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Effect of host plants on developmental and population parameters of invasive leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae)

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Abstract *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is one of the most serious pests of tomato, capable of causing 100% crop losses under favourable conditions. We studied the effect of different host plants on developmental and population parameters of this pest at 25 ± 0.5 °C temperature, 70 ± 5% relative humidity and 12 L: 12D photoperiod. Host plant had significant effect on the developmental biology and the population growth parameters of the pest. The leafminer developed fastest on tomato leaves and slowest on potato tubers. Population growth parameters like intrinsic rate of increase, net reproductive rate, finite rate of increase, doubling time and weekly multiplication rate of *T. absoluta* were highest on tomato leaves and lowest on potato tubers. Mean generation time was minimum on tomato leaves and maximum on potato tubers. Females developed on tomato leaves were more fecund than other hosts. Though, tomato was found to be the most suitable host plant of *T. absoluta*, yet, the pest developed and grew successfully on other alternate hosts like potato (*Solanum tuberosum* L.), brinjal (*Solanum melongena* L.) and pepino (*Solanum muricatum* Aiton). These hosts can, therefore, play an important role in the survival, population build up and overwintering of the miner. Further, under favourable conditions the miner can become a serious pest on these crops and need to be monitored on these crops as well.

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Introduction

Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae) is one of the most serious pests of tomato throughout the world (Desneux et al. 2011; Cocco et al. 2015a; Cuthbertson et al. 2013; Oztemiz 2013; Sharma and Gavkare 2017). The larvae cause damage by mining into the leaves, shoots, flowers, buds and fruits (Sharma and Gavkare 2017). Under favourable conditions, this pest is capable of causing 100% crop losses in tomato (Cocco et al. 2015b). Though, tomato is the most preferred host of *T. absoluta,* yet it has also been reported to infest potato, brinjal, common bean, tobacco and many other plants of the families Solanaceae, Fabaceae, Cucurbitaceae, Euphorbiaceae, and Amaranthaceae (Bayram et al. 2015; Mohamed et al. 2015). Some non-solanaceous host plants were, however, unsuitable for the growth and development of *T. absoluta* (Bawin et al. 2016). There are few reports on the trophic relationship between this pest and its alternate host plants (Caparros Megido et al. 2013; Abbes et al. 2016; Bawin et al. 2016), yet the information on the growth potential of *T. absoluta* on its host plants except tomato and potato is missing. Further, the host plant utilization by insects depends upon the physical, chemical, physiological and morphological defences of the hosts which ultimately affect the life history traits of the insect (Singer et al. 2004). Life table parameters especially intrinsic rate of increase, net reproductive rate and generation time express the biotic potential and the population growth of a species in the future generations (Frel et al. 2003; Sauvion et al. 2005). These parameters are strongly affected by the food quality which varies with the host plants (Sauvion et al. 2005; Sharma and Chandel 2009). Knowledge of the host range and their suitability (in terms of survival, development and growth potential) to the pest helps in understanding the dispersion behaviour of the insect in the environment and to guide pest managements decisions (Hill et al. 2004). *T. absoluta* has invaded India in 2014 (Sridhar et al. 2014) and has now been spread to almost all parts of the country where tomato is grown (Sridhar et al. 2014; Kalleshwaraswamy et al. 2015; Shashank et al. 2015; Sharma and Gavkare 2017). Being a new entrant, much work has not been done on this devastating pest in the country. The present study, therefore, aims at to study the effect of host plants like tomato, *Solanum lycopersicum* L. (leaves and fruits), potato, *Solanum tuberosum* L. (leaves and tuber), brinjal, *Solanum melongena* L. and pepino, *Solanum muricatum* Aiton on developmental biology and population growth parameters to understand survival and growth potential of *T. absoluta* on these alternate hosts. The study also be useful to understand the possible role of alternate host plants on population or overwintering of the pest in the absence of the main crop (tomato).

Material and methods

Host plants and insect culture

Four host plants namely tomato (leaves and fruits), potato (leaves and tuber), brinjal (leaves) and pepino (leaves) were chosen for the study. Tomato, potato and brinjal were cultivated at the experimental farm of the Department of Entomology, YSP University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India, whereas, pepino was raised at the experimental farm of the Department of Vegetable Science of the University as per the standard package of practices of the University. The culture of *T. absoluta* was obtained from the stock culture maintained in the Bio-control Research Laboratory of the Department of Entomology and reared on the respective hosts for one generation before using for the experiments. The environmental conditions used to rear the insect and conduct the experiments were 25 ± 0.5 °C temperature, 70 ± 5% relative humidity and 12 L: 12D photoperiod. The adults of second generation were transferred to insect rearing cages for mating and provided10% honey solution in cotton swabs as food. After 48 h each host substrate was exposed separately to the moths for egg laying.

Developmental biology, survival and growth index

Eggs laid on a single day by the females from the second generation on each host plant were used in the experiments. Leaves of tomato, potato, brinjal and pepino; and slices of tomato fruit and potato tuber were individually exposed to 12–15 pairs of *T. absoluta* for 24 h for egg laying. However, the insect could not be reared on potato slices and whole potato tubers were used, hence, no observations were recorded for individual larval instars. 10% honey solution in cotton swabs was given as food for adults. In each case 30 eggs were selected and placed individually in petri dishes (9 cm diameter). These eggs were observed daily for hatching, and observations on egg development time and survival were recorded. Newly emerged larvae were reared individually on the respective hosts in petri dishes under-lined with moist filter paper towel. The larvae were examined daily for moulting and their food was changed after every 24 h till the last larva pupated. Observations on the development time and survival of each larval instar were recorded. Pupae thus obtained were sexed (Genç 2016) and placed individually in glass tubes for adult emergence. Observations on the duration of pupal development, survival and sex ratio were recorded.

Adults developed from the pupae were kept in pairs in glass chimneys containing host substrate for egg laying and 10% honey solution in cotton swabs as food. The oviposition substrate was observed for egg laying and replaced daily till the last adult died. The food was also replaced daily. Observations on daily survival, fecundity, adult longevity, pre-oviposition period, oviposition period and post-oviposition period were recorded.

Larval growth index, pupal growth index and overall immature growth index were calculated by dividing the survival rate of each growth stage by development time (Setamou et al. 1999).

Population growth parameters

Daily survival and fecundity data were used to construct life-fertility tables of the pest on each host separately to calculate the population growth parameters (Birch 1948; Carey 2001) as under:

x = age of the individuals in days (pivotal age), lx = the proportion of females still alive at age x (survival rate) and mx = the number of female eggs laid per female at the age x (fecundity rate). Data thus obtained were used to calculate the following population growth parameters or fertility parameters.

i) The net reproductive rate (R_o): rate of multiplication of the population in each generation, measured in terms of females produced per generation, calculated as $R_o = \Sigma lxmx$
ii) Intrinsic rate of natural increase (rm): calculated by using the expression $\Sigma\ (e^{-rmx}\ lxmx) = 1$.
iii) Mean generation time (T): the mean period elapsing from the birth of parents to the birth of offspring, calculated by the formula:

$$T = \mathrm{Log}_e R_o / rm.$$

iv) Finite rate of natural increase (λ): the number of times the population increases per unit time, calculated by the formula:

$$\lambda = \mathrm{Antilog}_e rm.$$

v) The weekly multiplication rate: the number of times the population increases in a week, calculated by the formula:

$$WM = e^{7rm}$$

vi) The doubling time (DT): the time taken in days by a species to double its population, calculated by the formula:

$$DT = \log_e 2/rm.$$

Data analysis

The jackknife procedure was used to recalculate the above parameters. The jackknife method removes one observation from the original data set and recalculates the parameter of interest from the truncated data set. These new estimates, also called as pseudovalues, were further used to calculate the fresh values of each parameter which served as replications for the parameter to calculate mean and standard error (Meyer et al. 1986; Maia et al. 2000).

Data on the development time, fecundity, and population growth parameters of the pest on different hosts were subjected to one-way analysis of variance and significantly different ($p = 0.05$) means were separated by least significant difference (LSD).

Results

Developmental biology, survival and growth index

Mean development time of each developmental stages of *T. absoluta* on different host plants differed significantly (Table 1). Incubation period was shortest (3.30 days) on tomato leaves and longest (6.94 days) on potato tubers. Larval development of *T. absoluta* was the fastest (15.1 days) on tomato leaves followed by potato leaves, tomato fruits, brinjal leaves, pepino leaves and potato tuber. Similarly, the pupal period was the shortest (10.4 days) on tomato leaves and longest on potato tubers, pepino and brinjial leaves. The pest took 28.88, 32.47, 32.88, 42.27, 47.73 and 60.14 days to complete the immature development (egg-adult emergence) on tomato leaves, potato leaves, tomato fruits, brinjal leaves, pepino leaves and potato tubers, respectively. Both male and female longevity differed significantly among different host plants, and was shortest on brinjal and pepino leaves and longest on potato tubers (Table 2). Females lived longer than males in each case. Food source had no significant impact on pre-oviposition period of the pest, whereas oviposition period, post-oviposition period and fecundity varied significantly among different hosts (Table 2). Though the female longevity was the highest on potato tubers, the oviposition period was shortest (5.67 days) on this host. The longest oviposition period was recorded in females reared on tomato leaves. The post-oviposition period was longest (12 days) on potato tubers and shortest on brinjal and pepino leaves. Fecundity of the pest was highest (175.38 eggs/female) on tomato leaves followed by tomato fruits, brinjal leaves, pepino leaves and potato tuber (20.66 eggs/female). Sex ratio (M: F) varied from 1: 0.88 on brinjal leaves to 1: 1.5 on pepino leaves.

The mortality and growth indices for egg, larva, pupa and overall immature stage of *T. absoluta* on different hosts are presented in Table 3. The egg and larval

Table 1 Mean development time (days ± SE) of different developmental stages of *Tuta absoluta* on different hosts

Development stage	Host plant						Statistics
	Tomato leaves	Potato leaves	Brinjal leaves	Pepino leaves	Tomato fruits	Potato tuber	
Egg	3.30 ± 0.01d	4.30 ± 0.10c	5.89 ± 0.59a	6.39 ± 0.11a	5.09 ± 0.17b	6.94 ± 0.20a	$F_{5,116} = 31.52$ p = < 0.001
I instar	3.23 ± 0.10b	4.22 ± 0.09b	4.71 ± 0.17b	6.59 ± 0.15a	5.05 ± 0.09b	–	$F_{4.98} = 111.6$ p = < 0.001
II instar	3.80 ± 0.13c	4.14 ± 0.08c	4.18 ± 0.13c	9.81 ± 0.14a	6.10 ± 0.12b	–	$F_{4.94} = 382.4$ p = < 0.001
III instar	4.11 ± 0.13b	3.95 ± 0.15b	3.82 ± 0.13b	6.69 ± 0.17a	5.90 ± 0.12a	–	$F_{4.95} = 75.30$ p = < 0.001
IV instar	2.96 ± 0.17b	3.75 ± 0.12b	7.06 ± 0.20a	4.56 ± 0.16b	4.84 ± 0.11b	–	$F_{4.94} = 91.98$ p = < 0.001
Total larval period	15.10 ± 0.11f	16.20 ± 0.11e	19.10 ± 0.25c	26.00 ± 0.14b	17.40 ± 0.15d	37.40 ± 0.19a	$F_{5.104} = 2774.0$ p = < 0.001
Pupa	10.40 ± 0.10c	11.80 ± 0.01b	15.60 ± 0.13a	15.10 ± 0.13a	12.3 ± 0.18b	16.10 ± 0.11a	$F_{4,90} = 326.5$ p = < 0.001
Egg-adult emergence	28.88 ± 0.22e	32.47 ± 0.31d	42.27 ± 0.19c	47.73 ± 0.42b	32.81 ± 0.27d	60.14 ± 0.38a	$F_{5.90} = 6696.0$ p = < 0.001

Means followed by different letters in the same row are significantly different by LSD post-hoc test ($p < 0.05$)

mortality was the lowest (13.3 and 0%, respectively) on tomato leaves and highest (43.3 and 16.7%, respectively) on potato tubers. The pupal mortality was highest (16.7%) on potato tubers, whereas, no pupal mortality was observed on tomato fruits. Daily survival rate and fecundity of female moths is presented in Fig. 1. Insects reared on tomato leaves had minimum (16.6%) immature mortality and 83.4% individuals developed into adults, whereas those reared on potato tubers experienced maximum (76.7%) mortality during the immature stages and only 23.3% individuals reached the adult stage. The maximum daily fecundity (female eggs/female) was on 3rd or 4th day after the start of the egg laying. The growth indices of egg, larva, pupa and overall immature stage (egg to adult emergence) were also the highest (26.3, 6.6, 9.3 and 2.9, respectively) on tomato leaves and the lowest (8.2, 2.2, 5.2 and 0.4, respectively) on potato tubers (Table 3).

Population growth parameters

Food source had significant impact on the population growth parameters namely, net reproductive rate (Ro), intrinsic rate of increase (rm), mean generation time (T), finite rate of increase (λ), doubling time (DT) and weekly multiplication rate (WM) of *T. absoluta* (Table 4). The net reproductive rate was the highest (75.6 females/female/generation) on tomato leaves and lowest (2.1 females/female/generation) on potato tubers. The intrinsic rate of natural increase, also called as specific growth rate, ranged from 0.1316 females/female/day on tomato leaves to 0.0128 females/female/day on potato tubers. The mean generation time of *T. absoluta* was minimum (32.8 days) on tomato leaves and maximum (62.2 days) on potato tubers. The finite rate of increase of *T. absoluta* was 1.349, 1.261, 1.211, 1.133, 1.098 and 1.031 on tomato leaves, tomato fruits, potato leaves, brinjal leaves, pepino leaves and potato tubers, respectively. *Tuta absoluta* is expected to double its population in 4.49, 5.89, 7.86, 10,54, 15.26 and 44.8 days with a weekly multiplication rate of 2.84, 2.09, 1.79, 1.5, 1.36 and 1.09 on tomato leaves, tomato fruits, potato leaves, brinjal leaves, pepino leaves and potato tubers, respectively.

Discussion

Tuta absoluta was able to complete development on all the hosts under study with four larval instars on each hosts. Earlier Torres et al. (2001), EPPO (2005), Pereyra and Sanchez (2006) and Ganbalani et al. (2016) reported

Table 2 Mean(± SE) pre-oviposition period, oviposition period, post-oviposition period, adult longevity, fecundity and sex ratio of *Tuta absoluta* on different hosts

Parameter	Host plant						Statistics
	Tomato leaves	Potato leaves	Brinjal leaves	Pepino leaves	Tomato fruits	Potato tuber	
Pre-oviposition period (days)	1.63 ± 0.18a	1.44 ± 0.17a	1.66 ± 0.21a	2.66 ± 0.30a	1.66 ± 0.21a	2.33 ± 0.33a	$F_{5, 32} = 1.94$ $p = 0.12$
Oviposition period (days)	9.13 ± 0.40a	7.22 ± 0.22b	6.67 ± 0.33bc	6.0 ± 0.26c	7.17 ± 0.40b	5.67 ± 0.66c	$F_{5, 32} = 11.92$ $p = < 0.001$
Post-oviposition period (days)	7.25 ± 0.31c	6.44 ± 0.29d	4.83 ± 0.40e	5.33 ± 0.33e	10.33 ± 0.49b	12.0 ± 1.52a	$F_{5, 32} = 29.13$ $p = < 0.001$
Male longevity (days)	13.62 ± 0.42c	11.11 ± 0.48d	10.50 ± 0.88e	10.66 ± 0.42de	14.66 ± 0.42b	15.66 ± 0.66a	$F_{5, 32} = 13.03$ $p = < 0.001$
Female longevity (days)	18.0 ± 0.46c	15.11 ± 0.30d	13.16 ± 0.65e	13.50 ± 0.62e	19.16 ± 0.40b	20.33 ± 0.66a	$F_{5, 32} = 30.23$ $p = < 0.001$
Fecundity (eggs/female)	175.38 ± 6.92a	71.44 ± 2.80c	47.0 ± 6.61d	27.16 ± 1.95e	112.5 ± 12.08b	20.66 ± 2.96f	$F_{5, 32} = 79.0$ $p = < 0.001$
Sex ratio (M:F)	1: 1.08	1: 0.9	1: 0.88	1: 1.5	1: 1	1: 0.75	

Means followed by different letters in the same row are significantly different by LSD post-hoc test ($p < 0.05$)

four larval instars of *T. absoluta* on tomato. Tomato leaves seems to be the most suitable food for the pest as all the parameters related to the development and population growth were better on tomato leaves than other foods under study. Present results agree with the findings of Pereyra and Sanchez (2006) who reported that tomato is a more suitable and nutritionally better host than potato. In the present study, the larval period of *T. absoluta* varied from 15.1 days on tomato leaves to 37.4 days on potato tubers. Larval period of the pest on tomato leaves reported in the present study is slightly higher than recorded in earlier studies at similar temperature conditions (Pereyra and Sanchez 2006; Erdogan and Babaroglu 2014; Duarte et al. 2015; Silva et al. 2015; Ganbalani et al. 2016). Our results also agree with those of Sridhar et al. (2015) who reported that *T. absoluta* develops faster on tomato than potato and brinjal at 29 ± 1 °C. The differences in the larval development time reported in different studies could be due to the differences in rearing temperature, tomato cultivars and the geographical populations of the insect used in different studies. Herbivore development can also be influenced by differences in rearing conditions, nutritional quality of the host plant and cultivation substrate of the crop (Bernays and Chapman 1994; Mohamadi et al. 2017). Pupal period of the pest observed in the present study was higher than reported by Torres et al. (2001), Duarte et al. (2015) and Ganbalani et al. (2016). In our study, the total immature development of the pest was completed in 28.88 days on tomato leaves and 60.14 days on potato tubers. Earlier reports (EPPO 2005; Cuthbertson 2011; Erdogan and Babaroglu

Table 3 Mortality and growth index (GI) of immature stages of *Tuta absoluta* on different hosts

Host	Egg		Larva		Pupa		Egg-adult	
	Mortality (%)	GI	Mortality (%)	GI	Mortality (%)	GI	Mortality (%)	GI
Tomato leaves	13.3	26.3	0.0	6.6	3.3	9.3	16.6	2.9
Potato leaves	30.0	16.3	3.3	6.9	3.4	8.2	36.7	1.9
Brinjal leaves	40.0	10.2	3.3	5.1	6.7	6.0	50.0	1.2
Pepino leaves	36.7	9.9	10.0	3.5	3.3	6.4	50.0	1.0
Tomato fruits	26.7	14.4	10.0	5.2	0.0	8.1	36.6	1.9
Potato tubers	43.3	8.2	16.7	2.2	16.7	5.2	76.7	0.4

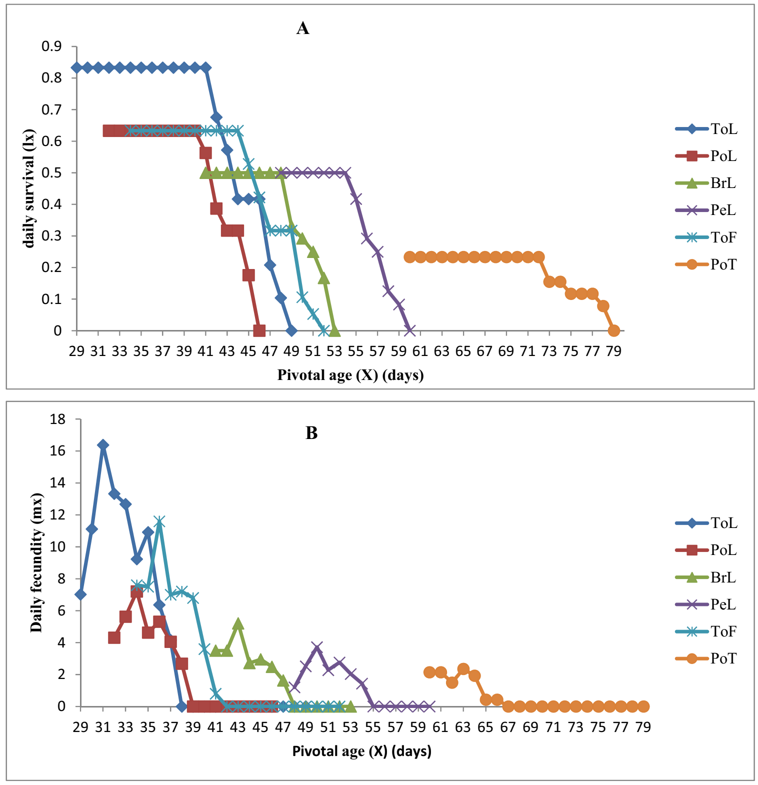

Fig. 1 Age specific survival (**a**) and fecundity (**b**) of *T. absoluta* on different hosts (ToL: tomato leaves; PoL: potato leaves; BrL: brinjal leaves; PeL: pepino leaves; ToF: tomato fruits; PoT: potato tubers)

2014; Ganbalani et al. 2016) reveal that *T. absoluta* completes immature development in 21.87 to 35 days on tomato at 25–26 °C. Like other parameters oviposition period of the miner was also longest on tomato leaves followed by potato leaves, tomato fruits, brinjal leaves, pepino leaves and potato tubers. Oviposition period of *T. absoluta* not only varied with the host plant, but, also among different cultivars (5.08–16 days) within tomato (Erdogan and Babaroglu 2014; Gharekhani and Salek-Ebrahimi 2014; Duarte et al. 2015; Silva et al. 2015; Ganbalani et al. 2016; Krechemer and Foerster 2017). Adult longevity of the miner also varied significantly with the host plant, being shortest on brinjal and pepino leaves and longest on potato tubers. The females lived longer than the males in each case. The female longevity on tomato leaves recorded in the present study (18 days) was almost same (18.16 days) to that reported by Erdogan and Babaroglu (2014), Slight variations in the results obtained in different studies could be attributed to the different varieties on tomato used in different

Table 4 Population growth parameters of *Tuta absoluta* on different hosts

	$Ro = \Sigma lxmx$	$Rm = \Sigma(e^{-rmx}lxmx)$	$T = Log_e R_o / rm$	$\lambda = Antilog_e\ rm$	$DT = log_e\ 2/rm$	$WM = e^{7rm}$
Tomato leaves	75.6 ± 3.0a	0.1316 ± 0.0014a	32.8 ± 0.2a	1.349 ± 0.005a	4.49 ± 0.41a	2.84 ± 0.18a
Potato leaves	21.0 ± 0.8c	0.0848 ± 0.0013c	36.5 ± 0.4b	1.211 ± 0.004bc	7.86 ± 1.10c	1.79 ± 0.13c
Brinjal leaves	10.8 ± 1.6d	0.0543 ± 0.0032d	44.5 ± 0.2c	1.133 ± 0.008d	10.54 ± 3.95d	1.50 ± 0.17d
Pepino leaves	8.5 ± 0.7e	0.0409 ± 0.0012e	51.5 ± 0.5d	1.098 ± 0.003d	15.26 ± 2.88e	1.36 ± 0.06d
Tomato fruits	35.5 ± 3.8b	0.1007 ± 0.0029b	36.5 ± 0.2b	1.261 ± 0.008b	5.89 ± 0.91b	2.09 ± 0.19b
Potato tubers	2.1 ± 0.4f	0.0128 ± 0.0023f	62.2 ± 0.1e	1.031 ± 0.006e	44.8 ± 28.29f	1.09 ± 0.04e
Statistics	$F_{5,32} = 148.5$ $p < 0.001$	$F_{5,32} = 389.3$ $p < 0.001$	$F_{5,32} = 817.9$ $p < 0.001$	$F_{5,32} = 344.8$ $p < 0.001$	$F_{5,32} = 4.73$ $p < 0.001$	$F_{5,32} = 15.14$ $p < 0.001$

Means followed by different letters in the same column are significantly different by LSD post-hoc test ($p < 0.05$)

studies. The fecundity of the pest varied significantly with the host in the order tomato leaves > tomato fruits > potato leaves > brinjal leaves > pepino leaves > potato tubers. Earlier Sridhar et al. (2015) also reported highest fecundity of the pest on tomato followed by potato and brinjal. Fecundity of *T. absoluta* on tomato (175.38 eggs/female) obtained in the present study falls within the fecundity range (47.54–260 eggs/female) reported in previous studies (Uchoa-Fernandes et al. 1995; Pereyra and Sanchez 2006; Erdogan and Babaroglu 2014; Duarte et al. 2015; Silva et al. 2015; Sridhar et al. 2015; Ganbalani et al. 2016).

The growth index of immature stages combines the survival rate and the development time into a single value (Setamou et al. 1999) and a higher survival rate and shorter development time results into a higher growth index. Growth index ultimately provides an indication of the suitability of the host plant, higher the index more suitable the host plant is (Greenberg et al. 2001). The growth indices of egg, larva, pupa and overall immature stage (egg-adult emergence) were highest on tomato leaves followed by tomato fruits, potato leaves, brinjal leaves, pepino leaves and potato tubers indicating that tomato is the most suitable host for the pest followed by potato leaves, brinjal leaves, pepino leaves and potato tubers. Immature mortality was also lowest on tomato leaves and highest on potato tubers.

Fertility tables summarize the data on the age specific survival and fecundity of the species to determine the net reproductive rate (Ro) and intrinsic rate of natural increase (rm). The intrinsic rate of natural increase (rm) is a measure of the biotic potential of the species and the advantage of using this parameter is that it integrates the survival rate, fecundity, sex ratio and length of generation into a single value. Hence, instead of comparing several life history parameters, a single comparison based on the intrinsic rate of increase can be applied (Havelka and Zemek 1999). The intrinsic rate of increase can be used to determine the finite rate of increase (λ) of the species, which depicts the number of times the population increases per unit time. Population growth parameters such as intrinsic rate of increase, net reproductive rate and finite rate of increase are influenced by the nature and quality of the food (Pereyra and Sanchez 2006; Chen et al. 2010; Farahani et al. 2012; Golizadeh et al. 2017). In the present study, the values of intrinsic rate of increase, net reproductive rate and finite rate of increase of *T. absoluta* were highest on tomato leaves and lowest on potato tubers. It can therefore be inferred that among all the food sources under study, tomato leaves were the most suitable for the pest. Selection of a suitable host is also crucial for mass rearing of the species for experimentation especially during the initial years of its invasion into new area. The intrinsic rate of natural increase of *T. absoluta* on tomato (0.1316) was nearly similar to that reported (0.1046–0.1606) in the previous studies (Pereyra and Sanchez 2006; Erdogan and Babaroglu 2014; Duarte et al. 2015; Silva et al. 2015; Ganbalani et al. 2016). Pereyra and Sanchez (2006) reported an intrinsic rate of natural increase of the pest on potato as 0.08 which is again almost same to the present study (0.0848).

Nutritional value of the host affects the survival rate and fecundity of the insect and hence the intrinsic rate of increase (Tsai 1998). Better nutrition enables the pest to grow faster and reduces the mean generation time (Price 1997; Ganbalani et al. 2016). In the present study *T. absoluta* grew faster and had better intrinsic rate of increase on tomato indicating that tomato is a nutritionally superior host plant for the pest as compared to other hosts under study. A shorter generation time (T) on tomato would also reduce the time of exposure of *T. absoluta* to natural enemies under field conditions (Price et al. 1980). It means that the pest will have more survival and fecundity on tomato. A large number of plants have been listed as hosts of *T. absoluta* (Colomo et al. 2002; Bayram et al. 2015), however, the studies regarding the suitability of most of them as host plant to the pest are lacking. *Capsicum annuum* L. for example, mentioned as the host plant of *T. absoluta* (Bayram et al. 2015) could not be included in the present study as in the preliminary study the pest neither oviposited nor fed on the host. Studies report that *T. absoluta* feed on potato, but, has never been considered (Garcia and Espul 1982; Colomo et al. 2002). In the present study, the pest developed and grew successfully on potato, brinjal and pepino under laboratory conditions, suggesting that these hosts nad play important role in population and overwintering of the pest, and under favourable conditions it can become a pest on these crops. The potato and makoi (*Salanum nigrum* L.) (Cocco et al. 2015a) and attaining a pest status on solanaceous plants (Bawin et al. 2016) has already been reported. The demographic parameters of the pest on these host plants would be useful to assess its biotic potential on these host plants and to evaluate the host-plant quality (Sanchez and Pereyra 1995; Sanchez et al. 1997).

Conclusion

In the present study, tomato was found to be the most suitable host plant of *T. absoluta*, yet, the pest developed and grew successfully on other alternate hosts like potato, brinjal and pepino. These hosts can play an important role in the survival, population buildup and overwintering of the miner and need continuous monitoring for the pest. Further under favourable environmental conditions, spatial and phonological synchronization, lack of natural enemies, etc. the pest can become a serious pest on these crops.

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Compliance with ethical standards

Conflict of interest There is no conflict of interest among the authors.

References

Abbes, K., Harbi, A., Elimem, M., Hafsi, A., & Chermiti, B. (2016). Bioassay of three solanaceous weeds as alternative hosts for the invasive tomato leafminer *Tuta absoluta* (Lepidoptera: Gelechiidae) and insights on their carryover potential. *African Entomology, 24*, 334–342.

Bawin, T., Dujeu, D., De Backer, L., Francis, F., & Verheggen, F. J. (2016). Ability of *Tuta absoluta* (Lepidoptera: Gelechiidae) to develop on alternative host plant species. *The Canadian Entomologist, 148*, 434–442.

Bayram, Y., Buyuk, M., Ozaslan, C., Bektaş, O., Bayram, N., Mutlu, C., Ates, E., & Bukun, B. (2015). New host plants of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in Turkey. *Journal of Tekirdag Agricultural Faculty, 12*, 43–46.

Bernays, E. A., & Chapman, R. F. (1994). *Host plant selection by phytophagous insects*. New York: Chapman and Hall.

Birch, L. C. (1948). The intrinsic rate of natural increase of an insect population. *Journal of Animal Ecology, 17*, 15–26.

Caparros Megido, R. C., Brostaux, Y., Haubruge, E., & Verheggen, F. J. (2013). Propensity of the tomato leafminer, *Tuta absoluta* (Lepidoptera: Gelechiidae), to develop on four potato plant varieties. *American Journal of Potato Research, 90*, 255–260.

Carey, J. R. (2001). Insect biodemography. *Annual Review of Entomology, 46*, 79–110.

Chen, W., Leopold, R. A., & Boetel, M. A. (2010). Host plant effects on development and reproduction of the glassy-winged sharpshooter, *Homalodisca vitripennis* (Homoptera: Cicadellidae). *Environmental Entomology, 39*, 1545–1553.

Cocco, A., Deliperi, S., Lentini, A., Mannu, R., & Delrio, G. (2015a). Seasonal phenology of *Tuta absoluta* (Lepidoptera: Gelechiidae) in protected and open-field crops under Mediterranean climatic conditions. *Phytoparasitica, 43*, 713–724.

Cocco, A., Serra, G., Lentini, A., Deliperi, S., & Delrio, G. (2015b). Spatial distribution and sequential sampling plans for *Tuta absoluta* (Lepidoptera: Gelechiidae) in greenhouse tomato crops. *Pest Management Science, 71*, 1311–1323.

Colomo, M. V., Berta, D. C., & Chocobar, M. J. (2002). El complejo de himenópteros parasitoides que atacan a la "polilla del tomate" *Tuta absoluta* (Lepidoptera: Gelechiidae) en la Argentina. *Acta Zoologica Lilloana, 46*, 81–92.

Cuthbertson. (2011). Development rate of *Tuta absoluta* under UK glasshouses conditions. *Agriculture and Horticulture Development Board*, 25.

Cuthbertson, A. G. S., Blackburn, L. F., Northing, P., Mathers, J. J., Luo, W., & Walters, K. F. A. (2013). Population development of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) under simulated UK glasshouse conditions. *Insects, 4*, 185–197.

Desneux, N., Luna, M. G., Guillemaud, T., & Urbaneja, A. (2011). The invasive south American tomato pin worm, *Tuta absoluta* continue to spreading afro-Eurasia and beyond: The new threat to tomato world production. *Journal of Pest Science, 84*, 403–408.

Duarte, L., Martinez, M. A., & Bueno, V. H. P. (2015). Biology and population parameters of *Tuta absoluta* (Meyrick) under laboratory conditions. *Revista de Proteccion Vegeta, 30*, 19–29.

EPPO. (2005). EPPO datasheets on quarantine pests: *Tuta absoluta*. EPPO Bulletin, 35, 434–435. Available on: http://www.eppo.org/QUARANTINE/insects/*Tuta_absoluta*/DS_*Tuta_absoluta*.

Erdogan, P., & Babaroglu, E. (2014). Life table of the tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). *Journal of Agricultural Faculty of Gaziosmanpasa University, 31*, 80–89.

Farahani, S., Talebi, A. A., & Fathipour, Y. (2012). Life table of *Spodoptera exigua* (Lepidoptera: Noctuidae) on five soybean cultivars. *Psyche, 2012*, 1–7. https://doi.org/10.1155/2012/513824.

Frel, A. G., Cardona, H. C., & Dorn, S. (2003). Antixenosis and antibiosis of common beans to *Thrips palmi*. *Journal of Economic Entomology, 93*, 1577–1584.

Ganbalani, G. N., Shahbaz, M., & Fathi, S. A. A. (2016). Life history and life table parameters of the *Tuta absoluta* (Lepidoptera: Gelechiidae) on twelve commercial tomato cultivars under laboratory conditions. *Journal of Crop Protection, 5*, 273–282.

Garcia, M. F., & Espul, J. C. (1982). Bioecología de la polilla del tomate (*Scrobipalpula absoluta*) en Mendoza. *República Argentina.*, 135–146.

Genç, H. (2016). The tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae): Pupal key characters for sexing individuals. *Turkish Journal of Zoology, 40*, 801–805.

Gharekhani, G. H., & Salek-Ebrahimi, H. (2014). Life table parameters of *Tuta absoluta* (Lepidoptera: Gelechiidae) on different varieties of tomato. *Journal of Economic Entomology, 107*, 1765–1770.

Golizadeh, A., Ghavidel, S., Razmjou, J., Fathi, S. A. A., & Hassanpour, M. (2017). Comparative life table analysis of *Tetranychus urticae* Koch (Acari: Tetranychidae) on ten rose cultivars. *Acarologia, 57*, 607–616.

Greenberg, S. M., Sappington, T. W., Legaspi, B. C., & Setamou, M. (2001). Feeding and life history of *Spodoptera exigua* (Lepidoptera: Noctuidae) on different host plants. *Annals of the Entomological Society of America, 94*, 566–575.

Havelka, D. J., & Zemek, R. (1999). Life table parameters and oviposition dynamics of various population of the predacious gall-midge *Aphidoletes aphidimyz*. *Entomologia Experimentalis et Applicata, 91*, 481–484.

Hill, C. B., Li, Y., & Hartman, G. L. (2004). Resistance of *Glycine* species and various cultivated legumes to the soybean aphid (Homoptera: Aphididae). *Journal of Economic Entomology, 97*, 1071–1077.

Kalleshwaraswamy, C. M., Murthy, M. S., Viraktamath, C. A., & Kumar, N. K. K. (2015). Occurrence of *Tuta absoluta* (Lepidoptera: Gelechiidae) in the Malnad and Hyderabad-Karnataka regions of Karnataka, India. *Florida Entomologist, 98*, 970–971.

Krechemer, F. S., & Foerster, L. A. (2017). Development, reproduction, survival, and demographic patterns of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) on different commercial tomato cultivars. *Neotropical Entomology, 46*, 694–700.

Maia, A. H. N., Luiz, A. J. B., & Campanhola, C. (2000). Statistical inference on associated fertility life table parameters using jackknife technique: Computational aspects. *Journal of Economic Entomology, 93*, 511–518.

Meyer, J. S., Ingersoll, C. G., McDonald, L. L., & Boyce, M. S. (1986). Estimating uncertainty in population growth rates: Jackknife vs. bootstrap techniques. *Ecology, 67*, 1156–1166.

Mohamadi, P., Razmjou, J., Naseri, B., & Hassanpour, M. (2017). Population growth parameters of *Tuta absoluta* (Lepidoptera: Gelechiidae) on tomato plant using organic substrate and biofertilizers. *Journal of Insect Science, 17*, 36.

Mohamed, E. S. I., Mahmoud, M. E. E., Elhaj, M. A. M., Mohamed, S. A., & Ekesi, S. (2015). Host plants record for tomato leaf miner *Tuta absoluta* (Meyrick) in Sudan. *Bulletin OEPP/EPPO Bulletin, 45*, 108–111.

Oztemiz, S. (2013). Population of *Tuta absoluta* and natural enemies after releasing on tomato grown in greenhouse in Turkey. *African Journal of Biotechnology, 12*, 1882–1887.

Pereyra, P. C., & Sanchez, N. E. (2006). Effect of two solanaceous plants on developmental and population parameters of the tomato leaf miner *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). *Neotropical Entomology, 35*, 671–676.

Price, P. W. (1997). *Insect ecology*. New York: Wiley 888 pp.

Price, P. W., Bouton, C. E., Gross, P., Mcpheron, B. A., Thompson, J. N., & Weis, A. E. (1980). Interactions among three trophic levels: Influence of plants on interactions between insect herbivores and natural enemies. *Annual Review of Ecological Systems, 11*, 41–65.

Sanchez, N. E., & Pereyra, P. C. (1995). Life table of the soybean looper *Rachiplusia nu* (Lepidoptera: Noctuidae) in the laboratory. *Revista de la Sociedad Entomologica Argentina, 54*, 89–96.

Sanchez, N. E., Pereyra, P. C., & Gentile, M. V. (1997). Population parameters of *Epinotia aporema* (Lepidoptera: Tortricidae) on soybean. *Revista de la Sociedad Entomologica Argentina, 56*, 151–153.

Sauvion, S., Mauriello, V., Renard, B., & Boissot, N. (2005). Impact of melon accessions resistant to aphids on the demographic potential of silverleaf whitefly. *Journal of Economic Entomology, 98*, 557–567.

Setamou, M., Schulthess, F., Bosque-Perez, N. A., Poehling, H. M., & Borgemeister, C. (1999). Bionomics of *Mussidia nigrivenella* (Lepidoptera: Pyralidae) on three host plants. *Bulletin of Entomological Research, 89*, 465–447.

Sharma, P. L., & Chandel, R. S. (2009). Effect of food quality, survival and fertility parameters of *Henosepilachna vigintioctopunctata* (Fabricius). *Journal of Insect Science, 22*, 418–423.

Sharma, P. L., & Gavkare, O. (2017). New distributional pest *Tuta absoluta* (Meyrick) in north-western Himalayan region of India. *National Academy Science Letters, 40*, 217–220.

Shashank, P. R., Chandrashekar, K., Naresh, M., & Sreedevi, K. (2015). Occurrence of *Tuta absoluta* (Lepidoptera: Gelechiidae): An invasive pest from India. *Indian Journal of Entomology, 77*(4), 323–329.

Silva, D. B., Bueno, V. H. P., Lins Jr., J. C., & Lenteren, J. C. V. (2015). Life history data and population growth of *Tuta absoluta* at constant and alternating temperatures on two tomato lines. *Bulletin of Insectology, 68*, 223–232.

Singer, M. S., Rodrigues, D., Stireman, J. O., & Carriere, Y. (2004). Roles of food quality and enemy-free space in host use by a generalist insect herbivore. *Ecology, 85*, 2747–2753.

Sridhar, V., Chakravarthy, A. K., Asokan, R., Vinesh, L. S., Rebijith, K. B., & Vennila, S. (2014). New record of the invasive south American tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in India. *Pest Management in Horticultural Ecosystems, 20*(2), 148–154.

Sridhar, V., Nitin, K. S., Onkara, N. S., & Nagaraja, T. (2015). Comparative biology of south American tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) on three solanaceous host plants. *Pest Management in Horticultural Ecosystems, 21*, 159–161.

Torres, J. B., Faria, C. A., Evangelista, W. S., & Pratissoli, D. (2001). Within-plant distribution of the leaf miner *Tuta absoluta* (Meyrick) immatures in processing tomatoes, with notes on plant phenology. *International Journal of Pest Management, 47*, 173–178.

Tsai, J. H. (1998). Development, survivorship and reproduction of *Toxoptera citricida* (Kirkaldy) (Homoptera: Aphididae) on eight host plants. *Environmental Entomology, 25*, 1190–1195.

Uchoa-Fernandes, M. A., Della, L. T. M., & Viella, E. F. (1995). Mating, oviposition and pupation of *Scrobipalpula absoluta* (Meyrick) (Lepidoptera: Gelechiidae). *Anais da Sociedade Entomologica do Brasil, 24*, 159–164.