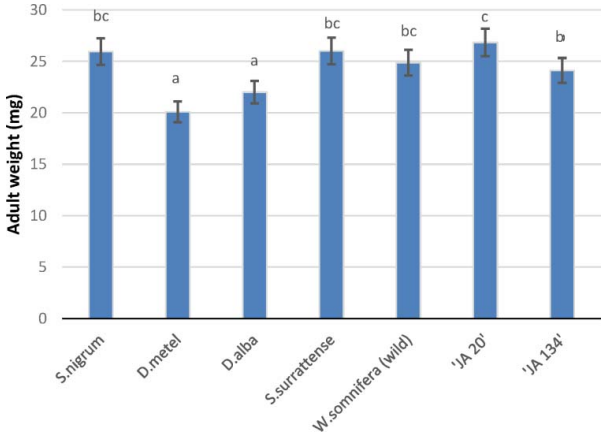

Figure 2. Mean adult body weight (female) of *E. vigintioctopunctata* on host plants.

3.4. Effect of host plants on population parameters

Population parameters, viz. net reproductive rate (Ro), intrinsic rate of increase of population (r_m) and generation development time (T) differed among the host plants. Highest Ro was recorded for *E. vigintioctopunctata* fed on *S. surattense* (305.90 female offspring/female/generation) followed by "JA 20", "JA 134", *S. nigrum*, *W. somnifera* (wild), and lowest on *D. metel* (53.60 female offspring/female/generation). Similarly, intrinsic rate of increase of population (r_m) was also highest on *S. surattense* (0.140) and lowest on *D. metel* (0.073). Furthermore, the generation development time (T) was shorter on *S. surattense* (40.95 days) than on other host plants. Higher GI values were recorded on *S. surattense* and "JA 134" (9.37 and 9.18, respectively) and the lower on *D. metel* (2.23) followed by *D. alba* (3.64) (Table 5).

4. Discussion

The developmental potential of *E. vigintioctopunctata* was evaluated on excised leaves of seven solanaceous

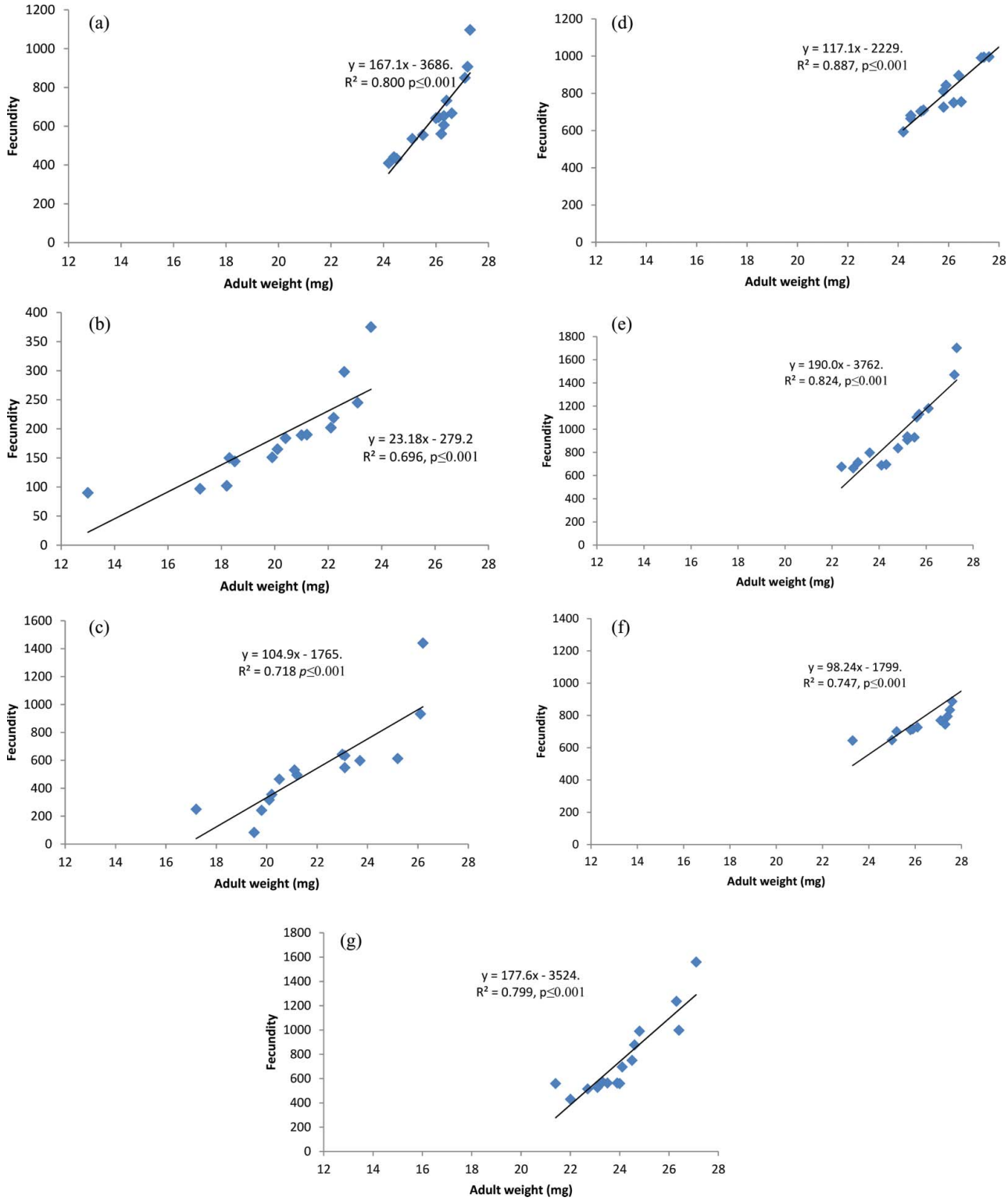

Figure 3. (a) Relationship between adult body weight (female) and fecundity on *S. nigrum*. (b) Relationship between adult body weight (female) and fecundity on *D. metel*. (c) Relationship between adult body weight (female) and fecundity on *D. alba*. (d) Relationship between adult body weight (female) and fecundity on *S. surattense*. (e) Relationship between adult body weight (female) and fecundity on *W. somnifera* (wild). (f) Relationship between adult body weight (female) and fecundity on "cv. 'JA 20'". (g) Relationship between adult body weight (female) and fecundity on "cv. 'JA 134'".

plants of medicinal importance. The purpose of using excised leaves was to limit uncontrolled variation among whole plants within species so that the insect parameters assessed in the study could be fairly assessed across host plants. The use of exercised leaves is a standard method for providing uniform plant material in laboratory studies of this kind (Sachan & Rathore 1979; Hossain et al. 2009). Many plants contain secondary substances that affect feeding, survival and reproduction in phytophagous insects (Gupta & Thorsteinson 1960; Hsiao & Fraenkel 1968), hence to limit such influence, source eggs for establishing insect

Table 5. Effect of different host plants on population parameters of *E. vigintioctopunctata*.

Host plants	Net reproductive rate (Ro per generation)	Intrinsic rate of natural increase (r_m per day)	Mean time of generation development (T)	Growth index (GI)
S. nigrum	239.95	0.098	55.48	8.31
D. metel	53.60	0.073	54.64	2.23
D. alba	120.12	0.082	58.33	3.64
S. surattense	305.90	0.140	40.95	9.37
W. somnifera	236.20	0.099	57.23	5.99
"JA 20"	250.79	0.116	48.87	7.47
"JA 134"	262.58	0.112	50.56	9.18

cultures were collected from different host plants and reared on same host plants. It is also evident from the results of the present study that the host plants significantly affected development time of life stages, survival of immature stages, oviposition periods, body weight and fecundity. The role of host plants in regulating the insect population in terms of development, survival, reproduction and life table parameters was also reported by many works on other insects (Richards 1961; Varley & Gradwell 1970; Liu et al. 2004; Hasan & Ansari 2010, 2011).

The larval development time of *E. vigintioctopunctata* varied among different hosts. For example, it was longest on *D. metel* followed by *D. alba*, shortest on *S. surattense* followed by *S. nigrum* and intermediate on *W. somnifera* (wild), "JA 20" and "JA 134". Studies of Dhamdhere et al. (1990) revealed a longer development period (33.96 days) for this pest when fed on *D. alba*, which is 4.61 days more than the present findings (29.35 days). Sachan and Rathore (1979) observed two day longer development period (21.21 days) at 27 °C than the present findings (19.27 days) on *S. surattense* at 28 °C. Shorter developmental duration of immature stages (eggs, larvae and pupae) on *S. surattense* and *S. nigrum* suggests that they are relatively nutritious compared with *Datura* spp. These hosts could be used as trap crops in the management of this pest. Shorter larval development time of *E. vigintioctopunctata* on *S. nigrum* was also reported by earlier works (Dhamdhere et al. 1990; Ramzan et al. 1990; Sharma & Chandel 2009). The development period reported by them was 2.71–5.39 days longer than the developmental period (19.60 days) reported in the present study. The difference could be due to slightly higher temperature used in the study. The host plants belonging to *W. somnifera* (wild, "JA 20" and "JA 134") exerted more or less similar effect on the development of the insect indicating the possibility of similar nutritional status and host texture. Pupal development time also varied among host plants, being shortest on *S. nigrum* and longest on *D. alba*. The findings of Sachan and Rathore (1979) and Richards and Filewood (1988) also revealed that host plants could influence pupal development of *E. vigintioctopunctata*.

Apart from the clues obtained from developmental period on various host plants, the survival of immature stages on different host plants also will help in deciding suitable hosts. The survivals of eggs (per egg hatch) and larvae were significantly affected by host plants. For instance, egg survival was lowest on *D. metel* and was highest on *S. surattense*. Larval survival was dramatically affected, ranging from 51.0% on *D. metel* to 100.0% on *S. surattense* and "JA 134". Lowest larval survival on *D. metel* and *D. alba* indicates that they are least suitable hosts for growth and development of *E. vigintioctopunctata*. Some studies have indicated that variation in nutritional value of host plants (Font et al. 2005; Padilla et al. 2007; Scalzo et al. 2008) and presence of chemicals such as toxins and digestibility reducers (Schoonhoven et al. 2005; Sushilkumar et al. 2007) may interfere with the physiology of the herbivore and reduce the growth and survival of different life stages. Overall, the findings on life history parameters of *E. vigintioctopunctata* clearly indicate that the host plants like *S. surattense*, *S. nigrum*, *W. somnifera* (wild), "JA 20" and "JA 134" are suitable over *D. metel* and *D. alba* for growth and development. These findings are in agreement with the reports of Sachan and Rathore (1979) and Dhamdhere et al. (1990). Shorter development times, higher rates of reproduction with low mortality rates of developmental stages of an insect on a host indicate greater suitability of that host (Awmack & Leather 2002).

The length of pre-oviposition, oviposition and post-oviposition period differed among the host plants. Though all the test plants belong to same family, female adults developed on *Datura* spp. took more time (an average of 13.31 days) for gonad maturation than other test plants (an average of 7.52 days). The findings of Sachan and Rathore (1979) also confirm that EV took longer time for laying eggs on *Datura* spp. (12.6 days) and relatively shorter time on other solanaceous hosts. In contrast, much longer pre-oviposition period (32.3 days) was reported by Richards and Filewood (1988) for epilachnines feeding on Solanaceae. They also reported that the length of the pre-oviposition period of Epilachninae was influenced by the family of plant on which they feed, and to a lesser extent by particular plant species within the family. Oviposition period was longer on preferred host plants (ranging from 35.50 to 53.42 days) and shorter on less preferred hosts like *Datura* spp. (ranging from 18.17 to 26.29 days). Post-oviposition period followed the similar trend which is being lowest on *Datura* species. The exception was on *S. nigrum* with a period of 7.25 days. The length of the oviposition period is affected by

specific plant species rather than by a particular plant family indicating that selection of the correct host plant is of prime importance to a gravid female (Richards & Filewood 1988).

The mean numbers of eggs laid per female ranged from 183.96 to 637.08 eggs depending on host plants. A ranking of fecundity in order of decreasing is: *S. surattense* > "JA 20" > *W. somnifera* (wild) > *S. nigrum* > "JA 134" > *D. alba* > *D. metel*. The differences in egg laying on different host plants demonstrated that possibility of chemical cues mediated host plant selection in *E. vigintioctopunctata*. Larvae feeding on *S. surattense*, "JA 20", *W. somnifera* (wild), *S. nigrum* and "JA 134" produced comparatively heavier adults, ranging from 24.1 to 26.8 mg than *Datura* species ranging from 20.1 to 22.0 mg. It is supposed that the preferred host plants could have supplied the insects, the important material which would have increased the fecundity by accumulation of nutrients in insects and consequently produced fertile insects big in size and weight. This phenomenon is also supported by Awmack and Leather (2002) who reported that host plant quality affects fecundity, egg size, quality and other reproductive strategies of herbivorous insects at both individual and the population scale.

Host plants significantly influenced the longevity of adults. Adults lived longer on all test plants except *D. alba* and *D. metel* which could be attributed to the unsuitability of these species. Findings of Sachan and Rathore (1979), Richards and Filewood (1988) and Ghosh and Senapati (2001) are in agreement with the present findings. The adult female life span was longer on host plants belonging to *W. somnifera* (wild, "JA 20" and "JA 134"), which is similar to the findings of Venkatesha (2006) and Sharma and Chandel (2009).

The information on development period and fecundity provide clues with regard to the suitability of the host to support a complete insect life cycle, but this data should be linked to population parameters such as reproductive rate (Ro) and intrinsic rate of population increase (r_m), as they are important indicators in population dynamics of insects (Birch 1948; Varley & Gradwell 1970; Liu et al. 2004). The net reproductive rate (Ro) reflects potential of host plants to contribute to insect populations under given climatic conditions. Ranking of host plants based on decreasing values of Ro yields: *S. surattense* > "JA 134" > "JA 20" > *S. nigrum* > *W. somnifera* (wild) > *D. alba* > *D. metel*. Among the host plants, *S. surattense* contributed more to the population dynamics of *E. vigintioctopunctata*. It is supposed that *Datura* spp. were suboptimal for reproduction, thereby, contributed lesser to the pest population.

The intrinsic rate of population increase (r_m) indicated that the *E. vigintioctopunctata* reared on all host plants exhibited exponential population growth. The *E. vigintioctopunctata* fed on *S. surattense*, "JA 20", "JA 134", *W. somnifera* (wild) and *S. nigrum* yielded a higher r_m indicate these plants support faster development, higher survivorship and oviposition rates. Higher Ro and r_m were also reported by Sharma and Chandel (2009) for *E. vigintioctopunctata* on *W. somnifera*. *Datura* spp. recorded a lower r_m value indicating least suitability to *E. vigintioctopunctata*. Similarly, less mean length of generation development (*T*) on *S. surattense* further confirms that it is highly suitable for growth, development and reproduction of *E. vigintioctopunctata*.

Similarly, the GI emphasizes the importance of both survival and developmental time in measuring food quality (Setamou et al. 1999). Shorter development time, higher survival rates, higher Ro, and r_m and GI values recorded on *S. surattense* indicate that it is the most preferred host for *E. vigintioctopunctata* while *D. metel* being the least preferred host followed by *D. alba*. Food quality offered by other host plants was intermediate. The ill effects of aqueous extract of leaves of *D. metel* on developmental period, survival of immature stages, oviposition, pupae formation and adult emergence of *E. vigintioctopunctata* as reported by Islam et al. (2011) also confirm the present results.

To summarize, this study provides information on fitness of *E. vigintioctopunctata* on seven solanaceous host plants. Understanding the differences in life parameters of *E. vigintioctopunctata* on different host plants could have practical implications in pest management. For instance, the study suggests that the less preferred host plants like *D. metel* and *D. alba* for *E. vigintioctopunctata* require prolonged feeding relative to other crops such as *S. surattense*, *S. nigrum*, *W. somnifera*, "JA 20", "JA 134" and consequently leads to higher levels of leaf consumption and crop damage. *D. metel* and *D. alba* might have had high antibiosis resistance against *E. vigintioctopunctata*, and thus were less favourable as hosts evaluated for this pest, as indicated by longer development time and lower values of Ro, r_m and GI. The longer feeding and development times of *E. vigintioctopunctata* on *D. metel* and *D. alba* may allow longer windows of opportunity for the biological control agents. Shorter development time, higher values for survival, growth rate, Ro and r_m, and GI and less mean generation time (*T*) for *E. vigintioctopunctata* on *S. surattense* indicate that it is a highly preferred host for growth, development, survival and reproduction. Other hosts on the row were *S. nigrum*, "JA 134", "JA 20" and *W. somnifera* (wild). *S. surattense*, *S. nigrum*, *D. metel*, *D. alba* and *W. somnifera* (wild) are commonly found as weeds in and around the field, where *W. somnifera* cultivars "JA 20" and "JA 134" are cultivated. They might serve as reservoir or alternate host plants and contribute to the local insect population pool. If the availability of reservoir hosts becomes limiting, infestation in cultivated *W. somnifera* might occur at high levels leading to outbreaks.

The work in these studies suggests that crops like *S. surattense*, *S. nigrum* and *W. somnifera* could be used as trap crops for this pest. Knowledge of how solanaceous host plants influences the population parameters of *E. vigintioctopunctata* could help to understand the population dynamics and select for the proper measures in management of this pest.

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